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National Proceedings: Forest and Conservation Nursery Associations—1997

Regeneration
Reforestation
Restoration

The Seedling is the Key

Technical Coordinators:

THOMAS D. LANDIS, National Nursery Specialist, USDA Forest Service, Pacific Northwest Region, Cooperative Programs, P.O. Box 3623, Portland, OR 97208-3623; TEL: 503/808-2344; FAX: 503/808-2339; (e-mail: nurseries@aol.com).

JAN R. THOMPSON, Department of Forestry, Iowa State University, 251 Bessey Hall, Ames, IA 50011 TEL: 515/294-0024; FAX: 515/294-2995; (e-mail: jrrt@iastate.edu).

Layout and Editing:

ALETA C. BARTHELL and KENT E. GIARD, USDA Forest Service, Pacific Northwest Region, Cooperative Programs, P.O. Box 3623, Portland, OR 97208-3623.

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1997

Thomas D. Landis and Jan R. Thompson,
Technical Coordinators

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This proceedings is a compilation of 27 papers that were presented at the regional meetings of the forest and conservation nursery associations in the United States in 1997. The Northeastern Forest Nursery Association Conference was held in Bemidji, MN on August 11-14, 1997; and the Western Forest and Conservation Nursery Association meeting was held in Boise, ID, on August 19-21, 1997. The subject matter ranges from seed collection and processing; through nursery cultural practices; to harvesting, storage and outplanting.

Keywords: Bareroot seedlings, container seedlings, nursery practices, reforestation.

Note: As part of the planning for this symposium, we decided to process and deliver these proceedings to the potential user as quickly as possible. Thus, the manuscripts did not receive conventional Forest Service editorial processing, and consequently, you may find some typographical errors. We feel quick publication of the proceedings is an essential part of the symposium concept and far outweighs these relatively minor distractions.

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WESTERN FOREST AND COSERVATION NURSERY ASSOCIATION MEETING

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BUSINESS MEETINGS

MEETING REVIEW

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WIndicates that a paper was presented at the meeting, but was not received for this publication. A summary of all papers is provided on pages 144-150. The author can be contacted using the attendance list in the back of the book.

Northeastern Forest Nursery Association Conference

Bemidji, Minnesota

August 11-14, 1997

Timber Management on the Chippewa National Forest[1]

B. Brittain[2]

The Chippewa National Forest is a forest of approximately 661,000 total acres. It has 180,000 acres of nonproductive lands for timber including:

- Wetlands
- Experimental forests
- Special uses
- Research Natural Areas (RNAs)
- Miscellaneous other areas not considered appropriate for timber management.

I may as well mention the Superior National Forest too. It is much larger with approximately 2,100,000 acres:

- 1,450,000 acres are considered unsuitable or inappropriate for timber management
- Much of this is the Boundary Waters Canoe Area Wilderness (BWCAW)
- Remainder is the same as the Chippewa National Forest.

Much of the commercial forest land in both National Forests is in the aspen cover types. Years ago, at least in the 1950's and 60's, aspen was considered a weed species for the most part. An area in this cover type:

- Was often cleared by shearing with a dozer, then piled or windrowed.
- Pine or spruce was then planted, usually at a 6' x 8' spacing for around 900 trees an acre
- Many of these plantations have already been thinned one time.

From 1966 to 1972, the Chippewa planting program averaged 3,290 acres a year, and the Superior's averaged 6,150 acres a year.

Our planting programs both peaked in 1968 with the Chippewa planting 4,832 acres and the Superior planting 7,405 acres.

Our present planting programs are much smaller:

- Chippewa averaged 904 acres the past four years
- Superior averaged 1,533 acres over this same period.

The main reason for reduced planting is that our first Forest Plan stated that we would no longer convert one forest type to another:

- If we cut an aspen stand, we had to regenerate aspen
- The same for jack pine, birch, etc..

Table 1 shows our reforestation efforts the past four years. Our replant acreage didn't used to be this high:

- One reason is that we no longer use herbicides
- Another is that we do not shear, windrow, and machine plant anymore
- Disc trenching or spot scalping and hand planting are used to prevent disturbing so much soil as with shearing.

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[1]Brittain, B. 1997. Timber Management on the Chippewa National Forest. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1-2.

[2]Forest Silviculturist, USDA Forest Service, Chippewa National Forest, Route 3, Box 244, Cass Lake, MN 56633; Tel: 218/335-8600.

Table 1.

	1997		1996		1995		1994	
	Chip.	Sup.	Chip.	Sup.	Chip.	Sup.	Chip.	Sup.
Plant (acres)	1,096	575/1208[1,2]	839	366/854	899	495/1155	781	523/1225
Seed (acres)	178	100	17	100	116	140	171	80
Nat Regen (acres)	3,000[2]	7,540	3,762	9,118	5,421	5,615	6,461	5,671
M Trees (#)	567	230	543	241	679	223	494	185
M Containers (#)	11	483	—	241	1	408	—	497
Replants[3] (acres)	369	—	165	—	171	—	299	—

Estimate
[2]Seedl ing/Containers
[3]Superior does not replant; this encourages mixed stands.

So we lose a sizeable number of seedlings to competition now that years ago were controlled by better site preparation and release with herbicides. Our release now is basically all handcutting:

- This works for woody species but not grass and forbs
- Most plantations need a minimum of three releases to get them off to a good start.

Basically, our forest types are managed as follows:

- ***Aspen:*** clear-cut/natural regeneration
- ***Hardwoods:*** mostly intermediate cuts/natural regeneration
- ***Red and white pine:*** evenaged/shelterwood cuts, natural and artificial regeneration
- ***Jack pine:*** clear-cut/plant, seed, or natural regeneration
- ***Black spruce:*** strip clear-cut/seed or natural regeneration.

I'll be happy to try to answer questions at the designated time.

Overview of State Land Forest Management in Minnesota[1]

Bob Pajala[2]

MINNESOTAFORESTS

Pre-European settlement Minnesota was approximately two-thirds forested. Today the state is approximately one-third forested with some 16.7 million acres of forest land in all ownerships. Some 23% of the current forest is owned by the state. Counties own 16%, the federal government owns 21%, forest industry owns 8%, and private woodland owners own 32%. A key feature of the forests of Minnesota is that the forest-prairie interface transects the state from north to south. This puts virtually all of the tree species on the western edge of their range and creates some unique silvicultural challenges for foresters.

STATE LAND MANAGEMENT

Minnesota Department of Natural Resources (DNR) Division of Forestry manages some 4.4 million acres of forest land, 60 % of which is classed as commercial forest. Some 30,000 acres are harvested annually. One-third of the harvested sites are reforested by planting or seeding. Two-thirds of the harvested sites are reforested by natural means such as suckering or natural seeding. State law requires all state land harvested sites be reforested with appropriate species and stocking. The annual timber sales from state forest land are now around 600,000 cords or $ 11,000,000 to $ 12,000,000 per year. State forest management also includes the maintenance of a 2,000+ mile forest road system (Table 1).

REFORESTATION PRACTICES

Natural regeneration

Natural regeneration is the preferred regeneration method. Silviculture systems featuring suckering, stump sprouting, seed tree and shelterwood are typical natural regeneration methods used on state forest land.

Site preparation

If planting is the regeneration method, the first step is site preparation. Patch scarification, often in conjunction with herbicide application, is the preferred site preparation technique. The objectives of site preparation are to leave as much of the organic layer undisturbed as possible, provide micro-sites for successful establishment of seedlings, and reduce competition on the site.

Planting and seeding

All state forest planting is done by private contractors and almost all of that is done by hand. Half of the planting is done by hoedad and half by planting bar.

Table 1. FY1996 State Land Reforestation Accomplishments

Natural Regeneration Silviculture Systems	21,900 acres
Planting	3,584 acres
Site Preparation	4,713 acres
TimberStand Improvement	2,965 acres

[1]Pajala, R.E. 1997. Overview of State Land Forest Management in Minnesota. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 3-4.

[2]Forest Development Program Coordinator, Minnesota DNR, Division of Forestry, Box 44, 500 Lafayette Road, St. Paul, MN 55155-4044; Tel: 612/297-3515; Fax: 612/296-5954;e-mail: (bob.pajala@dnr.state.mn.us).

Survival is similar with both methods. A total of some four million seedlings are planted per year.

Some three-quarters of the planting stock is bare root stock produced by two DNR nurseries. The rest is containerized stock procured from a number of private vendors. Container stock is preferred on very rocky sites where shallow soils make it hard to plant seedlings with long root systems. Three-quarters of planting are conifers. Red pine, white pine, jack pine and white spruce are the major conifer species planted. Red oak, white oak, green and white ash and black walnut are the major hardwood species planted.

Seeding is almost all done by helicopter. Black spruce seeding constitutes the bulk of the aerial seeding program and has been quite successful.

Timber Stand Improvement

The major timber stand improvement practice is release. Release is used on one-third to one-half of planted sites. Herbicide, both aerial and ground applied, is the typical release practice. Hand release is being used more each year.

Future Reforestation Direction

The amount of reforestation on state forest land is related directly to timber harvesting. The ratio of natural to artificial regeneration silviculture systems will probably remain close to the present 2:1. Plantations of the future will have increased within-stand diversity and be comprised of native species. Plantings and seedings, as well as natural regeneration sites will incorporate visual quality, water quality and biodiversity best management practices.

Beltrami County Natural Resource Management[1]

Mark Reed[2]

TAX-FORFEITED LANDS

Prior to the 1980's, Minnesota's fifteen counties with natural resource management programs struggled to build professional management programs with very small budgets, lack of professional staff and years of catch-up work on tax forfeited lands which had been largely neglected. Many of these lands are highly productive and contain an abundance of natural resources. These factors, coupled with a surging upswing in demand by a growing wood products industry, an escalating recreational demand, and a growing environmental awareness, have created a keen interest in county-administered tax forfeited land which is a large segment of Minnesota's forest resource and have become a major factor in Minnesota's economy, forest industry, and future well-being.

The county tax forfeited lands in the State of Minnesota are truly assets to be treasured, retained and their diverse resources wisely managed over the long term. Pressure to return tax forfeited lands to the private sector has sometimes been a point of concern which had, in the past, threatened a valuable resource.

To alleviate this concern, in 1979 the Minnesota State legislature enacted an "in lieu of tax" statute (MN Statute 477 A) to encourage retention of tax forfeited lands and provide compensation to local taxing districts for the loss in tax base as a result of the retention. Payments to counties began in 1980 and are based upon the acreage of public ownership within each county.

Although tax relief is a primary objective, a portion of the payment is dedicated to intensified natural resource management and subsequent improvement of all resources on tax forfeited lands. Several legislative studies were conducted which justify these payments to counties.

To further intensify natural resource management on county lands, in 1985, the Minnesota Legislature provided for the first forest-intensification grants to counties with a grant to St. Louis County for a pilot project. County Forestry Assistance State Grants were distributed to all counties with Land Departments based upon acres of commercial forest land in each county. Said grants were eliminated by legislative action in 1991.

These payments and grants have been very beneficial in the rapid development of professional natural resource management on county-administered tax forfeited lands. This bodes well for the future of these lands and resources and for the people of the State of Minnesota.

LANDSMANAGED

Minnesota counties manage 32% of the commercial forest lands managed by public agencies which is 17% of all commercial forested lands in the state. From these lands, the counties supply 35% of all wood commercially harvested from public agency lands in Minnesota which equates to 13.49% when all ownerships are considered.

[1]*Reed, M. 1997. Beltrami County Natural Resource Management. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 5-7.*

[2]*Beltrami County Natural Resource Management, 315 5th St., NW, Bemidji, MN 56601; Tel: 218/759-4210.*

In addition to retaining 2.8 million acres of land, most of which is in dedicated Memorial Forest and nearly all of which is open for public entry, counties also make substantial provisions for recreation and other public services for the people of Minnesota.

REFORESTATION

Prior to 1980, due to inflation and rising energy costs along with a weak timber market, the overall planting efforts of the counties had been declining. In the late 1970s, the counties collectively planted approximately 1,000 acres per year.

In the 1980s, there was a substantial increase in the amount of acres planted on county-administered tax forfeited lands. From 1980 to 1990, counties planted approximately 60,000 acres. This was due in part to funding through the BWCA Grant and the County Forestry Assistance Grant. By 1990, both these grants were complete and planting programs leveled off to average approximately 3,000 acres per year.

Additionally, counties have shown their innovative nature as they strive to improve timber quality and resource production for the future. Many counties are members of the Minnesota Tree Improvement Cooperative and have taken the initiative to establish and maintain seed orchards which will soon produce genetically improved seed and trees for the future.

Experimental plantings of various native and non-native trees are also pursued on a regular basis to provide diversity and expand alternatives for future wood products.

HARDWOOD MANAGEMENT

Quality hardwood management on county lands has shown a steady increase in the 1980s. In the period from 1980 to 1990, acres of managed hardwoods have more than tripled. The emphasis has shifted from a volume production philosophy to a quality improvement philosophy, because growing quality hardwood products is the key to a successful hardwood management program.

Since 1980, various county land departments have:

- Expanded hardwood planting with a variety of species obtained from high quality seed sources

- Participated in interagency workshops to increase awareness of techniques to increase quality hardwood growth, ensure adequate hardwood regeneration, enhance wildlife habitat, and improve aesthetic values

- Applied timber stand improvement practices to improve hardwood quality

- Been involved in logger and sawmill operator workshops to maximize quality products retrieved from county lands.

Hardwood acres properly managed now not only produce immediate income, but increase the potential for much greater income and diversity of forest benefits in future years.

WILDLIFE MANAGEMENT

County land departments strive to promote a diverse, healthy forest which provides a wide range of habitats for both game and nongame species.

BELTRAMI COUNTY

Beltrami County is located in the northwestern part of Minnesota with its county seat located in Bemidji. The department is responsible for the management of approximately 150,000 acres of tax forfeited lands. Of this, approximately 125,000 is commercial timber land. Four field foresters oversee the management on these lands.

PLANTING PROGRAM

Beltrami County has a relatively aggressive planting program. We plant approximately 500,000 trees per year. Species planted include: red pine, jack pine, white pine, white spruce, and balsam fir. Red pine and jack pine are our predominant species. The following are our observations regarding our regeneration program:

Successful planting often depends on measures such as reduction of competing vegetation and removal of physical obstacles. Mechanical site preparation in conjunction with a chemical application has been a successful practice to ready a site for young seedlings. The county uses either a Bracke Scarifier or a TTS disc trencher when preparing a site to be planted. Chemical application is applied either before mechanical treatment or simultaneously with mechanical treatment. The department has observed that sites treated with chemical a few weeks prior to mechanical treatment tend to provide a better planting site than those sites where chemical is applied at the same time as the mechanical treatment. We have also found that coarse textured soils are harder areas to establish a plantation. This may be a function of the site itself making it difficult for the seedling to establish itself, or difficulty in properly planting the seedling.

Handling of the trees is also an important aspect of successful plantations. The number one issue for success is the handling of the seedlings from the time they leave the nursery to when they are put into the ground. There are many variables that can affect the final success or failure of these seedlings. These include:

- Storage temperature
- Storage duration
- Storage in the field
- Planting technique.

The sooner the trees are planted the better the success. The later in the season (after a lengthy storage period) the better chance for failure. Also the later in the season (as temperatures increase) the better chance of failure. The later in the season, the better success with containerized seedlings.

Beltrami County is committed to a sustainable resource and, through proper regeneration of its lands, this goal can be accomplished.

Changes to Ontario's Forest Tree Seedling Production: 1992 to 1997[1]

Thom McDonough[2]

Thank you for the opportunity to speak to you all once again and to bring you up to date on what has happened to Ontario's seedling production program over the past couple of years. 1 hope you will permit me to depart somewhat from giving you the plain details about what happened so that I can also tell you a bit about the human side of these changes; the response of staff-with the hope that should anyone one here go through a similar change, you will be able to anticipate, just a bit, how your experience might go.

Government seedling production has a very long history in Ontario. Because it has such a long history, government involvement in seedling production created generations of nursery staff, local economies and traditions. Our oldest nursery in Ontario has even been established as an Ontario historical site. A history such as this creates attachments. Attachments that are made with people, many of whom find it difficult to separate the history of the nursery from their own family histories. Far from being a bad thing, this attachment to such a government institution resulted in the pride that our nursery production staff took in their work. The attachment resulted in the high quality of stock that was produced. 1 am sure this is the same for all nurseries with long histories, whether they are government or privately run.

Histories are important to the point that they remind us where we have been as nursery people. But histories of nurseries, no matter how long and how illustrious they might have been, do not, can not prevent changes from occurring. Change, like rocks, death and taxes, is inevitable. From what has been our experience in Ontario, we can say that it is very difficult to predict how change will occur, how long or short the time frame will be, and why it will occur.

The first nursery in Ontario was established in 1908 near the town of St. Williams in south-western Ontario. This nursery was created to produce seedlings for planting on large areas of blow sand and other heavily eroded and damaged farm land areas. Other nurseries followed from 1920 on, until there were ten nurseries in Ontario providing both bareroot and container seedlings for reforestation programs on Crown and private land.

At the height of production levels in the 1980's the nurseries along with container production were pumping out in the vicinity of 200 to 210 million seedlings per year. Even at these production levels, nurseries were not operating up to the capacity for which they had been built or improved.

A substantial change occurred in the mid -1980's with the transfer of the container programs to the private sector. With considerable government assistance, a large number of private growers got into the production of containerized reforestation stock. In a sense, and with the benefit of hindsight, this marked the beginning of the end of government-run seedling production. The government bareroot nursery staff often refer to this

[1]*Donough, T. 1997. Changes to Ontario's Forest Tree Seedling Production:1992 to 1997. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 8-11.*

[2]*Nursery Stock Cultural Specialist, Forest Renewal Section, Ministry of Natural Resources, 70 Foster Drive, Sault Ste. Maire, ON P6A 6V5 CANADA.*

change as the start of the decline of their work. Such a view is understandable, but unfortunately it obscures the tremendous developments that have occurred in container seedling production in our province and does not take into account the large areas of harvested forest that were perfectly suited for the container seedling stock type.

In 1992, just five years ago, the Ministry of Natural Resources (MNR) began the first in what became a series of re-organizations. This began as an attempt to chart a new direction for the MNR and to try and flatten out what had become a very large government structure. Team work was introduced with the intent to eliminate some of the middle management and to put the decision making more in the hands of the people in the field. As part of this re-organization, the nurseries were taken out of the regional management system that existed and were centralized under a head office manager.

As fate would have it, at the same time that this re-organization was working itself out, the Ontario government was hit by a substantial reduction in available funding due to the general recession that was being felt throughout North America. Government funding had to be cut and each Ministry was reviewed to see what constraints could be applied to their programs. Under centralized management, the nurseries were a prime target as they were prime locations for operational and salary allocations of funds.

During the same period of time, container production, supported with good research and continued improvement of facilities and product quality, was gaining more and more market share of the total numbers of seedlings planted in the province.

Undergoing an internal review as part of the constraint exercise, it was determined that the government bareroot nurseries were operating at between 60 and 70% capacity. It became obvious that this could not be continued over time with the funding reductions that were occurring and that some form of rationalization of the nursery production system would be needed. As a result, four nurseries (Thunder Bay, Midhurst, Chapleau, and Gogama) were identified for closure. This closure was to be phased in as stock was allowed to mature for shipping purposes. These facilities ceased operation in the spring of 1994. Staff from these nurseries were absorbed into the MNR.

The recession continued, available government funding continued to decline, and the MNR was continuously reviewing how it went about its business. Without sufficient operational funding needed to continue, it soon became clear that the work that the MNR did was going to have to change.

In January of 1995, the OMNR issued a new document, "Direction 90's - Moving Ahead in 1995", that identified the need for the Ministry to concentrate on those roles that were most vital to ensuring that the provincial interests in resource management were defined and achieved. It was felt that Ministry staff were tied up in many repetitive, operational activities that locked them into routine day to day work that did not add to their ability to improve resource management. We were doing too much "fire fighting" - issues, and little in the way of planning for the future of our resources.

It was also felt that given the fiscal realities, budgets and staff were unlikely to grow, and indeed would have to shrink. The Ministry could not continue to add to its many responsibilities (CFSA and Timber EA decision) and try to do more with less. The target had been set. The MNR was going to move more towards the "steering" of things as opposed to the "rowing".

As the government contemplated these moves, the nurseries in northern Ontario were confronted for the first time with the need to set a price for seedling stock. This was in anticipation of the forest users having to be responsible for purchasing their own stock. The prices arrived at, in trying to make the nurseries break even, gave some of our clients a considerable amount of gas, accustomed as they were to free seedlings.

Within ten months, with budgets continuing to shrink and with the market for bareroot seedlings continuing to decline, the Ministry of Natural Resources announced further closures of government nurseries in October of 1995. The nurseries of Orono, Kemptville and Thessalon were the operations involved in this round of cutbacks. This rationalization of our nurseries would not be a phased-in event, but would result in the immediate closure of the operations following the spring lift in 1996. It was intended that the land, buildings and assets of the nurseries along with the remaining seedlings would be sold as soon as possible. These.nurseries were not sold as going concerns but were to be tendered as surplus

Crown lands. Staff were declared redundant and were given notice of layoff.

At the time, it was also suggested that the remaining three nurseries, St. Williams, Swastika and Dryden, should be privatized as "going concerns" in order to continue to have the bareroot stock type available as a stock option for reforestation.

In 1996, a new business plan was created for the MNR and that plan outlined the roles that the Ministry saw for itself as its "core" duties. For four years, the government nursery production system had been reduced. Now, despite the historical place nurseries have held in Ontario's forest management system, the continued production of nursery stock was confirmed as not being a part of the MNR's core business. The new business plan for the Ministry also confirmed the earlier decision to privatize the three remaining nurseries and our Forest Renewal Section initiated a process that would result in the privatization through the issuing of a request for proposals.

The Government of Ontario in the meantime was looking at privatization on a Provincial level of certain programs of the civil service. As a result, they created a Privatization Secretariat to develop a process and to lead any privatization effort in the province. Given that the MNR had already made a decision on its own to privatize the remaining three nurseries, the Provincial Privatization Secretariat felt that the nurseries could be the pilot to establish the process. To this end, consultants have been hired to look at the marketability of the nurseries, public consultations have taken place, and the Privatization Secretariat is considering what the next steps will be. Tn the interim, the three nurseries are continuing to carry out seeding and other cultural activities. The intent is still to hand over operational nurseries to new private ownership.

If you were to ask government nursery staff about the changes that have taken place, I am sure that many will tell you that the changes have been catastrophic. As a former nursery manager, I would have to agree with that assessment, but only in terms of the impact that these changes have had on the staff. Who had long histories of dedicated work and commitment to reforestation in Ontario. But the line that has to be drawn here has to acknowledge their contribution. The changes have not been an indictment of poor performance or of a poor quality product. The changes were brought about by external forces that nursery staff could do little about. For those three facilities remaining, privatization will occur. I believe that as this era ends, we have to celebrate the contribution that the government nurseries made, the contribution of the people who are our nurseries. An end has been reached and it is time to move on.

The private sector will, 1 am confident, pick up the bareroot production in as much as the market for this seedling type will bear it. No doubt, there will be a learning curve and problems will be encountered with consistency of quality and quantity. But as in the container industry, with co-operation between those who have the technology and knowledge and the private industry, quality bareroot seedlings will be available for so long that a market exists for their use.

Do we have any concerns about bareroot production in the future? Yes we do. We are concerned about the transfer of our technology to the private section. Will they (private sector owners) be able to produce the quality and quantity of bareroot seedlings on a consistent basis? How long will it take them to get up and running? Will our staff find opportunities for employment in the private sector? Will the clients, conditioned to subsidized seedling prices, pay the increased cost for seedlings that is likely to be established? Will appropriate silvicultural decisions be made with respect to planting stock type and quality? These are all questions that the Forest Renewal Section has an interest in tracking.

Despite the concerns in the nursery end of things, the other changes that have been made with respect to responsibility for forest management in Ontario have resulted in less uncertainty for silvicultural programs and far more optimism.

The OMNR has negotiated with timber companies (large and small) to have them take over much of the responsibility for the operational activities associated with forest management. To fund this, a trust has been established to provide for appropriate funding levels. The money for this trust fund comes from a renewal charge that is applied to forest harvesting activities. The revenue from this charge is placed in a trust fund, in the name of the company or Sustainable Forestry Licence (SFL) holder. When any forest management work is carried out on the site, the SFL holder or company applies back to the fund for repayment once the work is completed. In this way, there is always funding available. The rates for the renewal charge are also set up so that the fund will not be depleted.

What has occurred is that for the first time in Ontario, forest renewal activities can be planned for over a larger time frame than one fiscal year. The money is guaranteed to be there and is not subject to changes in government spending directions or constraints. Forest management is based on long term planning and now there is funding that can be depended upon in advance of one fiscal year.

As I had mentioned, an era in Ontario's forest management program has ended. A new era has been started and hopefully, this era will be as successful as was the first. The goal of the MNR continues to be the sustainable management of all our natural resources for the benefit of the people of Ontario. The responsibilities to achieve this goal have been shared with a wider number of stakeholders who will have to fill very large shoes indeed as they manage Ontario's forested lands.

IRRRB Growth Chamber: Tree Seedlings Produced for Mineland Reclamation[1]

Daniel R. Jordan[2]

Abstract—To successfully establish vegetation on the abandoned mined lands in northeastern Minnesota, we need superior quality tree seedlings to ensure both higher survival rates and lower reclamation costs. Therefore, the Iron Range Resources and Rehabilitation Board has built two growth chambers in Chisholm, MN to produce the superior quality seedlings we need to carry out our mineland reclamation program. Growth chambers allow total control over light, temperature, humidity and air quality thereby allowing seedling production in the shortest period. Since the Mineland Reclamation Division began producing our own seedlings in March 1982, over 2.8 million containerized seedlings of 49 different species have been produced. The primary species grown for our program are *Pinus banksiana* (37%), *Pinus resinosa* (19%), and *Picea glauca* (17%). We plant our seedlings for reforestation, erosion control, aesthetic plantings, vegetative barriers, and wildlife habitats.

[1] *Jordan, D. R. 1997. IRRRB Growth Chamber: Tree Seedlings Produced for Mineland Reclamation. In: Landis, T.D.; Thomspon, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 12.*

[2] *Senior Natural Resources Forestry Specialist, Iron Range Resources and Rehabilitation Board. Mineland Reclamation Division, PO Box 392, Chisolm, MN 55719; Tel: 218/254-3369; Fax: 218/254-5539.*

Forest and Conservation Nursery Trends in the United States[1]

by Thomas D. Landis[2], Clark W. Lantz[3], Ronald P. Overton[4], and Frank Burch[5]

Abstract- Although 1.5 billion seedlings were grown by forest and conservation nurseries in the United States in 1996, this was less than previous years and continued a decreasing national trend in tree planting. The South grew over three-quarters of the seedlings in the nation, and demand is predicted to remain high in this region. The only region where seedling production increased was the Northeast which was due to the small, private nursery sector. Nursery production was significantly down in the West due to decreased demand for reforestation stock after timber harvest on government lands. Other national nursery trends include a growing preference for larger stock types, and an increasing demand for non-commercial, native plant species that are used for a variety of biodiversity and restoration outplantings.

SEEDLING DEMAND AND NURSERY PRODUCTION

National - In the U.S., over 1.5 billion seedlings were grown and shipped for outplanting in 1996. This represents a decrease of 7% from the previous year and is consistent with the national decrease in tree planting - the lowest since 1982. Forest industry has remained the largest nursery category with 54% of the total seedling production in 1996, and this proportion has remained relatively constant over the past decade (Figure 1). On the other hand, seedling production from all types of government nurseries has steadily decreased in the last 10 years (Moulton and Snellgrove 1997).

South - The Southern states continue to be the largest seedling production region, growing over three-quarters of the seedlings in the U.S. (Figure 2). Seedling demand has been high for the past several years due to high southern pine stumpage prices of $400 to 500 per thousand board feet (M bd ft). This high demand represents a true "free-market" situation as both federal and state cost-share funding has been going down. There is also a reforestation backlog from the 1995-1996 season when drought caused considerable mortality in many plantations, and wildfires burned many forested acres in Arkansas, Oklahoma and Texas. It is estimated that about 50 million more pines and 6 million more hardwood seedlings could have been outplanted last year if nursery stock had been available. This year seedling demand remains high and many nurseries are already sold out.

[1] *Landis, T.D.; Lantz, C. W.; Overton, R.P.; Burch, F. 1997. Forest and Conservation Nursery Trends in the United States. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 13-16.*

[2] USDA Forest Service, Cooperative Programs. P.O. Box 3623, Portland, OR 97208-3623; Tel: 503/808-2344; Fax: 503/808-2339; e-mail: (nurseries@aol.com).

[3] USDA Forest Service, Cooperative Forestry, 1720 Peachtree Rd., Atlanta, Ga 30367; Tel: 404/347-3554; Fax: 404/347-2776

[4] USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Ave, Saint Paul, MN 55108; Tel: 612/649-5241; Fax: 612/649-5238

[5] USDA Forest Service, Timber Management, PO Box 96090, Washington, DC 20090-6090; Tel: 202/205-0946

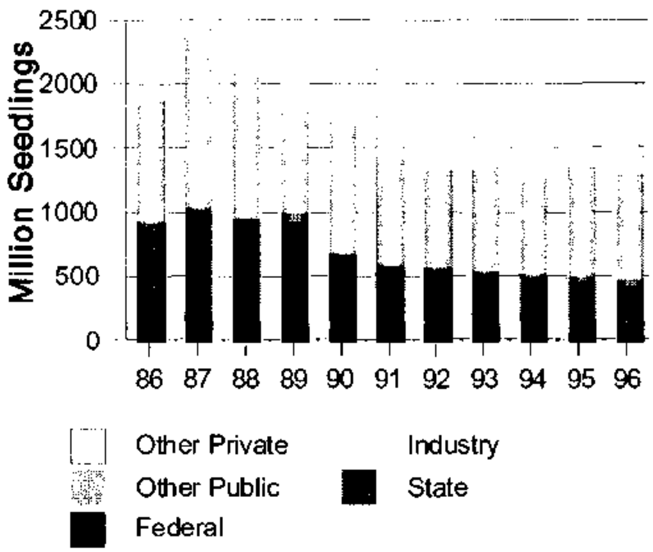

Figure 1. National nursery production by ownership category for the decade 1986 to 1996

On private land in the South, we believe that intensive management on the most productive sites will alleviate the pressure for timber production on public land. All forest tree seedlings in the South are grown from genetically-improved seed except for the "minor" species. State forestry organizations in Arkansas and Mississippi have initiated restrictions on which seed sources can be outplanted when cost-share funding is used. This was necessary because some landowners were ordering non-local sources which, although they grow faster initially, are more subject to cold injury and other environmental stresses over the long run. Forest industries are experimenting with larger seedlings which are grown at lower seedbed densities, and survive better and grow faster than smaller seedlings. State nurseries in the South are feeling budget squeezes, and privatization continues to threaten the Virginia Department of Forestry nurseries.

Northeast - The Northeastern States, in contrast to the other Regions, showed a 28% increase in production levels from last year, producing about 9% of the seedlings in the U.S. (Fig. 2). This increase occurred in the "other industry" nursery sector, i.e., private nurseries not owned by forest industries. State nursery production in the Northeast declined slightly from 1995, continuing a 7-year trend in this segment of the industry, which, although it still produces about one-half of all reforestation stock in the Region, is at it's lowest production level in the last three decades.

Seedling demand continues to increase for a more diverse number of species in the Northeast for riparian buffer, ecological restoration, and wildlife outplantings, along with a continuing demand for traditional timber species. Many states nurseries have reduced production of exotic species in favor of increasing production of native species. At the same time, the average number of plants per order have declined. Smaller order sizes and increased numbers of species grown have combined to raise seedling production costs in the Northeast.

Competition between public and private nurseries continues to be an issue in the Northeast. As in the rest of the U.S., the nature and the intensity of this issue varies on a state-by-state basis. Recent attempts in both Minnesota and Wisconsin to address the issue through a formal agreement between the State nurseries and private nursery associations failed when the State Attorney Generals in those states ruled that such an agreement would violate anti-trust laws.

West - The Western States produced around 13% of the seedlings in the U.S. in 1996 (Fig. 2). Federal, state and local government nurseries accounted for over half of the seedling production in this region, but this was down 38% from last year (Moulton and Snellgrove 1996). Since much of the forest land in the West is

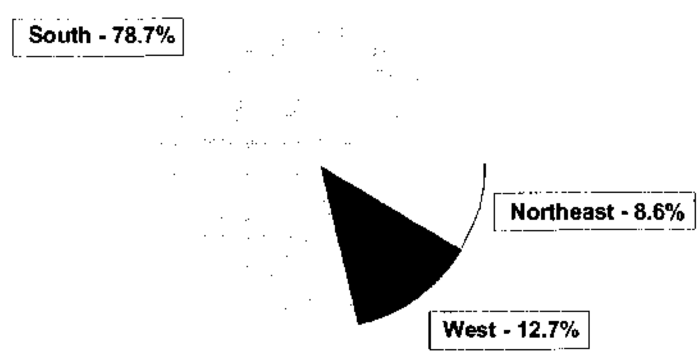

Figure 2. Forest and conservation nurseries produced 1,529,000,000 seedlings in the U.S. in 1996, and the Southern States accounted for over three-quarters of the total production.

managed by the government, this trend can be at least partially explained by the decrease in timber harvesting on Forest Service and other federal government lands (see following section).

In the past decade, there has been a steady increase in the average size of seedlings that are being grown in Pacific Northwest nurseries. Transplants of all types are becoming increasingly popular, especially the 1 + 1 bareroot and container transplant stock types. In the Coast Range of Washington and Oregon where brush competition is intense, foresters are requesting large transplants - from 30 to 50 cm (12 to 18 in.) in height and 5 to 10 mm in caliper (0.2 to 0.4 in.). For example, the Webster Forest Nursery of the Washington Department of Natural Resources sold mostly 2+0 seedlings in the 1986-1987 season but ten years later, the ratio had changed dramatically to over 50% transplants (Table 2).

Table 2 - The proportion of transplants to seedlings increased significantly in the last 10 years in many Northwestern US nurseries (courtesy of T. Ramirez, Washington Dept. of Natural Resources)

Stock Type	1986-1987	1996-1997
2 + 0 Seedlings	90%	48%
Transplants	10%	52%

Several factors have contributed to this trend. Burning restrictions have left more slash on the outplanting sites and fewer mechanical and chemical site preparation options are available. In addition, many foresters are using less herbicide for site preparation because of environmental restrictions. The most important reason, however, is the fact that larger seedlings just grow faster. New "Free-to-Grow" reforestation standards have created a demand for larger stock that will not only survive but will get up and grow quickly. And, foresters are realizing that seedling price is a relatively small part of the overall cost of reforestation.

As was mentioned in the South and Northeastern area, there is an increased demand for native noncommercial plants for a wide variety of uses, especially habitat restoration and diversity plantings. Of particular interest in the Northwest is the "salmon crisis". Restoration of salmon habitat is creating a demand for a variety of native 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 smaller 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. Grass seed has become a major crop at some Western nurseries like the J. Herbert Stone nursery in Oregon. Because so little is known about how to grow many of these plants, federal and state government nurseries are developing propagation protocols that can be shared with other growers.

THE NUMBER AND SIZE OF USDA-FS NURSERIES IS DECREASING

Over the past decade, the largest proportional decrease in seedling production came from federal government nurseries (Fig. 1), which can be explained by the reduction in timber harvest on Forest Service lands in the West. In the mid 1970's, Congress mandated that the Forest Service bring its timber lands to full production and the resulting "reforestation backlog" created a huge demand for seedlings. So, existing Forest Service nurseries were brought to full production and new nurseries were built, including the Albuquerque Nursery in New Mexico and the J. Herbert Stone nursery in Oregon. By the late 1980's, however, the reforestation backlog was gone and the seedling demand from western National Forests has been steadily decreasing ever since.

The Forest Service has been closing nurseries starting back in 1985 with the Mt. Sopris nursery in Colorado (Table 2). The Albuquerque Nursery was a casualty of the artificially inflated reforestation backlog in the Southwest because, although it was designed for a capacity of almost 20 MM seedlings, it only produced 2MM at its peak and then was finally closed in 1990. The nursery phase-out continues as Wind River Nursery in western Washington was closed just this Summer, and the Bend Pine Nursery in Oregon and the Humboldt nursery in California are slated to be closed in the next two years. By the end of the century, there will only be 7 Forest Service nurseries in the US with 5 of them in the Western States (Figure 3).

Table 2 - The USDA Forest Service has been closing nurseries for the past 15 years due to decreased demand for reforestation after timber harvest.

Nursery Closed*	Location	Average Seedling Production (MM)		Year
		Bareroot	Container	
Mt. Sopris	Carbondale, CO	4	1.5	1985
Eveleth	Eveleth, WI	5	0	1987
Albuquerque	Albuquerque, NM	2	0	1990
Wind River	Carson, WA	20	0	1997
Bend Pine	Bend, OR	5	0	(1999)
Humboldt	McKinleyville, CA	12	0	(1999)

* = Parentheses indicate planned closing dates

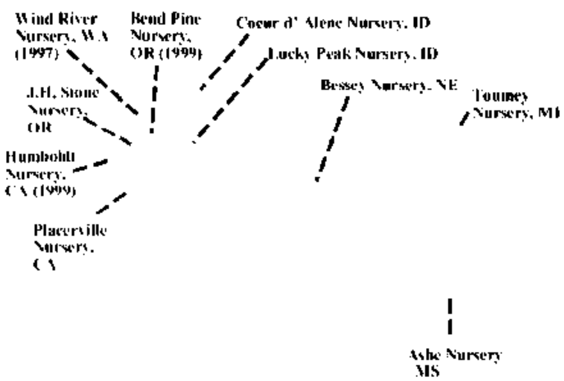

Figure 3. Location of USDA Forest Service nurseries in the U.S. in 1997 (Dates in parentheses indicate planned year of closure).

Because most federal nursery stock is used for reforestation after logging, this reduced demand for seedlings can be attributed directly to the removal of federal lands from the base of commercial forest land. Habitat protection for the spotted owl and other endangered species like the marbled murrelet have halted timber harvest on federal lands across the Pacific Northwest. So, due to these Endangered Species Act restrictions and some overharvesting in the 1980's, timber harvest has plummeted in Oregon and Washington - from 5.2 billion bd ft in 1987 to 401 million bd ft in 1995. This has caused a complete collapse of the reforestation program on some National Forests such as the Umpqua NF in southwestern Oregon where the planting program decreased from 282 MM in 1989 to just 13 MM bd ft in the last 6 years - a decrease of over 95%. Others, like the Olympic National Forest in Washington are outplanting no seedlings for standard reforestation.

The future of timber harvesting and therefore reforestation on the National Forests remains uncertain. Just this year, environmental groups like the Sierra Club and the Native Forest Network have revealed their true intent - "zero cut": which means no more timber harvesting on federal lands.

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Cold Hardiness Measurement to Time Fall Lifting[1]

Richard W. Tinus[2], Karen E. Burr[3]

Abstract—Cold hardiness measurement has been found to be one of the most informative physiological tests developed over the last 15 years, and it is precise and quick enough to guide management decisions. The relationships among cold hardiness and other physiological attributes important to lifting and storage success are known for some species such as ponderosa pine and Douglas-fir, but this information is lacking for many other species important in reforestation. The objective of this study was to determine the relationship between cold hardiness at time of fall lifting and outplanting success. We sought a threshold of cold hardiness that would indicate that seedlings were ready to lift and store, as others have found (cf. Simpson 1990).

At cooperating nurseries, seedlings of several conifer species were lifted at weekly intervals during fall 1996 starting three weeks before the normal lifting season began. Cold hardiness was measured on a subsample and the remaining seedlings were overwintered in cold storage and then outplanted as a simulated forest plantation in spring 1997. In fall 1997 survival and growth were measured.

Preliminary results from the Saratoga Nursery (NY) showed that there was indeed a relationship between cold hardiness at time of lifting and field survival of white and red pine, but this relationship for two Norway spruce seedlots was more complex. White pine could have been lifted one week earlier than when operational lifting began, red pine two weeks earlier, and perhaps one of the two spruce seedlots could have been lifted three weeks earlier. Preliminary results at General Andrews Nursery (MN) showed that white pine was ready to lift when operational lifting began but not earlier. Red pine and an Ontario source of white spruce could have been lifted one week earlier, and a central MN source of white spruce would have had no loss in survival if lifted three weeks earlier.

For northern nurseries that must discontinue fall lifting prematurely because of frozen soil, it will usually be valuable to be able to start lifting a week or two earlier, if it can be done with confidence.

INTRODUCTION

Over the last 20 years physiological tests have been developed as a means to evaluate the condition of tree seedlings (Burr et al. 1990, Glerum 1984). Such tests are especially useful when the trees are not growing, and changes in condition are not readily seen. We have been researching physiological testing for the last 15 years and have found measurement of cold hardiness to be one of the most informative tests, as well as being precise, amenable to rigorous statistical analysis, and quick enough to use for management decisions (Burr et al. 1990).

We know a great deal about the dynamics of cold hardiness in Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), and Engelmann spruce (*Picea engelmannii* (Parry)

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[1]*Tinus, R.W.; Burr, K.E.. 1997. Cold Hardiness Measurement to Time Fall Lifting. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 17-22.*

[2]*Southern Research Station, USD A Forest Service, 2500 S. Knoll, Flagstaff AZ 86001; Tel: 520/556-2104; Fax: 5201556-2130.*

[3]*Coeurd'Alene Nursery, USDA Forest Service, 3600 Nursery Rd., Coeur d'Alene ID 83814.*

Engelmann). We also know how cold hardiness is related to root growth potential, bud dormancy, and general resistance to the stresses associated with lifting, packing, and overwinter storage. For the western species we have studied the threshold for readiness to be lifted and stored is a 50% index of injury of-22°C. In fact, we have built a cold hardiness model which is driven by photoperiod, temperature, and degree of hardiness, and we have used the model successfully to tell the Forest Service Southwest Region when they should ask their contractor to pull and pack their container stock into cold storage, and when the operation needs to be completed (Tinus 1996).

However, we do not have this kind of information for many of the other species important to reforestation, although there is good reason to believe they would respond similarly. Furthermore, many nurseries begin fall lifting based on calendar date and past experience, but without a means to evaluate how year to year variations in climate affect the readiness of seedlings to be lifted. In northern climates especially, it would be valuable to be able to begin fall lifting a week or two earlier, if it could be done with confidence.

Therefore, the objective of the studies we initiated during the fall 1996 lifting season was to determine the correspondence between cold hardiness at time of lifting and outplanting success. We sought a threshold of cold hardiness that could be used as a readily measured indicator of when the trees were ready to lift.

THESTUDY

The two cooperating nurseries in the Northeastern Area were the General Andrews Nursery at Willow River MN and the Saratoga State Nursery, Saratoga Springs NY. The species selected were red pine (*Pinus resinosa* Ait.), white spruce (*Picea glauca* (Moench) Voss), and Norway spruce (*Picea abies* (L.) Karst), which are grown in high volume, and white pine (*Pinus strobus* L.) because of the current attention it is getting as a neglected component of the ecosystem. We used one seed origin of the pines and two of the spruces.

Starting three weeks before the nurseries normally would begin lifting and continuing each week until lifting was complete (or until the soil froze), 112 seedlings of each selected species and seed origin was lifted. One hundred of these were packaged and placed in cold storage using the standard packing and storage technique at that nursery. The other 12 were sent by overnight mail to the Forest Service Coeur d'Alene Nursery's Quality Assurance Laboratory, Coeur d'Alene ID, for measurement of cold hardiness. In addition, the study nurseries reported their daily maximum and minimum temperatures, which were used in an attempt to model cold hardiness as a function of local photoperiod and temperature.

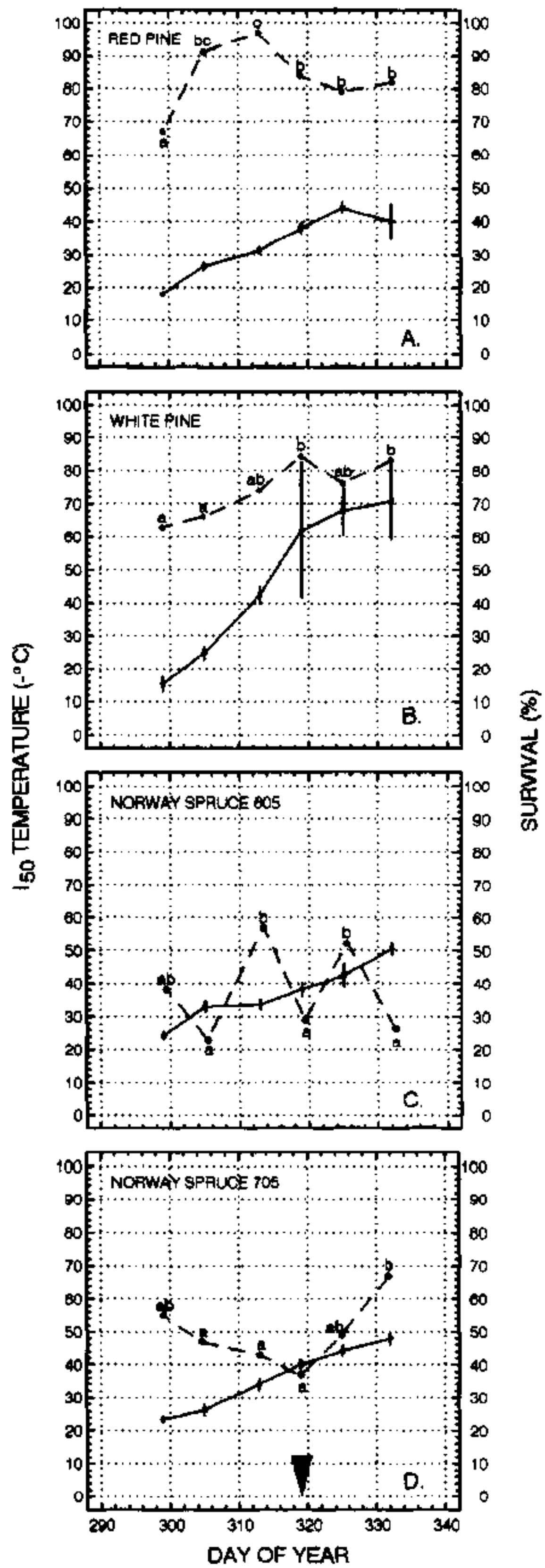
COLD HARDINESS MEASUREMENT

There are a number of ways to measure cold hardiness, but the one selected was the freeze-induced electrolyte leakage test (FIEL), because it is precise, amenable to rigorous statistical analysis, and gives results within three days (Burr et al. 1990).

The procedure is to remove a sample of needles, cut them into 1 cm segments, and put 10 segments in each of 28 culture tubes with 0.5 ml of distilled water. Four of the tubes are put in a refrigerator at about 2°C and not frozen. These are the controls which measure the amount of electrolytes that leak out when there is no damage except for the cut ends of the needle segments. The remaining tubes are placed in a low temperature alcohol bath at -2°C, where the deionized water in the tubes is nucleated to form ice with #8 lead shot chilled to -80°C. The temperature of the bath is then lowered at a rate of 5°C per hour, so that the rate of cooling does not confound the effects of the actual test temperature. At each of six preselected temperatures four tubes are removed and placed in a refrigerator to thaw. The temperatures are selected to span the expected range from no damage to complete kill, so that the relationship between temperature and injury can be determined. After thawing, distilled water is added to bring the volume to 6 ml to aid measurement, and all of the tubes are placed on a shaker to incubate 20 hours overnight.

The next day, conductivity of the water in each tube is measured. The reading measures the electrolytes that have leaked from the tissue in response to damage from cold. Next, the tubes are boiled to kill the tissue completely, and they are returned to the shaker overnight. On the third day the conductivity is measured again. This time the reading measures the total electrolytes present.

Figure 1. Cold hardiness at time of lifting (solid line) and field survival (dashed line) at Saratoga State Nursery (NY) of (A) red pine, (B) white pine, and Norway spruce (C) lot 605, and (D) lot 705. Vertical lines (cold hardiness) are 95% confidence intervals; if they do not overlap, data points are deemed significantly different. Letters indicate differences at p = .05 by the Chi squared test; data points that do not have the same letter are significantly different. Arrow indicates date when operational lifting began.



From this body of data an index of injury is calculated which represents the percent of electrolytes that leaked out in response to low temperature damage. From this we calculate the temperature that causes a 50% index of injury and its 95% confidence level. In terms of avoiding damage in the nursery, this is not the figure to use, because, of course, 50% injury is much greater than is acceptable[4] (I_{50}), but we use it for comparisons because we can estimate it most precisely with the greatest level of confidence.

The seedlings that had been lifted at weekly intervals and stored overwinter were outplanted in May 1997 at each nursery in a simulated forest planting. The seed sources and lift dates were divided and planted as four randomized blocks for statistical purposes.

COLD HARDINESS RESULTS

With regard to the spruces, the behavior of the two sources of Norway spruce in New York was indistinguishable, and they were hardier than the pines from the beginning (Fig. 1 C & D). However, in Minnesota the two sources of white spruce hardened at the same rate, but the Ontario source hardened 15 days behind the central MN source (Fig. 2 C & D). In both MN and NY (not shown) throughout the measurement period, the rate of hardening of the spruces was rapid and linear (Fig. 3).

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[4] A 30% index of injury is approximately equivalent to an LT_{50} in a whole plant freeze test, and a 10% index of injury or less represents damage the seedlings can usually recover from.

The red and white pine in Minnesota behaved almost identically (Fig. 2 A & B). Both had little hardiness when measurements began, but gained it slowly over the next two weeks and thereafter more rapidly. Using the -22°C criterion for southwestern conifers, the pines would not have been ready until October 14, which is when the nursery normally begins lifting. However, the pines in New York hardened at different rates. The white pine hardened much faster than the red pine, but by the end of lifting both appeared to be reaching maximum hardiness, -40°C for red pine and -70°C for the white pine (Fig. 2 A&B).

OUTPLANTING SURVIVAL

Survival reported here is preliminary, because the tally was taken in NY the last week of July and in MN on August 11. Additional mortality and growth is expected by the end of the growing season.

Survival of red pine in New York lifted when operational lifting began (day #319) was high. Although it might have been even higher if lifted one or two weeks earlier, corresponding to an I_{50} of-26°C, this may not be biologically significant. However, three weeks earlier (Fig. 1 A, first lift date) is clearly too soon.

Plantation survival of white pine in New York lifted when operational lifting began (day #319) was high and remained so for the duration of lifting (Fig. 1B). It could have been lifted a week earlier without significant loss of survival, corresponding to an I_{50} of about -40°C, but not two or three weeks earlier.

Survival of Norway spruce source 605 also showed an unusual pattern (Fig. 1C). Significant week to week changes in cold hardiness and root growth potential have been observed a number of times before, but this is the first time we have seen it in field survival. There have been many lifting window studies in the past, but seedling samples have usually been lifted at two week or monthly intervals, so these studies would not have picked up the weekly variation seen here (cf. Heidmann and Haase 1991). Overall, there was no progressive change in survival, so disregarding the week to week variation, lifting of the 605 source could have started three weeks earlier without loss of field survival, corresponding to an I_{50} of-23°C.

Survival of Norway spruce was very poor, probably because of the very sandy site, and rainfall from the time of planting in May through the last week in July was about half of normal. Survival of source 705 was at its lowest when operational lifting began and increased significantly by the end of lifting (Fig. 1D). Survival of seedlings lifted up to three weeks earlier was at least as good as when operational lifting began.

At General Andrews Nursery white pine was ready to lift when operational lifting began (day #290), but not earlier, corresponding to an I_{50} of-30°C (Fig. 2B). Red pine could have been lifted a week earlier when it had an I_{50} of-15°C (Fig. 2A). The Ontario source of white spruce could have been lifted one week earlier when it had I_{50} of-23°C, but not sooner (Fig. 2D). The central MN source of white spruce could have been lifted up to three weeks earlier with no loss in survival, corresponding to an I_{50} of-25°C (Fig. 2C). However, with one exception survival throughout the lifting period was not very good, probably due to the site being very sandy, although summer rainfall was average.

DISCUSSION AND CONCLUSIONS

Results reported here are preliminary for two reasons. First, in order to present the material at the nursery meeting, survival tallies were made well before the end of the growing season. First season growth has yet to be measured, and some additional mortality can be expected, although this is likely to increase, rather than blur, the differences in survival between early and later lifted stock. Second, the first year of a study like this one must be considered a case history until it can be repeated.

The rate of hardening of most of the species and seed lots was very linear and did not appear to respond to short term fluctuations in the local temperature (Fig. 3 for example). If this is repeatable year to year, it will simplify modeling of weather data to predict cold hardiness. It may become possible to take one or a few cold hardiness measurements early in the season and project hardening in time to a benchmark I_{50} temperature when the seedlings will be ready to lift. Results from the first year of this study are very promising.

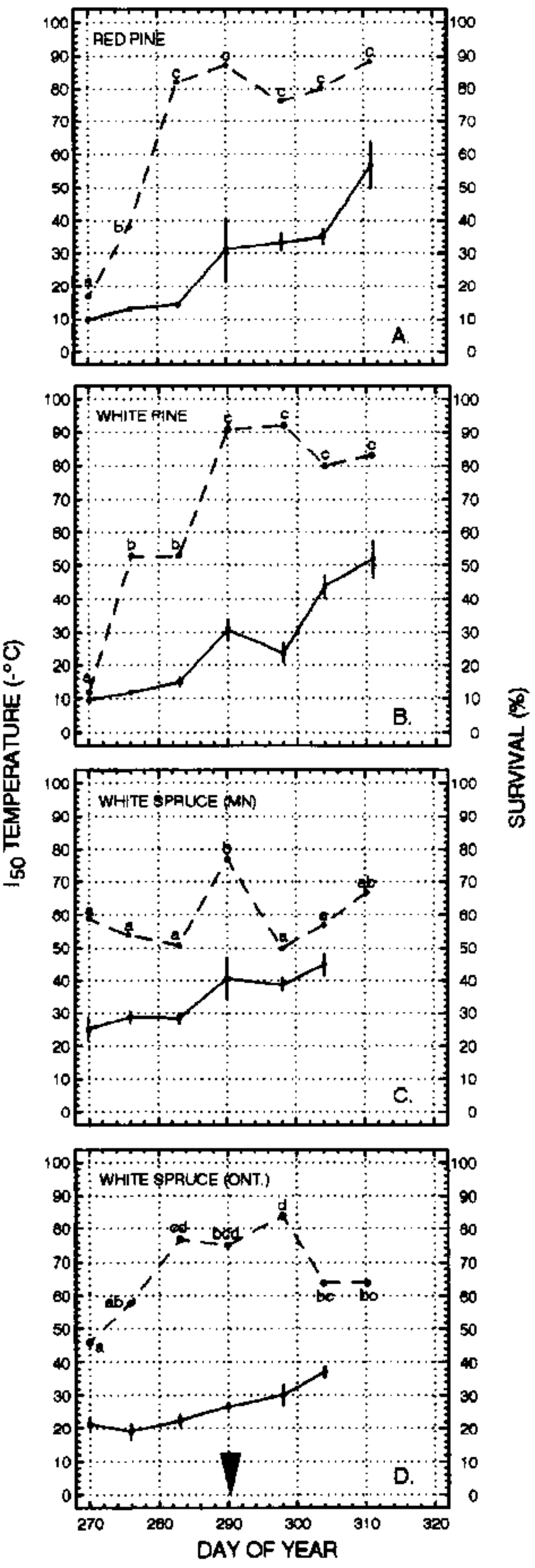

Figure 2. Cold hardiness (solid line) at time of lifting and field survival (dashed line) at General Andrews Nursery (MN) of (A) red pine, (B) white pine, and white spruce (C) from central MN, and (D) from Ontario. Vertical lines (cold hardiness) are 95% confidence intervals; if they do not overlap, data points are deemed significantly different. Letters indicate differences at p = .05 by the Chi squared test; data points that do not have the same letter are significantly different. Arrow indicates date when operational lifting began.

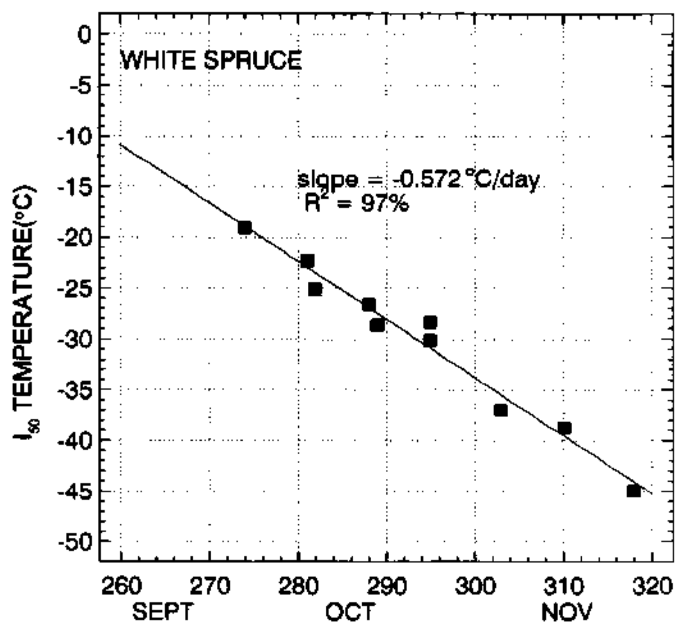

Figure 3. Regression of cold hardiness of MN white spruce versus day of year 1996 showing a high degree of linearity. Both seedlots are represented, but the Ontario source has been moved earlier by 15 days to overlap the MN source with maximum R^2.

ACKNOWLEDGEMENTS

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Soil Tillage Practices and Root Disease Management[1]

Jennifer Juzwik[2], R. R. Allmaras[3], and K. M. Gust[4]

Abstract - Field studies were conducted in North Central states nurseries to investigate the soil conditions resulting from operational tillage and their potential effect on root disease development. Compacted soil layers, or hard-pans, were found in pine fields of two nurseries that use rotary tillers after sub-soiling but prior to sowing and use moldboard plows for incorporating cover crop residue. Water flow through undisturbed soil in rotary tiller - associated pans (10 to 15-cm depth) was slower than in non-compacted soils above and below the pan and compared to non-compacted areas of the fields. Vertical distribution profiles of soil-borne *Fusarium* spp. at each of five nurseries reflected the type of tillage implement used to incorporate cover crop material that ultimately served as substrate for fungal population increase. When a moldboard plow was used for incorporation and soil fumigation subsequently conducted, depth of fumigation was found to be inadequate for reducing *Fusarium* levels below 18 cm in methyl bromide - chloropicrin, metam sodium, and dazomet (when incorporated by rotary tiller) treated fields. Implications of these results to management of root disease in pine fields are discussed.

INTRODUCTION

Root disease can cause significant mortality of conifer nursery seedlings and negatively affect growth and quality of live seedlings remaining for lifting and shipping. Cultural practices, especially those involving soil management, are important in managing root diseases. Practices that influence the occurrence and level of these diseases include soil tillage, soil water management, mulching, sowing of infested seed, fertilization, and soil fumigation (Sutherland and Anderson 1980). The latter is the pest management option often selected for use in bare-root nursery fields with a history of root disease. However, the availability and use of a single pest management tool that focuses on the pest(s) may lead nursery managers away from considering the cultural conditions that may have led to the disease situation (Sullivan 1997). For example, tillage implements may produce compacted soil layers that impede internal drainage in a soil profile. Prolonged periods of wet soil conditions may then promote root rot development (Juzwik etal. 1994).

Studies were conducted in five forest nurseries in three North Central states from 1994 - 96 to: 1) investigate physical and biological soil conditions resulting from standard cultural practices and their relationship to root disease development, and 2) investigate effects of incorporation implement on dazomet fumigation efficacy. Results and application of these studies are summarized in this paper.

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[2]*USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, MN 55108; Tel: 612/649-5114; Fax: 612/649-5285; e-mail: (juzwi001@maroon.tc.umn.edu).*

[3]*USDA Agricultural Research Service, 439 Borlaug Hall, University of Minnesota, St. Paul, MN 55108; Tel: 612/625-1742; e-mail: (allmaras@soils. umn. edu).*

[4]*former Graduate Student, Dept. of Plant Pathology, 495 Borlaug Hall, University of Minnesota, St. Paul, MN 55108.*

SOIL COMPACTION AND IMPEDED DRAINAGE

Resistance of nursery soils to penetration was measured at 15 mm increments from the soil surface to a 42 cm depth in 2 + 0 pine fields at three nurseries in 1994 - 95. Soils in the surveyed fields ranged from loamy sands (Minnesota nursery) to sandy loams (Wisconsin nursery) to sand soils (Michigan nursery). The fields were irrigated to approach saturation and systematic measurements were made with a highly sensitive cone penetrometer within 2 hours after irrigation ceased.

Significant increases in the force required to insert the cone penetrometer at a controlled slow speed is indicative of compacted soil layers. The penetrometer readings through the vertical soil profile in four fields at the Minnesota and Wisconsin nurseries revealed two peaks of increased resistance (Figure 1). No such peaks were evident in the Michigan field. A gradual increase in resistance is expected in all fields due to increasing overburden weight as soil depth increases.

The compacted layer detected at approximately 10 to 15 cm depth in the Minnesota and Wisconsin fields were attributed to use of rotary tillers in the fields. The pans were formed after only one or two tillage events that occurred just prior to establishment of the pine crop, but after sub-soiling had been performed. The second compacted layer occurred between 30 and 36 cm and was most evident in the Wisconsin nursery fields. These hard-pans were attributed to the use of moldboard plows (30 cm maximum operating depth) for incorporation of cover crops in the two nurseries. These pans tended to persist despite sub-soiling operations conducted after cover crop incorporation. The lack of distinct compacted layers in the Michigan nursery field is attributed to the sole use of a tandem, double-gang disc for all soil tillage operations. In sumary, then, the differences in pan occurrence and depth reflected the different tillage implements used at the nurseries for at least five years.

Depending on the severity of the compaction within observed compacted soil layers, downward water movement may be retarded enough to ultimately contribute to higher disease severity in areas of fields where such compaction occurs (Schwalm 1973; Juzwik et al. 1994; Juzwik and Rugg 1996). Root disease was observed in a portion of the white pine field at the

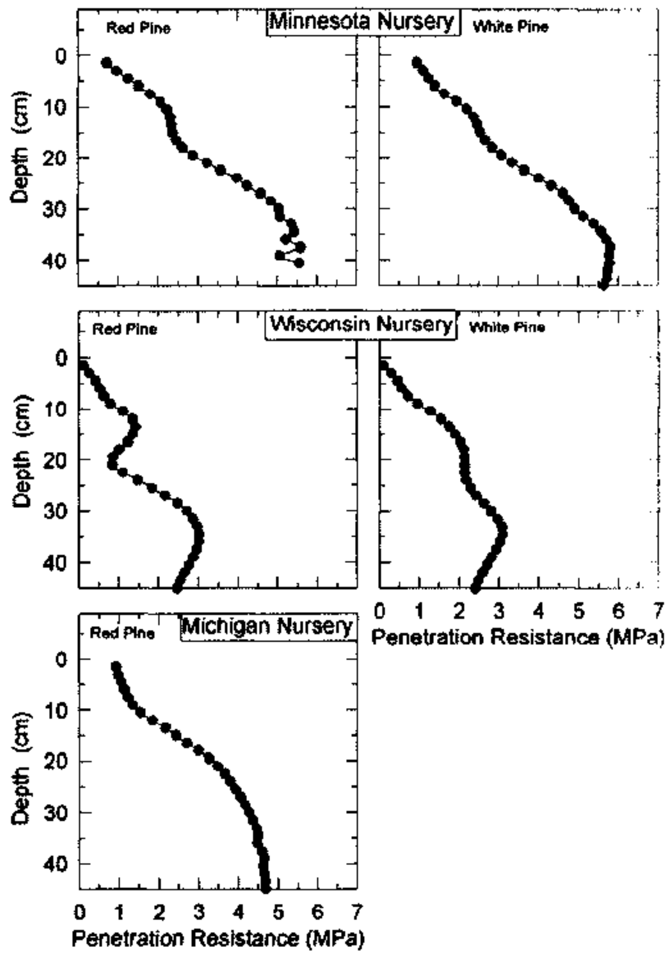

Figure 1. Penetrometer resistance as a function of soil depth under 2 + 0 pine seedlings at three bareroot forest tree nurseries.

Minnesota nursery in which penetrometer measurements had been taken. Rate of water movement through the soil profile in affected portions of the field was compared with that in adjacent unaffected areas. Undisturbed soil cores (5 cm long x 5 cm diameter) were removed from five different layers in the vertical profile and rate of water movement through the cores was determined in the laboratory for measuring saturated hydraulic conductivity, or K_{sat} (Klute and Dirksen 1986). The K_{sat} measurements for soils in the affected areas were significantly lower (i.e. slower rate of water flow) in all depth increments tested than those for the same depth increments in soils of the unaffected plots (Table 1).

The rate of vertical water movement through soils in the Wisconsin nursery was also examined using the same methodology. The K_{sat} in the 8 to 13-cm depth increment (the tiller attributed compacted layer previously

Table 1. Rate of water flow (K_{sat}) through undisturbed soil cores taken from different depths in white pine field of the Minnesota nursery.

Soil Depth (cm)	Root Disease Affected Plots (cm/hr)	Non-Affected Plots (cm/hr)
0-5	14.3	20.9
5-10	14.8	19.9
10-15	13.8	20.1
15-20	11.6	18.8
23-28	11.7	18.9

mentioned) in the white pine field was significantly lower (ave. 14.4 cm/hr) than the value expected for the soil type when no soil compaction is found (ave. 18.4 cm/hr).

In summary, the K_{sat} data for white pine fields in both nurseries suggest that impeded drainage following significant irrigation or rainfall events can cause sufficient physiological stress to predispose seedlings to disease development (Allmaras et al. 1988).

COVER CROP RESIDUE PLACEMENT AND BUILD-UP OF SOIL-BORNE *FUSARIUM*

Populations of *Fusarium* spp. were determined for soils in the same nursery fields used for the penetration resistance studies. The number of propagules (colony forming units, cfu) in 6-cm depth increments for the 0 to 42-cm depth zone were determined for the five 2 + 0 pine fields.

The vertical *Fusarium* population profiles were similar in the Minnesota and Wisconsin nursery fields, while a different profile was found for the Michigan field (Figure 2). Operational fumigation had been conducted in the Minnesota (metam sodium) and the Wisconsin nursery (methyl bromide - chloropicrin) prior to sowing of the pine crop. Fumigation was not used in the Michigan field.

The population peaks observed in the 0 to 6-cm layer in the Minnesota and Wisconsin fields were attributed to build-up in *Fusarium* spp. that occurred after soil fumigation and is explainable by: 1) re-infestation via blowing soil and infested seed (Vaartaja 1962; Ocamb and Juzwik 1993), and 2) subsequent proliferation of introduced *Fusarium* on carbon sources from growing seedling roots and surface mulch. The deeper population peak (18 to 24-cm depth) is attributed to: 1) *Fusarium* that survived fumigation treatment (probably because propagules were below the effective fumigation zone), and 2) build-up of the *Fusarium* on carbon sources from cover crop material incorporated by moldboard plows prior to fumigation and sowing of the pine crop. Previous studies (e.g. Staricka et al. 1991) have shown that the majority of surface residue incorporated by moldboard plows is deposited just above the maximum working depth of the implement.

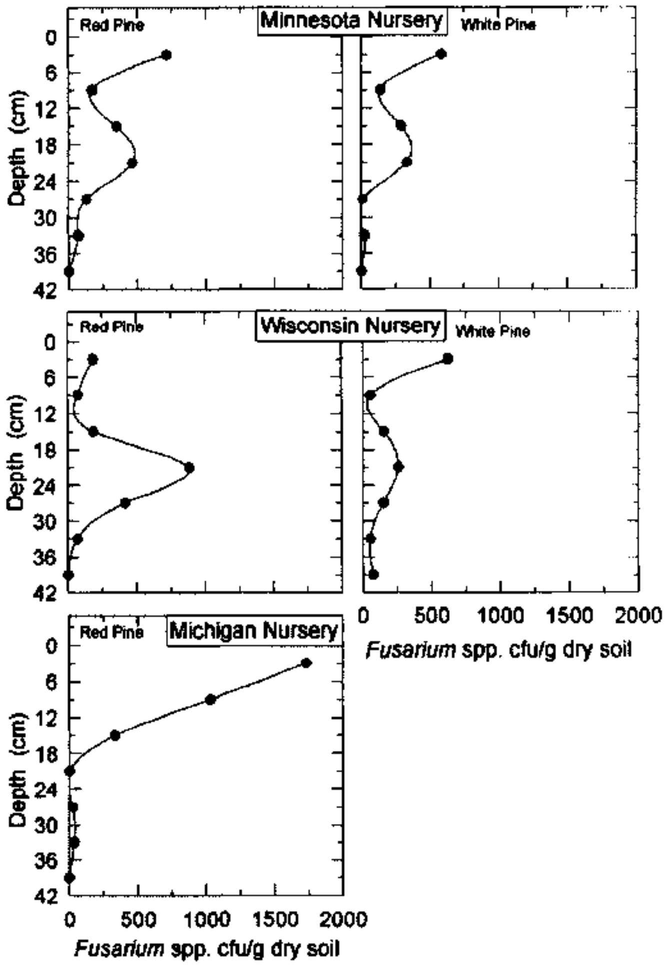

Figure 2. Populations of Fusarium spp. in bulk soil from various depths in 2 + 0 pine seedling plots in three bareroot forest tree nurseries.

The vertical *Fusarium* population profile in the Michigan nursery was highest at the soil surface and decreased to negligible levels in the 18 to 24-cm depth increment. This observed pattern is attributed to several events. First, the absence of fumigation is one reason for the higher levels of *Fusarium* observed in the 0 to 18-cm zone. Secondly, the surface mulch and proliferating roots of seedlings during the 1 + 0 and 2 + 0 years served as substrate for *Fusarium* build-up in the upper depth increments. Finally, the cover crop material incorporated by a disc also served as substrate for *Fusarium* increase. Incorporation patterns of surface residue by a disc differs from the incorporation patterns characteristic of moldboard plows (Staricka et al. 1991; Thompson et al. 1994). The steadily declining *Fusarium* population observed from 0 to 21 -cm depth is consistent with the decreasing concentration of incorporated cover crop material with depth when a disc is used for incorporation.

In summary, vertical distribution profiles of soil-borne *Fusarium* spp. at each nursery reflected the type of tillage implement used to incorporate cover crop material which ultimately served as substrate for fungal population increase. Negligible levels of *Fusarium* spp. were found below the maximum depth of tillage implement disturbance in all locations.

FUMIGATION DEPTH AND SOIL-BORNE FUNGAL POPULATION PROFILES

The effect of maximum fumigation depth on vertical distribution of *Fusarium* populations in nursery soils was determined during dazomet incorporation trials conducted at a second Wisconsin nursery and a second Michigan nursery in 1994 and 1995.

In the Wisconsin nursery trial, 560 kg/ha of dazomet was applied to the soil surface with a Gandy spreader in a field slated for white pine seedling production. The granular material was immediately incorporated into the sandy loam soil (with soil moisture content at 60% of field capacity) using either a rotary tiller with 22 cm long bent tines or a spading machine with six 13 cm wide by 18 cm long spades. The surface was then rolled and a water seal maintained for two weeks using overhead irrigation. Populations of *Fusarium* spp. in the soil were determined immediately prior to fumigation (mid-August), four weeks after fumigation, and in August of the second growing season of the white pine crop.

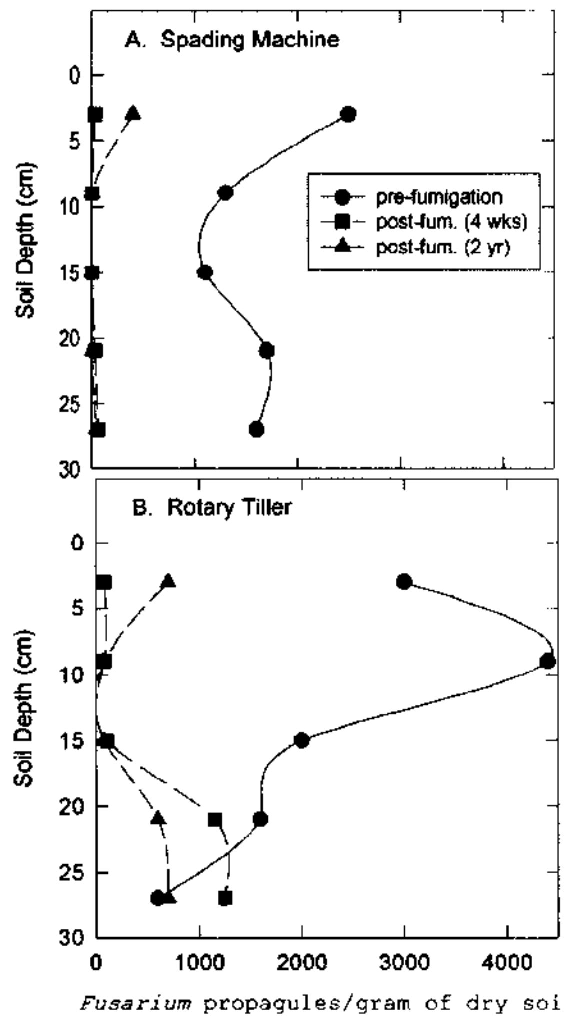

Figure 3. Vertical profile of *Fusarium* spp. soil populations before and after fumigation in Hayward Nursery dazomet incorporation trial. A. Spading machine has 25 cm effective incorporation depth. B. Rotary tiller has 12 cm effective incorporation depth.

The operational incorporation depth of the spading machine was known to be twice that of the rotary tiller used (Juzwik et al. 1997). The deeper dazomet incorporation by the spading machine resulted in excellent and sustained reduction in *Fusarium* propagules from 6 to 30 cm (Figure 3). In contrast, the rotary tiller incorporation of dazomet resulted in similar and sustained reduction in fungal populations only between 6 and 18 cm. Since white pine roots often reach and exceed 18 cm early in the 2 + 0 year in this particular nursery, root rot would be expected to occur in the lower portion of seedlings growing in such a field. Furthermore, one of the reasons dazomet fumigation may not give adequate control of root rot in forest nurseries may be due to the use of similar rotary tillers for product incorporation.

Knowledge of the vertical distribution of potential pathogenic fungi in nursery soil would be useful in determining fumigant rate and depth required when fumigation is utilized. In the Hayward trial field, significant levels of *Fusarium* spp. (> 500 CFU/gram of dry soil) were detected from 0 to 30-cm depth. This deep distribution is probably due to the fact that a moldboard plow was used to incorporate cover crop residue in that particular field prior to fumigation. Thus, just knowing that a moldboard plow was used for residue incorporation would suggest that fumigation depth required for effective *Fusarium* control would be 25 cm or greater. Results of a second fumigation trial conducted at Tourney nursery, Watersmeet, MI, support this reasoning. Specifically, the pre-fumigation populations of *Fusarium* in the soil were significant only between 0 and 15 cm (Figure 4). This reflects the fact that a disc was used to incorporate cover crop residue prior to the fumigation. In comparing dazomet incorporation results for the three different implements tested at Tourney, all were equally as effective in placing dazomet in the 0 to 15-cm soil zone as shown by the similar reductions in *Fusarium* levels four weeks after fumigation and one year later during the 1 +0 growing season of the white pine crop.

In summary, consideration should be given to where pathogenic organisms are most likely building up in the soil profile before fumigation is used. Extensive survey of vertical soil-borne fungal populations in nursery fields scheduled for fumigation is not feasible or practical. However, results of these studies suggest that by just considering what tillage implements are used to incorporate residues will give a good idea of maximum depth of fumigation required for control of potential pathogens. Likewise, Staricka et al. (1991) could predict the depth of crop residue placement merely by knowledge of the tillage tool(s) used. Ideally, shallower residue distribution such as that associated with disc incorporation would be desirable for fields scheduled for chemical fumigation. A lower rate of chemical fumigation would also be possible if one is dealing with soil volume in the 0 to 15-cm soil zone compared to higher rate needed for effective fumigation of a greater soil volume contained in the 0 to 30-cm zone.

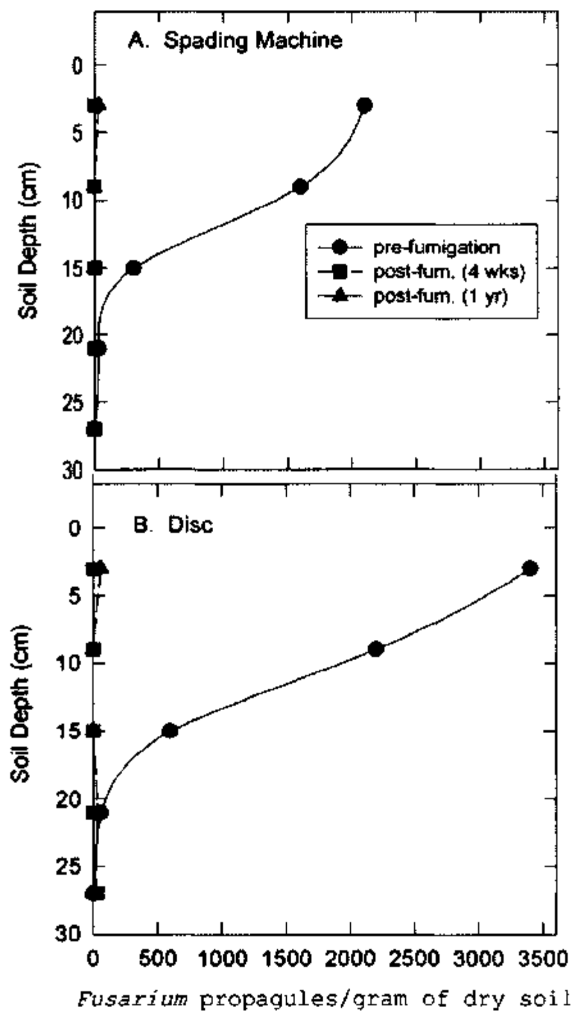

Figure 4. Vertical profile of *Fusarium* spp. soil populations before and after fumigation in Tourney Nursery dazomet incorporation trial. A) Spading machine has 25 cm effective incorporation depth. B) Disc has 15 cm effective incorporation depth.

CONCLUSIONS

Nursery managers could use tillage to control depth placement of cover crop residue and subsequent build-up of fungal propagules, adjust tillage practices to prevent tillage pans within the seedling root zone (Allmaras et al. 1994), and maintain near field capacity soil moisture levels for seedling growth in their integrated management of root disease in pine crops. Consideration of tillage practices effects on residue placement can also be the basis for more effective and wise use of chemical fumigation.

ACKNOWLEDGEMENTS

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Incorporation of Surface-Applied Materials by Tillage Implements[1]

D. L. Stenlund[2], J. Juzwik[3], R. R. Allmaras[4], and S. M. Copeland[5]

Maximum depth and uniformity of incorporation of surface-applied materials by rotary tillers, a spading machine, and a disc cultivator were compared in Wisconsin nursery (loamy sand soil) and Michigan nursery (sandy loam soil) trials using ceramic sphere tracers (I - 3 mm dia). The tracers or beads were spread uniformly over the soil surface and different tillage implements were then operated through these areas as they traveled the length of each study field. Results of these trials are applicable to situations involving incorporation of such materials as granular fumigants or herbicides, granular fertilizers, peat, and cover crop residues.

Results:

The maximum depth of consistent bead incorporation for each implement in the Hayward Nursery (WI), trial as measured across the working width of each was:

Gramegna spading machine	10 inches
Fobro Kultipak 1700 rotary tiller;	5 inches
Kuhn rotary tiller	5 inches
Northwest rotary tiller	8 inches

The "peaks and valleys" observed in tracer recovery in the vertical soil profile across the width of the implement path of travel mirrored the number of tools (i.e. flanges or spades) per implement. Based on amount of beads spread on the surface, one bead should have been recovered per $^{3}/_{4}$-inch depth increment to a 12-inch depth if a completely uniform distribution were achieved. In comparison to this standard, the Gramegna gave a distribution closest to the ideal with one to seven beads recovered per depth increment down to 10 inches compared to that found for the other equipment. The second best implement for uniformly incorporating beads was the Northwest tiller. Incorporation by all three rotary tillers led to concentrated clusters of beads, but the longer length of the Northwest tiller tines resulted in deeper occurrence of those clusters.

In the Tourney nursery trial (Watersmeet, MI), the maximum depths (inches) of consistent tracer incorporation across the sampled width for the implements (full width for the Gramegna and Fobro; half width for the disc) were:

Gramegna Spading Machine	7.0 inches
Fobro 1250	3.5 inches
John Deere disc cultivator	5.0 inches

The most consistent distribution down to 5 inches across the sampled increment width was found for the disc

[1]Stenlund, D.L.; Juzwik, J.; Allmaras, R.R.; and Copeland, S.M. 1997. Incorporation of Surface-Applied Materials by Tillage Implements. In: Landis, T.D.; Thomspon, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 29-30.

[2]Minnesota Department of Transportation, Environmental Services Division, 3485 Hadley Ave. N., Oakdale, MN, 55128; Tel: 612/ 779-5638; Fax: 612/779-5109; e-mail: stenl001@maroon.tc.umn.edu.

[3]USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Ave, St. Paul, MN 55108; Tel: 612/649-5114: Fax 612/649-5285; email: (juzwi001@maroon.tc.umn.edu).

[4] USDA Agricultural Research Service, 430 Borlaug Hall, University of Minnesota, St. Paul, MN 55108; Tel: 612/625-1742

[5]Soil Scientist, USDA Agricultural Research Service, 439 Borlaug Hall, University of Minnesoa, St. Paul, MN 55108

which had been run twice through the trial plots in opposite directions. The Gramegna also gave fairly uniform distribution to 7 inches but with an unexplained gap in the center of the working width that was consistent in each of the six replicate plots.

Discussion:

The maximum depth of incorporation and soil disturbance in these and related dazomet trials (not discussed here) was greatest for the spading machine in trials at the two nurseries. Differences in penetration depths were observed between the nurseries for the Fobro and the Gramegna, and these were attributed to pre-incorporation soil conditions, i.e. no tillage just prior to incorporation in the Wisconsin nursery versus tillage with a disc just prior to the Michigan incorporation trial. The more shallow maximum depth of consistent bead incorporation in the Michigan nursery may also be due to the increased ground speed of implement operation (2 mph for all three implements) compared to the Wisconsin trial in which ground speed varied according to implement based on equipment distributors' recommendations. The most uniform distribution of surface applied materials was obtained using the spading machine when comparing the two trials.

Application:

Selection of tillage implement to use for incorporating surface applied material should be based on the result desired. For instance, vertical distribution of target pests should be considered when incorporating the granular fumigant dazomet. Nursery operations staff should also remember that soil compaction may also result from tillage implement use in moderate to high soil moisture conditions, particularly with rotary tillers with sharper tine angles.

Preliminary Evaluation of Fungicides for Control of Damping-Off Disease in Container Grown Red Pine Seedlings[1]

Jill D. Pokorny[2] and Jana K. Rykhu[2]

INTRODUCTION

Historically the fungicide benomyl has been widely used by greenhouse managers to control damping- off diseases in container grown conifer seedlings. In 1991, product labeling for benomyl underwent major changes and all greenhouse and ornamental uses were eliminated. Greenhouse managers, no longer able to use benomyl, were faced with the immediate need to identify effective alternative fungicides. This study was undertaken to investigate the effectiveness of several alternative fungicides in controlling damping-off diseases in red pine seedlings, grown under operational greenhouse conditions and naturally occurring disease pressure.

The decision to design this study using operational greenhouse conditions and naturally occurring disease pressure was made in response to the immediate need to identify alternative fungicides and transfer this information quickly to greenhouse managers, and the lack of pathological information relating to disease development. Baseline data regarding the species of pathogenic fungi occurring on red pine, and specific disease inoculum levels that incite disease symptoms are unknown, and the determination of such data would have required many months of laboratory and greenhouse testing.

Seedlings were grown using cultural practices consistent with common greenhouse operations including the reuse of surface disinfected styroblocks and the sowing of seed which received no surface washing or fungicide seed treatment. The seedlings were grown under conditions of naturally occurring disease pressure and were not artificially inoculated with pathogenic fungi. It was speculated that disease inoculum would be present in cracks and crevices of reused styroblocks and in/on seeds. Damping-off and root rot disease did develop, and disease pressure was sufficient to cause a significant reduction in seedling quality in the untreated control treatment when compared to the fungicide treatments.

The fungicides tested in this study were selected based on their availability for purchase and their efficacy against fungi that commonly incite damping-off disease in container grown conifer seedlings. For example, Banrot has demonstrated efficacy against damping-off and root and stem rot diseases caused by *Pythium, Phytophthora, Fusarium, Rhizoctonia,* and *Thielaviopsis* in ornamental and nursery crops. Cleary's 3336, containing the active ingredient thiophanate-methyl, breaks down to the same active ingredient as benomyl and has activity against species of *Fusarium* and *Rhizoctonia* spp.

MATERIALS AND METHODS

Red pine seeds (lot# 0118-2), collected from seed collection stands in the Chequamegon National Forest, were used in this study. Seeds were sown in 240 cell styroblocks, with a soil volume of 2.3 cubic inches per cell. Seedlings were maintained in the greenhouse for 4

[1]*Pokorny, J.D. and Rykhu, J.K. 1997. Preliminary Evaluation of Fungicides for Control of Damping-Off Disease in Container Grown Red Pine Seedlings. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 31-33.*

[2]*State and Private Forestry, USDA Forest Service, 1992 FolwellAve., St. Paul, MN 55108; Tel: 612/649-5247.*

months and fertilized twice weekly with Peter's Starter (9-45-15) during the first month after germination and weekly thereafter with Peter's Finisher (4-25-35). Fungicide treatments were applied at sowing and at 1 month intervals for a total of 4 applications per treatment. Treatments included: 1) Banrot (8 oz./100 gal.), 2) Cleary 3336 (1.5 lb./200 gal.) and 3) untreated control. Treatments were arranged in a randomized block design, with 3 replications and 240 seedlings per replication.

Seedlings were examined at 2-week intervals to determine seedling survival counts, and all seedlings exhibiting symptoms of damping-off were collected and cultured to determine the presence of root infecting fungi. Four months after planting, seedling height, caliper, and stem and root dry weights were determined on 20 randomly selected seedlings per replication, for a total of 60 seedlings per treatment. Data were analyzed using the statistical program Statistix. Analyses of variance were performed and treatment comparisons were made using the HSDtest ($p = 0.05$).

Table 1. Fungicide effectiveness of Banrot and Cleary's 3336, applied as soil drenches, on mean seedling survival of container grown red pine seedlings.

Treatments	Mean Seedling Survival
Banrot 40 WP	238.0 a[1]
Cleary's 3336 50 WP	238.3 a
Untreated Control	230.3 a

[1] means followed by the same letter do not differ significantly (HSD, p= 0.05)

RESULTS

Although no significant differences were observed in seedling survival between treatments (Table 1), significant differences were observed between treatments for several seedling quality parameters measured including seedling height, caliper, stem dry weights and root dry weights (Table 2). All fungicide treatments resulted in significantly taller seedlings than the untreated control treatment. All fungicide treatments resulted in significantly increased stem caliper measurements than the untreated control treatment. All fungicide treatments resulted in significantly increased stem and root dry weights than the untreated control treatment.

Fungi associated with symptomatic seedlings were recorded (Table 3). A total of 38 seedlings exhibited symptoms of damping-off during the 4 month duration of the study, across all treatments. All symptomatic seedlings were cultured and Pythium sp. and Fusarium sp. were the most frequently isolated fungi. Pythium sp. and Fusarium sp. were isolated from 82% and 26% of the total number of symptomatic seedlings cultured, respectively.

DISCUSSION

Banrot 40 WP and Cleary's 3336 50 WP, applied as soil drenches at monthly intervals, were effective in producing significantly higher quality seedlings than the untreated control treatment, when seedlings were grown under operational greenhouse conditions and naturally occurring disease pressure. It should be noted that the fertilization and irrigation schedules implemented in this study were designed to promote seedling health and the avoidance of over or under watering.

Table 2. Fungicide effectiveness of Banrot and Cleary's 3336, applied as soil drenches, on several seedling quality parameters of container grown red pine seedlings.

Treatments	Mean Seedling Height[1]	Mean Stem Caliper[2]	Mean Root Dry Weights[3]	Mean Stem Dry Weights[3]
Banrot 40 WP	8.06 a[4]	1.00 a	0.37 a	1.40 a
Cleary 3336 50 WP	7.74 a	1.02 a	0.43 a	1.30 a
Untreated Control	5.88 b	0.81 b	0.27 b	0.53 b

[1] measured in cm, [2] measured in mm, [3] measured in grams, [4] means followed by the same letter do not differ significantly (HSD, p=0.0)

Table 3. Number of symptomatic seedlings, by treatment, that yielded Pythium and Fusarium sp. in culture.

Treatment	Pythium sp.	Fusarium sp.	Total Number of Symptomatic Seedlings
Banrot 40 WP	4	0	6
Cleary's 3336 50 WP	3	0	3
Untreated Control	24	10	29
Total # of Seedlings	31	10	38
% of Total Seedlings	82	26	100

The fact that seedlings were not challenged with a specific amount of disease inoculum, and disease inoculum levels could vary between individual styroblocks, prevents us from drawing conclusions regarding fungicide efficacy and specific inoculum densities levels. Further studies should be conducted that better control the variability in disease inoculum levels. However, before this next phase of testing can be accomplished, the pathogenic species of Pythium and Fusarium must be identified, and inoculum densities that incite disease must be determined. Care must be taken to determine inoculum densities that result in disease incidence representative of those encountered under operational greenhouse conditions, but that do not overload the system.

SUMMARY

This study provides information on the fungi which contribute to root disease of red pine seedlings growing under operational greenhouse conditions and preliminary efficacy data for two soil-applied fungicides in controlling damping-off disease. Successful management of damping-off diseases in container grown conifer seedlings requires an integration of control strategies that include proper cultural practices and the use of fungicides. Cultural practices must be implemented that reduce the presence of disease inoculum and promote an environment conducive to seedling health. Following is an example of an integrated approach to the management of damping-off diseases in container grown conifer seedlings:

1. Clean and disinfect styroblocks/containers.

- Rinse containers with a high pressure water wash (100 psi) to physically remove planting media, roots, algae and otherdebris.
- Disinfect containers using a proven method:

-bleach	0.5% solution for 10 seconds, buffered to pH 7.0
- steam	95 °C for 1 minute
-hot water	80 °C for 10 seconds
- heated soap	5% solution at 80 ° C for 10 seconds
-hydrogen peroxide	10% solution for 10 seconds
- sodium metabisulphite	55% solution for 10 seconds

2. Cleanse seed.

For all of the following methods, place seed in mesh bags that have twice the volume of the bulk seed to ensure adequate movement and agitation of the seed.

- running water	48 hours, with aeration
- bleach	40% solution for 10 minutes. For use only on thick-coated seeds such as pine and Douglas fir. Do not use on seed of larch, spruce and true firs.
- hydrogen peroxide	3% solution for 3 -5 hours, followed by a 48 hour running water rinse.
-ethanol	Not well tested and may inhibit seed germination. 95% solution for 15 seconds was ok on Douglas fir seeds, however, many other species have not tested.

3. Implement a fertilization regime that promotes overall seedling health and desired shoot-to-root ratios.

4. Implement an irrigation schedule that avoids extremes in soil moisture levels.

5. Apply fungicides at sowing and at one month intervals, as needed.

- Sowing: use broad spectrum fungicides that have activity against Pythium, Phytophthora, Fusarium and Rhizoctonia spp. Examples include Banrot G and Banrot WP.
- Monthly applications: rotate with fungicides that have activity against Fusarium and Rhizoctonia spp. Examples include fungicides that contain thiophanate-methyl such as Cleary's 3336, Fungo and Domain.

Improving Minnesota's White Pine[1]

Robert A. Stine[2]

Abstract—Interest in white pine has been growing in Minnesota during the last decade, leading to a recent task force report containing comprehensive regeneration strategies and recommendations. One recommendation is that the number of white pine trees and the number of acres with young white pine trees should be doubled within the next seven years. Also, the number of acres in white pine cover type should be doubled within the next 50 years. In 1997, the Minnesota legislature appropriated $1.12 million to begin implementing this recommendation. The appropriation will be divided among private, county, and Minnesota Department of Natural Resources (DNR) lands.

A significant amount of the funding will be spent on regeneration practices, including planting of seedlings. Planting will occur in a variety of contexts, ranging from pure white pine to mixed species plantings. On county and state lands, more than 1,700 acres will be planted with white pine in spring, 1998. More than 1.2 million seedlings are needed to complete the planting program, although there are not that many seedlings growing in Minnesota ready for outplanting in 1998. The number of acres to be planted or white pine seedlings needed on private lands is not known at this time.

A second recommendation calls for research on deer predation, regeneration systems, genetic improvement, and blister rust management. The legislature appropriated $380,000 for such research. Genetic research is emphasizing two areas. One is developing material that is genetically resistant to blister rust, since there is currently no eastern white pine material with proven blister rust resistance. A second project is developing material that is faster growing, particularly under conditions of partial shade. It will be used in combination with silvicultural systems that help avoid blister rust.

Things are looking up for white pine. Interest levels are high, planting programs are expanding, and funding is available for some much needed research. To have any long term impact, the current level of enthusiasm needs to be sustained over an extended period. Perhaps the best way to do that is to show positive results from the new initiatives through a concerted effort by everyone involved.

INTRODUCTION

Interest in white pine has been growing in Minnesota during the last decade. Along the way, a symposium was held that attracted more than 600 participants, harvesting was curtailed, comprehensive regeneration strategies and recommendations were developed, and finally, funding was made available for a variety of activities related to growing white pine.

These developments represent a significant shift in attitude about growing white pine. Before the mid-1980s, attention focused primarily on the difficulties in growing white pine, including deer browse, white pine weevil (*Pissodes strobi)*, and white pine blister rust (*Cronartium ribicola)*. The general consensus was that growing white pine, for the most part, was simply not worth the effort.

[1]*Stine, R.A.. 1997. Improving Minnesota's White Pine. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 34-37.*

[2]*Department of Forest Resources, College of Natural Resources, University of Minnesota, 175 University Road, Cloquet, MN 55720-9594.*

However, a few voices in the wilderness continued to extol the virtues of white pine and scientific evidence about how to grow it became more available. Starting with a small group of people talking about genetic improvement possibilities for the species, interest continued to expand. It culminated with the 1992 White Pine Symposium in Duluth, attracting more than 600 participants. The Symposium remains perhaps the largest regional gathering of natural resource professionals ever held in Minnesota.

The Symposium acted as a catalyst for individuals and organizations to put more effort into growing and managing white pine. Planting, pruning, and deer browse protection all increased. Genetic improvement programs to develop blister rust resistant material and faster growing material intensified. Progress was made in all areas, but some citizens were still concerned about the number of white pine trees being harvested. In 1996, legislation was introduced to place a moratorium on white pine harvesting on state-owned lands until the Minnesota DNR developed a management plan for the species.

In response, the DNR formed a work group to develop regeneration strategies for white pine. The work group developed a set of recommendations, summarized below (State of Minnesota 1996):

1. Appropriate silvicultural systems, including long term monitoring and care, should be used to ensure retention and regeneration of white pine on suitable sites throughout its pre-settlement range in Minnesota.

2. The number of white pine trees and the number of acres with young white pine trees should be doubled within the next seven years. The number of acres in white pine cover type should be doubled within the next 50 years.

3. Over the long term, management activities should increase the acreage and spatial dispersion of older white pine stands. They should also create an age distribution of white pine stands that is more balanced than the current distribution.

4. Harvesting activities should be planned and conducted within the context of silvicultural systems designed to increase the growth and/or regeneration of white pine.

5. Critical research in the areas of deer predation, regeneration systems, genetic improvement, and blister rust management should be conducted and reported as quickly as possible.

6. Educational materials and programs that explain and promote white pine management should be developed and distributed to resource managers and private land owners.

7. Site level ecological classification systems should be completed because of their usefulness in identifying suitable white pine sites.

8. Best Management Practices (BMP) type audits should be used to evaluate the success of specific regeneration activities. Forest Inventory and Analysis data should be used to evaluate the accomplishment of goals related to the abundance, age distribution, and spatial dispersion of white pine.

9. Budgeting and funding decisions should support activities that help accomplish the goals stated above.

NEW FUNDING

In 1997, the Minnesota legislature appropriated $1.5 million to begin implementing the recommendations. The appropriation divides the funds among various land owner groups and provides funding for specific research, as shown below.

$600,000 the first year and $600,000 the second year are for programs and practices on state, county, and private lands to regenerate and protect Minnesota's white pine. Up to $280,000 of the appropriation in each year may be used by the commissioner to provide 50 percent matching funds to implement cultural practices for white pine management on nonindustrial, private forest lands at rates specified in the Minnesota stewardship incentives program manual. Up to $ 150,000 of the appropriation in each year may be used by the commissioner to provide funds to implement cultural practices for white pine management on county-administered lands through grant agreements with individual counties, with priorities for areas that experienced wind damage in July 1995. $40,000 each year is for a study of the natural regeneration process of white pine. The remainder of the funds in each fiscal year will be available to the commissioner for white pine regeneration and protection on department-administered lands. $ 150,000 the first year and $150,000 the second year is appropriated to the commissioner for a grant to the University of Minnesota's College of Natural Resources for research to reduce the impact of blister rust on Minnesota's white pine.

The DNR's final fiscal year 1998 allocation of funds is shown below. Some funding may shift from DNR lands to private lands in 1999 (Table 1).

Table 1.

Private Lands	$190,000
County Lands	150,000
DNR Lands	220,000
Research (Natural Processes)	40,000
Research (Blister Rust)	150,000
Total	$750,000

A significant amount of the funding will be spent on regeneration practices, including planting of seedlings. Planting will occur in a variety of contexts, ranging from pure white pine to mixed species plantings. On county and state lands, more than 1,700 acres will be planted with white pine in spring, 1998 using the following methods (Table 2):

Table 2.

Planting where white pine will be the main tree species	754 acres
Planting groups of white pine on favorable sites within other upland conifer plantings	227 acres
Planting white pine under existing tree cover	330 acres
Including white pine in mixed species plantings where white pine will not be the main species	399 acres
Total	1,710 acres

More than 1.2 million seedlings are needed to complete the planting program, including 273,000 on county lands, 723,000 bareroot seedlings on state land, and 209,000 container seedlings, also on state land. The number of acres to be planted or white pine seedlings needed on private lands is not known at this time. Of interest to nursery growers is that there are not 1.2 million seedlings growing in Minnesota that will be ready for outplanting in 1998.

GENETIC RESEARCH

With a fairly sizable expansion of white pine planting, there is increased opportunity to plant genetically improved material. The Minnesota Tree Improvement Cooperative has two projects underway that will provide such material. One is concentrating on developing material that is genetically resistant to blister rust. A second project is developing material that is faster growing, particularly under conditions of partial shade.

Blister rust resistance

At this time, there is no eastern white pine material with proven blister rust resistance. A test of clones in the USDA Forest Service Oconto River seed orchard is less than a decade old, and is thus too young to provide definite results. A test of 800 families planted near Tofte, Minnesota in the early 1970s has yielded some trees without blister rust, but almost no resistance across members of the same family was found.

About 200 rust-free, high-vigor trees from Tofte were grafted and placed in a breeding arboretum at the Cloquet Forestry Center. They will be crossed with one another, and the resulting full-sib families will be screened for rust resistance. A significant portion of the research funding provided by the Minnesota legislature is supporting this breeding arboretum and research on early flower induction and early screening techniques. It is estimated that three or four generations of breeding and selection are needed to develop genetically resistant white pine.

In the interim, the Minnesota DNR and St. Louis County established seed orchards that include Minnesota sources from the USDA Forest Service Oconto River seed orchard. The seed from these orchards may have rust resistance, but it has not yet been documented. These orchards are just starting to produce seed, and will serve as a source of seed until the more intensive breeding and selection work on the Tofte material can be completed.

Increased growth rate

Genetically resistant white pine will be very useful, but there are also management techniques that can be used to avoid blister rust, and several other pests. Fast growing trees have several advantages when managing white pine. In an understory situation they may be able to compensate somewhat for the loss of growth normally associated with partial shade. Faster growing seedlings are likely to grow beyond deer browse problems sooner than slower growing seedlings. Finally, pathological pruning can begin sooner and trees can be pruned up to nine feet (the level below which most infection occurs) more quickly on faster growing trees than on slower growing ones.

Using material from approximately 50 trees selected for good growth, Itasca County and Rajala Companies are establishing a clonal seed orchard. Once it begins flowering, a progeny test will be conducted to identify the fastest growing clones. Additional breeding, testing, and selection work will follow.

CONCLUSION

Things are looking up for white pine right now. Interest levels are high, planting programs are expanding, and funding is available for some much needed research. To have any long term impact, the current level of enthusiasm needs to be sustained over an extended period. Perhaps the best way to do that is to show positive results from the new initiatives. For the nursery industry, that means growing high quality white pine nursery stock using the best seed sources available. The Minnesota Tree Improvement Cooperative is committed to working with nursery growers to help make this happen.

LITERATURE CITED

For more detailed information about white pine, readers are referred to the following publications:

Proceedings, White Pine Symposium: History, Ecology, Policy and Management. Duluth, MN. September 16-18, 1992. Stine, R. A. and M. J. Baughman (eds.). 202pp.

Minnesota's White Pine, Now and for the Future. A report by the White Pine Regeneration Strategies Work Group. Dec. 19, 1996. State of Minnesota, Department of Natural Resources. 66pp.

Recommendations to Improve Public Involvement in White Pine Timber Management Planning on Minnesota DNR Timber Lands. A report by the White Pine Timber Management Planning Public Involvement Process Work Group. August 15, 1997. State of Minnesota, Department of Natural Resources.

Breeding and Nursery Propagation of Cottonwood and Hybrid Poplars for Use in Intensively Cultured Plantations[1]

Don E. Riemenschneider[2]

INTRODUCTION

Intensively cultured poplar plantations are well known in the Southern and Northwestern United States where they have made significant contributions to industrial fiber supplies. Intensively cultured plantations are less well known in the Northeastern United States, where research and pilot-scale studies have focused on the production of alternative fuels. But, several factors have recently combined to increase interest in intensively cultured plantations in the North Central region, especially in Minnesota. In response, about 10,000 acres of hybrid poplar plantings have been established as of 1997. A few operational scale plantings are as old as age seven years, but most are three to four-years-old or younger. In addition, interest is increasing in using hybrid poplars to aid in the restoration of stream and river-side vegetation. In response to the aforementioned needs, much work has been done in breeding and selecting new fast growing, disease resistant poplars. In the following sections I present a brief description of the genus *Populus,* the kinds of inter and intra-specific breeding that is being done, and how hybrid poplars are propagated in nursery operations. For additional information the reader is referred to a recently published, extensive review of the biology of *Populus* (Stettler et al. 1996).

TERMINOLOGY

The terminology surrounding poplars can be confusing. The term "poplar" is generally used in reference to members of two sections of the genus *Populus,* section *Aigeiros* and section *Tacamahaca.* Section *Aigeiros* contains Eastern cottonwood, which is native to the Eastern United States. The aforementioned sections contain several other cottonwoods (Table 1), most of which can be hybridized, although not always without difficulty. Hybrids between species have commonly been referred to as "hybrid poplars". Hybrids between members of the same species, such as Eastern cottonwoods, are not commonly referred to as hybrid poplars, or even as hybrids, although they should be if rigorous crop nomenclature guidelines are applied. Thus, to avoid confusion in the following, I refer to hybrids between cottonwood species as "hybrid poplars" and to Eastern cottonwoods as "cottonwoods".

THE GENUS *POPULUS*

The genus *Populus* is represented by as many as 30 species in six sections (Table 1). Species are found throughout the northern hemisphere, including North America, Europe, and Asia. However, no species are found naturally in the southern hemisphere. Taxonomic

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[1]Riemenschneider, D.E. 1997. Breeding and Nursery Propagation of Cottonwood and Hybrid Poplars for Use in Intensively Cultured Plantations. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 38-42.

[2]USDA Forest Service Forestry Sciences Lab. 5985 Hwy. K, Rhinelander, WI 54501; Tel: 715/362-7474.

classification within the genus is debated, like all classifications. For example, different authorities recognize as few as 22 to as many as 85 species (Eckenwalder 1996). Part of the discrepancy is due to the presence of hybrids, which should not be assigned as species. The remaining differences are due to the ongoing debate between taxonomic "lumpers" and "splitters" (Eckenwalder 1996) which can probably not be resolved in the short term. There is general agreement for the species commonly used in cottonwood and hybrid poplar breeding. One exception is the species commonly referred to as *P. maximowiczii* (Zsuffa 1995) which is considered by Eckenwalder (1996) to be a member of the species *P. suaveolens.*

BREEDING *POPULUS* IN THE NORTHEASTERN UNITED STATES

Poplar breeding in the Northeast has been pursued, off and on, for at least 60 years. The breeding objective has been to produce selected clones with demonstrated growth potential, resistance to *Septoria* stem canker (and other diseases), and ability to form roots from dormant unrooted hardwood cuttings (Riemenschneider et al. 1996). Species and species hybrids differ in the extent to which they meet the above criteria and because of this several approaches have been pursued simultaneously.

Most recent breeding research in the Northeast has been targeted towards the development of fast growing, disease resistant Eastern cottonwood (*P. deltoides).* Extensive collections of Eastern cottonwood open-pollinated families have been made. Progenies have been tested in replicated trials and clonal selections have been made based on test results. Early results from regional trials conducted at Westport, Minnesota; Ames, Iowa; Madison, Wisconsin; and East Lansing, Michigan suggest that pure Eastern cottonwood selections may be competitive with some hybrids in growth rate. One limiting factor to pure Eastern cottonwood is that rooting ability of hardwood cuttings is often erratic, with variation due to clone, site, and annual weather fluctuations often contributing to the unpredictable response. Because of unpredictable rooting, recent attention has been given to exploring two additional breeding approaches: the production of new interspecific Fl hybrids, and incorporating rooting ability into Eastern cottonwood through backcrossing.

Inter-specific breeding and selection among poplars in the Northeastern United States has actually been pursued since about 1930, beginning with the work of E. Schriener at Oxford Paper Company. That breeding eventually gave rise to the commercial hybrids that are today identified with the prefix NE (i.e. NE222, see Hansen et al (1994) for recent test results). More recent breeding research has been conducted with the specific aim of producing new clones for the North Central region, including Minnesota (Mohn et al. 1994). For example, several hybrid families between Eastern cottonwood and balsam poplar (*P. balsamifera*), European black cottonwood (*P. nigra*), and Japanese cottonwood (*P. maximowiczii*) were produced (Mohn et al. 1994). Early results suggested that hybrids between Eastern cottonwood and Japanese cottonwood had very high growth potential, but might be susceptible to *Septoria* canker.

An alternative to the development of first generation inter-specific (F_1) hybrids is advanced generation backcrossing. In such a breeding scheme a recurrent species of primary interest (Eastern cottonwood) is hybridized with a non-recurrent species that contributes one or more traits of interest. Then, the hybrid progeny are backcrossed to the recurrent parent repeatedly to capture most of the original genotype while artificial selection is applied to each generation of progeny to maintain the trait(s) of interest from the non-recurrent species. We have implemented this strategy by crossing Eastern cottonwood with black cottonwood (*P. trichocarpa*) *a* species whose hybrids readily produce a root system from hardwood cuttings. Then, selected F_1 progeny were hybridized back to Eastern cottonwood. We currently have over 600 first generation backcross (BC_1) progeny from 10 families with which to begin a selection program. The original BC_1 trees are located at the Forestry Sciences Laboratory at Rhinelander, Wisconsin while cuttings from each original tree have been used to establish a replicated clonal trial of the same genotypes at Grand Rapids, Minnesota.

Overall, breeding research has produced several hundred new clones of pure Eastern cottonwood, F_1 hybrids, and backcross progeny which are in clonal trials. In addition, the formation of the new Minnesota Hybrid Poplar Research Cooperative has allowed us to produce about 20,000 new progeny of pure Eastern cottonwood and poplar hybrids. Overall, past and newly emerging breeding research will be used to develop an

Table 1. Sections and species of the genus *Populus.* Species names without brackets are according to Zsuffa (1995). Species names within brackets represent the alternative classification according to Echenwalder (1996).

Section	Species
Abaso Echenwalder	*P. mexicana*
Turanga Bunge	*P. euphratica* Olivier
	P. ilicifolia (Engler) Rouleau
	P. pruinosa Schrenk
Leucoides Spach	P. *lasiocarpa* Oliver
	P. *wilsonii* Schneider [P. *glauca* Haines]
	P. *heterophylla* L.
Aigeiros Duby	P. *nigra* L
	P. *deltoides* Marshall
	P. *fremontii* S. Wantson
	P. *sargentii* Dode [P. deltoides, s.l.]
	P. *wislizenii* Sargent [P. deltoides, s.l.]
Tacamahaca Spach	P. *angustifolia* James
	P. *balsamifera* L
	P. *cathayana* Rehder [P. suaveolens, s.l.]
	P. *ciliata* Royle
	P. *koreana* Rehder [P. suaveolens, s.l.]
	P. *laurifolia* Ledebour
	P. *maximowiczii* A. Henry [P. suaveolens, s.l.]
	P. *simonii* Carriere
	P. *suaveolens* Fischer
	P. *szechuanica* Schneider
	P. *trichocarpa* T. & G.
	P. *yunnanensis* Dode
Populus	P. *adenopoda* Maximowicz
	P. *alba* L
	P. *davidiana* (Dode) Schneider [P. tremula]
	[P. *gamblei* Haines]
	P. *grandidentata* Michaux
	[P. *guzmanantlensis* Vazquez & Cuevas]
	[P. *monticola* Brandegee]
	P. *sieboldii* Miquel
	[P. *simaroa* Rzedowski]
	P. *tremula* L.
	P. *tremuloides* Michaux

extensive breeding program to support the need for fast growing, disease resistant poplars in the North Central United States.

PROPAGATION STRATEGIES

Multiplication of select Eastern cottonwood and hybrid poplar clones is based on vegetative propagation, for several reasons. First, vegetative propagation allows all forms of genetic variation to be exploited, thereby speeding genetic improvement. Genetic variation in a plant population can be divided into several sources. It is not important to understand the theoretical basis for such a division. It is, however, important to understand how those sources affect the relation between propagation strategies and breeding strategies. Plants that can only be propagated by seed can be genetically improved, as evidenced by modern agriculture. But, seed-based propagation generally restricts genetic improvement to utilization of additive genetic variation, which can be a small portion of total genetic variation. Vegetative propagation, in contrast, permits utilization of all forms of genetic variation because the intact genotype, or clone, can be transferred from the breeding population to commercial deployment without sexual recombination.

Second, unrooted cuttings can be planted at very low cost, compared to seedlings. Hybrid poplar cuttings are now offered in commercial quantities at prices that range from $0.11 to $0.15, depending on quality control specifications. Cuttings can also be field planted very quickly compared to seedlings. Last, deployment of poplars as monoclonal blocks results in highly uniform stands that can be managed, harvested and processed very efficiently compared to intensively cultured seedling populations or compared to natural forest stands. Requisite genetic diversity in field plantings can be achieved by establishing a mosaic of different clones, with each clone in its own monoclonal block.

As an intermediate propagation strategy, some genotypes that are difficult to root in field plantings can be planted as cuttings in the nursery, then field planted as 1-0 rooted plants the next year. Our experience has been that a 1-0 rooted plant can outperform an unrooted cutting of the same genotype, which can offset the additional cost associated with the nursery propagation step.

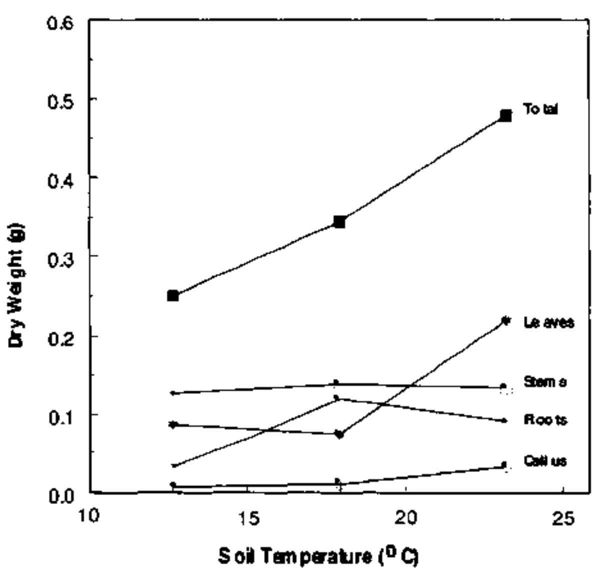

Figure 1. Soil temperature affects total dry weight growth and the distribution of dry weight among leaves, stems, roots, and wound callus. Data are from a nursery experiment where 31 clones of Eastern cottonwood and two inter-specific hybrids were planted under controlled soil temperatures, then harvested for dry weight determination after two weeks.

Propagation for commercial plantings consists of several processes. First, cuttings of a desired clone are planted at close (say, 0.3m x 0.3m) spacing and grown for 1 year. Then, tops are harvested from December through about February, depending on location, and the current terminal is subdivided into cuttings. We recommend that cuttings be 8 to 10 inches (20 cm to 25 cm) long with a basal diameter no greater than 3/4 inch (1 cm) and no less than 3/8 inch (2 cm) (Dickmann et al. 1980). Cuttings are bundled, bagged in plastic and stored refrigerated or frozen until just prior to the onset of adequate planting conditions. Cut stumps sprout (coppice growth) the next spring, producing an aggressive plant usually with multiple shoots which can be harvested annually. Such a cutting production planting is referred to as a stool bed and can remain in production for 5 to 10 years.

Prior to planting cuttings are removed from cold storage and soaked in water for 3 to 5 days until root primordia are visible as bumps on the cutting, but not so long as to induce actual root emergence. Site preparation and planting guidelines have been given in great detail elsewhere (Hansen et al. 1993).

Hansen et al. (1986) recommend planting hybrid poplar cuttings in the field when soils have warmed to 10°C (50° F). Guidelines for planting Eastern cottonwood in relation to soil temperature have not been previously developed. However, current research suggests that Eastern cottonwood can be reliably propagated if soil temperatures are allowed to reach about 18°C (65° F) (Figure 1). In this study, we planted cuttings of 30 clones of Eastern cottonwood at three soil temperatures maintained by buried heating pads. Soil temperature not only affected rooting ability (Figure 1), but also affected shoot growth, leaf growth, total plant biomass accumulation, and the relative distribution of growth between roots and shoots (Figure 1). In addition, not all clones performed the same across all soil temperatures (genotype x environment interactions were significant). I present these preliminary results because it is important to know that conditions exist wherein a difficult-to-root species (Eastern cottonwood) can be induced to root reliably. It is also important to note that rooting and growth distribution are complex traits that clearly require further study.

Overall, commercial deployment of intensively cultured hybrid poplar can significantly augment existing aspen fiber supplies. In addition, production of hybrid poplar cuttings for direct field planting and production of 1 -0 rooted cuttings for field planting present the opportunity for a new, potentially valuable nursery crop. For example, consider an intensive culture program of 100,000 acres. On a 10 year rotation, about 10,000 acres would be planted annually providing a demand for nearly 7,000,000 cuttings if field plantings are established at a spacing of 8 feet × 8 feet. If the average price per cutting were $0.12, then the total cutting crop would be worth about $800,000 annually. Nursery operators thus stand to profit significantly from an intensively cultured hybrid poplar program. Nursery operators also stand to influence the success or failure of such a program because quality of planting stock in many ways predetermines survival, growth and uniformity of commercial stands. Nursery operators are also responsible for ensuring that clonal identities are not confused during propagation so that genotypes are propagated without error and sold as advertised. Above all, no clone should be brought to market unless its growth, rooting ability, and especially disease resistance have been established by long term field testing.

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Dormancy-Unlocking Seed Secrets[1]

Carole L. Leadem[2]

Abstract-It is difficult, if not impossible, to know a priori what type of treatment is needed to break seed dormancy. However, knowing the reason(s) why seeds are dormant may offer clues about what seeds need for dormancy release. An evaluation of the habitat in which a particular species is found also may point to the most effective dormancy treatment if the requirements for a particular species are unknown. Dormancy may be due to: unfavourable climatic conditions, immaturity, a light requirement, genetic variation, or protection against predation. Depending upon the type of dormancy, stratification, light, leaching, scarification, growth regulators, or high O_2 concentrations may be used to promote germination. Treatments such as stratification may have to be modified to meet the particular physiological requirements of different species. Five different types of stratification are presently used to release dormancy of forest trees.

WHY DO WE NEED TO UNDERSTAND SEED DORMANCY?

"What folks here really need—is just to look at a seed and know what kind of treatment it needs to germinate."

This sentiment frequently has been expressed by those attempting to grow plants from seeds when little or nothing is known about their germination requirements. Understandably, they wish the answers could be handed to them on a silver platter. Unfortunately, there is no silver platter, but there may be other means of obtaining the information they require. One approach is to try to determine the most probable reason for dormancy, then to apply a suitable treatment to satisfy the dormancy requirement. To do this, however, requires some understanding of seed dormancy, and the context in which dormancy occurs.

WHAT IS SEED DORMANCY?

Dormancy is a naturally occurring phenomenon of many plants to maximize the chances that seeds will germinate at an appropriate time. Dormancy may be defined as:

> *the physical or physiological condition of a viable seed that prevents germination even in the presence of otherwise favourable germination conditions.*

Thus, seeds are considered dormant when they fail to germinate even though they have adequate light and water, and suitable temperatures for growth (which for temperate species are usually in the range of 15 to 30°C). Alternately, dormancy can be defined as:

> *a seed characteristic, the degree of which defines what conditions should be met to make the seed germinate.*

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[1]*Leadem, C. L. 1997.* Dormancy-Unlocking Seed Secrets. *In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 43-52.*

[2]*Research Plant Physiologist, B.C. Ministry of Forests, Glyn Road Research Station, PO Box 9536, Stn. Prov. Govt., Victoria, British Columbia, Canada V8W 9C4.*

This definition may be more useful in understanding dormancy because it suggests that dormancy is variable, rather than constant, which is the situation that we generally encounter in the native populations of many species.

WHAT ARE THE TYPES OF DORMANCY?

In the very simplest sense, the fundamental cause of dormancy is the inability of the embryo axis to overcome the constraints acting against it. These constraints may originate from within the embryo (endogenous or embryo dormancy) or from the tissues surrounding the embryo (exogenous or coat-imposed dormancy) (Table 1). Understanding whether dormancy originates from within or outside of the seed helps to determine the most appropriate dormancy treatment. Some seeds have both endogenous and exogenous dormancy, and may require a combination of treatments.

Table 1. Types of seed dormancy

Type of Dormancy	Cause of dormancy
Exogenous	*Coat-imposed*
Physical	impermeability
Chemical	inhibitors
Mechanical	restraint
Endogenous	*Embryo-imposed*
Morphological	immaturity
Physiological	metabolic requirement

WHY DOES DORMANCY OCCUR?

Dormancy is a biological mechanism to ensure that seeds will germinate at a time and under conditions that will optimize the chances for the growth and survival of the next generation. The reasons for dormancy will vary, depending upon the species and their environment. The following section describes a variety of situations in which dormancy enhances a species' chances for survival.

Unfavourable climatic conditions for germination

Dormancy strategies may differ according to the characteristics and the timing of critical events of individual life cycles. For example, long-lived species such as pines, which require almost three years from cone bud initiation to seed maturation, would not be expected to have the same dormancy characteristics as small herbaceous annuals that germinate, flower, and set seed within three months.

Pattern 1. Maturation culminates in dormancy
In many tree species, seed maturation is accompanied by the induction of a state of dormancy (Figure 1). This is an advantage for tree seeds of temperate regions that mature in late summer to early fall, since immediate germination would leave vulnerable seedlings exposed to harsh winter conditions. In nature, dormant tree seeds remain inactive until favourable growing condi-

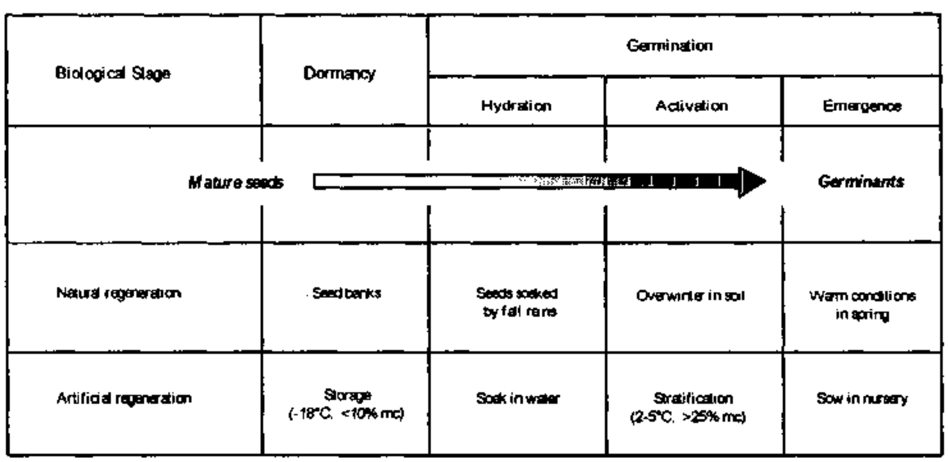

Figure 1. Comparison of the major stages of seed maturation, dormancy and germination in the natural and artificial regeneration of tree seedlings.

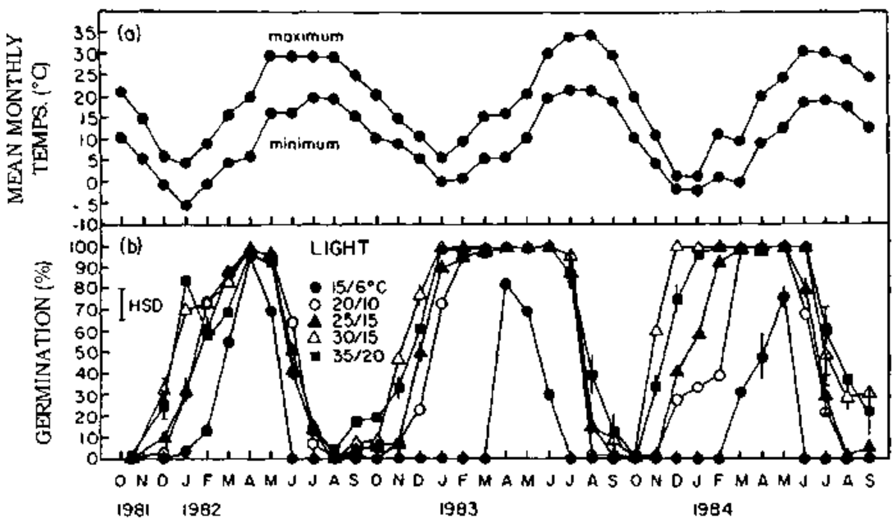

Figure 2. Witchgrass seeds *(Panicum capillare)* exhibit alternating cycles of dormancy and nondormancy (Baskin and Baskin 1985). (a) mean maximum and minimum temperatures monitored at the test site in Lexington, KY. (b) germination of fresh and buried (2 to 35 months) seeds in controlled environment chambers under various temperatures. Fourteen hr light was given during the high temperature period.

tions occur the following spring, although some may remain dormant for two growing seasons or more. Once dormancy is broken, however, seeds of this type generally do not re-enter the dormant state.

Pattern 2. Cyclic dormancy.
Buried seeds of small herbaceous plants and grasses exposed to natural seasonal temperature changes may exhibit annual cycles of dormancy and nondormancy. For example, fresh and buried witchgrass seeds that are dormant in early October become nondormant during late autumn and winter (Baskin and Baskin 1985). During spring and summer, however, seeds progressively lose their ability to germinate, as they gradually re-enter dormancy (Figure 2).

Incomplete development

Immaturity may result in poor germination. Seeds may be immature because they have been harvested too early, or because they were collected from high elevation or high latitude areas that experience shortened growing seasons. Although, strictly speaking, immaturity is not a type of dormancy, it is mentioned here because some treatments for breaking dormancy have been modified to treat immature seeds (see below).

Light requirement

Small seeds lack the reserves to physically reach the soil surface if they are too deeply buried in the soil. To prevent germination of buried seeds, many small seeds have an inherent light-sensing mechanism which responds to the red and far-red portions of the light spectrum. Such seeds germinate when exposed to red light. Red light is predominant in full sunlight, so exposure to red light acts as an environmental signal that seeds are on or near the surface of the soil. Germination is prevented if seeds are in darkness, or exposed to far-red light. Light that is rich in far-red light is characteristic of the illumination that seeds would receive under a dense forest canopy.

This light mechanism is common in spring ephemerals that germinate and bloom early in the year. Typically, these species are found on the forest floor of hardwood forests, and the response to light ensures that they germinate and complete their reproductive cycles before the hardwood canopy closes.

Genetic variation (or, not putting all your eggs in one basket)

Wild oats *(Avena fatua)* produce seeds every year, but dormancy can vary among different members of the same population, with some individuals remaining viable in the soil up to seven years after they are produced (Naylor and Jana 1976). Variable dormancy has also been observed in seeds of white spruce *(Picea glauca* Moench.Voss)(Wang 1976) and Japanese red pine (*Pinus densiflora* Sieb. and Zucc.)(Asakawa and Funita

1966) that were produced by the same trees in different years.

The expression of dormancy in natural seed populations is known to be under genetic control (Naylor 1983, Edwards and El-Kassaby 1995), so variable dormancy possibly represents an evolved survival strategy to extend germination over many years and different environmental conditions. Variable dormancy ensures that, no matter what the present environment, at least some members of the population will survive and produce seeds for the next generation—a kind of an insurance policy against environmental change. It is conceivable that variable dormancy is an universal phenomenon in natural populations of most plant species.

Protection against predation

Physical dormancy is common in many dry regions of the world—from deserts to the dry tropics. Many species inhabiting these areas have seed coats or pericarps that are very hard or impermeable to water to protect the seeds from insects and other predators.

Protection against time (seed longevity)

In regard to their capability for long storage, seeds can be classified as either orthodox or recalcitrant. Orthodox seeds, e.g., the seeds of most temperate trees, gradually dry as they mature. The progressive induction of dormancy is an integral part of this maturation drying. As a consequence, orthodox seeds have the ability to remain viable for long periods in a desiccated state (less than 10% moisture content). Recalcitrant seeds remain at a relatively high moisture content (mc) once they are mature, and typically are produced by species native to moist tropical regions. Characteristically, the seeds are nondormant, because environmental conditions such as temperature and moisture are always suitable for germination. Recalcitrant seeds usually germinate soon after maturity, and rarely can be stored beyond three months (Chin 1990). Many orthodox seeds need dormancy-release treatments to germinate, but recalcitrant seeds do not.

Legume seeds are orthodox seeds with very hard seed coats that are impermeable to water and gases. They are masters of longevity; lupine seeds found in a lemming burrow by a Yukon mining engineer were able to germinate and produce healthy, flowering plants after 10,000 years (Porsild *et al.* 1967). No conifer seeds can match this feat, but they still can be successfully stored for many years (at -18°C and 5-9% mc). Under these storage conditions, germina-

TABLE 2. Dormancy-release treatments

Treatment	Description
Stratification	Moist chilling at 2-5°C; removes metabolic blocks, weakens seed coats, increases germination-promoter levels
Light	Exposure to specific wavelengths; stimulates the phytochrome system
Leaching	Soaking in water; removes inhibitors from seed coats
Scarification	Chemical (sulphuric acid) or mechanical (abrasion) treatment; breaks down seed coats
Plant growth	Enhance natural levels in favour of germination, or trigger regulators other metabolic pathways leading to germination
High oxygen concentrations	Supply respiration; remove metabolic blocks

tion in some British Columbia collections of Douglas-fir, white spruce, lodgepole pine, and yellow pine seeds has remained high (more than 80%) even after 30 years (Leadem 1996).

WHEN TO RELEASE DORMANCY?

When the mc of a mature seeds falls to 5-10% (<5% mc will result in death), it can remain viable over long periods (Figure 1). With this degree of dehydration, however, metabolic activity is virtually nonexistent (Figure 1). Seeds must again become physiologically active, i.e., hydrated, by soaking in water for several hours to several days before any dormancy-release treatment is given.

HOW TO BREAK DORMANCY?

Once they are physiologically active, dormant seeds can be stimulated to germinate using treatments that emulate natural conditions or satisfy certain physiological requirements. A list of the different types of dormancy treatments, and a brief description of how they are assumed to break seed dormancy are summarized in Table 2. A more complete discussion of the various dormancy-release treatments are given below.

Table 3. Procedure for traditional stratification

Process	Soak	Stratify	Incubate
Time	24 or 48 h	3 to 4 wk	3 to 4 wk
Temperature	20 to 25°C	2 to 5°C	20 to 25°C
MC	to >30%	30 to 60%	30 to 60%

Stratification

Stratification is the most consistently effective dormancy-release treatment for many tree seeds. Stratification enables seeds to germinate more quickly and completely, and can sometimes eliminate the need for other special conditions, such as light. The choice of a suitable dormancy-release treatment can broaden the range of environmental conditions, e.g., temperature, under which germination can occur (Figure 3). Even when the total germination percentage does not change, the germination of most tree seeds is more rapid after they have been stratified (Figure 4). Damaged seeds, or those of low vigour, may deteriorate during stratification (Leadem 1986); in such cases, the seeds should be sown without chilling.

Stratification simulates winter conditions by exposing moist seeds to cold temperatures. Seeds are soaked in water (hydrated) usually for 24 h, drained, then placed in a plastic bag or other container, and refrigerated (2C to 5C) for several weeks (Table 3).

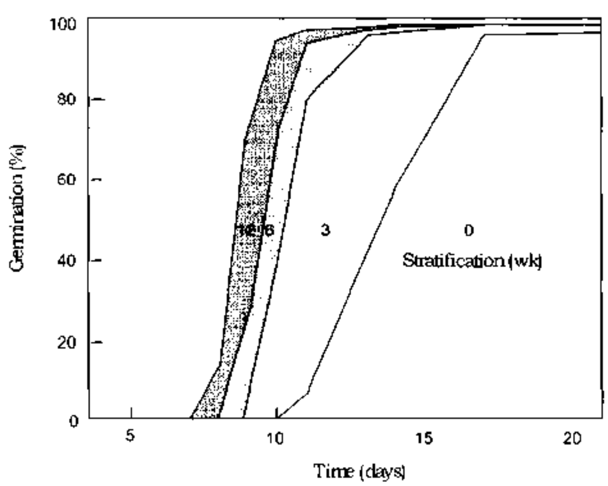

Figure 3. Germination of western hemlock seeds after stratification for 0, 3, 6, and 12 weeks (Edwards 1973)

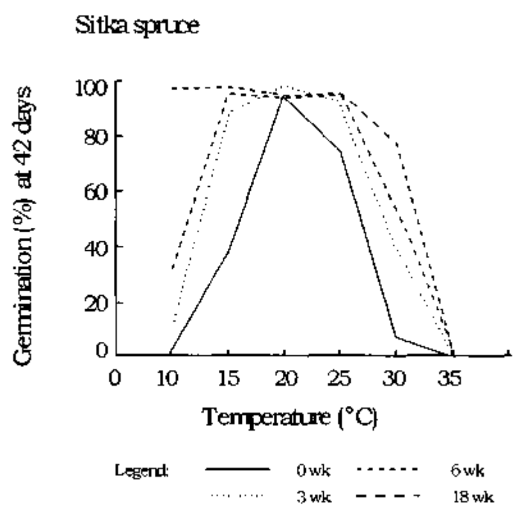

Figure 4. Germination of Sitka spruce seeds at different temperatures after stratification for 0, 3, 6, 18 weeks (Jones and Gosling 1994)

Table 4. Procedure for Stratification-Redry

Process	Soak	Stratify	Redry	Stratify	Incubate
Time	48 h; change after 24 h	4 wk	4 to 8 h	12 wk	3 to 4 wk
Temperature	20 to 25°C	2 to 5°C	20 to 25°C	2 to 5°C	20 to 25°C
MC	to >30%	30 to 60%	25% to 30%	25%	25 to 60%

Traditional stratification techniques may be insufficient to stimulate germination in some conifer species. The true firs (amabilis, grand, noble, and subalpine) respond best to a two-part stratification called stratification-redry (Edwards 1985, Leadem 1986, Tanaka and Edwards 1986, Leadem 1989). *Abies* seeds that receive the stratification-redry treatment are able to germinate more quickly and more completely (Figure 5).

For the stratification-redry treatment, seeds are hydrated for 48 h and then stratified for 4 weeks at 2°C to 5°C; seed mc is high, usually above 40% (Table 4). The seeds are then dried to 25-30% mc and chilled for an additional 12 weeks. Moisture is a critical factor in the application of the stratification-redry treatment. *Abies* seeds require very long stratification, but also have the capability to germinate at the temperatures used for stratification. With the stratification-redry treatment, seeds receive the extended chilling they require, but emergence of the radicle (i.e., evident germination) is prevented because seed mc is kept at low levels. The stratification-redry treatment has also been found effective for some sources of Douglas-fir seeds, but not for other tree species, perhaps because the correct redry me has not been found.

Some seeds, such as *Acer macrophyllum,* require extended stratification, but the optimum duration for individual seed sources is unknown. An empirical procedure for seeds with variable dormancy is to place the hydrated seeds (> 30% mc) at 2°C to 5°C, and maintain them at low temperatures until about 5% of the seeds germinate (Table 5). For *Acer macrophyllum,* this is about 60 to 120 days (J. Zasada, pers. comrn. 1996). Germination of the least dormant individuals at low temperatures generally indicates that dormancy also has been released in the remaining, more dormant seeds, and that the seeds are ready to be transferred to wanner temperatures for testing or seedling production.

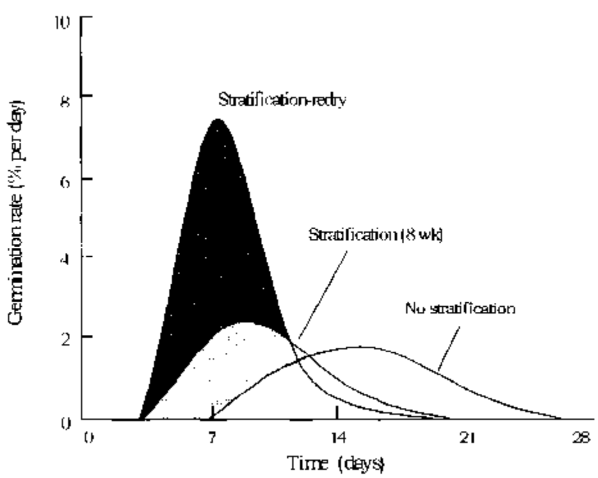

Figure 5. The rate of germination of amabilis fir seeds after 0 and 8 weeks stratification and stratification-redry treatment (Leadem 1986)

Table 5. Stratification procedure for seeds with variable dormancy

Process	Soak	Stratify	Incubate
Time	48 h; change after 24 h	X wk* (*5% germ.) X=60-120 d	3 to 4 wk
Temperature	20 to 25°C	2 to 5°C	20 to 25°C
MC	to >30%	30 to 60%	30 to 60%

Table 6. Procedure for compound stratification (warm + cold)

Process	Soak	Stratify-w	Stratify-c	Incubate
Time	48 h; change after 24 h	X wk* (*5% germ.); *X=3-5 wk*	6 wk	3 to 4 wk
Temperature	20 to 25°C	20 to 25°C	2 to 5°C	20 to 25°C
MC	to >30%	30 to 60%	30 to 60%	30 to 60%

A variation of the preceding method is the compound stratification treatment used for *Pinus monticola* and for immature seeds (Table 6). The treatment is referred to as compound stratification because the seeds are exposed to both warm and cold temperatures. The usual combination used for *Pinus monticola* is 30 days "warm" stratification (20°C to 25°C) followed by 60 days "cold" stratification (2°C to 5°C). However, the duration of warm stratification may vary, depending upon the seed source. Thus, seeds are kept under warm conditions until about 5% of the seeds show evidence of germination, and then they are transferred to cold temperatures (D.W.G. Edwards pers. comm. 1996). Compound stratification also works well on *Chamaecyparis nootkatensis.*

A procedure developed for beechnuts and other European hardwood seeds by Suszka *et al.* (1996) may also prove effective for removing the dormancy of North American hardwood seeds. It is similar to both the "variable dormancy" and "stratification-redry" treatments described above (Tables 4/5). It involves hydrating the seeds to a predetermined mc ("Y"), depending on the species (e.g. 30% mc for beechnuts), then chilling the seeds at this mc for X+2 weeks (Table 7). The duration of treatment (expressed in weeks), is represented as "X", or the time when 10% of the seeds have germinated. This length of stratification is sufficient to break dormancy, but germination is prevented because moisture levels are controlled during the chilling period.

After treatment, the seeds can either be sown, or re-dried to below 10% mc and stored for several years (Muller and Bonnet-Masimbert 1989; Muller et al. 1990). They can be sown at any time and they will germinate readily as they are no longer dormant. This

Table 7. Procedure for variable dormancy of deeply dormant hardwood seeds

Process	Soak	Stratify	Incubate
Time	Until mc = Y	X + 2 wk *X=1 to 8 mo.*	3 to 4 wk
Temperature	20 to 25°C	2 to 5°C	20 to 25°C OR
MC	*(e.g., Y=30%)*	Y% mc	store @2-5°C, 10% mc

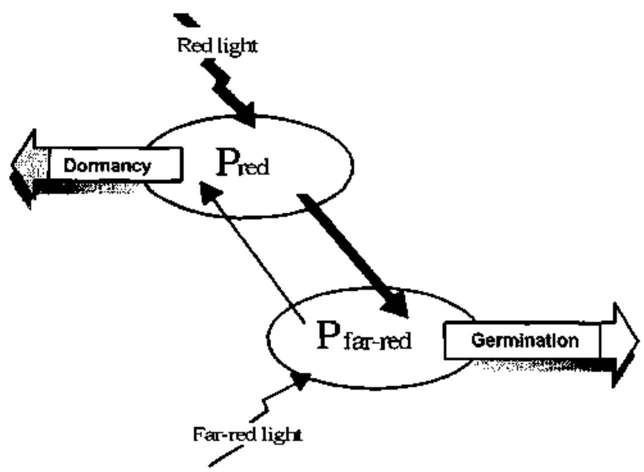

Figure 6. Absorption of far-red light converts the pigment phytochrome $_{farred}$ (usually the active form) back to phytochrome $_{red}$ (the inactive form). This reaction is reversible, depending on the relative amounts of red and far-red light. In sunlight, red light is predominant, whereas far-red light is predominant in canopy-filtered light.

dormancy-breaking treatment is usually applied after storage, but it can also be applied before storage, i.e., immediately after collection. The time period "X" can be considered to be an indication of the degree of seed dormancy, and potentially could be used to compare the dormancy levels of different seed sources. The period "X" is 1 to 3 months for beechnuts *(Fagus sylvatica)*, 5 to 6 months for wild cherries, (*Primus sativum)*, and 6 to 8 months for ash *(Fraxinus* spp.) (Muller 1993, Suszka *et al*. 1996).

Light

Some seeds require light to stimulate germination, but, as with other dormancy-release treatments, the seeds must be fully hydrated to respond. The light stimulus is received through the phytochrome system, which operates as an on/off switch for many physiological processes in plants (Figure 6). Germination is usually stimulated by exposure to red light (660 nm) and inhibited by exposure to far-red light (730 nm). The intensity of light required to activate the phytochrome system is low, and 1 to 5 lx (comparable to bright moonlight) can be sufficient.

Seeds lying on or near the soil surface receive enough light to trigger germination if all other conditions have been satisfied. In the nursery, the light requirement is generally met during the routine handling of hydrated seeds. The light requirement for germination may be affected by treatments such as stratification. For example, unstratified seeds of species that require light for germination will germinate in darkness once they have been stratified.

Table 8. Habitat and dormancy treatment (The Aluminium Platter)

Habitat of origin	Dormancy treatment
Temperate region by cold winters	Stratification
Short growing season (alpine, boreal forest)	Warm + cold stratification
Understory species, small seeds	Light
Dry climate (grassland, desert)	Leaching, scarification
Warm, high humidity	Scarification

Leaching

The coats of some seeds contain inhibitors that must be leached, or washed out. In temperate regions, seeds are leached naturally when they fall to the ground and are drenched by fall rains. This is a mechanism also found in desert species, which use the leaching of inhibitors in the coats by rainfall as an environmental signal that sufficient water is present for germination and growth.

Scarification

Scarification is an important technique for breaking the dormancy of many hard-seeded legume tree species, e.g., *Acacia, Leucaena, Albizia*, that are an important component of tropical forests. Hard seed coats are a means of protecting seeds from fungal and insect attack under conditions of high temperatures and high humidity. Mechanical or chemical degradation of the seed coat is necessary for germination, and in nature, is often facilitated by seeds passing through the intestinal tract of birds and other animals. When seeds or fruits are eaten by animals, enzymes in the digestive system assist in breaking down the seed coats so that seeds can germinate. Thus, in a very general sense, predation might be considered a dormancy-release treatment!

Tropical species such as teak (*Tectona grandis*) may be scarified by alternate drying and soaking. The seeds are soaked in water, then left in direct sunlight for several days. This cycle may be repeated many times, or until evidence of coat degradation is apparent. Hard seed coats also may be degraded by partial fermentation, or by exposure to light-to-moderate fire. The seeds are burnt after they are covered with a layer of grass (Willan 1984). Few temperate forest species require scarification [Schopmeyer (1974) does not recommend it for any British Columbia trees], but seed coats are sometimes clipped to facilitate the germination of hard-seeded pines (Hoff and Steinhoff in press, Leadem 1985). Species common to some desert zones sometimes are mechanically scarified by tumbling, wire brushes, or hot water soaks.

Plant growth regulators

Application of plant growth regulators (especially gibberellic acid and cytokinin) have been shown to enhance germination of hardwoods, but have limited effectiveness for conifer species (Leadem 1987).

CONCLUSION -IS THERE A "SILVER PLATTER"?

The short answer is "no", but practically speaking, it may be possible to offer an "aluminium platter". The aluminium platter is an approach for determining the type of dormancy a particular species exhibits, by examining the type of habitat in which the seeds are found. From this, a probable reason for dormancy may be surmised, and the appropriate treatment applied (Table 8).

The essence of this approach is to evaluate the general climatic pattern of the region in which the species naturally occurs. Are environmental conditions fairly uniform during the year, or is the climate characterized by cold, near-freezing temperatures during the winter months? In tropical regions where the climate is relatively uniform, the seeds may be nondormant, and require no treatment. However, in temperate regions that experience a range of temperatures during the year, stratification is probably needed to break dormancy.

In northern or high elevation areas that are very cold or covered by snow for most of the year, the growing season may not be long enough for seeds to mature naturally. In such cases, a period of warmth may be needed to promote embryo growth and complete the maturation process, so compound stratification should be used. On the other hand, small seeds and those of understory species in deciduous forests would probably respond to light treatment. If the species naturally occurs in dry grasslands or desert areas, the seeds may require leaching or scarification to germinate.

The above inquiries likely will only provide part of the information needed to propagate plants from seeds. Other factors may have to be considered, such as the physical properties of the seeds, or whether the seeds are usually subject to predation. The type of predator may offer clues as to the type of dormancy treatment required. Hard seeds which have evolved to resist predation by insects and molds generally require mechanical or chemical scarification, but other seeds, enclosed in a fleshy fruit that is eaten by birds and other animals, often need extended stratification to germinate. In some instances, treatments that are known to be effective for closely-related species may be successfully applied.

Sometimes even logic, and trial-and-error will fail to provide the required answers. Once all other avenues have been explored, we may have to accept that, at least for the present, some seed secrets will remain hidden from our view.

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Considerations for Conditioning Seeds of Native Plants[1]

Robert P. Karrfalt[2]

INTRODUCTION

The conditioning of seeds of native plants can be seen as having three main components: biological, physical, and administrative. These three interact and at different stages one can be more prominent than the others. However, each must be given its appropriate consideration if quality seed is to be available for native plant regeneration. The biological component is most important because it is the care and direction given this biological component that will determine regeneration success. Seed supplies with high viability and high vigor are indispensable. Therefore, compromises in the biological component should be minimized as seeds are conditioned. This point is often overlooked when time or money are in limited supply. This paper traces the conditioning of seed beginning with harvest, to extraction and cleaning, to storage, and ending with a brief discussion on quality control, quality assurance, and seed certification.

SEED COLLECTIONS

How much to collect is determined by how much is needed. This is determined by the annual amount needed to supply nursery and direct seeding requirements and how many years' supply is needed. Availability and ease of collection in any particular year may also modify these amounts. During good seed crops, extra amounts of seed might be collected if the collection can be made economically.

Where to collect is of course determined by where seed will be planted. It is critical to use adapted material. When genetic studies are not available to define seed transfer zones, then the use of local sources is the best consideration. The definition of local is often a point of debate. The closer the collection site is to the planting site the better the adaptation one could assume. However, other realities might determine the collection site. For example, the most local source could well have been totally destroyed by a large fire or too many years of land use that excluded the desired species. Extrapolating from decades of provenance research on forest trees, which are native plants, too, in the broad sense of the word, maximum boundaries for local source could be defined as no more than 500 feet change in elevation and no more than 100 miles north or south of the planting area. Genetic studies may demonstrate broader or narrower bands of adaptation. Local conditions need to be kept in mind. Changes in soil types and hardiness zone can occur over shorter distances than those mentioned above and would require different definitions oflocal.

When to collect is the question of maturity index. What are the changes in color, moisture content, and seed morphology that tell when a seed is mature? These indices almost always involve knowledge of the seed structures. Consultation with a reference such as Agricultural Handbook 450 (Schopmeyer, 1974) or careful study of unfamiliar species will show where the essential seed structures are for evaluating maturity.

[1]*Karrfalt, R.P. 1997. Considerations for Conditioning Seeds of Native Plants. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 53-56.*

[2]*National Tree Seed Laboratory, USDA Forest Service, Route 1, Box 182B, Dry Branch, GA 31020-9696; Tel: 912/751-3552; Fax: 912/751-3554.*

POST HARVEST STORAGE

Temperature and seed moisture are the critical factors in post harvest storage when seeds are in long term storage. Seeds collected dry need to be kept dry and cool. Good air circulation is important for dry seeds so they can continue to dry. In drier areas of the west, air circulation might not be necessary, but this should be verified. Cool temperatures are here defined as those temperatures not above the ambient temperature. Do not put seed in unventilated sheds, or closed vehicles in the sun. Seeds collected moist need to be kept in cool moist conditions. Cool moist conditions would be anywhere from ambient to near freezing temperatures. The critical point to watch in storing moist fruits is to avoid heating from high seed respiration rates or fruit fermentation. Length of post harvest storage will be species dependent. Some species like cottonwoods and willows need to be processed in the shortest possible time as their life is short if not dried to storage moisture contents rapidly. Ideally, the faster a species can be put into permanent storage the better the viability and vigor. Realistically, most species can be kept for several months if not at high moisture with little or no measurable loss of quality.

CONDITIONING STEPS AND EQUIPMENT

Drying is often a first step in conditioning seeds and is mandatory if seeds are moistened in any step. The most effective and efficient method of drying is in pressurized driers where air is uniformly forced through the seed lot. These can be very simply made from an open topped box that serves as a plenum and mesh bottom trays with solid sides that can be placed on top of the plenum and each other. The trays need to fit together tightly enough to prevent significant air leaks between them. When multiple stacks of trays are used, it is simplest to have a separate fan for each stack in order to eliminate the air balancing problems of multiple stack driers. Without the use of pressurized driers, the seed will only dry at the surface. Drying at the surface only necessitates spreading the seed one or two seeds deep, or frequently turning the seed to bring the moist seed to the surface to dry. Both options take more space and time to accomplish the drying.

Threshing can be done with machinery or by hand. A hammer mill is one machine that can be used but might lead to heavy damage (Young, 1983). A grist mill can be used, especially if the grinding plates are modified to minimize damage. In a grist mill two plates rub over each other and the distance between them is adjustable. When the distance is set at the thickness of the seed but less than the thickness of the fruit, the plates will cut or rub away the fruit while the seeds pass out usually unharmed. The plates can be replaced or covered with cloth, carpet, sand paper or other suitable material. Such a grinder can be obtained for a few hundred dollars (Dalpiaz, 1993). A brush machine is very effective at singularizing, extracting and dewinging many dry seeds and fruits (Karrfalt, 1992). The action of the brush machine is to rub fruits or seeds against a wire shell until the seed is extracted from the fruit or a wing is removed. Dust from the extraction is completely confined by the machine's vacuum dust control. In a trial where winterfat utricles were hand rubbed with a scrub brush on both a round wire screen and a square wire screen, the square wire screen was determined to be more effective in extracting the seeds. More seeds were removed from the fruit in the same amount of time. Therefore, it is believed that a square wire shell is best for the brush machine.

The brush machine can be mimicked by rubbing the fruit on a screen by hand with a brush. This hand method might be suitable for the very smallest of lots but too time consuming on larger lots. Dust can also be a problem for the worker in hand rubbing the seed. Good ventilation or dust removal should be provided.

For very small seeds with hairy appendages, such as anemone, a filament thresher can be used. This machine is a column aspirator with monofilament strings spinning on a central axle. As seeds are fed into the machine, they are carried upward by the air column. As the monofilament lines cut the hairs from the seeds, they become less buoyant and fall out of the air column. The seeds without hairy appendages are collected at the bottom of the column.

Basic Cleaning is usually done with aspirators, blowers, screen machines or air-screen machines. Except for the smallest of lots, continuous flow machines are more productive. To make maintaining lot integrity easiest, machinery should be the type where all surfaces can be seen. Air and small screens usually remove all the dust and fine particles while larger screens are good at removing larger particles.

Round and flat particles can be separated with an inclined draper. The draper is a flat conveyor belt that is held at an adjustable pitch. The steeper the pitch the more easily round objects roll down the belt while the flatter objects are carried up the belt to a collection container. Juniper berries and leaf particles are easily separated with a draper. A board covered with a cloth can accomplish the same separation.

Long and short particles can be separated with an indent cylinder. This is frequently needed because many native plant seed lots contain pieces of stems (long particles) because stems are often threshed with the seeds (short particles). In this device an indented horizontal cylinder is rotated with the seeds inside. The seeds are caught by indents in the cylinder and carried upward until they finally drop from the indents into a collection trough. The stem particles are either not caught in the indents or fall out quickly because their centers of gravity are outside of the indent. The separation can be made by hand, by using the cylinder by itself, or having a board or piece of plastic with indents.

Heavy and light particles can be separated by water in some cases and by the specific gravity table or precisely controlled air columns. Both air columns and specific gravity tables are more effective if the seed has been sized with screens. The air column simply lifts the lighter particles up to a collection point. The specific gravity table uses air to stratify light and heavy particles and then oscillation of the table to push the heavy particles of seeds out from under the lighter seeds. This action pushes the heavier particles up the slope of the table, while the lighter particles flow down the slope of the table. Air pressure gauges and tachometers on both of these devices make them easier to adjust.

Rapid evaluations of seed quality are important for making adjustments to the equipment and for determining when the work is done. Cutting tests have been used for generations and provide some quick answers. X-ray is the most effective because of the great amount of detail that is available almost instantly. Tetrazolium tests are sometimes possible in about 30 minutes and could be useful. At other times they can take a few days and are, therefore, not as useful in conditioning seed. Rapid evaluations of seed moisture content are very necessary to good seed management. Electronic moisture testers can be calibrated to test seed moisture instantly. A minimum of 3 to 8 ounces of seed is required to use most electronic meters and, therefore, the meters may not work with very small lots.

"How good is good enough?" is a question sometimes not asked or answered. To answer this question intelligently requires knowing how the seed will be used. No fine trash is tolerable when vacuum sowing is done as the vacuum holes will likely become clogged with trash requiring down time to clean the sower. More trash is tolerable if the seed is to be broadcast seeded in flats or nursery beds. Stem particles need to be removed if a drill type sower is used but maybe can remain if hydroseeding is done. Container growing usually requires higher standards of seed quality than direct seeding or nursery beds. Weed seeds are usually intolerable in all seed lots for conservation uses because of the danger of introducing weeds into a natural system. Maybe it is not known how the seed will be handled and a very thorough upgrading is needed to cover all eventualities.

QUALITY CONTROL

Quality control is the process of watching out for mistakes. It requires an excellent tracking system with unambiguous seed lot identification. The Seed Regulatory and Testing Branch of the USDA Agricultural Marketing Service administers the Federal Seed Act. It is the opinion of the branch that many native plants come under the act and that the way sources of material are named can be misleading. For example, to refer to bitterbrush collected in Ada county Idaho as "Ada County Bitterbrush" is to imply it is a named variety and, therefore, misleading. They prefer a fixed term, such as "germplasm" be used in naming source collections to differentiate them from named varieties. This has been proposed to the Association of Official Seed Certifying Agencies and will likely be adopted by AOSCA as a recommendation to the individual states. Under this proposal the Ada county bitterbrush would be bitterbrush of "Ada county germplasm." Other identifying numbers and letters on the seed lots need to be used in ways that clearly are unique. Simplicity in defining lot numbers is also important to avoid mistakes.

Good quality control requires constant monitoring for damage and quality. Every step in the process should be checked for any possible deleterious effect on viability. This requires periodic checks before and after each step in handling. Steps to be particularly concerned with are conveying steps and threshing or dewinging steps. In the author's experience, most seed damage occurs at these steps. Vacuum is a very nice way to sometimes collect or transfer seeds. However, vacuum moves seeds very rapidly and if they are stopped too suddenly against a hard surface, fatal damage can occur.

High quality and regular training and supervision for all workers is indispensable. They should be a regular part of the seed program.

QUALITY ASSURANCE

Quality assurance is a growing concern throughout the world. It is showing up in most manufacturing and service industries. It is related to quality control but is broader in scope. Quality assurance has to do with the confidence that others have in your competence. It is not necessarily complicated but usually quite detailed. Simply put, it is to plan what to do, do what is planned, and prove it was done. Seed certification has these elements of quality assurance. A plan is made to collect seed from a certain location, the collection is made, and by relying on inspection by the crop improvement agency, third party verification is provided that the work has been done correctly.

Why should we be concerned about quality assurance for seeds of native plants? First there are many publics who feel they have a right and an obligation to speak out on the management of public and private land. Highly effective and verifiable documentation can demonstrate to these concerned parties and legal authorities that artificial regeneration is as good as or possibly better at maintaining biodiversity and adaptability of plant populations.

A second part of quality assurance programs is communication with the customer. Recent studies have shown that the number of owners of rural lands is increasing, that the parcels are becoming smaller, and the owners increasingly are absentees living in urban areas. These factors all add up to a public that is not knowledgeable enough to ask the important questions about seed source. An attitude of not telling about seed sources and propagation procedures until the buyer asks is likely to leave the uninitiated buyer making mistakes. It may leave the landowners purchasing plants or seeds not suited to their lands which is bad for the environment on the whole and puts artificial regeneration in a bad light because of planting failures. The International Organization for Standardization, nicknamed ISO, has developed model standards, ISO 9000, that are used or serve as a pattern for quality assurance programs in many service and manufacturing enterprises (Katner, 1994). There is also an ISO 14000 that deals with environmental management standards (Cascio et. al., 1996).

How and who would develop quality assurance programs for nurseries and the native plant seed sector? The Association of Official Seed Certifying Agencies is already familiar with this type of work and has an active Tree, Shrub and Native Plants committee. The American Seed Trade Association also has an active Tree, Shrub and Native Species committee. These two groups would, therefore, be natural participants. Nursery associations and conservation groups would necessarily also be involved in developing standards. An effective accreditation program would simply formalize and standardize, in an easily communicated format, all the steps that a responsible conscientious nursery manager or seed supplier would want to do. By careful planning, the cost of the program will be negligible and the dividends substantial.

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The Tetrazolium Estimated Viability Test for Seeds of Native Plants[1]

Victor Vankus[2]

Abstract--The demand for seed and planting stock of native species has grown substantially over the past several years. The demand is driven by federal and state agencies, conservation groups and the public that want to use the plants for a wide range of land management applications. Seed producers and nurseries need clean, viable, high quality seed of native species. Seed testing is an important component in the production process of these seeds and test results can be used to manage a variety of activities. One of the tests commonly used to evaluate seed viability of native plant species is the tetrazolium or TZ test. The TZ test is accurate and can be conducted within a few days by an experienced analyst.

INTRODUCTION

The demand for seed and planting stock of native species has grown substantially over the past several years. The demand is driven by federal and state agencies, conservation groups and the public that want to use the plants for a wide range of land management applications. In the context of this paper, native plants can be defined as those plants endemic to a particular area that have not been traditionally used by land managers or produced by the seed and plant production industries for timber, ornamental and other uses. This would include grasses, wildflowers, forbs, wetland and many hardwood tree and shrub species. In order to meet the demand for these species, more seed companies and nurseries are working with these plants than ever before. Seed producers and nurseries need clean, viable, high quality seed of these species. Seed testing is an important component in the process of producing high quality seeds and plants. Test results can be used to manage a variety of activities from seed production and processing to nursery production and commercial sales. One test commonly used to evaluate seed viability is the tetrazolium or TZ test.

THE TETRAZOLIUM ESTIMATED VIABILITY TEST

The TZ test was developed in Germany in the early 1940's by Georg Lakon and introduced in the United States after World War II. The use of the test has increased and expanded since then because it can be completed quickly, usually within a few hours. This is a faster method of determining seed viability than a standard germination test and TZ results are commonly used in place of germination test results. The procedure is also used to determine the viability of ungerminated seed at the end of a germination test.

The TZ test measures the activity of the dehydrogenase enzymes used in the respiration process. Respiration is the cellular process of breaking down sugars to produce energy, carbon dioxide, and water, using oxygen. The enzymes react with substrates releasing hydrogen ions to the soluble tetrazolium chloride salt solution. The salt solution is reduced by the hydrogen ions. The colorless TZ salt solution is changed into an insoluble reddish compound called formazan. If the embryo and possibly

[1]*Vankus, V. 1997. The Tetrazolium Estimated Viability Test for Seeds of Native Plants. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 57-62.*

[2] *USD A Forest Service, National Tree Seed Laboratory, Dry Branch GA 31020.*

endosperm or secondary nutrient reserve or storage tissues are actively respiring, formazan will be present and the tissues will stain red. Seed viability is determined by evaluating the amount of area stained, the intensity of staining, the pattern of staining and by evaluating other critical characteristics including turgidity, presence and damage of essential structures, abnormalities, and pathogen presence.

The estimated viability of a seed lot is based on the number of seeds per testing sample that display the required staining, structural and other characteristics necessary to classify a seed as viable. A viable seed is considered to be capable of producing a normal seedling under favorable conditions. Classifications of normal or abnormal, healthy or damaged are elaborated on in much detail in seed testing TZ handbooks.

Table 1 outlines the basic procedure and materials required to conduct TZ tests.

The International Seed Testing Association (ISTA) and the Association of Official Seed Analysts (AOSA) have TZ testing handbooks. The 1985 ISTA handbook is a little hard to use but the information is thorough. The proposed 1998 AOSA publication (an update of the 1970 AOSA publication) will have introductory pages with general information and basic instructions and then specific procedures listed by family for approximately 300 genera in over 90 families. Most families will have one set of procedures listed for preparation, staining and evaluation.

Some families with a large number of diverse genera will have two or three sets of procedures listed. The

Table 1. The Tetrazolium test procedure and materials required.

Step and Description		Materials Required
Preconditioning.	Imbibing seed on a wet substrate or soaking in water. This makes it easier to cut the seed in the preparation step and it will facilitate the staining process.	Preconditioning and staining require beakers, watch glasses, petri dishes, paper towels, germination blotters and filter paper.
Preparation forstaining.	In order for the TZ solution to come into contact with the tissues inside of the seed coat, the seed will usually need to be cut or pierced.	Tools to cut, pierce and crack seeds: razor blades, needles, clippers and tweezers.
Staining.	The tissue of the seed must be exposed to the TZ solution for some minimum amount of time at a set temperature.	Tetrazolium solution consisting of 2,3,5-triphenyl tetrazolium chloride, a buffer additive to balance the pH and water. Solution should be stored in an amber bottle designed for light sensitive material.
Post staining.	The seed may require another cut or removal of the seed coat to observe the vital tissues that need to be analyzed during the evaluation phase.	Temperature control units. An oven cabinet or germinator that can maintain 20° to 40° C. for staining and a refrigerator to store the TZ solution in or to hold stained seed for an extended period of time.
Evaluation.	This step can be quite complex and is beyond the scope of this paper but it basically consists of looking at the embryo and the other tissue to see if it has stained.	Evaluation tools. Light, magnification, handbooks.

handbooks are a guide that contain procedures that can be used by analysts with limited experience. The directions will establish satisfactory test conditions that will allow an analyst to evaluate good staining results on viable seed. Once an analyst is familiar with a particular method or has worked with a particular genera or family for some time and is familiar with the intricacies of preparation and evaluation, strict adherence to the guidelines may not be necessary to produce reliable, accurate results. These are reference books, not rule books.

The most important requirements to performing accurate, reliable tests are training and practice! It is much easier for an analyst to learn how to conduct a TZ test if they have access to the handbooks and if they can receive training from experienced analysts. The USDA Forest Service, National Tree Seed Laboratory and the Oregon state seed laboratory in Corvallis, Oregon routinely provide training on conducting TZ tests and are familiar with native plant species. There are many state and commercial seed laboratories that conduct TZ tests but most do not provide training. Most seed laboratories focus primarily on testing agricultural species and do not have the money, personnel, time or experience with native plants required to develop and teach a workshop that covers this subject.

Testing genera that do not have procedures established requires a bit of investigation by the analyst. The analyst should determine whether or not there are procedures developed for other genera in the family with a similar seed morphology. If there are, it is likely that the same procedures can be used. If there isn't any information on the family or if there are not any genera with a similar seed morphology, there are likely to be genera of another family that do have similar morphological characteristics and these procedures may be used as a starting point. It is a good idea when testing seed of a new species or genera, to test a seed sample of known viability. This will allow the analyst to see what healthy seed look like when stained and will eliminate some of the uncertainty each analyst has when testing a new species for the first time. Using seed lots of a known viability is also useful when training new analysts. As with any type of seed testing procedure, the results of the test are only as good as the sample taken and sent to the lab. Proper sampling procedures must be followed to obtain a representative sample.

A few of the companies that sell chemicals (including TZ chloride) and laboratory supplies and the contact information for the seed testing associations are listed in Table 2. The cost of equipment and supplies are listed in Appendix A.

Table 2. Sources of chemicals and supplies for TZ testing.

FisherScientific	800-766-7000
Aldrich	800-558-9160
Baxter	800-328-9696
Sigma	800-325-3010
Hoffman Manufacturing Inc	800-692-5962
Seedburo	800-284-5779
Carolina Biological Supply	800-334-5551

Association of Official Seed Analysts
201 North 8th Street, Suite 400
PO Box 81152
Lincoln NE 68501-1152
402/476-3852 TEL
402/476-6547 FAX

International Seed Testing Association
PO Box 412
8046 Zurich
CH-Switzerland
41-1-371-34-27 FAX

Conducting TZ tests is time consuming and requires a variety of materials and expertise. Unless a large number of samples will be tested, it is more cost effective to have tests conducted at a seed testing laboratory. Some of the public and privately owned laboratories that conduct TZ tests on some types of native plant species (as opposed to agricultural species) include those listed in Table 3.

Table 3. Seed testing laboratories that conduct TZ tests.

State Laboratories	California, Colorado, Idaho, Montana, Nebraska, New Mexico, North Dakota, Oregon and Utah
Private Laboratories	Seed Testing of America(STA) in Longmont, CO, Ransom Seed in Carpinteria,CA
Federal Laboratories	USDA Forest Service, National Tree Seed Laboratory Dry Branch, GA

There are also state Crop Improvement Association laboratories in some states. Seed companies may also have people trained to conduct TZ tests on native species.

TETRAZOLIUM AND GERMINATION TESTING OF NATIVE PLANTS

The results of a TZ test are based on live seed as opposed to the germination test which is a measure of viability based on the actual number of germinants under a defined set of test conditions. A germination test can provide accurate, reliable data on many native plant species. Two common problems with using a germination test, though, are that there may not be any published information on how to germinate a species and that successful germination may require a lengthy stratification or pretreatment period to overcome dormancy.

A dormant seed can not germinate even if there are otherwise favorable germination conditions. Dormancy can either be structural or chemical. A seed coat that blocks the uptake of water is considered a structural barrier. Chemical or physiological dormancy means that there is a chemical pathway that is blocked by an inhibitor or that may need to be established to allow the development or transport of essential chemical compounds or nutrients that are necessary to initiate germination. Breaking or overcoming physiological dormancy can take many months of stratification or conditioning. Completing this process however does not guarantee that all of the dormant seed will germinate.

Table 4. Tetrazolium Test Result Applications.

Seed Harvest.	If seed collection of a particular species is time consuming or costly, a TZ test on a small collection will provide more information on viability than a cut test. This will prevent wasting time and money on seed that is not worth collecting.
Processing.	A TZ test can be used to determine if a seed lot was damaged during seed cleaning, reducing viability.
Production.	Land managers and nurseries often need to sow or plant before germination test data is available. Tetrazolium test results can be used to determine the number of seeds that need to be planted to produce the required number of plants.
Commerce.	Tetrazolium tests provide a measure of quality upon which seed trade can be based. At the July 1997 meeting of the Association of Official Seed Certifying Agencies (AOSCA), participants relayed information indicating that prices for some native plant seed lots are determined by the field results (Karrfalt, 1997). Using TZ test results may help reduce some of the uncertainty present in this arrangement. Some states allow labeling and certification of some seed lots based on TZ tests.

Table 5. Advantages and Disadvantages of Tetrazolium Testing.

Advantages	Disadvantages
-Rapid estimate of seed viability	-Requires specialized training and experience
-Dormancy not generally a factor	-Labor intensive
-Detection of seed vigor	-May not detect minor damage
-Reliable backup for germination tests	-May not detect disease or fungal infection or chemical orfungicide damage
-Best when used as part of a germination test	-Test result interpretation and application
	-Cost

Dormancy and environmental test conditions that can influence the results of a germination test do not usually affect a TZ test. Although dormant seed can be difficult to stain, an experienced analyst can determine the viability of a dormant seed lot.

The germination test and the TZ test both provide information about a seed lot that a grower or land manager can use. Sometimes, depending on the species, the information from either one of the tests is enough to base a decision on. Other times it isn't and it can be beneficial to have results of both types of tests. While the two tests will produce similar end results, a TZ test is not designed to determine the degree of dormancy present in a seed lot. This kind of information is produced by a germination test. For this reason, some seed laboratories, Ransom Seed Laboratory for example, will not conduct a TZ test alone. Determining which test will provide the data required depends on the species and on how the test results will be used. Ideally, the TZ test procedure will be used as part of a germination test to determine the number of potential germinants and the number of dormant seed. The two tests together also provide the best information on the type of damage that may have caused a seed lot to deteriorate.

TETRAZOLIUM TEST RESULT APPLICATION

Tetrazolium test results can be used throughout the process of producing seed and plants. Tables 4 and 5 list the applications and the advantages and disadvantages of tetrazolium testing. Since so many native species have seed that are difficult to germinate, using a TZ test is the best alternative at this time. The TZ test is a tool. Like any tool, it has an application that it was designed for and it has its limitations. A TZ test can provide fast, reliable information on the viability of a seed lot. The test can take from a few hours to a few days, but this is much faster than a standard germination test. The TZ test also requires specialized training and experience. An analyst unfamiliar with TZ testing has to have knowledge of seed morphology and have the ability and time necessary to learn how to evaluate or "read" a stain. The cost of the test and interpreting the results are also considerations.

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Appendix A. Equipment and Supplies Price List

		Laboratory set-up	Minimum to conduct
2,3,5-Triphenyl Tetrazolium chloride	10 gram bottle, cs of six	$270	$270
Buffer chemicals			
KH_2PO_4 (Potassium Phosphate Monobasic)	500 grams	$40	$40
Na_2HPO_4-$7H_2O$ (Sodium Phosphate Dibasic Heptahydrate)	500 grams	$37	$37
Beam balance		$130	$130
Amber bottle	1 gallon	$10	$10
Glycerol	1 liter	$100	
Gibberellic Acid	1 gr not less than 90%	$20	
pH Tester		$60	
Razor blades	cs of 100	$7	$7
Clippers	set of two	$20	$20
Tweezers		$24	$24
Beakers	assorted sizes	$200	
Beveled watch glasses	cs of twelve	$50	
Petri dishes	cs of 500	$130	
Blotters	per 1000	$70	$70
Hand lens		$20	$20
Magnification Scope w/ light		$1000	$1000
Incubator	desk size	$800	
ISTA 1985 TZ Handbook		$30	$30
AOSA 1998 TZ Handbook		$50	
	Approximately	$3100	$1650

This price list provides an approximate equipment and supply cost for the fewest items necessary to conduct a TZ test and for a small laboratory-type operation. The most costly item not included in a minimum set-up is the incubator. Tetrazolium tests can be conducted at room temperature but the seeds will take longer to stain and the temperature can not always be controlled. An estimate of $800 is on the low side for an incubator. Most incubators are larger than desk size and cost between $1500 to $3000.

The other major cost to consider is labor. An experienced analyst can prepare and evaluate a TZ test on 200 seeds in roughly 45 minutes. Some species take less time, others more.

Most seed laboratories charge between $35 and $65 per lot. Some labs have one set fee for all TZ tests while others set the price depending on the species to be tested. Forty-two tests at $40 each is approximately $1700. Seventy-eight tests at $40 each is approximately $3100. Most seed processing companies and nurseries do not conduct their own TZ tests. It is usually more cost effective to send the few samples each year that need to be tested in this manner to a seed lab.

You Want Us to Do What!? Diversifying Plant Products at the J. Herbert Stone Nursery[1]

David Steinfeld[2]

INTRODUCTION

It seems like only yesterday when a few of us were talking in the hallways after a coffee break about what we might do with our nursery fields when the demand for seedlings fell off. One suggested, "why don't we plant native grasses?" It was as wild an idea as suggesting that a cattle rancher try growing chickens. This was 1990 and we had been riding high on what seemed like a tidal wave of seedling orders for reforesting areas created by the fires and increased logging of the late 1980's. Looking back at this period, it seems that we, in a Forest Service nursery, were in the center of the cyclone as the rest of the Forest Service and Bureau of Land Management were swirling in forest politics. One thing seemed certain, when the storm settled there would be less demand for bareroot seedlings for reforestation. Less demand for seedlings meant more fields fallow, which would lead to higher seedling costs and ultimately less demands for seedlings. This negative cycle was something we wanted to avoid. Keeping our fields in crops, whether it be conifers or some other plant material, was one way to keep it from happening. This paper describes how we accomplished the transition to diversification of our plant products and at the same time, met the changing plant material needs of many of our federal land managing customers.

NATIVE GRASS SEED PROGRAM

Native grasses did not come up in our conversations until a year later when Wayne Rolle, forest botanist for the Rogue River National Forest, walked through the door with 15 little bags of seed he had collected from native stands of grass in the surrounding Siskiyou Mountains. "Do you want to grow these? I can't seem to locate a grass seed farmer interested." So began our native grass program.

The program started very small. We sowed Wayne's 15 species on small plots in a part of the field that never had grown a very good conifer crop due to it's hard soil and poor drainage. The seeds were sown in the fall amidst a few snickers from onlookers. Yet many of us were curious and even some, like myself, could be seen on our hands and knees, on many mornings, watching them grow. By the following spring, most of the grasses had grown into large plants, covering much of the beds. Since these plots were next to the main road, the clients who visited us were curious too and subsequently spread the word to their botanists and others resource people back at their field offices. Over the next few years we received bags of field-collected seed from field offices all over Oregon, Northern California and Montana with instructions to sow them in our beds for grass seed production.

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[1]*Steinfeld, D. 1997. You Want Us to Do What!? Diversifying Plant Products at the J. Herbert Stone Nursery. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 63-67.*

[2]*USDA Forest Service, J. Herbert Stone Nursery, 2606 Old Stage Rd., Central Point, OR 97502; Tel: 503/776-4281; Fax: 503/776-3764.*

Figure 1. Jack Campbell looks over the first crop of *Elymus glaucus*

The learning curve was steep. Stratification seemed simple for most species -just soak, sow, and in a week they germinate. But for 25% of the species we had to experiment with special stratification treatments to break dormancy. Learning how to grow grass plants in four-foot-wide nursery beds designed for bare root conifers was another challenge. We tried a variety of methods and eventually settled on sowing the rows a foot apart during mid to late fall and covering the beds with a sawdust mulch. We learned that the late fall sow avoided many of the weed species that germinate during the warmer late summer and early fall weather. Late fall sowing was just one of the many methods we used to put a dent in our weed problems. We also learned to attack them with brush hoe weeders, mechanical path weeders, flame throwers, hand weeders and eventually herbicides. Since our aim was to cultivate pure seed, our hand weeders needed to weed out any plant, including grass species, that did not belong in the seedlot. Six years, 55 acres in production and 20 tons of seed later, we can finally stick a grass straw (native that is) between our teeth with pride.

The intent of the native grass program from the beginning was to produce breeder seed for grass seed growers who would use it to grow bulk quantities. We believed that our nursery operations were ideal for this purpose. Our 4 foot beds and all the equipment designed for them lent themselves to growing small orders of seed. The challenge we faced was growing the seed source collections we were receiving for the same species without mixing pollen between seed sources.

The trick was to grow these seed sources far enough apart (150 to 300 feet depending on the species) to avoid the risk of pollen contamination. This meant that we had to keep track of all collections and their locations in our fields. For some of the 24 species that we grow, this was not a problem since there were few seed sources, but for other species like *Elymus glaucus.* we needed to locate growing areas on our 210 acre nursery to isolate over 25 separate collections. Keeping track of all of this is much like a hotel owner scheduling rooms for 24 families where no two members of the same family could have rooms next to each other. It is not uncommon to hear our native grass seed manager, Colleen Archibald, who has around 120 collections a year to keep track of, say "the rooms are getting full for that species!"

Figure 2. Native Grass Seed Program Manager, Colleen Archibald, with a handful of recently harvested *Elymus glaucus* seed.

For species like *Elymus glaucus* and *Bromus carinatus,* the rooms are getting full. Fortunately, some of our local farmers are becoming interested in producing native grass seed. There are now a half a dozen local private growers producing seed on contract for the Forest Service and Bureau of Land Management. Our nursery is a source of expertise for these growers and we will refer our clients to them for seed production. Most of these growers are experienced farmers who are learning how to obtain very high yields from these easy-to-grow species. However there are many species that are still too difficult and risky for them to be interested in growing. Until this changes, we continue to work with the more challenging species.

As of this year, harvested grass seed from our nursery has been shipped to 32 ranger districts and BLM resource areas for a variety of projects such as restoring meadows, wildfire erosion control, road obliteration and weed control. For these clients, sowing native grass seed is a new experience, requiring experimentation and monitoring. One such project, administered jointly by the Bureau of Land Management and the Forest Service near Eugene, Oregon, evaluated how native grass seedlings would work on road cuts for erosion control. They compared eight treatments of applying native grass seed including: hydromulching, hand sowing, and installing several types of erosion control netting or mulches over the seed. They also compared the success of these native grasses to a sterile wheat mixture commonly used for these purposes. According to Jenny Dimling, Forest Botanist for the Willamette National Forest, the native grass treatments worked as well as the sterile wheat on the roadcuts in this area and all treatments met the objective of the project - to stabilize the roadcuts. Projects like these are invaluable in building our experience base for the proper application of these species.

CONTAINER PRODUCTION OF DIVERSE SPECIES.

The early 1990's was a time when the Forest Service and BLM would place very serious attention on a non-commercial tree species - the Pacific yew. As it turned out, this species would take on the unique role as "poster" plant for plant diversity on federal forests. Taxol, a chemical located in the bark and needles of the tree, had been found to be effective in treating ovarian cancer. With the production of the new drug, harvesting of the bark began in earnest and the need for yew seedlings for reforesting these areas was created. In 1992 the nursery built a greenhouse and shadehouse to meet the orders. We grew between 60 and 80 thousand yew plants annually, propagated mainly from cuttings. This continued for several years until the demand for yew bark ended on federal lands, as well as the requests for Pacific yew seedlings. But in its place came requests for a variety of different species and stocktypes for restoration projects.

In the mid 1990's a new emphasis on watershed restoration began to generate orders for native plants for erosion control projects. One such project is located on a very erosive site in the high Siskiyou Mountains on the Rogue River National Forest. Attempts at establishing a soil cover by sowing native grass seed or by fall planting native shrubs were unsuccessful. Results from a study in 1995 by Dr. Nan Vance, PNW Research Station, indicated that with the proper species, timing and techniques, restoration of these sites is very possible. Between 1996 and 1997, over 10 thousand native grass seedlings were planted by a Jobs-in-the-Woods crew at McDonald Basin. The grasses were grown for three months in Styro 6 containers and planted within several weeks of snow melt. Over time these seedlings are expected to stabilize some of the erosive granitic soils that are contributing sediment to the Little Applegate watershed, a key watershed for salmon habitat.

Watershed specialists are also restoring riparian areas with deciduous species like willows, maples, cottonwoods and aspen. A project to improve the fish habitat of the Applegate Reservoir in Southern Oregon, using native willows, has been in progress for the past 7 years. As with most reservoirs, the type of vegetation that can endure submersion during the spring and portions of the summer months, and extreme drought the rest of the year, is very limited. Willow is a good species for this environment, however the standard methods of establishment, like sticking or waddling, do not work in these drastically changing conditions. Ashland Ranger District project spokesperson, Laura Hardin, states that the seedlings must be planted in the fall and winter months when the water level of the reservoir is down. It is important that root initiation begin immediately after planting, three or four months

Figure 3. Jobs-in-the-Woods crew member plants native grass seedlings at McDonald Basin

Figure 4. Yohan Visser, greenhouse manager, next to large western red cedar and western hemlock

before they become submersed in the spring. She needed a willow with roots, so she has been ordering a Deepot 40 stuck with vegetative material collected from willow stooling beds we have established at the nursery for her district. Since this type of container comes in a rack of 20, the seedlings are easily transported to the planting sites by the Boy Scouts and other community groups that are involved with this project. The goal of this project is to plant a total of 7,000 seedlings over the life of the project.

"Bigger is better" is a relatively new approach to the reestablishment of conifers. Portions of our shadehouse now look like a small forest where we currently have an inventory of 10,000 large containers ranging in size from one gallon to five gallon. These are being used for recreational areas, riparian zones, and restoration areas. The Siuslaw National Forest began experimenting with large potted seedlings several years ago in an effort to reestablish conifers in the riparian areas of the coast range. According to reforestation specialist Ed Obermeyer, many of the stream systems lack large logs that are essential for good salmon habitat. Establishing conifers will eventually supply these stream systems with logs and much needed shade. The challenges that these clients face are an extremely dense shrub understory that limits the survival and growth of bareroot or container-ized seedlings and the very rocky soils associated with stream terraces. They realized they needed a larger tree. On a trip down to the J. Herbert Stone Nursery 5 years ago, Ed and others from the Siuslaw National Forest saw the large campground trees we were growing and realized the potential for their unique sites. Using 2 to 4 foot high western hemlock and western red cedar grown in 1 gallon to 4 gallon containers, they learned that this stocktype could survive in the cobbly soils and were tall enough to quickly outgrow the shrub understory.

Campgrounds are another environment where large potted trees are being planted. They are being used to create visual screens between campsites and to replace trees that have died. Establishing small seedlings in these areas is often impossible because they are overlooked by most unsuspecting campers (I know from personal experience, having spent an uncomfortable night sleeping on several small seedlings!). Taller trees have been purchased in the past but often from seed sources and even species not endemic to the site. Seedlings grown in 4 gallon containers or larger, from locally collected seed sources, not only command greater respect from the camper but are well adapted to the site.

In and amongst the potted trees that dominate our shadehouse facilities are an assortment of shrub and forb species. Currently we are growing a wide variety of species in all types of containers and propagative material. Many of these are small orders for specific revegetation projects - species like huckleberries, Oregon grape, thimbleberry, salal and snowberry are being grown for the moist forests; oaks, Whipple vine, manzanita and bitter cherry for the drier climates. Propagating many of these species is often by trial and error, since very little can be found in the literature on how to propagate them. Often the orders for these species are not consistent from year to year, with some years lacking any orders at all. Weekly monitoring and yearly consolidation of this information for each species helps us carry over our learning experiences between years.

BAREROOT PRODUCTION OF DIVERSE SPECIES.

Growing diverse species in our bareroot fields is not new to our nursery. For many years we have received requests from our drier site clients to grow bitter brush and mountain mahogany. This year for instance, we are growing 100 thousand bitter brush seedlings for the Goosenest Ranger District in Northern California. The silviculturists on this district work with their range and wildlife specialists planting their harvested units with a mix of ponderosa pine and bitter brush seedlings. The objective is to produce forage for deer that migrate through these areas in the winter and grazing cattle during the summer months, while establishing a new forest. Dave Ross, reforestation specialist for the district, sees a future district planting program to restock between 200 and 400 acres a year with this combination of species.

In wetter climates, like western Washington and Oregon, Forest Service and BLM personnel are requesting moisture-loving species like maples and alders. These species are being used to revegetate decommissioned roads and watershed restoration projects. Responding to two successive years of flooding on the Gifford Pinchot National Forest, district watershed specialists and fisheries biologists have identified many disturbed areas in need of revegetation. One of the major problems associated with the flooding was landslides. Until these areas are revegetated, they will contribute sediment to the river systems. According to Gail Bouchard, plant specialist for the Wind River Ranger District, deciduous trees, like Sitka alder, vine maple and cascara, can quickly return cover and stability to these disturbed sites. She is currently gearing up to plant 10 large slides next spring. Seedlings will be planted only inches apart across the slope to create a live silt fence every 10 to 20 feet. We will be supplying over 50,000 1 -0 bareroot Sitka alder to this project. One of the major obstacles in meeting these requests is obtaining enough viable seed for germination. Seed from many of these species have low germination rates and do not store for very long. The challenge to our nursery is learning how to obtain optimum seed viability through special seed handling and culturing practices.

DIVERSIFICATION HAS CHANGED OUR NURSERY

The diverse species program at J. Herbert Stone Nursery now accounts for 15 percent of our income from the sale of native plant materials. In the past 7 years it has literally changed the landscape of the nursery as well as how we manage it. Not only have we been able to keep our fields in full production, we have also been able to maintain a vital workforce too. We estimate that the work generated from the production of diverse species is responsible for 5 full-time positions. This is work that is shared across the workforce and spread throughout the year. We used to think that the winter and spring months were our busiest time of year, between lifting and processing of seedlings and sowing the 1 -0's and culturing the 2-0's. Summer and fall were periods to relax and regroup. The diverse species program has changed that! Now, between harvesting grass seed in the summer and sowing grass beds in the fall we are busy year round.

In a time of downsizing, having the equivalent of five additional employees has given us the depth and stability needed to maintain the production of high quality plant materials, including the production of bareroot conifers for reforestation. Growing a wide variety of species (over 100) and stocktypes has also challenged all of us working at J. Herbert Stone Nursery to grow professionally and creatively. These are intangible benefits, yet I believe they are the ingredients that have helped develop a highly motivated workforce that is responsive to the changing needs of our clients.

Figure 5. Culturist, Steve Feigner, looks over a crop of 1-0 Sitka alder

Natural Resources Conservation Service (NRCS) Native Plants for the Pacific Northwest[1]

Scott Lambert[2]

INTRODUCTION

The Plant Materials Program of USDA Natural Resources Conservation Service (formerly Soil Conservation Service) has been working with and developing plant cultivars since the 1930's for conservation purposes. The Plant Materials Program, through Plant Materials Centers (PMC), have evaluated and released conservation plants that were collected in the USA as well as other parts of the world. Initially, the program concentrated on testing, evaluating, releasing cultivars, and maintaining original seed or plants of conservation grasses and legumes for rangelands and pasturelands, trees and shrubs for windbreaks and shelterbelts, and cover crops for roadbanks and croplands.

PLANT MATERIALS CENTERS

The NRCS PMCs are now predominantly focusing on North American native shrubs, grasses, grass-like plants, legumes, and wildflowers for conservation, restoration, revegetation and rehabilitation purposes. NRCS has cooperatively released almost 200 cultivars of North American native plants for commercial seed or plant production.

Currently, most of the NRCS Plant Materials studies at the Pacific Northwest PMCs involve native species, especially for wetland and riparian sites. The Pacific Northwest PMCs are located at Corvallis Oregon, Pullman, Washington, and Aberdeen, Idaho; with some studies at Lockeford, California, and Bridger, Montana. The native plant studies include developing methods and techniques for plant propagation, genetic and ecotypic variations within species, seed production and storage, establishment and maintenance of native plantings and onsite monitoring studies, in addition to the evaluation of materials for release purposes. Other federal and state agencies, universities, groups, and individuals are collaborating on many of these efforts to generate technical plant information for public use.

Purposeful genetic manipulation, such as breeding, of germplasm was not practiced during the development of most of the NRCS native cultivars. Unintentional genetic manipulation, genetic drift, can and does occur in the development of native plant cultivars. Certain practices are employed to reduce the level of genetic drift. All cultivars are produced in an environment very similar to the original site. Breeding systems for each cultivar are identified and populations are adequately isolated to diminish potential outcrossing. Multiple harvesting of seed in a growing season captures much of the seed and genetic variability within a population. The original seed or plants of the original native materials are maintained at the Plant Materials Centers and are used as a base germplasm. The number of generations of seed production are restricted and overseen by State seed certification agencies.

The latest effort to maintain the genetic integrity of native plant materials released from the Plant Materials Program is the adoption of the Pre-Varietal release concept. Native plants released under the Pre-Varietal program do not require the rigorous multiple-generation

[1]*Lambert, S. 1997. Natural Resources Conservation Service (NRCS) Native Plants for the Pacific Northwest. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 68-70.*

[2]*USDA-NRCS, 127 Johnson Hall, NATRS, WSU, Pullman, WA 99164-6410; Tel: 509/335-7093; e-mail: (lamberts@wsu.edu).*

evaluation process associated with cultivar releases. Plant materials can be released much more quickly and fewer, if any, generations occur beyond the original collection site.

Certified seed and nursery stock, of NRCS cultivars and Pre-varietal releases are commercially grown by private seed producers and nurseries to be sold and distributed for conservation plantings.

Native shrub cultivars have been released by NRCS and cooperators from sources originating in the Pacific Northwest states—Washington, Oregon, Idaho, Montana, and northern California. At least 20 released cultivars and numerous selections have been in evaluations at PMCs and are listed in Table 1 (location and responsible PMC in parentheses).

NRCS has also released eight native shrub cultivars originating from plants indigenous to central and southern California.

In addition, cultivars or selections of native grasses, grass-like plants, legumes and wildflowers were originally collected from indigenous stands in the northwestern states (Table 2). The original source state or province and responsible PMC are in parentheses following the plant name. Most native plant cultivars have been cooperatively relased with other agencies and state agricultural experiment stations (Table 2).

Table 1. Native shrub cultivars from NRCS Plant Materials Centers.

Skamania select Sitka alder, in evaluation	(southwestern WA, Corvallis PMC)
Owyhee select fourwing saltbush, in evaluation	(ID, Aberdeen & Pullman PMCs)
'Wytana' fourwing saltbush	(eastern Montana, Bridger PMC)
'Mason' red-osier dogwood	(western Washington, Corvallis PMC)
Trailar' western clematis	(central Washington, Pullman PMC)
'Umatilla' snow buckwheat	(northcentral Oregon, Pullman PMC)
'Lassen'bitterbrush	(northeastern California, USFS & Lockeford PMC)
'Curlew' Drummond's willow	(northern Washington, Pullman PMC)
'Silvar[1] coyote willow	(southeastern Washington, Pullman PMC)
'Rivar' Mackenzie's willow	(southeastern Washington, Pullman PMC)
'Clatsop' Hooker's willow	(northwestern Oregon, Corvallis PMC)
'Rogue'arroyo willow	(southwestern Oregon, Corvallis PMC)
'Rivar' Mackenzie's willow	(southeastern Washington, Pullman PMC)
'Plumas'Sitka willow	(northern California, Corvallis PMC)
Blanchard blue elderberry	(pre-varietal, northern Idaho, Pullman PMC)
'Bashaw' Douglas' spirea	(western Washington, Corvallis PMC)
Okanogan selection common snowberry	(northern Washington, Pullman PMC)

Table 2. Other native plants from NRCS Plant Materials Centers.

'Canbar' Canby's bluegrass	(Washington, Pullman PMC)
'Shemman' big bluegrass	(Oregon, Pullman PMC)
'Bromar' mountain brome	(Montana, Pullman PMC)
———tufted hairgrass	(western Oregon, Corvallis PMC)
———California oatgrass	(western Oregon, PMC)
Roswell selection Baltic rush	(western Idaho, Aberdeen PMC)
'Nezpar' indian ricegrass	(Idaho, Aberdeen PMC)
'Rimrock' indian ricegrass	(Montana, Bridger PMC)
Centennial selection Nebraska sedge	(central Idaho, Aberdeen PMC)
Fish Lake selection Columbia sedge, in evaluation	(OR, USFS &Corvallis PMC)
'Goldar' bluebunch wheatgrass	(Washington, Aberdeen PMC)
'Whitmar' beardless bluebunch wheatgrass	(Washington, Pullman PMC)
'Secar' Snake River wheatgrass	(Idaho, Pullman)
'Primar' slender wheatgrass	(Montana, Pullman PMC)
'Pryor' slender wheatgrass	(Montana, Bridger PMC)
'Sodar' streambank wheatgrass	(Oregon, Aberdeen PMC)
'Critana' thickspike wheatgrass	(Montana, Bridger PMC)
'Schwendimar' thickspike wheatgrass	(Oregon, Pullman PMC)
'Bannock' thickspike wheatgrass	(ID, WA & OR sources, Aberdeen PMC)
'Rosana' western wheatgrass	(Montana, Bridger PMC)
'Magnar' basin wildrye	(British Columbia, Canada, Aberdeen PMC)
Trailhead' basin wildrye	(Montana, Bridger PMC)
'Arlington' blue wildrye	(western Washington, Corvallis PMC)
'Elkton' blue wildrye	(western Oregon, Corvallis PMC)
'Hederma' pine lupine	(western Oregon, Corvallis PMC)
Clearwater selected alpine penstemon	(Idaho, Aberdeen PMC)

Propagating Woody Riparian Plants in Nurseries[1,4]

R. Kasten Dumroese[2], Kathy M. Hutton[3], David L. Wenny[2]

Abstract—We provide basic information for nursery production of ten genera of riparian plants. These plants can easily be grown as a one-year crop in an enclosed or open-sided greenhouse using many of the same basic cultural practices developed for reforestation species.

Key Words—propagation, riparian, container-grown, fertilization

RIPARIAN PLANTS

Just what does that title mean? Well, speaking for most nursery managers, we know about "propagating," and "nurseries'" is self-explanatory. It's not much of a stretch to define "woody" — for traditional forest nursery managers that means none of that grassy stuff (i.e., *Carex, Scirpus).* But what does "riparian" mean? According to the dictionary, a riparian plant is any plant growing along a natural water course. Well, using a broad definition like that includes many plants, probably many that we already grow but don't think of as "riparian." For example, in central Washington *Artemisia* spp. (sagebrush) is often considered a riparian plant. For the scope of this paper, we'll focus on what many view as more traditional riparian plants: *Alnus, Amelanchier, Betula, Crataegus, Populus, Primus, Rosa, Salix, Sambucus,* and *Symphoricarpus.*

SEED PROCESSING & BAREROOT CULTURE

A review of seed processing techniques and bareroot culture for many of these plants was published by Shaw (1984) and will not be repeated here. Readers interested in bareroot production may also wish to read Morgensen's (1992) paper on *Salix* and *Populus* production, and nutrition considerations provided by Davey (1984). If you're planning hardwood production, you may also wish to read Finnerty and Hutton (1993) for things to consider before venturing further.

PROPAGATION TECHNIQUES

Four propagation methods are used for riparian plants in container nurseries: root cuttings, hardwood cuttings, softwood cuttings, and seed. ***Root cuttings*** are a special technique and usually only used on *Populus tremuloides.* A review of asexual reproduction of *P. tremuloides,* including root cuttings, is found in Campbell (1984) and specific instructions for collecting and growing root cuttings are provided by Schier (1978). This technique is very labor intensive, both in the field and in the nursery, and is therefore very expensive and seldom used in production nurseries. However, it may be the only propagation technique available, especially if a particular male clone is needed.

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[1]*Dumroese, R.K.; Hutton, K.M.; Wenny, D.L. 1997. Propagating Woody Riparian Plants in Nurseries. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 71-76.*

[2]*Forest Research Nursery, Department of Forest Resources, University of Idaho, Moscow, Idaho, 83844-1137. e-mail (dumroese@uidaho. edu) or(dwenny@uidaho. edu).*

[3]*Plants of the Wild, PO Box 866, Tekoa, Washington, 99033.*

[4]*Idaho Forest, Wildlife and Range Experiment Station Contribution Number 842.*

Cuttings from dormant tissue, usually woody stems with well-formed lateral buds, are called ***hardwood cuttings***. This technique is the most-used method because most *Populus* and *Salix* species are propagated this way. Species propagated via hardwood cuttings include *Cornus stolonifera (C. sericea), Populus* spp. (except *P. tremuloides), Salix* spp., and *Symphoricarpus albus.* Cuttings are usually made from stooling beds in late winter or early spring (December-February) and kept dormant by refrigerated storage. For container production, typical cuttings are 4-8 inches long (10-20 cm) with many lateral buds (Fig. 1). Cuttings may or may not be dipped in rooting hormone and/or fungicides, and are usually stuck directly into 1:1 peat:vermiculite in containers in which they'll be grown. Stuck cuttings are often misted until roots form.

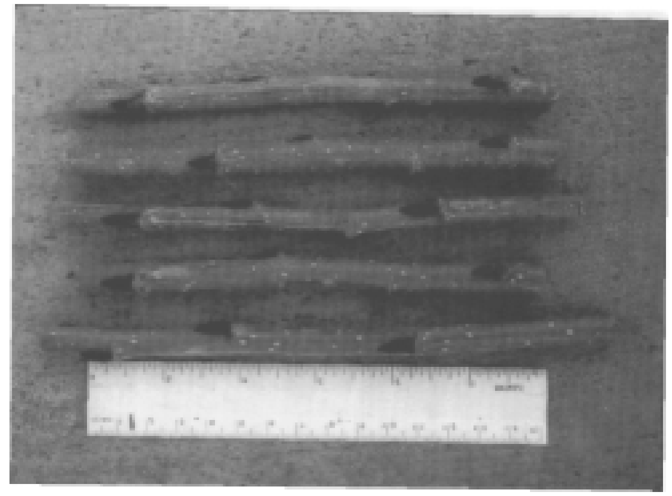
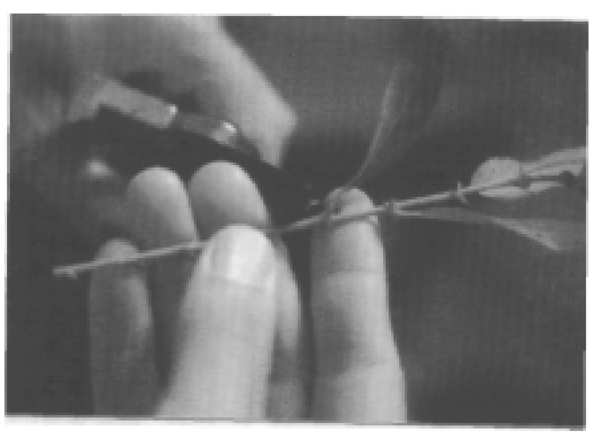


Figure 1. Hardwood cuttings of *Populus* ready to be planted.

Cuttings made from actively growing tissue, often terminal tips, are called ***softwood cuttings.*** *Amelanchier alnifolia, Cornus stolonifera, Crataegus* spp., *Populus* spp. (except *P. tremuloides), Prunus* spp., *Salix* spp., and *Symphoricarpus albus* are species propagated this way. Usually, cuttings 3 to 5 inches long (8-10 cm) are clipped, and leaves are removed from the bottom half to two-thirds of the cutting (Fig. 2). The severed end of the cutting may or may not be dipped in a rooting hormone and/or fungicide. Cuttings are stuck into a well-drained mix, but occasionally right into 1:1 peat:vermiculite. Usually, retained leaves are clipped in half and shoot tips are removed to reduce transpirational losses, and cuttings are kept under high humidity to maintain turgor. Although softwood propagation can be done later in the crop year so a second crop of softwood cuttings could be planted after a hardwood cutting crop is stuck, it is seldom used in production facilities.

The most common method of producing riparian plants, including some *Populus* and *Salix* species, is ***seed*** propagation. This technique is easiest for most nursery managers because we're familiar with seed and have automated equipment for planting it. Common plants grown from seed include *Alnus* spp., *Amelanchier alnifolia, Betula* spp., *Cornus stolonifera, Crataegus* spp., *Populus* spp. (including *P. tremuloides), Primus* spp., *Rosa* spp., *Salix* spp., and *Symphoricarpus albus.* Although we may be accustomed to using seed,



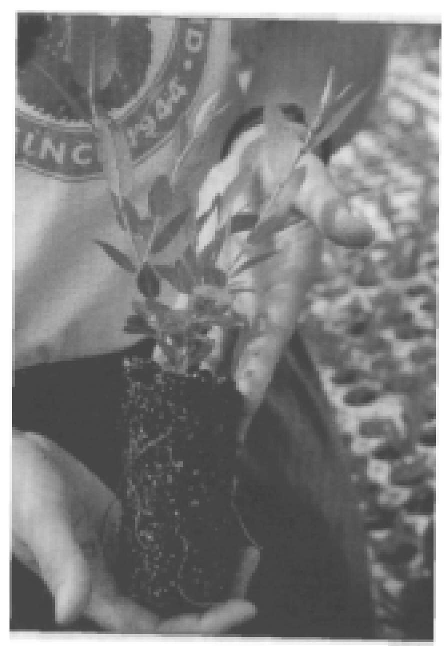


Figure 2. A *Salix* softwood cutting ready to be planted (left) and after growing three months (right).

we may not be as accustomed to growing riparian, non-traditional, species. Other problems can include unavailability of good seed in sufficient quantities, poor seed quality, a lack of proven stratification techniques, and difficulty in obtaining year-to-year consistency with seedling establishment.

NURSERY & SPECIES DESCRIPTIONS

Below we describe some techniques currently used at our nurseries. Most of these have developed through trial and error, and work reasonably well at our facilities. These descriptions are intended to give you some insight as to where to begin your production process.

Nursery Protocols—Plants of the Wild

Plants of the Wild (POTW) grows one crop each year within an enclosed greenhouse. Seeds requiring stratification are placed into mesh bags and buried in moist vermiculite for the necessary duration at 35°F (1-2°C). Seeds and cuttings are planted between March and June (depending on plant growth rates) into Ray Leach Super Cells (10 in^3 and 49 seedlings per ft^2; 90 ml and 527 seedlings per m^2) filled with 1:1 peat:vermiculite. Perlite is used as a top mulch. Seedlings receive periodic fertilization. All plants receive one application of Peters' Plant Starter (N:P:K = 9:45:15) at 90 ppm N immediately after thinning or about 3 weeks after cuttings are stuck. Plants are then given 200 ppm N of Peters' Peat Lite Special (N:P:K = 20:20:20) at three different frequencies depending on their growth rate. "Low" frequency plants grow rapidly and are fertilized once every two weeks. "Medium" plants are fertilized once each week and "high" frequency plants, because they grow slowly, receive fertilizer twice each week. All other irrigations are plain water. Once target heights are met, plants are fertilized with 9:45:15 at 90 ppm N continuing the same frequencies (low, medium, high) as those established with the 20:20:20 applications.

Nursery Protocols—University of Idaho

The University of Idaho (UI) grows one crop per year in an open-sided, lexan-covered structure. Most seeds requiring stratification are placed in mesh bags, soaked in running water for 48 hours, and then suspended within a plastic bag hung inside a cooler at 33-34°F (1 °C) for the necessary duration. Some species are sown directly into their containers (described below) during late October or early November to simulate more natural conditions and allow nursery workers to do some planting work during the fall slow period, rather than the hectic spring months. For fall sowing, containers are filled with 1:1 peat:vermiculite, seeds are planted, top-coated with a 0.5-cm-deep layer of silica grit, the medium is watered to saturation, and the entire container placed into cold storage (33-34°F (1 °C)). Fall sown containers are removed from storage in late May (unless they begin growing sooner). Seeds stratified in mesh bags and cuttings are planted between late May and early June into the Ventblock 45/340 (615A; 20 in^3 and 20 seedlings per ft^2; 340 ml and 215 seedlings per m^2) filled with 1:1 peat:vermiculite medium. Plants receive constant fertilization. Usually, plants are watered and fertilized twice each week. After thinning (about 3 weeks after sticking cuttings), all plants receive Peters' Conifer Starter (N:P:K = 7:40:17) at a rate of 42 ppm N twice each week for one month (8 applications). Then plants receive Peters' Conifer Grower (N:P:K = 20:7:19) at either 120 or 192 ppm N the first irrigation each week, and CAN-17 (liquid calcium ammonium nitrate; N:P:K:Ca = 17:0:0:8.8) at either 102 or 162 ppm N during the second irrigation each week. Plants receiving low rates of 20:7:19 receive low rates of CAN-17, and *vice versa.* Applications of Grower/CAN-17 continue for about two months (about 8 applications of Grower and 8 applications of CAN-17), then all plants receive Peters' Conifer Finisher (N:P:K = 4:25:35) at 24 ppm N alternated with CAN-17 at 102 ppm N until seedlings are extracted from their containers (about 3 months) and placed into cold storage.

Alnus spp.

POTW grows three species of alder *(rubra, sinuata, incana (tenufolia))* while the UI produces only *A. sinuata.* At both nurseries, plants are started from stratified seed (at least 90 days) and target height is 10 inches (25 cm). Seedlings at POTW are given the "medium" fertilizer frequency. At the UI, seedlings receive 20:7:19 at the 192 ppm N rate alternated with CAN-17 at 162 ppm N. Top-pruning is avoided.

Although neither nursery uses cuttings, *A. incana* can be successfully grown from hardwood cuttings. Jave and Everett (1992) achieved 76% rooting with a combination of cold treatment and rooting hormones.

Growth of these species may also be increased by inoculating with *Frankia* (a nitrogen-fixing, soil-inhabiting microorganism) four weeks after germination

(Subramaniam and others 1991). Root collar diameters and heights of inoculated plants were 2 and 4 times greater, respectively, than non-inoculated plants 13 weeks after sowing.

Amelanchier alnifolia

Both nurseries grow this plant from seed. Seeds are cold-moist stratified at POTW for at least 120 days; seeds are fall sown at the Ul. Target height is around 16 inches (40 cm). *Amelanchier* is given the "medium" fertilizer frequency at POTW, while at the Ul they receive 20:7:19 at 120 ppm N alternated with 102 ppm N CAN-17. At the Ul, when plants are 8 inches (20 cm) tall the first time, they're top-pruned to 6 inches (15 cm) to make a fuller plant and increase root collar diameter. POTW top prunes only when seedlings exceed target height.

Betula spp.

Betula papyri/era and *B. occidental is* are both grown from seed. Seeds are cold-moist stratified for 60 days at Ul and 90 days at POTW. At POTW, seeds are just barely covered with perlite after sowing, but at the Ul grit is not applied until after seedlings have emerged since they germinate better in the light. Target height is 16 inches (40 cm) and top pruning is avoided. Seedlings are given "medium" fertilizer frequencies at POTW; at the Ul they receive 120 ppm N via 20:7:19 alternated with CAN-17 at 102 ppm N.

Cornus stolonifera

This species can be propagated from hardwood or softwood cuttings and seed (Fig 3). Collection of hardwood cuttings generally follows the same protocol as that for *Populus trichocarpa* (see below). However, our experience is that customers prefer the appearance of seed-propagated material, and it's easier to grow from seed (Fig. 4). At POTW, seeds are acid-scarified (30-60 minutes in sulfuric acid) before 90 days of stratification. At the Ul, seeds are fall sown directly into containers. Target height is around 16 inches (40 cm). *Cormts* is considered a "low" fertilizer frequency plant at POTW, while at the Ul they receive 20:7:19 at 192 ppm N alternated with 162 ppm N via CAN-17. At the UI, when plants first reach a height of 8 inches (20 cm), we top prune them to 6 inches (15 cm) to make a fuller seedling and increase root collar diameter. At POTW plants are pruned only when they exceed target height.

Figure 3. A crop of *Cornus stolonifera* growing in Ray Leach Super Cells.

Crataegus douglasii

Currently grown at POTW, this species exhibits extremely variable seed germination. Seed gathered by the same collector, from the same stands, cleaned the same way, and stratified with the same method (90-120 days in moist vermiculite) may vary in germination between 20 and 80%. If it germinates, target height is around 10 inches (25 cm). Seedlings are fertilized at the "medium" frequency. Pruning is avoided.

Populus spp.

POTW grows both *Populus tremuloides* and *P. trichocarpa*, while only *P. tremuloides* is grown at the Ul. *Populus trichocarpa* is grown from hardwood cuttings. Cuttings are collected during winter and refrigerated until planting. Ideal cuttings are 8 inches (20 cm) long, about 0.25 inch (5 mm) in diameter, and have visible buds along the length (Fig. 1). Cuttings are dipped in 1:10 Dip-N-Grow: water immediately before planting. On warm, sunny days, cuttings are misted for 3 minutes once every 90 minutes but only once every 3 hours on cool, cloudy days. Cuttings receive one application of 9:45:15 at 90 ppm N, but receive 20:20:20 only sparingly (about once a month) in an attempt to keep height growth in check. Target height is 16-20 inches (40-50 cm). Once terminal buds have formed, seedlings receive 9:45:15 at 90 ppm N once every two weeks.

Populus tremuloides seeds must be freshly harvested (no more than one year old) and can be sown without stratification. At the Ul, sown containers are placed into a fog house (90+% relative humidity and 80°F (27°C)) until germination is complete (usually less than one week). At POTW, sown containers are placed directly into the greenhouse. Seedlings at POTW receive one application of 9:45:15 at 90 ppm N, and one application of 20:20:20 at 200 ppm N when seedlings arc about 2 inches (5 cm) tall. Until terminal buds are set, seedlings receive 20:20:20 sparingly (once each month) in an attempt to keep height growth in check. At the UI, seedlings receive 20:7:19 at 120 ppm N alternated with CAN-17 at 102 ppm N. Pruning is avoided at POTW while seedlings may be pruned at the UI to maintain the target height of 16-20 inches (40-50 cm).

Prunus virginiana

This species is grown from seed at both nurseries. Seeds are given at least 180 days stratification at POTW; seeds are fall sown at UI. Target height is around 16 inches (40 cm). When *P. virginiana* plants at the UI first reach 8 inches (20 cm) in height, they are pruned to 6 inches (15 cm) to enhance root collar diameter. Seedlings receive fertilizer at the "medium" frequency at POTW; at the UI seedlings receive 120 ppm N via 20:7:19 and CAN-17 at 102 ppm N.

Rosa **spp.**

Rosa nutkana and *R. woodsii* are grown at POTW from seed stratified 120 days. Target height for both species is around 10 inches (25 cm). The first time seedlings are 8 inches (20 cm) tall, they are top-pruned to 6 inches (15 cm) to make them fuller and increase root collar diameter. Seedlings receive fertilizer at the "medium" frequency.

Salix **spp.**

POTW grows around ten species of willow, with *Salix rigida "Mackenziena" S. scoideriana, S. exigua, S. lassiandra*, and *S. sitchensis* being produced in the largest quantities. All plants are grown from hardwood cuttings following the same cutting and fertilization protocols as that for *Populus trichocarpa* (see previous). Target height is around 16 inches (40 cm). Pruning is avoided as cut stems tend to turn black and die back to the first viable bud. Usually, rooting is 80% or better, the exception being *S. scouleriana*, an upland willow, which often roots in the 40-80% range. Edson and others (1995) increased the rooting of 3- to 5-inch-long (8-10 cm) hardwood and softwood cuttings by treating them with 0.3% IBA; hardwood cuttings rooted at 73% and softwood cuttings at 87%.

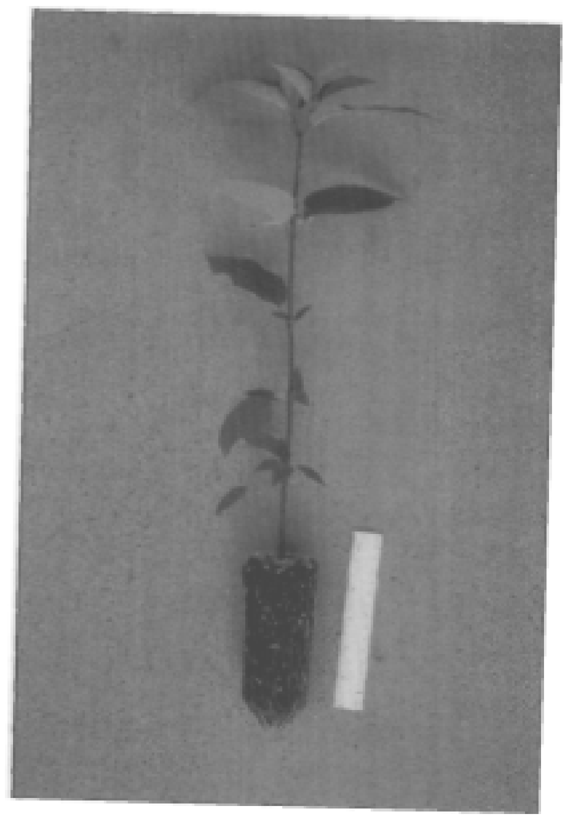


Figure 4. Four-month-old *Cornus stolonifera* plants growing in a Ventblock 45/340 (615A)(left) and an individual seedling (right).

***Sambucus* spp.**

Three species (*cerulea, racemosa,* and *racemosa* var. *melanocarpa*) are grown at POTW from seed stratified 120 days. When given the "medium" frequency of fertilizer, *Sambucus* grows rampant in the greenhouse (24-30 inches (60-75 cm)), but a target height is rather irrelevant as the shoot dies back to the ground the first winter. The robust height growth is a trade off necessary to accumulate sufficient roots to hold the plug together.

Symphoricarpus albus

At POTW *Symphoricarpus* is grown from hardwood cuttings following the protocol described for *Populus trichocarpa,* except that cuttings are dipped in 1:5 Dip-N-Gro:water. The best success ideally, is by rooting one-year-old suckers from plants in recently logged areas. Target height is 16 inches (40 cm) and can be reached only by using "high" frequency fertilization.

CONCLUSIONS

The more common woody riparian plants are relatively easy to grow using techniques, fertilizers, and growing medium used in traditional conifer production programs. As with all cultural programs, keep detailed records to help refine and define the evolution of the propagation technique that works at your specific facility.

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Propagation of Native Plants for Restoration Projects in the Southwestern U.S. - Preliminary Investigations [1]

David R. Dreesen[2] and John T. Harrington[3]

Abstract-*Seed* treatments to enhance germination capacity of a variety of native tree, shrub, forb, and grass species are reported. Scarification methods including hot water immersion (HW), mechanical scarification (MS), tumble scarification (TS), proximal end cuts (PEC), and sodium hypochlorite (SH) have been tested: *Psorothamnus fremontii* (HW, TS), *Ceanothus integerrimus* (HW), *Ceanothus sanguineus* (HW), *Rhusglabra* (HW), *Ptelea trifoliata* (PEC of seed separated by size and color), *Rubus strigosus* (SH), *Oryzopsis hymenoides* (TS), *Coleogyne ramosissima* (TS), and a variety of native woody and herbaceous perennial legume species (HW, TS, MS). Gibberellic acid treatments were examined to overcome endo-dormancy of *Alnus tenuifolia, A. oblongifolia, Rubus strigosus,* and *Oryzopsis hymenoides.* Vegetative propagation methods investigated include mound layering of *Platanus wrightii,* root propagation of *Populus tremuloides,* and pole plantings of riparian understory species *(Amorpha fruticosa, Baccharis glutinosa, Forestiera neomexicana,* and *Chilopsis linearis).*

INTRODUCTION

Restoration of disturbed lands in the southwestern U.S. has become a primary mission of many federal and state land management agencies and a regulatory requirement for extractive industries. Frequently, containerized or bare-root plant materials are used for reclamation activities following severe disturbance or for introduction of woody plant species formerly present on poorly managed lands. These plant demands have increased interest in propagation techniques and production methods for obscure native woody species. The lack of propagation information for many native species used in ecosystem restoration prompts nurseries to rely on experimentation to resolve propagation problems or forgo producing certain species. This problem is compounded by the scarcity of propagules (seed or vegetative material) of some species or ecotypes.

Seed propagation of native species often requires growers to rely on information from closely related horticultural species for seed treatment requirements. While this information is useful, many species are produced by the horticulture industry because of their ease of propagation as well as other horticulturally important traits. Secondly, seed used in the horticulture industry is often produced under optimum management conditions with seed lots having high percentages of viable seed. In contrast, seed lots of limited quantity and with unknown levels of viability are most often encountered by conservation nurseries. Therefore, two significant factors must be addressed to develop seed propa-

[1]*Dreesen, D. R. and Harrington, J. T. 1997. Propagation of Native Plants for Restoration Projects in the Southwestern U.S.- Preliminary Investigations. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 77-88.*

[2]USDA-NRCS, Plant Materials Center, 1036 Miller Street, SW Las Lunas, NM 87031; Tel: 505/865-4684; Fax: 505/865-5163

[3]New Mexico State University, Mora Research Center, Mora, NM 87732

gation protocols for many native plants: first, seed refinement, or eliminating non-viable seed from the seed lot, and second, overcoming obstacles to germination of recalcitrant species. These obstacles frequently fall into two categories: impermeable seed coats and dormant seed. Typically, scarification and stratification techniques are used to overcome these obstacles, respectively.

Seed refinement procedures for many tree and shrub species are well known (Young and Young 1992, Schopmeyer 1974a). Seed refinement involves increasing the percentage of viable seeds in a seed lot and is often accomplished by seed sizing and liquid or air separation techniques. However, seed refinement techniques for many reclamation species have not been published or conventional techniques are not suitable due to seed properties. For example, seeds with integuments or wings often preclude the use of conventional gravity separation techniques.

Often, seed production of many species in native stands is sporadic with up to ten years intervening between adequate seed crops. Vegetative propagation offers an acceptable alternative propagation system to meet production requirements. The horticulture industry is a good source for vegetative propagation information of species not historically produced in conservation nurseries. However, the differences between horticultural varieties and reclamation ecotypes are very pronounced, largely due to adventitious rooting being strongly controlled by genetics. Cultivar releases in the horticulture industry have often been attributed to the ability to produce adventitious roots.

This paper will address some of our experience in the seed propagation of native tree, shrub, forb, and grass species. These simple experiments are aimed at resolving problems with total germination percentage, rate of germination (germination speed; days to total germination of a seed lot), and germination uniformity. Benefits associated with improving germination percent are straightforward. Improvements in germination speed and uniformity can dramatically influence seedling quality and production costs. In addition, several promising vegetative propagation techniques are discussed. The paper is organized by the type of treatment or propagation method being examined. Within each section a summary report is provided on the species or group of species evaluated.

SEED PROPAGATION

Scarification Studies

Psorothamnus fremontii

This woody leguminous shrub found in the Mojavean and Navajoan Deserts of the Colorado Plateau has various pseudonyms including *Dalea fremontii* (Benson and Darrow 1981). Common names applied to this species include Fremont dalea, indigo bush, and Johnson dalea (Benson and Darrow 1981). The source of seed for this experiment was the Glen Canyon National Recreation Area in northeastern Arizona and southeastern Utah. A means of improving total germination and germination rate was essential because of limited seed supplies. Previous trials with 2-year-old seed had shown that traditional mechanical scarification (Forsburg J seed scarifier) resulted in excessive seed breakage and was therefore not an acceptable scarification technique.

Seed was fractionated into large (11/64 to 13/64 inch (4.3 to 5.2 mm)), medium (9/64 to 11/64 inch (3.6 to 4.3 mm)), and small seed (7/64 to 9/64 inch (2.8 to 3.6 mm)) using round hole screens. Two scarification treatments were evaluated, hot water soak and tumbling mechanical scarification. The hot water treatment involved immersing 5 to 10 g of seed in 100 ml of 90°C water and letting stand for 1 hour. After immersion, the seed was separated into floating seed, swollen sinking seed, and non-swollen sinking seed. The mechanical scarification used a rock tumbler (one-liter capacity) with 100 g of pea-sized (10 - 15 mm) gravel, 75 g of coarse carborundum grit, and a rotation rate of 60 rpm. Two batches of medium-sized seed were subjected to 1 day and 3 days of tumbling. Seed receiving no scarification treatment served as a control. Treated and control seed were planted in [288-cell square deep-plug] trays filled with Sunshine #1 Mix®. Seeds were immediately planted and placed in the greenhouse (23°C day, 15°C night). Germination was monitored weekly for the next 10 weeks. The study was replicated six times.

Seed size influenced germination with larger seed having faster and greater germination (Figure 1). The tumbling mechanical scarification of medium-sized seed resulted in better germination than the control and hot water treated seed and tumbling also significantly improved germination speed. As the duration of tumbling increased from one to three days germination speed was significantly increased; however only a

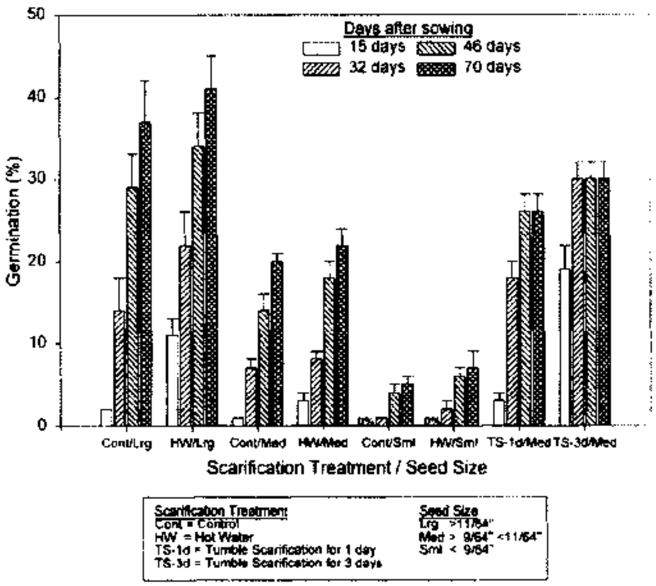

Figure 1. Effect of seed size, hot water and tumble scarification treatments on the germination (± standard error) of *Psorothamnus fremontii.*

minor 4% increase in total germination copmared with the control was observed. Hot water scarification treatments improved germination speed, while having only slight effects on total germination at the end of 70 days (Figure1).

The effect of seed size was evident across the three seed conditions (swollen, non-swollen, floating) following hot water incubation (Figure 2). Non-swollen seed had the greatest total germination at the end of the study (70 days) in all three seed sizes. Germination rate was fastest in the swollen seed in the two largest seed sizes, however, total germination was significantly less (at least 50%) relative to non-swollen seed. Only in the largest seed size did floating seed have greater germination rates than controls (Figure 2).

Using seed sizing can be a viable means of seed refinement in this species. If hot water scarification is used, partitioning seed into swollen, non-swollen and floating fractions could be used to further improve germination performance.

Leguminous Species

The water-impermeable seed coat of legume species generally requires scarification treatment to allow water imbibition and subsequent germination. Treatments often used to overcome obstacles associated with a hard, impermeable seed coat include hot water soaks, concentrated sulfuric acid, and mechanical scarification. Variation between and within species to these treatments makes prediction of treatment efficacy difficult. Also, scarification treatment methodology and severity may influence results.

Sulfuric acid treatments can be effective if the precise treatment time is known; excessive treatment duration can destroy most or all of the seed. Insufficient duration fails to adequately break down the hard seed coat. Difficulties in working with concentrated acid also dissuade some propagators from using this technique. Hot water soaks can be effective but research has shown that the germination response can be a function of both initial water temperature as well as the duration of the soak (Gosling et al. 1995). If this interaction is not known for a particular species, excessive temperature and/or duration can kill the seed. Some laboratory mechanical seed scarifiers can rapidly abrade seed coats through high-energy impact of seed against an abrasive medium such as sandpaper. Again, excessive treatment time can destroy a batch of seed. Seed of certain species are very easily damaged by these high-energy impacts, such as some *Lupinus* species, whose cotyledons are split apart by even the briefest conventional scarifier treatment. In some species even when breakage is not observed, these impacts can kill the embryo or damage other seed tissues. The need for

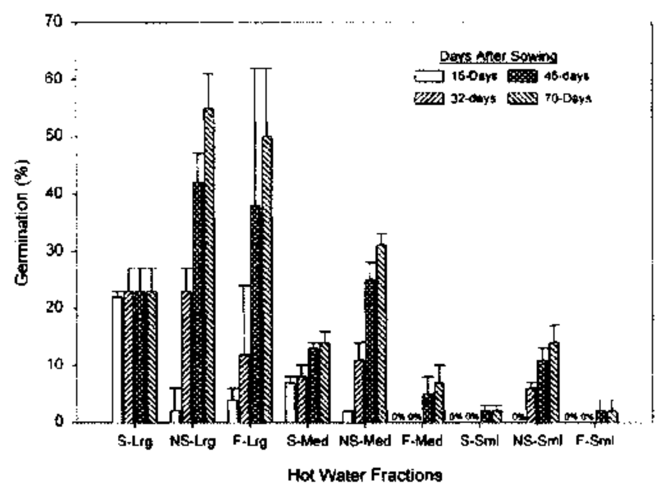

Figure 2. Germination (± standard error) of swollen (S), not swollen (NS) and floating (F) *Psorothamnus fremontii* seed after hot water treatment.

more reliable legume scarification information for use by propagators is substantial. Scarification information would also benefit land restoration specialists who drill or hydroseed legumes and often desire rapid germination.

Many nurseries prefer to use hot water or mechanical scarification to treat legume seed because the equipment for these treatments is available and because of the potential hazard of using sulfuric acid. A series of experiments were conducted on several legumes examining hot water treatments and two types of mechanical scarification. The scarification treatments evaluated were:

1) control - no scarification treatment other than that received during standard seed cleaning procedures;

2) hot water - pouring hot water (90°C) over seed batches and allowing to steep for 4 hours;

3) mechanical scarification - using a commercial small sample scarifier (ForsbergR) that employs a rapidly spinning paddle to throw seed against an abrasive lined drum (100 grit sand paper) for 3 to 75 seconds;

4) tumble scarification - using a rock tumbler with pea gravel and coarse carborundum grit for 2 to 3 hours (see Psorothamnus section);

Table 1. Germination percentage of legume seed subjected to scarification treatments.

				% Germination (Mean ± S. E.)			
Species	**Form**	**Origin**	**Seeds per Replication**	**Control**	**Hot Water**	**Mechanical Scarification**	**Tumble Scarification 2-3 Hrs**
Amorpha canescens	Woody	Native	25	57 ± 7	48 ± 2	3*± 1	58 ± 5
Amorpha fruticosa (C)[1]	Woody	Native	100	25 ± 2	76* ± 3	58*± 6	37*± 6
Amorpha fruticosa (LL)	Woody	Native	100	21 ± 2	62* ± 3	59*± 2	42*± 4
Caragana arborescens	Woody	Exotic	100	34 ± 2	0*± 0	4*± 1	27 ± 3
Prosopis pubescens (B)	Woody	Native	30	5 ± 2	12*± 1	92*± 3	3 ± 2
Prosopis pubescens (BdA)	Woody	Native	30	5 ± 3	23 ± 8	62*± 7	4 ± 1
Robinia fertilis	Woody	Native	30	31 ± 3	51 ± 7	17 ± 5	40 ± 6
Robinia neomexicana	Woody	Native	30	15 ± 4	39*± 4	78*± 2	17 ± 2
Astragalus lonchocarpus	Herbaceous	Native	20	8 ± 3	2 ± 2	52*± 2	2 ± 2
Astragalus missouriensis	Herbaceous	Native	25	13 ± 2	13 ± 5	75*± 2	88*± 2
Dalea aurea	Herbaceous	Native	30	33 ± 3	65*± 5	10*± 0	70*± 3
Hedysarum boreale	Herbaceous	Native	30	37 ± 4	52 ± 5	32 ± 5	39 ± 4
Lathyrus eucosmus	Herbaceous	Native	30	2 ± 2	0 ± 0	38*± 5	2± 2
Lotus oroboides	Herbaceous	Native	35	3 ± 0	30*± 1	77*± 11	7 ± 4
Lupinus alpestris	Herbaceous	Native	30	27 ± 6	40 ± 8	41 ± 13	42 ± 2
Lupinus perennis	Herbaceous	Native	30	72 ± 6	57 ± 3	52*± 2	89 ± 4
Oxytropis lambertii	Herbaceous	Native	30	22 ± 9	16 ± 1	59*± 3	39 ± 4
Oxytropis sericeus	Herbaceous	Native	30	3 ± 0	6 ± 2	73 ± 2	9 ± 2
Petalostemum candidium	Herbaceous	Native	30	53 ± 4	46 ± 9	48 ± 1	55 ± 3
Petalostemum purpureum	Herbaceous	Native	30	67 ± 3	64 ± 9	63 ± 4	63 ± 5
Thermopsls montanus	Herbaceous	Native	30	2 ± 1	48*± 10	37*± 7	3 ± 2
Thermopsis rhombifolia	Herbaceous	Native	30	1 ± 1	14*± 4	42*± 8	2 ± 2
Astragalus clcer	Herbaceous	Exotic	30	27 ± 2	51*± 2	62*± 5	36*± 1
Coronilla varia	Herbaceous	Exotic	30	29 ± 3	42*± 2	63*± 7	ND
Lathyrus sylvestris	Herbaceous	Exotic	30	53 ± 5	58 ± 5	27*± 4	52 ± 3
Lotus corniculatus	Herbaceous	Exotic	30	78 ± 4	3*± 2	22*± 3	ND
Medicago sativa	Herbaceous	Exotic	30	73 ± 2	75 ± 7	90*± 4	84*± 2

[1]C, LL, B, BdA refer to seed source locations.
[2]Percentages are significantly different from control ($P<0.05$).
ND - No data available.

Treated and control seed were planted in [288-cell square deep-plug] trays filled with Sunshine #1 Mix. Seeds were planted immediately after treatment and placed in the greenhouse (23"C day, 15°C night). The entire study was replicated three times.

Treatment responses were species and seed source specific with no one treatment generating a consistent effect (Table 1). Mechanical scarification resulted in the greatest gain in germination in woody legume seed lots evaluated. Five of eight seed lots had improved germination; however, the remaining three seed lots were negatively impacted by mechanical scarification. Tumble scarification improved germination only in the two ecotypes *of Amorpha fniticosa* and did not detrimentally effect the germination of any other seed lots evaluated. After these initial trials of tumble scarification, the need for longer treatment times became apparent. Hot water scarification improved germination in half of the woody legume seed lots. Only in *Amorpha fniticosa* was the gain in germination comparable to the gain from the mechanical scarification. All scarification treatments were detrimental to germination in *Caragana arborescens.*

Hot water and mechanical scarification treatments increased the germination of three herbaceous species, *Lotus oroboides, Thermopsis montanus,* and *Thermopsis rhombifolia* by factors greater than ten. Mechanical scarification was also highly effective on *Lathyrus eucosmus* and *Oxytropis sericeus. Astragalus cicer* and *Coronilla varia* benefitted from hot water and mechanical scarification treatments. Only in four of the 19 herbaceous species was short duration tumble scarification effective in promoting germination. In *Dalea aurea,* tumble scarification promoted total germination whereas mechanical scarification reduced total germination compared to controls. In three herbaceous perennial species, *Lupinus alpestris, Petalostemum purpureum,* and *Petalostemum candidium,* none of the treatments were significantly different from the controls. Mechanical scarification significantly reduced the germination *of Dalea aurea, Lathynis sylvestris, Lotus corniculatus,* and *Lupinus perennis.* Hot water treatment was detrimental to *Lotus corniculatus.*

The results above indicate the diversity of scarification behavior exhibited by leguminous species. Refinement of scarification procedures for legumes will require intensive investigation of different techniques on a variety of seed lots for each species.

Stratification Studies

Alnus tenuifolia and *Alnus oblongifolia*

Thinleaf alder, (*Alnus tenuifolia*), is a dominant shrub or small tree in riparian areas of the Rocky Mountains and Pacific Northwest. Arizona or New Mexican alder, (*A. oblongifolia*), is a riparian tree or shrub of the mid-elevation drainages in the mountains of southwestern New Mexico and southeastern Arizona (Vines 1960). Unlike *A. glutinosa* and *A. rubra,* little work has been done on the propagation of these species. Fresh seed of some *Alnus* species has been found to germinate without cold stratification; however, dried and dormant seed of the same seed lot had improved germination capacity following cold stratification (Schopmeyer 1974b). The need for cold stratification or prechilling can be variable among seed lots within species of alder (e.g. *A. rubra;* Young and Young 1992).

Three experiments were conducted to examine the effect of gibberellic acid (GA_3) concentration and incubation length on the germination of dried alder seed. Seed used in the first experiment was from the Rio Costilla watershed in north-central New Mexico. Thinleaf alder was the only species tested in the first experiment. Seed of both thinleaf alder and Arizona alder from the Gila National Forest in southern New Mexico was used in the second and third experiments. The first experiment examined the effect of GA_3 concentration. Seven levels of GA_3 were evaluated: 0, 31, 62, 125, 250, 500, and 1000 ppm. Seed batches of 100 seeds were placed into flasks containing 25 ml of the GA_3 solution and allowed to incubate for 44 hours. Flasks were placed on a shaker table to provide constant agitation. Following GA_3 treatment, seed was rinsed with distilled water and sown into [288-cell square deep-plug] trays filled with Sunshine #1 Mix and placed in the greenhouse (21°C days and 13°C nights). The entire study was replicated three times.

The second experiment differed in the seed sources evaluated and the incubation technique. Specimen tubes (75 ml) were filled with 25 ml aliquots of the respective GA_3 solutions and aerated using a porous aquarium stone connected with tubing to an aquarium pump. Following a 36 hour GA_3 incubation, seed was handled

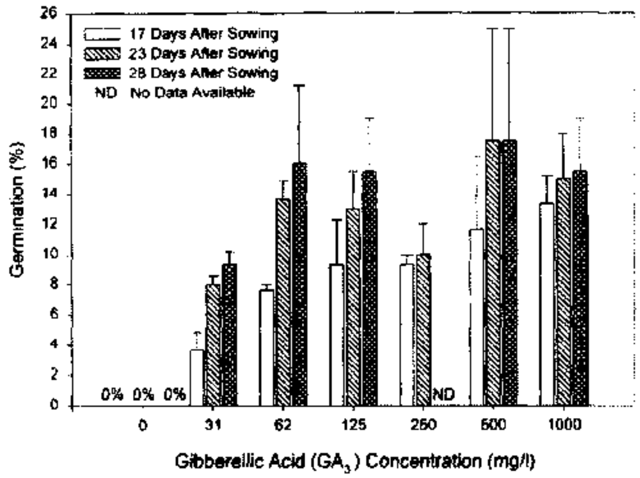

Figure 3. Germination percentages (± standard error) for *Alnus tenuifolia* seed soaked in gibberellic acid (GA_3) solutions of 0, 31, 62, 125, 250, 500 and 1000 mg/l

as described above. The entire study was replicated three times.

Incubation duration at lower concentrations of GA_3 was examined in the third experiment. Seed batches were incubated at 0, 125, 250, or 500 ppm GA_3 for 12, 24, or 36 hours. The incubation apparatus and seeding method was as described in the second experiment. The entire study was replicated three times.

Thinleaf alder seed from the Rio Costilla source required some level of GA_3 incubation for germination. Both germination speed and total germination was enhanced by GA_3 incubation (Figure 3). Germination speed increased with increasing GA_3 concentration, however total germination after 28 days was not improved by increasing concentration above 62 ppm GA_3. Both alder species from the Gila National Forest were able to germinate with no GA_3 treatment and only in thinleaf alder did GA_3 incubation improve germination after 28 days (Figure 4). Improvement in germination was slight going from 15% for control seed to 21% for the three highest GA_3 concentrations. The effect of GA_3 incubation duration and concentration was different for the two species. In Arizona alder, response to GA_3 was variable across concentration and duration, especially in the two intermediate concentrations of GA_3, 125 and 250 ppm (Figure 5). In thinleaf alder all treatments improved germination relative to controls. At the longest duration, 36 hours, 125 ppm GA_3 was sufficient to achieve maximum germination while at the shortest duration, 12 hours, germination continued to improve as concentration increased (Figure 6).

While these results are preliminary, it would appear there are strong species and source differences in response to GA_3 pretreatments in southwestern alders. At the highest concentrations evaluated, 500 and 1000 ppm GA_3, some seedlings became etiolated. Poor overall germination capacity of alder seed points to a need for seed refinement procedures. The winged pericarp on alder seed reduces the efficacy of density separations using airflow seed separators. Preliminary work with thinleaf alder seed indicates tumble scarification (see *Psorothamnus* section for details) effectively removes the wing which should allow better seed refinement. We have yet to show whether this seed classification will result in increased germination capacity.

Rubus strigosus

The ability of wild raspberry (*Rubus strigosus*) to colonize disturbed sites and form thickets via root sprouts make it a likely candidate for disturbed land revegetation efforts. Standard vegetative propagation procedures have been developed for production of commercial raspberry cultivars and could be used to produce cloned plant materials. However, to maintain some degree of genetic diversity and possibly reduce cost of production, emphasis should be placed on seed

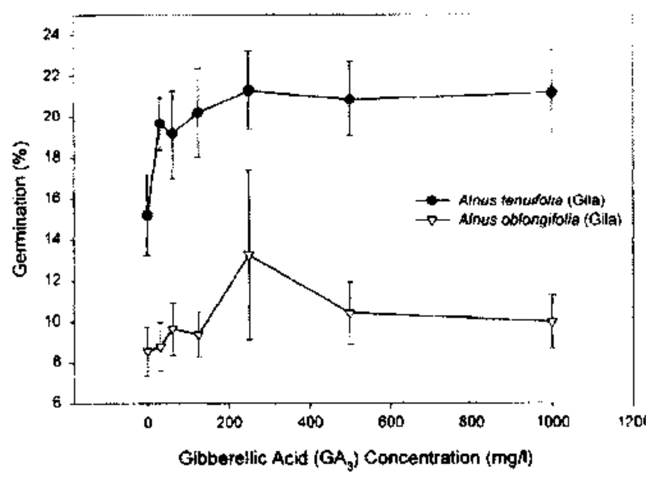

Figure 4. Germination (± standard error) after 28 days for *Alnus tenuifolia* and *A. oblongifolia* following 36 hour gibberellic acid (GA_3) incubation.

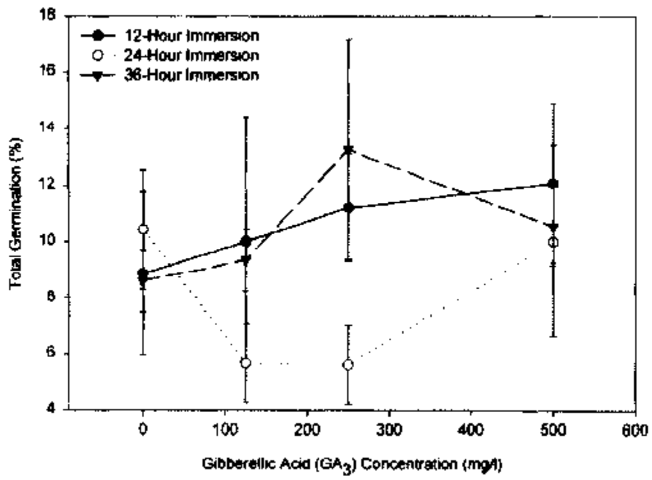

Figure 5. Influence of gibberellic acid (GA_3) soak concentration and duration on the germination (± standard error) of Arizona Alder *(Alnus oblongifloia)*

propagation. Treatment with a bleach solution (1% sodium hypochlorite) has been reported to enhance *Rubus* germination (Brinkmann 1974b, Rose et al. 1996). To examine the suitability of this technique on *Rubus strigosus*, fruits were collected from the Molycorp mine site in north-central New Mexico in early October and immediately depulped by fermentation for 2 weeks. Seed was then air dried and classified by density using an airflow seed separator. Only the heaviest seed, (average seed mass of 1.8 mg), was used in this experiment. Five durations (4, 8, 24, 48, 96 hours), of soaking in 1% bleach solution were evaluated along with a control consisting of a 48 hour soak in distilled water. In addition, four bleach/GA_3 treatments were used. These treatments consisted of: water soak (control), then 250 mg/1 GA_3 for 72 hours; 48 hour bleach incubation followed by a 72 hour, 250 ppm GA_3 incubation; 48 hour bleach incubation followed by a 72 hour, 1000 ppm GA_3 incubation; and, 96 hour bleach incubation followed by a 24 hour, 1000 ppm GA_3 incubation. Following all bleach and GA_3 treatments seed batches were rinsed thoroughly. Treated seed was sown in [288-cell square deep-plug] trays with Sunshine #1 Mix. Trays were then cold stratified (4°C) until first emergence was observed: 20 weeks for the GA_3 treated seed and 23 weeks for the remaining treatments. Trays were then placed in the greenhouse (23°C days and 13°C nights) to monitor germination. Bleach treatments were replicated four times while the GA_3 treatments were replicated six times.

Bleach treatments between 4 and 48 hours duration showed 2 to 3 times greater germination than the control and 96 hour treatments (Figure 7). Translucent seed coats were observed in a few seed in the 24-hour bleach incubation, for many seed in the 48-hour bleach incubation, and for all seed in the 96-hour incubation. The 96 hour bleach incubation resulted in slightly less than 10% of the seed beginning to disintegrate. Addition of a gibberellic acid incubation improved germination of both the 48 and 96 hour bleach treatments. On the basis of this limited study with one seed source, a 48 hour, 1 % sodium bleach treatment followed by a 72 hour, 250 ppm GA_3 incubation yielded the greatest improvement in germination percentage (73% versus the control at 17%).

Coleogyne ramosissima

Blackbrush (*Coleogyne ramosissima*) is a dominant shrub in many plant communities occurring in the transition between Mojavean and Sagebrush Deserts (Benson and Darrow 1981). Published literature indicates a prechilling (i.e., cold stratification) treatment is required for *Coleogyne* (Young and Young 1992). In initial trials, seed harvested from Glen Canyon National Recreation Area had 56% germination with no seed treatment but 83% with 7 weeks of cold stratification. A second study was conducted to examine other seed treatments in combination with cold stratification. Seed used in this study was 5-year-old seed from Canyonlands National Park. Four seed treatments were

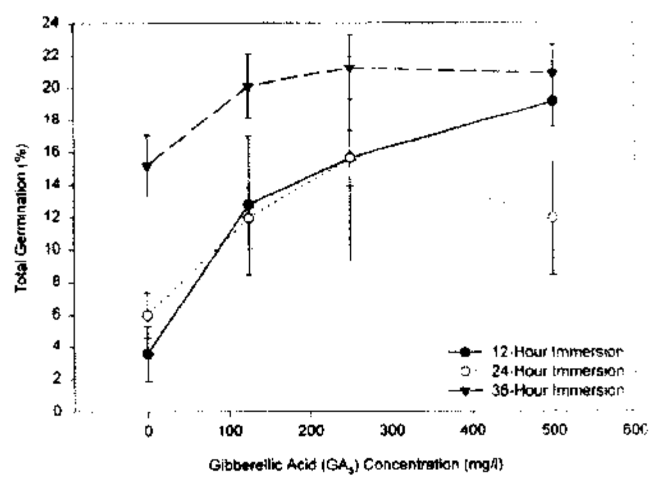

Figure 6. Influence of gibberellic acid (GA_3) soak concentration and duration on the germination (± standard error) *of Alnus tenuifolia.*

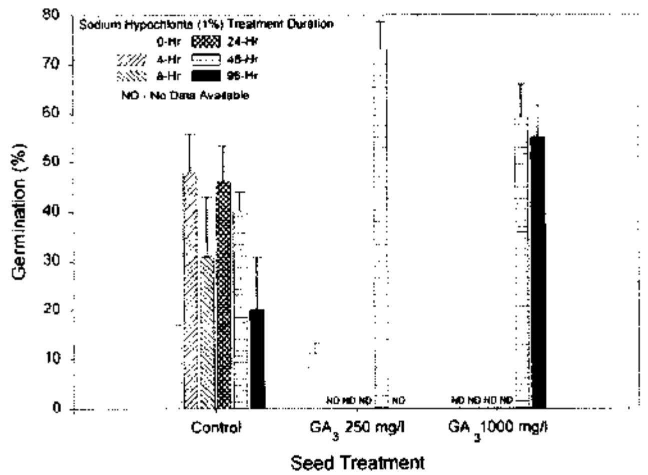

Figure 7. Effect of sodium hypochlorite (1%) treatment duration and subsequent gibberellic acid (GA_3) immersion on the germination (± standard error) of *Rubus strigosus*

examined. These treatments included a 24-hour soak in 250 ppm GA_3, a 24-hour soak in de-ionized water, a 24-hour tumble scarification (see *Psorothamnus* section for details), and a untreated control. All treated seed was rinsed thoroughly with distilled water. All treatments were then subdivided into groups receiving seven weeks of cold stratification and groups receiving no cold stratification. Seed was sown in [288-cell deep-plug] trays containing Sunshine # 1 Mix. Trays with seed receiving cold stratification were placed in plastic bags with aeration holes and placed in walk-in coolers (4°C); after seven weeks, they were removed from the cooler, taken out of the bags and placed in the greenhouse (21°C days and 13°C nights). Trays with non-stratified seed were immediately placed in the greenhouse (21°C day, 13°C night). The study was replicated three times.

Unlike the seed from the Glen Canyon National Recreation Area where seven weeks of stratification improved germination, blackbrush seed from the Canyonlands National Park did not respond to cold stratification. Cold stratification did not improve germination in any treatments with the exception of the tumble scarification treatment where germination was improved from 25% to 40% with cold stratification (Figure 8). However, untreated and unstratified control seed had a germination rate of 46%. Significant source and age differences are apparent in regard to germination improvement or requirement resulting from stratification of blackbrush.

Combination of Scarification/Stratification

Oryzopsis hymenoides

Indian ricegrass (*Oryzopsis hymenoides*) is an important reclamation grass on disturbed lands with sandy or rocky soils in the west and is being used increasingly as a xeriscape ornamental. Previous work has shown this species has recalcitrant seed. Studies by Khan (1997) indicate both seed coat and embryo dormancy exist in this species. Based on positive responses to tumble scarification and GA_3 treatments with other species, these methods were applied to attempt to enhance the germination of *O. hymenoides* >Nezpar[1].

Seed used in this experiment was from a commercial source. A factorial combination of tumble scarification of 0, 2, 5, and 7-days and GA_3 incubations (0 or 1000 ppm for 24 hours) were examined. Following treatment, seed batches were rinsed thoroughly and sown into [288-cell square deep-plug] trays containing Sunshine #1 Mix. Trays were then placed into the greenhouse (23°C day and 13°C night) and monitored for 28 days. The study was replicated 5 times.

Total germination improved with increasing duration of tumble scarification (Figure 9). This response was more pronounced in the GA_3 treated seed. These results indicate increasing the duration of tumble scarification causes a reduction in seed coat dormancy. Gibberellic acid treatment appears to overcome embryo dormancy

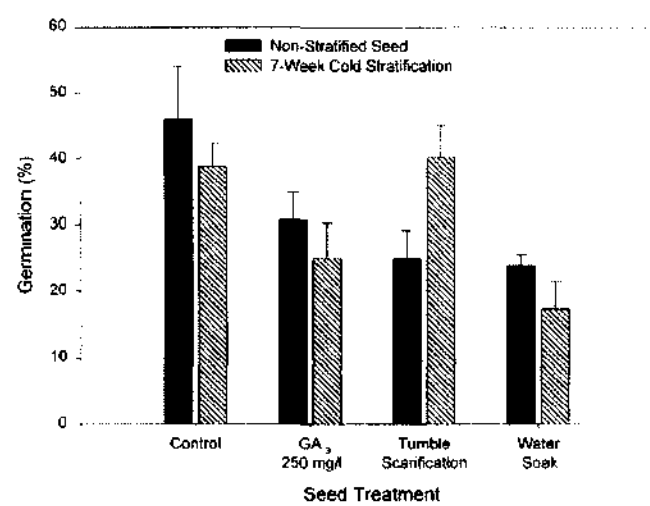

Figure 8. Effect of seed treatments on the germination (± standard error) of *Coleogyne ramosissima*.

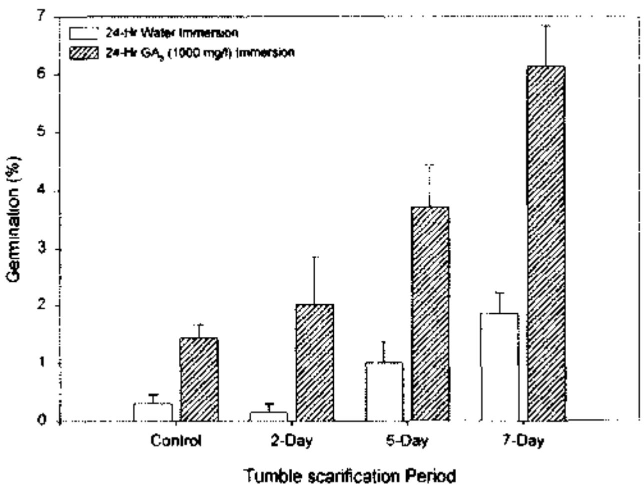

Figure 9. Effect of tumble scarification and subsequent immersion in gibberellic acid (GA_3) on the germination (± standard error) of *Oryzopsis hymenoides.*

(endo-dormancy).

Rhus spp. and *Ceanothus* spp.
Seed lots (2 to 3 g), from commercial sources, of *Ceanothus integerrimus, C. sanguineus,* and *Rhus glabra* were immersed in 90°C water or 25°C water for 22 hours. Treated seed were sown in [288-cell square deep-plug] trays with Sunshine #1 Mix and cold stratified for 12 weeks. Following cold stratification treatment the trays were placed into a greenhouse (23°C day, 15°C night). Germination was monitored for 24 days. Seed treated with the hot water had elevated germination relative to the seed soaked in room temperature water. Germination of hot water incubated seed versus the seed incubated at room temperature was: *C. integerrimus,* (73% vs. 3%) *C. sanguineus,* (66% vs. 7%) and *Rhus glabra* (29% vs. 1%). This enhanced germination by hot water treatments prior to cold stratification has been reported in these genera previously (Brinkman 1974a, Reed 1974).

Ptelea trifoliata
Common hop-tree (*Ptelea trifoliata*) is widely distributed with many varieties or subspecies found throughout the U.S. (Vines 1960). Seed used in this experiment was collected in 1992 and 1994 from the Cibola National Forest in canyon bottoms within the ponderosa pine zone. After rubbing to remove the winged pericarp, the seed was separated into 3 morphological classes: small (<13 mm length), large (>13 mm length), and triangular cross section. The seed was also classified as to color: light green throughout (Green), some light green sections along with tan or brown (Mix), and tan or brown throughout (Brown). This classification generated six seed categories as there were no seed in the large brown, small green or triangular mixed categories. To improve germination, the proximal end (i.e., attachment end) was cut using a scalpel until the void in the seed cavity was exposed. This proximal end cut was performed on half of the seeds in each seed lot. Treated and untreated (control) seed was sown into 288-cell flats containing Sunshine # 1 mix and cold stratified for 18 weeks at 4°C. This experiment was only conducted once.

Cutting the proximal end resulted in increased germination for all but the triangular brown seed class. Untreated seed in the triangular brown class had the highest germination rate (16%) of all the control seed classifications and was comparable to the germination rate of all but the large green and triangular green treated seed classes (Figure 10). The greatest germination observed was for the treated large green seed which had 50% germination.

The results indicate the potential for screening seed based on color, size and shape. The recommended procedure based on these results would be using large green seed and cutting the proximal end prior to an 18 week cold stratification treatment.

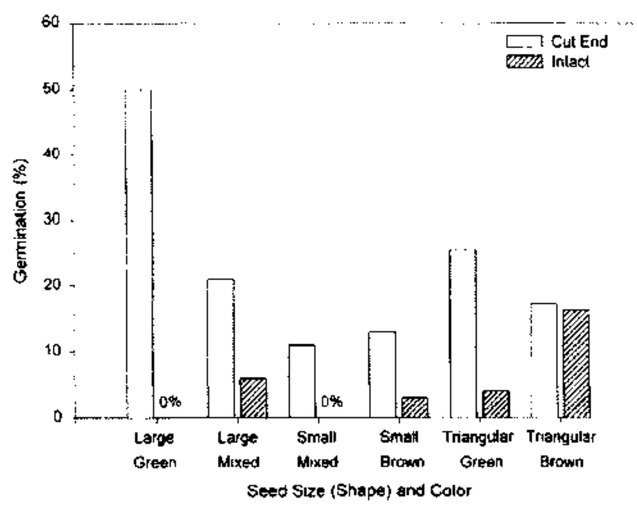

Figure 10. The influence of proximal end cut and seed size, shape, and color on the germination of *Ptelea trifoliata.*

Vegetative Propagation

Mound Layering of *Platanus wrightii*

Arizona sycamore (*Platanus wrightii*) is an important component of riparian ecosystems at mid-elevations in southwestern New Mexico and southeastern Arizona. As riparian restoration projects in these areas become more common, the demand for large containerized materials will likely expand. Although Arizona sycamore can be grown from seed, a more rapid production method for larger plant material is desirable. In addition, vegetative propagation could be used to preserve clones with desirable traits and when viable seed is not available.

Mound layering techniques are sometimes used to produce rooted cuttings of species not easily amenable to more traditional cutting propagation methods. Through trial and error, a methodology has been developed to produce large rooted whips of Arizona sycamore that could be used for production of large containerized stock or possibly as bare root planting material.

To develop stock plants, seedlings of a Gila River ecotype in l-gallon tree pots were planted in 1993 into sandy loam soil. Stock plants were heavily fertilized in May of each year. Surface soil was amended with sulfur on an annual basis to prevent chlorosis; alkalinity of irrigation water was approximately 150 mg/L as $CaCO_3$ with a pH of 8.0. During establishment, the stock plants were flood irrigated on a weekly basis during the growing season.

Dormant stems layered during the previous year were harvested just above the soil surface (2 to 5 cm) in early spring (March). Any residual media from the previous years mound was removed to allow new stems to easily emerge from the crown of the stock plants. By late May, new stems were approximately 0.5 meter high and the mounding process was initiated. One of three soilless media were used: a pumice, peat, and bark mix; a commercial peat and perlite mix; or, pumice alone. To reduce cost, a technique to minimize the amount of media required for mounding was employed. Inverted bottomless nursery containers were used to contain the mound. For smaller stock plants (fewer than 5 stems), a bottomless 5-gallon egg can was used; whereas, for large stock plants (from 5 to 15 stems) a container equivalent to a bottomless squat 20-gallon nursery can was used. The bottomless container was placed over the stems and filled with medium. No attempt was made to remove any leaves from the stems before filling the container. Mounds were fertilized during June with 50 (small mounds) to 100 grams (large mounds) of 17-6-12 controlled release fertilizer (SierraR 3-4 month plus minors).

A Roberts Mini-flow Spot-SpitterR was inserted into the top of the mounded medium to wet most of the mound surface (large stock plants required several Spot-Spitters). Mounds were irrigated daily during the growing season. Mounds were irrigated every 2 weeks in the winter if no precipitation had occurred. During winter months, all side shoots were pruned to ease harvest and reduce the potential leaf area of the propagule. Stems were in the mound layering system for a total of 9 to 10 months. In early spring (March), mounds were disassembled by removing the bottomless container and as much medium as possible by hand. Stems were severed 2 to 5 cm above the soil surface with loppers or pruning saw. Large stems were planted into 5-gallon containers coated with copper hydroxide paint (SpinOutR) and small stems (< 1.5 cm) into one-gallon tree pots.

Average number of large stems (caliper >1.5 cm) produced by 3 year old stock plants was 4 per plant in 1997. Several stock plants produced more than 10 large stems while others produced only one. Out of 73 large stems produced, 34% exhibited good to excellent rooting, 27% had poor to fair root development, and 39% were etiolated with few or no fine roots.

Large stem transplants with some root development had 100% survival when evaluated three months after transplanting. Etiolated large stems had 73% survival. Vigor of the large transplants (both rooted and etiolated) 3 months after transplanting was as follows: 74% with good to excellent vigor, 18% with poor to fair vigor, and 8% dead.

Transplanted stems exhibited slow growth until the root system was well developed. Spring application of sulfur and controlled release fertilizer were used. Each 5-gallon container was placed in a pot-in-pot system with copper-coated fabric (Tex-R7InsertR) between the two pots to limit roots from growing through the bottom pot into the soil. A Spot-Spitter inserted into each pot provided daily micro-irrigation of the newly transplanted stems; after the root system was well developed, the large leaf area necessitated daily watering. The 5-gallon transplants were ready for field planting approximately 10 months after potting.

Some preliminary work has been done with mound layering of other riparian woody species. Positive results have been obtained with Arizona alder, desert willow (*Chilopsis linearis*), false indigo bush, and three leaf sumac (*Rhus trilobata*). Stock plants of Arizona alder, thin leaf alder, and water birch (*Betula occidentalis*) are presently being grown to test mound layering of these species.

Novel Species for Understory Pole Plantings

Successful establishment of cottonwoods (*Populus* spp.) and willows (*Salix* spp.) using pole plantings is becoming an accepted restoration technique for disturbed riparian areas. This success has engendered interest in determining whether other woody riparian species could be planted as dormant pole cuttings. Use of long dormant cuttings (i.e., whips and poles) allows planting in deep holes reaching into the capillary fringe above the water table. Numerous successful pole plantings have resulted in many land managers adopting this technique for riparian restoration where the lack of persistent near surface soil moisture would limit survival of containerized stock or seeded materials.

Studies were required to determine whether other woody riparian shrub and tree species were amenable to pole planting technology. These investigations were started in 1994 by evaluating the survival of dormant hardwood cuttings planted into a flood irrigated agricultural field situation. A cutting's ability to survive and grow should be a good indicator of successful establishment by pole planting in riparian areas. Appreciable survival and growth was obtained with cuttings of New Mexico olive (*Forestiera neomexicana*), seepwillow (*Baccharis glutinosa*), one ecotype of desert willow, and one ecotype of false indigo bush. Little success was achieved with cuttings of three leaf sumac, Arizona sycamore, and one ecotype of desert willow and false indigo bush.

Limited plantings with these species have been performed in riparian areas to date. Preliminary results are promising for New Mexico olive, seepwillow, and false indigo bush. More extensive field-testing is required to validate these results and examine variability among ecotypes within species.

Table 2. Survival and vigor class percentages of *Populus tremuloides* propagated by root cuttings.

Clone	Percentage in Vigor Class				Percentage Alive
	Excellent	Good	Fair	Poor	
1	23	14	10	9	56
3	19	21	21	17	78
4	51	19	9	12	91
5	11	15	5	11	42
6	42	25	6	5	78
7	26	20	7	19	72

Propagation of *Populus tremuloides* from Root Cuttings

Vegetative propagation of quaking aspen (*Populus tremuloides*) using root cuttings is a traditional horticultural practice. More recent developments have used root cuttings to produce suckers, which are rooted as conventional softwood stem cuttings (Schier 1978). Our objective was to determine the efficacy of direct sticking root cuttings into 164 ml containers (Super Cell Cone-tainer). Cutting length and diameter were recorded before planting in order to relate root cutting dimensions and volume with survival and vigor of the resulting plant. Aspen stock plants were grown in 5-gallon containers using a pot-in-pot system. The stock plants were derived from 6 clones growing on the Molycorp mine site (Questa, NM). Root cuttings were taken from the periphery of the root ball in March. Average number of cuttings produced per stock plant was 9 large (> 6 mm diameter), 8 medium (4 to 6 mm), and 8 small (2 to 4 mm). Cutting diameter ranged from 2 to 13 mm and length ranged from 3 to 14 cm. Cuttings were immersed in a Captan suspension and stored at 4°C in damp peat moss until May when the cuttings were planted in a Sunshine #1 - perlite mix (2:1). Cuttings were inserted vertically with proper polarity into dibbled holes until the top of the cutting was just below the media surface.

Rooting success after eight weeks ranged from 42% to 91% (Table 2). In most instances, clones with higher rooting percentages had higher proportions of more vigorous plants. Data relating cutting size attributes to rooting and subsequent vigor have not been analyzed yet. These relationships will indicate the size of the smallest cutting which can be used and still obtain acceptable survival percentages and vigor.

IMPLICATIONS

As forestation projects continue to change from traditional reforestation to remediation of disturbed lands, nurseries will need to develop strategies for producing these difficult to propagate species. These studies and others indicate the need for more work to be done on the propagation of many of these plants. Emphasis will need to be placed on ecotypical variation, seed refinement, and the exploration of new seed and vegetative propagation techniques. The nature and size of these new planting (forestation) efforts will likely preclude the intensive efforts and expenditures which have optimized production of traditional timber species such as ponderosa pine, loblolly pine or douglas-fir. Rather the species required for restoration will be site specific and used in relatively small areas.

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The Expanding Potential for Native Grass Seed Production in Western North America[1]

T. A. Jones[2]

Abstract-Native grass seed production under cultivation has been practiced for many years but its extent has been limited by 1) lack of plant material, 2) seed planting, harvesting, and conditioning problems, and 3) inadequate markets. Numerous releases of native grasses (germplasm or cultivars) of many species by the USDA-NRCS Plant Materials Centers and other programs are in commercial production (Alderson and Sharp 1994). Specialized seed planting, harvesting, and conditioning (cleaning) equipment is now commercially available, allowing for successful seed production of species with seeds that shatter or are awned, chaffy, or fluffy. With the advent of policies and laws favoring the use of native seeds, production is generally far below market demands. A more sophisticated marketing system would help develop the native grass seed industry and enhance opportunities for both buyers and sellers.

BIOLOGY AND ADAPTATION

Like other plants, grasses can be categorized into C-3 (cool-season) or C-4 (warm-season) types according to their photosynthetic pathways. Cool-season grasses generally require a winter vernalization period and/or a short-day period followed by sufficiently long days for flowering. Flowering occurs earlier when plants are moved north and later when moved south. Optimal growth temperature ranges from 70 to 75 °F. Cool-season grass seedlings have an elongating coleoptile through which the first leaf emerges ("festucoid" development) (Ries and Hofmann 1991, Nelson and Moser 1995). The coleoptile node, where rooting initiates, remains below the soil surface with the seed. Planting cool-season grass seed too deep may prevent coleoptile emergence. The use of depth bands permits seeding at the proper depth (Horton et al.). Though there are several exceptions, e.g., inland saltgrass, prairie cordgrass, alkali cordgrass, sand dropseed, and alkali sacaton, most native grasses of the Intermountain Region are cool-season because of the preponderance of precipitation in the cooler months. Many are wheatgrasses and wildryes of the Triticeae tribe (Asay and Jensen 1996 a,b). Cool-season grasses may be planted in late summer, early spring, or late fall (dormant seeding) (Smith and Smith).

A special category of C-3 grasses is represented by the Stipeae tribe, i.e., the needlegrasses and ricegrasses (Stubbendieck and Jones 1996). Unlike other cool-season grasses, this group is unable to store fructans in the vacuole, a mechanism for storing carbohydrates at cool temperatures (Chatterton et al. 1989). Thus, their minimal and maximal growth temperatures are greater than for fructan-accumulators. Many Stipeae species are photoperiod-insensitive and require no vernalization, e.g., Indian ricegrass and green needlegrass. Stipeae species may be found in climates too warm for other C-3 grasses.

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[1] *Jones, T.A. 1997. The Expanding Potential for Native Grass Seed Production in Western North America. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89-92.*

[2] *USDA-ARS, Forage & Range Research Lab., Utah State University, Logan, UT 84322-6300; Tel: 801/797-3082; Fax: 8011797-3082; e-mail: (tomjones@cc.usu.edu).*

Warm-season grasses do not require a vernalization period, but may require sufficiently short days for flowering (Moser and Vogel 1995). Plants flower later when moved north and earlier when moved south (Moser and Vogel 1995, Voigt and Sharp 1995). Optimal growth temperature ranges from 80 to 85 °F. The warm-season grass seedling has an elongating shoot (mesocotyl) extending above the seed that elevates the coleoptile node ("panicoid development") (Ries and Hofmann 1991, Nelson and Moser 1995). If the roots become exposed, the seedling can quickly dessicate. Thus, establishment of warm-season grasses is generally more difficult than cool-season grasses. Therefore, planting warm-season grass seed too shallow often causes poor stand establishment. Most native grasses in the Great Plains and Southwest are warm-season, not only because of high summer temperatures, but also because of the preponderance of precipitation in the warmer months. Warm-season grasses are best planted in late spring (Moser and Vogel 1995).

As a rule-of-thumb, both cool- and warm-season grasses may be successfully moved 300 miles north or 200 miles south from their point-of-origin (Smith and Smith). A 550-foot change in elevation corresponds to 100 miles of latitude. These guidelines should be modified for particular species and sites by consideration of snow cover (snowfall and wind), evaporation, length of growing season, soil drainage, and slope/aspect. Grasses adapted to coarse-textured soils may frost-heave in heavier soils. Grasses adapted to heavy-textured soils may dessicate in coarser soils. Growth often improves when plants are moved north from their points of origin because of longer summer day lengths (Smith and Smith). However, this may increase the risk of winterkill or, in the case of warm-season grasses, hinder seed production because of the shortened growing season.

SEED PRODUCTION

Seed dormancy hinders stand establishment of many cool- and warm-season native grass species. Seed dormancy is determined by both the genotype of the mother plant and the environment (temperature and moisture) during seed maturation. The most common approach for breaking seed dormancy in seed fields is the late-fall dormant planting. A wet winter allows natural stratification, the subsequent loss of physiological seed dormancy, and early spring establishment, thereby avoiding the deleterious effects of late spring or summer droughts.

Bunchgrasses predominate in the dry-summer climate of the Great Basin, but in the Great Plains rhizomatous species are common. In many species, particularly rhizomatous cool-season grasses, heading declines rapidly after the first few seasons. Cultivation between rows to prevent sod-binding and the timely application of nitrogen fertilizer can increase heading and seed production. For increased seed production, grasses should be fertilized during production of seedhead meristems, i.e., before heading begins (Bolton et al. 1996). Cool-season grasses, therefore, should be fertilized in fall. Fertilization in spring will encourage vegetative growth at the expense of reproductive growth. Because of their later growth pattern, warm-season grasses can be fertilized in spring. As part of the natural environment, late-spring burns benefit stands of many warm-season Great Plains species by stimulating tillering (Moser and Vogel 1995).

SEED HARVESTING AND CONDITIONING

While species with determinate flowering and good seed retention are suitable for direct-combining, seeds of many native grasses are often a challenge to harvest. This may result from floral indeterminacy, seed shattering, or often both. These mechanisms may be helpful to the species in an evolutionary sense, but in a seed field they are obviously undesirable. Floral indeterminacy, the uneven ripening of the seed on a plant within or between heads, makes the choice of optimal harvest time problematic. Indeterminate flowerers may be successfully harvested at multiple points in time with seed strippers, but in practice most of the seed is collected at the initial harvest. Seed strippers do not work well with species that shatter, as they tend to increase shattering (Smith and Smith). Indeterminate, shattering species are best swathed under high humidity, windrowed, and picked up later after seed maturation in the windrow (Bolton et al. 1996).

Both hammer mills and debearders are used to remove awns (Bolton et al. 1996), but debearders are preferred because they cause less seed damage. The debearder removes awns by rotating a beater with pitched arms on a shaft within a steel drum (Smith and Smith). The steel drum has posts that protrude inward toward the beater. The drum posts may be adjusted to increase or decrease clearance with the beater post arms. Clearance, speed, and time must be calibrated for maximal awn removal and minimal seed damage.

RELEASE OPTIONS FOR PLANT MATERIAL

In the past, most native seed was marketed as either "common" or as a named cultivar. Common seed could not be certified because it had no "genetic identity". However, recent rule changes made by the Association of Seed Certifying Agencies facilitate certification of seed as germplasm that previously would have been sold as common seed. Release of germplasm does not require as great a degree of scrutiny as the traditional cultivar release. This certification mechanism is referred to as the alternative release system (Young 1995). Wildland-harvested seed or seed increased in a cultivated setting from wildland harvest may be certified by the site of origin, i.e., "source-identified". After evaluation with other accessions of the same species, the seed source may be officially released and registered as a "selected" class of certified germplasm. Additional testing would qualify material for the "tested" class. Further documentation of its merit would qualify the material for a traditional cultivar release. Therefore, in theory, the same material could be released more than once upon acquisition of greater documentation. The alternative release system combines the advantages of verified geographic source identity and minimized delays in release relative to the traditional cultivar release. As well as single-site material, a composite, in the case of a self-pollinated species, or a polycross, in the case of a cross-pollinated species, of seeds originating from multiple sites may qualify. The USDA-NRCS Plant Materials Program is now routing most of its grass releases though the alternative release system, using primarily the "selected" class.

Another concept in the release of native plant material is the ecological cultivar or "ecovar" (Wark et al. 1995). The objective of ecovar development is to provide material that is as genetically diverse as possible yet is agronomically improved for traits related to seed production. Ecovars would generally combine material from many different sources, although these would likely be from the same geographic region. At this time, no ecovars have been released. The greatest efforts in ecovar development are occurring in the prairie provinces of Canada.

MARKETING CHANNELS

Native grass seed is harvested from both wildland stands and cultivated fields. Grass seed production from cultivated fields will increase in the future because wildland harvest is limited (for some species, nonexistent) but is unlikely to meet demand. In contrast, most shrubs have seed production difficulties that discourage cultivated production. The shrub seed "picking" industry continues to thrive off wildland stands despite the release of plant material for commercial use. Wildland harvest of grass seed will continue to play a part in the seed industry for certain species that occupy level terrain, are found in near-monoculture, are difficult to establish or harvest in a cultivated setting, or demand only small quantities of site-adapted seed. Wildland seed harvest fluctuates greatly from year to year because of weather conditions, primarily moisture availability. Therefore, weather greatly influences prices.

Seed cleaning plants may contract seed production out to individual growers or pickers, produce seed in-house on their own fields, or both. Considerable trade occurs between seed companies, particularly those relatively distant geographically, to stabilize inventories and satisfy needs of regular retail customers. Some seed brokers neither grow nor clean seed, but attempt to "buy low and sell high" and offer additional services such as germination testing and consulting. Warehousing facilities are becoming increasingly important for government agencies with needs for short-notice restoration projects. Warehousing allows them to maintain supplies and hedge on prices. Conservation nurseries may wish to emphasize seed production of species that are only intermittently available in commerce as well as geographically important sources of more commonly available species.

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Application of Genetic Analyses to Native Plant Populations[1]

Betsy Carroll[2]

The National Forest Genetic Electrophoresis Laboratory (NFGEL) was created in 1988 as a national facility to assist resource managers in the USDA-Forest Service (FS). State-of-the-art research methods and technology are utilized to help managers answer questions related to genetic diversity and conservation of native plant populations, as well as monitoring tree improvement issues.

NFGEL MISSION

An appropriate discussion of NFGEL begins with our mission, which forms the foundation of our existence. Simply put, the NFGEL mission states, "To provide plant resource managers with the best genetic information possible". Underlying NFGEL's mission are three very important principles:

1) using *Quality Assurance* concepts to generate results and interpretations,
2) using the most *Current and Appropriate Methods*, and
3) producing results in *Cooperation with Clients.*

1) Quality Assurance

In today's society, with increasing controversies surrounding natural resource management, it is crucial that critical eyes keep watch over the kind of data that are being used for policy decisions. The information that is generated needs to be "quality science", which may, or may not, be equivocal to science *per se.* Good science is founded in the concepts of quality control and quality assurance. At NFGEL, the commitment to producing quality data comes with a price tag. It requires additional time and effort to ensure our results are repeatable and consistent over time.

2) Current and appropriate methods

NFGEL methods remain state-of-the-art through close cooperation with Pacific Southwest Forest and Range Experiment Station (PSW) and others in the research community. At the same time, we work closely with clients in defining the proposed project objectives and expected outcomes to ensure that our laboratory techniques are appropriate. Situations arise where other genetic analyses are more suitable (i.e. common garden studies). If so, we can recommend resources where you might accomplish the work. We do not hesitate recommending the most appropriate genetic tool available, even if it does not generate a project for NFGEL.

3) Cooperation with Clients

NFGEL strongly advocates an integrated approach to projects where interpretations and recommendations are a result of active participation by clients. The genetic component of a study is only one piece to the puzzle. Through cooperation, specialists provide the remainder of the story concerning biology, ecology, and politics surrounding a specific species and/or situation.

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[1]*Carroll, B. 1997. Application of Genetic Analyses to Native Plant Populations. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 93-97.*

[2]*USDA-FS, NFGEL, 2375 Fruitridge Road, Camino, CA 95709; Tel: 916/642-5065; Fax: 916/642-5099*

Hopefully, the resulting management decision reflects this clear intent of gaining a broad understanding of the issue.

WHO WE ARE

NFGEL is administered by the Eldorado National Forest, in Region 5 of the Forest Service. Isozyme lab work is conducted at our lab at the Placerville Nursery in Camino, CA. DNA work is conducted through a cooperative arrangement with Dr. David Neale at the PSW Institute of Forest Genetics, Placerville, CA.

Current personnel include a Director, Assistant Director, three Biological Lab Technicians, and a part-time Computer Programmer. Services provided to clients include assistance in proposal formulation, sampling design and collection, conducting lab analyses, and generating results and genetic interpretations for reports and peer-reviewed publications.

Historically, funding has been provided through the FS Washington Office, Timber Management staff within the National Forest System (NFS) branch. More recently, projects have been funded through the FS Botany program, and other benefiting functions. In addition, funded projects have been completed for other agencies, such as the U.S. Fish and Wildlife Service and the Bureau of Land Management.

FS GENETIC RESOURCE PROGRAM STRATEGIC PLAN

In 1992, the FS geneticists convened to develop a strategic plan for the national genetics program. The five imperatives that were developed include:

I. Genetic conservation
II. Ecosystem management
III. Tree improvement
IV. Education
V. Partnerships

As a result of this plan, NFGEL received a mandate to expand our scope of work. This expansion has included the addition of native plants, with particular emphasis on Threatened and Endangered species analyses. A tremendous amount of development work has been completed at NFGEL, since 1992, including studies on a broad range of plants, many with more challenging and complex genomes (polyploids) than the conifers we had concentrated on prior to 1992. The species studied to-date include those listed in Table 1:

Table 1. Different plants Studied by NFGEL.

Conifers	Other plants:
ponderosa pine	**Grasses:**
sugar pine	*Elymus glaucus*
jack pine	*Fescue idahoensis*
Jeffrey pine	*Bromus carinatus*
longleaf pine	
loblolly pine	**Plants:**
sand pine	*Lewisia* spp.
shortleaf pine	*Hackelia* spp.
slash pine	*Frasera* spp.
E.white pine	*Rorippa subumbellata*
limber pine	*Saxifraga* spp.
W.white pine	*Purshia tridentata*
lodgepole pine	
Douglas-fir	
Fraserfir	
Pacific yew	

WHAT WE DO

Currently, the questions posed to NFGEL fall in three main areas:

1) Tree improvement,
2) Conservation issues (threatened and endangered species), and
3) Native plants (restoration/revegetation).

Tree improvement studies focus on analyses generating information on conifer genetic patterns. Genotypes from individual clones are assayed to answer a multitude of concerns with superior trees, including seed identification, clonal mislabeling, effectiveness of controlled crosses, and overall effectiveness of seed orchards. Other studies assess geographic patterns of genetic diversity and management effects on genetic diversity occurring in natural stands.

In the Threatened and Endangered species arena, baseline information is needed, since the genetics of many plants have not been studied in the past. There is a need for information such as: How much diversity exists in this species? How genetically different are these populations? Do these populations constitute different species or subspecies? Has the genetic variation in a small, isolated population been reduced due to disturbance?

With the current focus on using natives for restoration/ revegetation purposes, there is a need to develop seed transfer guidelines, similar to conifers. The most common questions deal with how far native grass seed can be transferred and how far we can go to collect seed/ materials for restoring a site. Also, should species specific seed zones be delineated or can much more general zones be developed? If so, how ? Another question relating directly to nurseries is whether genetic integrity of a collection has been maintained in the production of seed increases. For most of these questions, our laboratory methods are the most appropriate technique. However, for seed transfer guidelines, common garden studies are more appropriate due to the adaptive significance of the results.

LEVELS OF GENETIC DIVERSITY

The level of genetic diversity that is studied in genetic analyses depends on the question at hand. Genetic differences can be estimated within individuals, among individuals, among populations, among species and other taxonomic levels, such as subspecies and varieties. At the individual level, several genes are examined to determine how many differences exist. This information on genetic differences builds over individuals and allows comparisons to be made relative to other individuals, other populations, other sites, other species and so forth. After collecting data from gels in the lab, various estimates are calculated to quantify levels of genetic diversity and amount of differentiation that occurs among groups. Examples for isozymes include: P (% polymorphic loci), A (# alleles/locus) and Ho, He (observed and expected proportions of heterozygous loci). This information can then be used to develop phenograms to describe similarities or genetic distances at the particular level of interest. Many questions related to ecosystem management can be answered through the use of genetic analyses. For example, determining how different or similar plant populations are relative to each other can be critical in determining conservation strategies.

TYPES OF GENETIC ANALYSES

Various tools have been developed in plant research based on earlier work in human genetics. Currently, some commonly accepted techniques include the following:

- Isozymes
- DNA
- RFLPs
- RAPDs
- Sequencing
- Common Garden studies

NFGEL conducts analyses looking at isozymes and DNA.

COMPARISON OF METHODS

It is essential that clear study objectives are determined to ensure that the appropriate genetic tool is utilized. To clarify how this determination is made, a brief comparison is presented here for three primary methods (isozymes, DNA, and common garden studies).

Isozyme methods have inherent advantages due to the large amount of published data which exist to provide relative comparisons within and between species. Isozymes also provide multi-gene data within individuals. In addition, large numbers of individuals can be surveyed in relatively short amounts of time at a reasonable cost. A disadvantage with isozymes is the limited number of genes to survey which is approximately 30 loci. This is a narrow sampling of the genome using genes primarily involved in plant respiration and having no apparent correlation with adaptive variation (i.e. growth).

With DNA, each specific procedure has its own advantages and limitations. Overall, DNA results reflect a direct measure of genetic differences while providing an unlimited number of genes to assay. DNA work generally requires less plant tissue than isozymes, but is expensive both in chemicals and labor. The evidence is inconclusive whether DNA results will show any relationship with adaptive traits, but researchers continue to study this aspect.

Data from DNA and isozymes can be used together, utilizing the less costly isozymes for the bulk of the study and adding DNA to provide additional differences. The addition of DNA data can be beneficial when uniqueness of individuals cannot be derived with isozymes alone. The data are somewhat interchangeable when investigating questions regarding genetic variation and the distribution of genetic patterns both within and among populations.

Common garden studies are sometimes discounted for the more appealing state-of-the-art molecular analyses. But, in much of the needed native plant work, common garden experiments are still a preferred option. Common garden experiments are best applied in situations where managers are concerned with survival and adaptation of plant materials on a restoration site. Morphological traits measured in these studies demonstrate adaptiveness of individuals through their growth and survival in a spectrum of environments. By eliminating the environmental variance, the remaining genetic influence can be evaluated. It would be most beneficial to spend the time and energy to conduct common garden evaluations, particularly in polyploid grasses where genetic interpretation is harder to obtain. The drawbacks in common gardens occur in the relatively slow time-frame and expense required, although, in comparison with conifers, this time-frame should be greatly reduced with native grasses.

HOW DO WE LOOK AT GENES?

Materials for DNA and isozyme analyses are collected and sampled similarly, although strategies and sampling intensities may differ, depending on the particular method and genetic level of measurement. Normally, fresh materials are shipped to NFGEL as seed, vegetative tissue, or wood. Collections for DNA analyses are more flexible than isozymes since DNA is present in all materials. Isozymes require specific collection windows when enzyme activity is optimal. Isozyme analysis usually requires germinated seed to stimulate enzyme activity before sample preparations are completed. In some cases, amplification of DNA is necessary to increase the amounts available to work with. Various methods are used to isolate and examine sections of DNA depending on which type of DNA is of interest (examples include ribosomal DNA, mitochondrial DNA, and chloroplast DNA). DNA and protein samples are placed on a gel medium and connected to power sources to separate protein/DNA based on mobility differences. After several hours, solutions are applied to make genetic differences visible on the gels. In the case of isozymes we are viewing products of genes (proteins) whereas DNA methods provide glimpses of the actual DNA. Patterns on gels are "scored" to generate data for several genes for each individual sampled. Once these data have been genetically interpreted and analyzed, we work with clients, integrating our genetic information with their localized knowledge of the question at-hand.

EXAMPLES OF NFGEL PROJECTS

In 1989, Hurricane Hugo swept through the Southeastern U.S. and decimated the FS Francis Marion Seed Orchard in South Carolina. Clonal identities were lost for the longleaf pine blocks with few superior genotypes remaining. Seed orchard managers were in need of any additional selected materials that could be identified from the remnant trees. NFGEL's task was to determine how many different clones remained in the salvaged individuals. Isozyme analysis was used to assess uniqueness between individuals with additional differences provided by DNA analyses. The final results showed that isozymes provided sufficient information at 6 gene loci to determine that 6 of the 12 individuals were unique, while 1 group of 4 and 1 group of 2 appeared to be genetically the same. With additional DNA information using RFLP analysis, uniqueness was increased to 9 individuals with the last group of 3 individuals probably belonging to the same clone.

An example of a Threatened and Endangered species project is the following study of two closely-related species of *Lewisia.* FS botanists in Region 5 disagreed with the recent treatment of these species in the *Jepson Manual*. *L. serrata* was taxonomically submerged under *L. cantelovii* to create one species. In addition, botanists were concerned with increasing collection pressure due to the desire to use *Lewisia* in urban landscaping. On the national forests, both are perennial species occurring on rocky cliffs above drainages.

Following isozyme analysis, NFGEL's conclusion agreed with FS botanists that distinct patterns occur in *L. serrata* and *L. cantelovii* with no gene flow between the two taxa. Our recommendation based solely on genetic interpretation is for _L. serrata_ to remain a separate taxon.

CURRENT NFGEL PROJECTS:

- Black's Mountain Experimental Forest - FS, Region 5,& PSW
  - -Establish baseline levels of genetic variation for species in these different life forms (ponderosa pine, bitterbrush, and Idaho fescue) to evaluate effects from silvicultural treatments

- Aspen - FS, Region 6
  - -Estimate levels and patterns of genetic diversity to assist in development of conservation strategies for restoration of aspen in riparian areas

- _Bromus carinatus_ and _Elymus glaucus_ - FS, Region 5 & 6
  - -Estimate levels and patterns of genetic diversity to obtain a cursory look at seed transfer guidelines

- Loblolly pine controlled crosses - FS, Southern Forest Experiment Station
  - -Evaluate percent of contaminants in seed produced from controlled pollinations based on various bag installation and removal dates

- _Hackelia venusta_ - FS, Region 6 & USFWS
  - -Clarify taxonomic status of a blue-flowered species and a white-flowered species
  - -Determine if gene introgression has occurred between _Hackelia venusta_ into another _Hackelia_ spp.

- Sugar pine - California Dept. Of Forestry (CDF)
  - -Compare genetic diversity levels of rust resistant trees and seed crops with the nearby seed zone at Mountain Home State Forest in California

- Limber pine - FS, Region 1
  - -Characterize the genetic diversity in an isolated stand in sw North Dakota
  - -Determine whether the stand originated from material brought in by Native Americans

CHALLENGES

As needs for native plants increase, resource managers need facilities to grow materials and have the confidence that materials used in site revegetation will be adapted and survive. The genetic integrity of plants collected for restoration needs to be maintained throughout sample collection, production , seed increases and outplanting. Any genetic shifts in plant materials from origin to restoration site should be monitored. With the current technologies available, these are some areas that NFGEL can help monitor.

Nursery Soil Fumigation[1]

Dick Karsky[2]

INTRODUCTION

Pathogens in the soil affect the growth of young trees at tree nurseries. Cultural practices, such as crop rotation, have been used to reduce the level of pathogens in the seedling beds. In addition, chemicals have commonly been used to sterilize the beds before seed is sown. These practices increase the chances of a successful seedling crop. Fewer treatments are needed to correct diseases that affect the seedlings. The two main chemicals used to sterilize the seedling beds are Basimid and methyl bromide. Methyl bromide, the fumigant of choice, has been found to be environmentally harmful and its use will be banned by the Environmental Protection Agency in the year 2001. Methyl bromide was very effective at controlling microorganisms and killing weed seeds.

The objective of this project is to find an economically and environmentally acceptable method of sterilizing soils. Steam has been used in Europe to prepare the soil for nursery operations. In the 1950's, steam rakes were used in the United States to treat soils. The temperature required for steam treatment to kill certain organisms is listed in Table I. They were abandoned when methyl bromide became available because it could be applied more quickly, was easier to use, and was effective against a wide range of organisms and weeds. During fiscal year 1995, Missoula Technology Development Center (MTDC) built a prototype steam treatment machine to obtain data on its effectiveness and cost of operation.

MTDC STEAM FUMIGATION DESIGN

MTDC has built and tested a portable steam treatment machine with a boiler capacity of 1 million BTU's. The MTDC design consists of a portable steam generator that is pulled through the field at very slow speeds (Figure 1). Initially, a tractor equipped with a creeper gear transmission was used to tow the machine, but the tractor could not go slow enough. The machine was adapted to include a self-powered winch. A deadman (a tractor for instance) is placed down the field and the winch cable is attached to it. The winch pulls the machine over the seedling bed at the slow speeds required. The winch cable passes through a loop mounted on the tongue of the steerable front axle, guiding the front steerable wheels. The steamer can be started up and operated

Table 1. Temperature required to kill certain organisms (from John Bartok, Jr.).

Temperature (°F)	Pests or weeds affected
115	Water molds (*Pythium* and *Phytophthora*)
120	Nematodes
135	Worms, slugs, centipedes
140	Most plant pathogenic bacteria
160	Soil insects
180	Most weed seeds
215	Few resistant weed seeds and plant viruses

[1]*Karsky, D. 1997. Nursery Soil Fumigation. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 98-108.*

[2]*MTDC, USDA Forest Service, Ft. Missoula Bldg. 1, Missoula, MT 59801; Tel: 4061329-3958; Fax: 4061329-3719.*

without too much attention. When the steamer reaches the end of a seedling bed, the deadman and the steamer are moved to an adjacent bed.

The steam from the generator and air from a blower (Figure 2) are mixed to obtain the desired temperature before being injected into the ground. Initially, the blade designed for injecting steam underground was similar to an undercutter blade used for root wrenching or root pruning (Figure 3). A hollow base was added to the bottom of the blade. This created a steam chamber. Openings at the back edge of this chamber below the blade allowed steam to be injected into the soil. The sides of the blade were constructed out of hollow rectangular tubing. The inside of these tubes were used as conduits for the steam from the blower/steam generator. Some observations on the performance of this blade included:

- In the lifted seedling beds where we operated the machine, the blade had a tendency to push soil well in front of its leading edge. This may have been caused by the blade's blunt edge, by the partially frozen ground during our tests, and by soil that was not consistent in texture.

- Some steam was lost as it came up through openings in the soil, around the ends of the steam injection blade, and near the temperature probe. If the soil had been uniformly tilled, this might not have been a problem. Steam was also lost where the machine's tires passed and compressed the soil. Even after some of the nozzles at the end of the injector blade had been closed off and the treatment width had been narrowed, the problem of steam loss at the ends of the blade was not completely eliminated.

Figure 1. The steam treatment machine in operation. A winch pulls the machine to the tractor, which acts as a deadman.

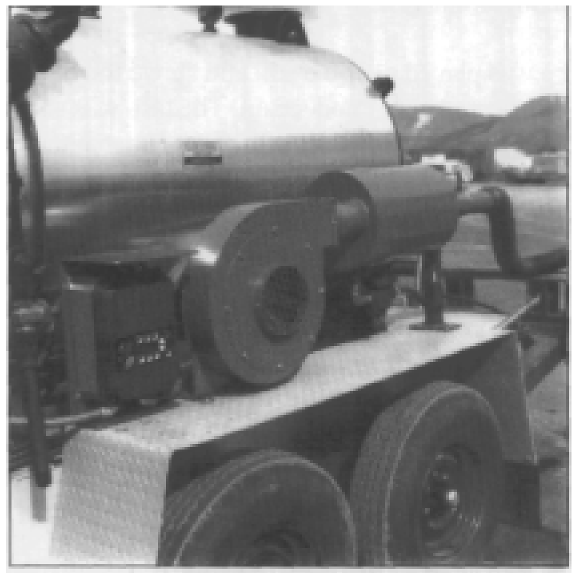

Figure 2. The electric blower adds air to regulate the temperature of the steam.

Figure 3. The initial steam injection system used an undercutter blade. Steam was vented from the back of the blade.

A stainless steel sheet was added over the injector blade surface to try to solve the problem of soil building up in front of the blade's leading edge. This may not be desirable on an operational machine because the stainless steel surface could be worn away quickly. The problem of soil buildup may also have been remedied by using different bed preparation techniques and by reducing the blunt edge of the blade. Instead, a different steam injection system was developed.

A tarp was placed over the soil and above the blade to trap the heated vapor and steam. The tarp was about 10 feet long, long enough to trap the heat and maintain the desired temperature for at least 20 minutes. A temperature probe was built and placed immediately behind the blade to record the temperature at three different levels below the soil surface.

Shank Steam Injection

The undercutter blade was replaced with a series of shanks spaced 6 inches apart in two separate rows. Steam was injected at the back of the base of those shanks (Figure 4). The steam was fed into a manifold and then to hoses connected to the shanks. This configuration of the steam treatment machine was evaluated during the preliminary tests conducted last fall at Forest Service nurseries.

Sweep Injection

In the spring of 1997 the machine was modified to inject the steam under a series of five 1/4-inch cultivator sweeps. The sweeps were mounted to the shanks and closed at the top. A flat plate was welded to the top of the sweep and a steam injector tube was added. The sweep looks like a triangular plate that is pulled through the soil (Figure 5). The sweeps improved the horizontal distribution of steam through the soil profile.

Figure 4. Steam injected behind vertical shanks was distributed more evenly through the seedbed than when steam was injected with the original undercutter injection system.

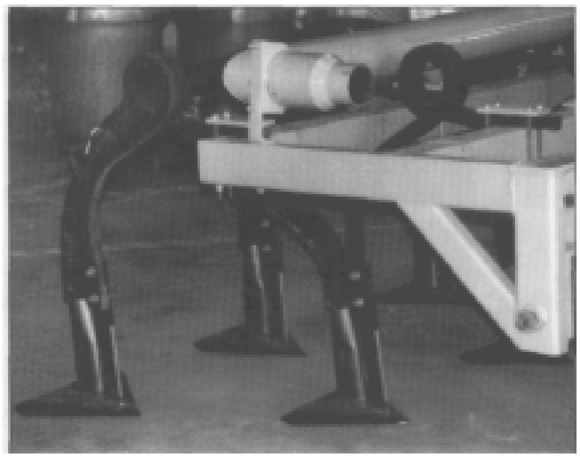

Figure 5. Sweeps (triangular plates) helped the shanks distribute the steam more evenly than when vertical shanks were used.

DISCUSSION

Steam is a promising technology that has been around a long time. It could be an economical alternative to methyl bromide fumigation. The success of steam treatment depends on how the steam is applied to the soil. Initially, MTDC started off with an undercutter blade that had a hollow bottom. Steam was injected underneath the soil along the back edge of the blade. The undercutter blade was replaced with a series of shanks that injected the steam into the soil every 6 inches across the standard 4 foot seedbed. The steam was injected to a depth of about 7 inches. The last modification reduced the number of shanks from 13 to 5 and added sweeps to apply the steam underneath the soil. This modification improved the temperature distribution in the soil. Additional modifications to the sweeps have been made to improve the mixing of the hot vapor with the soil, increasing temperature uniformity through out the soil profile.

Two areas of concern have surfaced so far. The main concern is the machine's speed. It takes about an hour to treat a 120-foot long, 4-foot wide nursery bed. Another problem is uniformly distributing steam in the soil. Temperatures monitored in the test plots vary from 105 to 160 °F across the width of the seedbed. A pasteurization temperature of 140 °F degrees is required to kill most pathogens, nematodes, and some weed seeds. Preliminary monitoring of the pathogens *Fusarium* and *Pythium* in the soil show that steam reduces their numbers greatly, but not as much as methyl bromide.

TEST RESULTS FOR 1996: USING SHANKS FOR STEAM INJECTION

In the fall of 1996 the steam treatment machine with the vertical shanks was taken to Forest Service nurseries at Coeur d'Alene, Placerville, and Medford for testing. These test plots were sampled before and after treatment and again in the spring of 1997 for pathogen levels.

Placerville Nursery (Placerville, CA)

September 19 to 20, 1996

Ambient Air Temperature 86°F (9/19/96) 83 °F (9/20/96)

Soil Temperature 74 °F at 2 inches and 68 °F at 4 inches (9/19/96); 58 °F (9/20/96)

Three 400-foot long, 5-foot wide beds were treated.

Observations:

- Treated soil temperature varied from 102 to 140 °F.
- Experimental small cultivator sweeps were tried to provided more uniform temperature distribution, but they also created more soil disturbance. The sweeps were positioned too close together. The sweeps had a tendency to pull or drag soil along (these small sweeps were not used in the latest modification.)
- The steamer operated 3 hours between water fills.

Macrophomina (chocolate root rot) is a problem at this nursery.

The vertical soil temperature profile after steam treatment is hown in Table 2, and populations of organisms before and after treatment are given in Table 3.

Table 2. Averages for soil temperature measured in September 1996 and analyzed by Jeff Stone, Oregon State University.

Depth (Inches)	Temperature (°F)
2	140
4	135
6	153
8	75
10	68

Table 3. Numbers of soil organisms in September 1996. Soil samples taken and analyzed by Jeff Stone, Oregon State University.

	Before steam treatment	After steam treatment
Pythium	300	200
Fusarium	1700	720
	Before methyl bromide treatment	After methyl bromide treatment
Pythium	480,480,380,380	10,0,6,0
Fusarium	2900,1800,1880, 1500	340, 140,120,0

Macrophomina Results (Reported by Susan Frankel in April 1997)

Two of the samples were tested for Macrophomina. The Macrophomina level was 2.2 sclerotia per gram before steam treatment at one area. The level was 2.1 sclerotia per gram after steam treatment. Steam was not very effective in reducing Macrophomina.

Methyl bromide fumigation reduced levels of Macrophomina from 2.3 sclerotia to 0 at one area and from 90 sclerotia to 0 at another area.

Coeur d'Alene Nursery (Coeur d'Alene, ID)

September 4 to 5,1996

Ambient Air Temperature	70 °F (9/14/96)	54 °F (9/15/96)
Soil Temperature	67 °F (9/14/96)	58 °F (9/15/96)

Five 100-foot long, 5-foot wide beds were treated.

Observations:

- Treated soil temperature varied from 102 to 140 °F.
- Cultivator sweeps provided more uniform temperature distribution, but also created more soil disturbance. Sweeps were positioned too close together.
- The steamer operated 3 hours between water fills.
- Pathogens of interest were fusarium and pythium.

Populations of both groups of potential pathogens were reduced by the treatment (Table 4). Averages for Fusarium were reduced from 408 to 287; those for Pythium from 101 to 25. Dazomet fumigation was more effective, reducing both pathogens to zero.

Table 4. Results of steam treatment on five plots at the coeur Nursery Nursery. Soil samples were taken in September 1996.

	Plot				
	1	2	3	4	5
Fusarium					
(before steam treatment)	749	272	408	204	408
(after steam treatment)	0	68	0	887	478
Pythium					
(before steam treatment)	136	75	95	109	88
(after steam treatment)	7	14	14	61	27

J. Herbert Stone Nursery (Medford, OR)

September 23 to 24, 1996

Ambient Air Temperature	65 °F (9/23/96)
Soil Temperature	59 °F
Vapor Temperature	180 °F

Three 150-foot long by 5-foot wide beds were treated

Observations:

- Treated soil temperatures ranged from 115 to 155 °F. One-half hour later, the soil temperature was still 102 °F at a depth of 5 inches.
- Soil was prepared by spading under a cover crop 2 weeks before treatment. A lot of organic matter collected on the shanks of the steamer, plugging up the injector shanks. The ground was spaded a second time, improving the bed for steaming. The spading appears to be an excellent method to prepare the soil. The soil at this site had a higher moisture content than at the other test sites. More BTU's were required to heat the moist soil, but the soil appeared to hold the heat better.
- The steamer used 25 gallons of diesel fuel in 4 to 5 hours of operation.
- The electric generator used 2 gallons of gasoline in 4 to 5 hours of operation.
- As an additional experiment, the area around the sprinkler pipelines was steamed to kill the growing vegetation. A tractor operated at its lowest forward speed (about 0.5 mph) pulled the steamer over the vegetation. Figure 6 shows the steamer with the steam chamber in operation.

Figure 6. A steam chamber applies steam directly above vegetation, allowing the steamer to kill weeds.

Results from further testing at J. Herbert Stone

Another steam treatment was conducted on October 3, 1997 in Field G, Unit 28, Beds D-F from irrigation riser 0.5 to 4.5 (120 feet). An untreated control plot was located in beds D-F from riser 4.5 to 6 (45 feet). The remainder of the unit was treated with Dazomet on October 11. Samples were taken the day after the steam treatment and all plots were sampled again on December 11. The results are whown in Table 5.

Immediately after treatment, steam appeared to reduce the levels of Fusarium as much as the pesticide Dazomet. Samples were taken this spring before sowing to compare the difference in population levels in areas treated with steam and areas treated with Dazomet. The results were not available for this report.

Table 5. Fusarium and Pythium levels before and after October treatment at Stone Nursery.

	Fusarium levels (parts per gram of soil)		
	October 3 (Before treatment)	October 4 (After treatment)	December 11 (Two months after treatment)
Untreated	—	—	16240
Steam treatment	37080	13200	21467
Dazomet	37080	—	13033

	Pythium levels (parts per gram of soil)		
	October 3 (Before treatment)	October 4 (After treatments\)	December 11 (Two months after treatment)
Untreated	—	—	0
Steam treatment	69	73	77
Dazomet	69	—	0

TEST RESULTS FOR 1997 USING SWEEPS FOR STEAM INJECTION COEUR D' ALENE TEST (JUNE 10 TO 11TH, 1997)

June 10, 1997

Sunny

Air temperature	80 to 83 °F
Soil temperature	72 °F at 2 inches 68 °F at 8 inches
Soil moisture content	13.46%
Ground Speed	1.5 feet per minute
Maximum vapor temperature	200 to 210 °F steam for 190 to 160 °F test plots 160 °F steam plus outside air for 130 to 150 °F test plots 160 °F Reduced steam flow plus maximum plus maximum outside air for 120 °F test plot

June 11, 1997

Cloudy and light showers

Air temperature	66 to 74 °F
Soil temperature	62 °F at 2 inches 64 T a t 8 inches
Soil moisture content	13.72%
Ground Speed	1.5 feet per minute
Maximum vapor temperature	200 to 210 °F steam for 190 to 160 °F test plots 160 °F plus outside air for 130 to 150 °F test plots 160 °F Reduced steam flow plus maximum flow outside 120 °F test plot

RESULTS

Temperature Uniformity

Figure 7 shows the temperature readings across a horizontal soil profile at depths of 1,4, and 7 inches. These readings were taken 2 minutes after steam treatment. The temperature at 1 inch and near the surface does not reach the desired 140 °F. Figures 8 and 9 show the same profile 20 and 48 minutes after steam application. Once the soil is heated, it holds that heat for long periods of time. Temperature migration toward the surface from the zone of application did not occur to the extent expected. Figure 10 shows the apparatus used to measure soil temperatures across the seed bed.

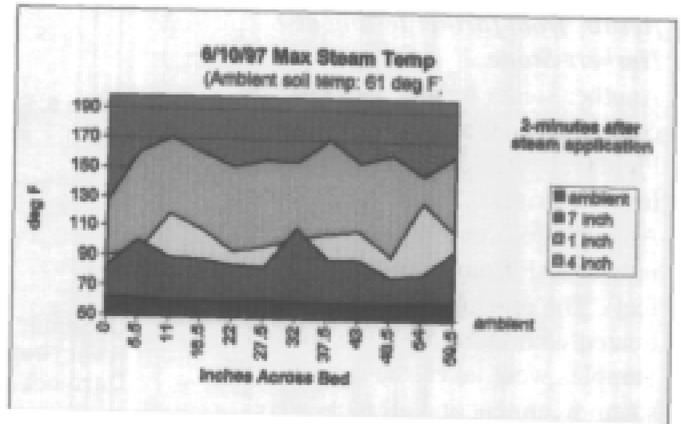

Figure 7. The horizontal temperature profile 2 minutes after steam application (using the sweep injection system).

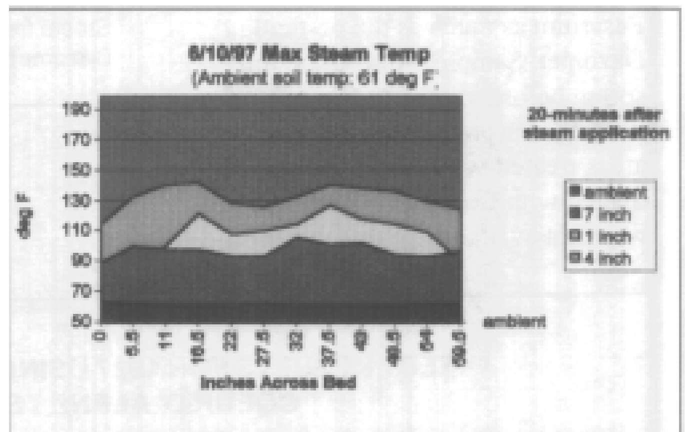

Figure 8. The horizontal temperature profile 20 minutes after steam application (using the sweep injection system).

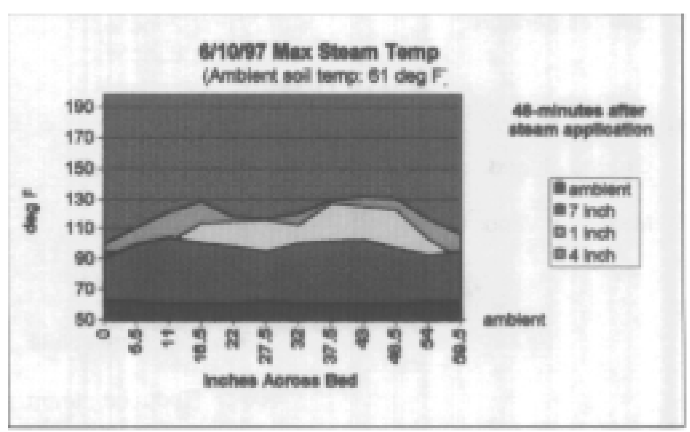

Figure 9. The horizontal temperature profile 48 minutes after steam application (using the sweep injection system).

Figure 10. The test apparatus used to measure soil temperatures horizontally across the seedbed. The instrument was placed on the soil surface immediately after steam treatment.

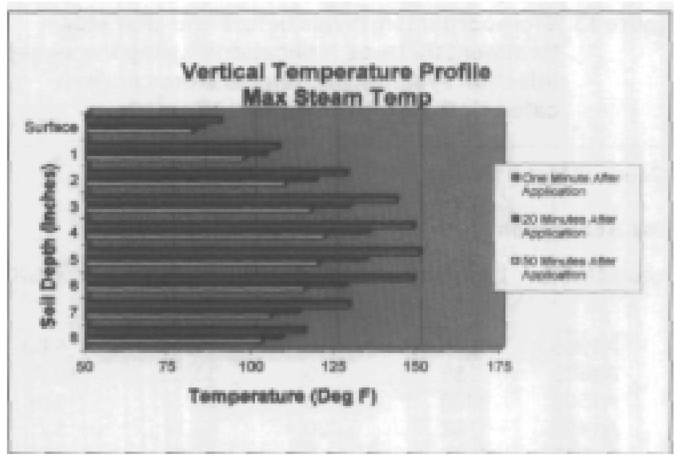

Figure 11. The vertical temperature profile showing soil temperatures at 1-inch intervals (using the sweep injection system).

Figure 11 shows the temperature readings across a vertical profile from the surface to a depth of 8 inches. The time intervals of 2, 20, and 50 minutes after application are shown on the same graph. Figure 12 shows the apparatus used to measure soil temperatures to a depth of 8 inches.

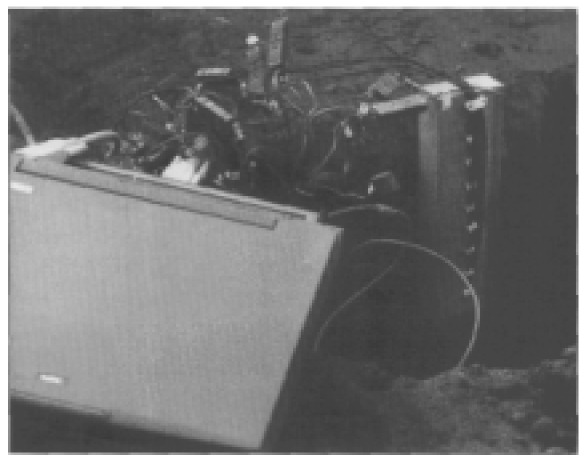

Figure 12. The thermocouple array used to determine the vertical soil temperature profile. A pit was dug for the instrument immediately after steam treatment.

Treatment Results

Figure 13 compares organism levels in soil samples obtained immediately before steam treatment with levels in samples taken 3 hours after treatment. Organism populations vary throughout the soil. One reason pathogen levels were not reduced or actually increased in some samples may be that the samples were taken from areas that did not reach the desired 140 degrees (see Figure 7). Trichoderma, one of the desirable soil organisms, is an indicator of temperatures desirable soil organisms can tolerate. Figure 13 shows that temperatures of 140 degrees and higher appear to greatly reduce their populations. Soil temperatures are indicated by the numerals in the sample numbers.

Soil Profile Information

Figure 14 shows the organism populations through a vertical profile from the surface to a depth of 7.5 inches. At depths below 6 inches the organism populations are significantly reduced. Figure 15 presents the information graphically.

Figure 13. Microoorganism levels before and after steam treatment for three replications (using the sweep injection system). Soil temperatures are indicated by the digits in the sample numbers.

Coeur d'Alene Nursery Soil Sample Results 6/97

1st Replication

Sample No.	Fusarium	Pythium	Trichoderma	T/F Ratio
		Before Treatment		
A190B	670	20	4425	6.60
A160B	335	10	3352	10.01
A150B	869	13	5613	6.46
A140B	737	20	4224	5.73
A130B	1075	0	4570	4.25
A120B	601	0	4076	6.78
		After Treatment		
A190A	0	0	0	0.00
A160A	0	0	67	0.00
A150A	335	10	2346	7.00
A140A	0	0	134	0.00
A130A	134	0	1412	10.54
A120A	1403	10	2339	1.67

2nd Replication

Sample No.	Fusarium	Pythium	Trichoderma	T/F Ratio
		Before Treatment		
B190B	737	30	2414	3.27
B160B	67	10	2479	37.00
B150B	67	0	871	13.00
B140B	268	20	4961	18.51
B130B	67	20	1273	19.00
B120B	67	0	1273	19.00
		After treatment		
B190A	1140	0	3218	2.82
B160A	134	0	134	0.00
B150A	0	0	470	0.00
B140A	67	0	269	4.01
B130A	0	0	67	0.00
B120A	468	0	2740	5.85

3rd Replication

Sample No.	Fusarium	Pythium	Trichoderma	T/F Ratio
		Before treatment		
C190B	134	10	1608	12.00
C160B	334	0	2138	6.40
C150B	1210	0	1344	1.11
C140B	401	0	2141	5.34
C130B	538	20	2755	5.12
C120B	268	20	1742	6.50
		After treatment		
C190A	0	0	134	0.00
C160A	0	20	201	0.00
C150A	0	0	0	0.00
C140A	67	0	602	8.98
C130A	0	0	1546	0.00
C120A	67	50	2141	31.95

Observations

- The injector sweeps must be 6 inches or deeper in the soil to prevent excessive steam loss to the surface and for maximum effectiveness in increasing soil temperatures. When the injector sweeps are shallower than 6 inches, steam is lost from the sides, around the shanks, and around the back edge of blade.

- When the injector sweeps are 6 inches deep or deeper, the top 2 inches of soil does not reach 140 °F for 20 minutes, the temperature needed to kill pathogens.

- It is more efficient to reduce the flow of steam than to increase air flow when reducing vapor temperature.

- Attaching a pulley on the tractor serving as a deadman reduced the winch's line speed by half. With this arrangement, the electric motor operated more efficiently

- The temperature front (the zone where heated soil met unheated soil) did not move much in the soil after the machine had passed. I assume the soil mass kept the temperature front relatively stable.

- Soil temperature was more uniform when the injector sweeps were used than when other systems were used.

- Narrowing the treated path so that the sweeps do not contact the tire path may prevent some steam from being lost out the sides. The tarp should be extended on both sides to help prevent steam loss.

- The PVC pipe used as a spreader bar under the tarp to disperse steam on the surface of the soil was not suitable for high temperatures.

- Two additional design concepts that may improve mixing the steam with the soil more completely are:

  1) Picking up the top 6 inches of soil and moving it through a steam chamber.

  2) Agitating the soil while steam is being applied.

Figure 14. Populations of soil microorganisms at different soil depths before treatment. Few of these microorganisms are found deeper than 6 inches in the soil.

Coeur d'Alene Nursery Soil Profile Sample Results 5/97

1st Replication - Tilled

Sample No.		Fusarium	Pythium	Trichoderma	T/F Ratio
AP-SUR(5.5)	0"(surface)	870	30	1874	2.15
AP-1.5	1.5"	736	40	1205	1.64
AP-3.0	3.0"	134	10	1338	9.98
AP-4.5	4.5"	134	0	1474	11.00
AP-6.0	6.0"	201	0	1472	7.28
AP-7.5	7.5"	67	0	269	4.01

2nd Replication - Tilled

Sample No.		Fusarium	Pythium	Trichoderma	T/F Ratio
BP-SUR(5.0)	0"	3360	34	2554	0.76
BP-1.5	1.5"	871	10	1807	2.08
BP-3.0	3.0"	1203	40	2005	1.67
BP-4.S	4.5"	941	0	3696	3.93
BP-6.0	6.0"	67	0	2285	31.10
BP-7.5	7.5"	0	0	336	0.00

3rd Replication - Unfilled

Sample No.		Fusarium	Pythium	Trichoderma	T/F Ratio
CP-SUR(5.5)	0"	2613	0	2747	1.05
CP-1.5	1.5"	2078	20	3486	1.68
CP-3.0	3.0"	268	40	2077	7.75
CP-4.5	4.5"	1814	20	3696	2.03
CP-6.0	6.0"	67	0	2138	31.91
CP-7.5	7.5"	0	0	802	0.00

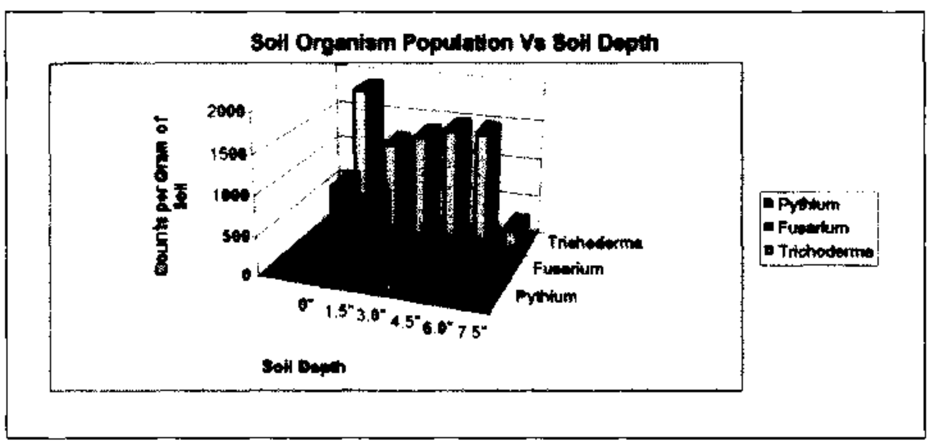

Figure 15. Graphic representation of soil microorganisms found at different soil depths before treatment.

PROJECT PRELIMINARY OBSERVATIONS

- Soil should be heat treated to a depth of 6 inches.

- To reduce the effects on the desirable organisms (*Trichoderma*, etc.) the treatment temperature should be no higher than 140 °F.

- The temperature of all the soil needs to be raised uniformly to the treatment temperature for treatment to be effective.

- Treatment is slow with the prototype experimental machine. A production version would need additional boiler capacity.

- Studies are needed to determine how fast pathogens reinvade the treated area.

ACKNOWLEDGMENTS

I wish to acknowledge the personnel at the Forest Service nurseries (Coeur d'Alene Nursery, Coeur d'Alene, ID; J. Herbert Stone Nursery, Medford, OR; Placerville Nursery, Placerville, CA) and the Montana State Nursery, Missoula, MT, for their help in this project. Bob James, Pathologist at the Coeur d'Alene Nursery and his staff analyzed the soil samples and returned the results quickly.

OTHER RELATED WORK

Robin Rose's Study for the Environmental Protection Agency

Robin Rose of the Oregon State University has received a grant from the Environmental Protection Agency to study the different methods of soil sterilization, including steam treatment. He will determine what effect steam has on weeds and pathogens and their reinvasion after steam treatment. One important item for his experiments is a precise and uniform application of heat. Test plots will be installed in early September. MTDC will supply the machine for the study.

Jim McDonald's Study at the University of California-Davis

Jim started a study to evaluate using microwaves for soil pasteurization. Recently he has been doing ohmic (resistance) and steam heating of greenhouse soils. He plans to look at the use of longer wavelength radio frequencies for heating, but has not done much work yet.

Aqua Heat

During a phone conversation, Chapman Mayo of AquaHeat, summarized Aqua-Heat's work with hot water to control microorganisms in the soil.

- The special tiller they modified produced uniform temperatures in the soil as the hot water was injected.

- The maximum soil temperature was about 160 °F.

- Treatment depth was about 10 inches. In sandy soil, the temperature gradient would move down below 10 inches after application.

- For weed control, hot water kills the weeds that are easy to kill. Some of the heartier weeds require repeated applications. Speed was critical. Treatment that was too fast produced temperatures that were too low, with poor results.

- No trials were conducted in which crops were raised in treated beds. The nursery where the test plots were installed was closed down after the test.

- The prototype machine was not scaled up, but could be if additional interest is shown.

- Aqua-heat is doing some development that emphasizes combining hot water treatment with friendly, less-toxic chemicals. The company is looking at incorporating a chemical to enhance residue control of *Fusarium*. Reinvasion of pathogens after treatment was noted after hot water treatment.

Stock quality assessment: Still an important component of operational reforestation programs[1]

Raymund S. Folk and Steven C. Grossnickle[2]

INTRODUCTION

As early as 1954, the need to grade seedlings for morphological and physiological quality was recognized (Wakeley 1954). Over the last 50 years, and especially during the 80's and early 90's, scientists and foresters studied ways to produce better seedlings through improved nursery culture, and developed tests to assess seedling quality. This interest in seedling quality led to numerous reviews (Sutton 1979; Chavasse 1980; Jaramillo 1980; Timmis 1980; Schmidt-Vogt 1981; Ritchie 1984; Glerum 1988; Lavender 1988; Puttonen 1989; Hawkins and Binder 1990; Johnson and Cline 1991; Omi 1991; Grossnickle and Folk 1993; and Folk and Grossnickle 1997), several publications (Duryea and Brown 1984; Duryea 1985; Rose *et. al.* 1990), as well as special issues of periodicals (*New Zealand Journal of Forestry Science,* 1980, Vol. 10, no. 1, and recently *New Forests,* 1997, Vol. 13, no. 1-3). As a result, nursery cultural practices and field-planted seedling have survival has improved. In British Columbia, average survival for container stock is greater than 80% (Bowden 1993).

The achievement of better cultural practices and high survival rates has erroneously given rise to the impression that stock quality assessment is a tool of the past. Consequently, actual assessment has often been confined to measures of height and diameter, a root growth capacity test for functional integrity, and a frost tolerance test to monitor stock for lifting. This view has been born out of a misunderstanding of the type of information that is provided by the different aspects of stock quality assessment.

Stock quality assessment is concerned with more than the achievement of high survival (Ritchie 1984; Grossnickle *et al.* 1991). Ritchie (1984) reported that seedlings could be measured for both material and performance attributes, and Grossnickle and Folk (1993) showed how these attributes could be used to determine both field performance potential and survival potential. The two measures are related but distinct from each other. Folk and Grossnickle (1997) demonstrated that field performance potential could be measured and related to actual performance on a reforestation site by measuring performance attributes under environmental conditions that better represented reforestation site conditions. This approach was first presented by Timmis (1980), and has only recently been adopted by operational seedling quality programs (Dunsworth 1997; Folk and Grossnickle 1997; Sampson *et. al.* 1997;. Tanaka *et. al.* 1997)

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[1]*Folk, R.S.; Grossnickle, S. C. 1997. Stock quality assessment: Still an important component of operational reforestation programs. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 109-119.*

[2]*BC Research Corporation, Forest Biotechnology Centre, 3650 Wesbrook Mall, Vancouver, BC V6S 2L2, Canada; Tel: 604/224-4331; Fax: 604/224-0540; e-mail: (steveg@bcr.bc.ca).*

There is still a need for stock quality programs that determine survival and field performance potential. The high cost of reforestation and poor survival on some sites has led foresters to demand some kind of quantification of survival potential and functional integrity of their stock. Despite high survival rates on most sites, foresters are demanding better growth performance from their seedling stock. This has been accentuated by changes in policy which have placed the financial and labor burden of reforestation on private timber harvesting companies. Requirements to meet a free-to-grow status in a fixed period of time, associated with penalties of reduced annual allowable cuts and limited harvesting access to lands adjacent to sites without this status, has resulted in a free-to-grow obligation that is part of the financial liability of timber companies. Consequently, forest companies want to plant stock that will help them remove this liability as soon as possible.

Field performance forecasting is also being used by producers of forest seedlings. The increase in privately run nurseries in many regions in Canada has resulted in seedling producers using the tools of stock quality assessment to improve their competitive edge by producing better quality seedlings, or stock types that are unique to their product list. The assessment of field performance potential has allowed private nurseries to compare their unique stock types to conventional stock types, and provide a list of quantifiable material and performance attributes for the client.

The following is a case study that will describe how a timber harvesting company and a nursery seedling producer in British Columbia have made use of the Stock Quality Assessment Program at BCRI (Vancouver, BC).

A CASE STUDY OF STOCK QUALITY ASSESSMENT IN AN OPERATIONAL REFORESTATION PROGRAM

Program objectives

Rustad Bros. & Co. Ltd. and Northwood Pulp and Timber Ltd., located in Prince George, British Columbia, Canada, plant approximately 10 million seedlings a year (approximately 50 to 70 major key requests), requiring a substantial investment in reforestation. Stock types included 1+0 and 2+0 frozen-stored and summer-shipped seedlings, grown in various container sizes and types, and three major conifer species (interior spruce, *Picea glauca x engelmannii;* interior Douglas-fir, *Psuedotsuga menziesii;* and lodgepole pine, *Pinus contorta*). The company foresters recognized that little information was available on the quality and readiness of their stock for planting. They wanted to have their stock assessed while in the nursery, at time of planting and shortly after planting to obtain information that would aid them in responding to potential stock problems or strengths. Such information would allow silviculturists to determine and drive actions at the nursery and in the field. The foresters wanted to integrate and calibrate seedling quality information with data collected

Table 1. Break-down of seedling populations tested at BCRI for stock quality, representing 7 million seedlings from the reforestation programs of Rustad Bros. & Co. Ltd. and Northwood Pulp and Timber Ltd. in Prince George, British Columia. (PI is lodgepole pine, Fd is Douglas-fir, and Sx is interior spruce)

Planting time	Number of Nurseries	Species	Stock-types	Number of Seed lots	Container Formats	Number of Key Requests	Range of Population Sizes
Spring Planting/ Frozen Stored	2	PI, Fd,Sx	1+0,2+0	12	211A, 313B, 410, 415B, 415D	14	100,000 to 450,000
Summer Planting	1	PI, Sx	1+0,2+0	9	410, 415B, 415D,515A 615A	15	2,000 to 778,000

from the field, and from the stock performance testing program, to develop standards as a historical reference for yearly comparisons, and maintain the information in a database as a component of their seedling management system. A similar approach has been utilized by the Weyerhauser Forest Company since 1985 in their seedling testing program (Tanaka *et. al.* 1997).

Two major objectives were identified by company silviculturists:

1) Monitor development, forecast variability, recommend shifts in nursery culture or time of lifting, and detect potential problems during the nursery production phase.
2) Determine the functional integrity (survival potential) and performance potential under defined environmental conditions.

Species, seed lots, and stock-types tested

Fourteen frozen-stored, and 15 summer-ship populations (key requests) were assessed. This included three species (lodgepole pine, Douglas-fir, and interior spruce), and seven stock-types (211 A, 313B, 410, 415B, 415D, 515 A, and 615A) (Table 1). A selection from both the frozen-stored and summer-ship populations are used to provide examples of the type of information that can be obtained from comprehensive testing in an operational program.

Assessment of variability

Early identification of height variability allows decisions to be made on how to best lift and package stock for planting. By assessing height variability, foresters are given information that aids in decision about the fate of populations or portions thereof. For example, efforts can be concentrated on planting small stock on sites with a low risk of vegetative competition, and vice versa. Populations that are candidates for this type of decision-making are those that are highly variable (i.e., coefficient of variation >20%), bimodal in height distribution, or below target. In the example given in Figure 1, all stock met the height targets set out by company silviculturists, but the S1 population had high height variability (>20%), and height was bimodal in distribution. By identifying this variability, silviculturists had the option of dividing the S1 population into two categories (e.g., 50%

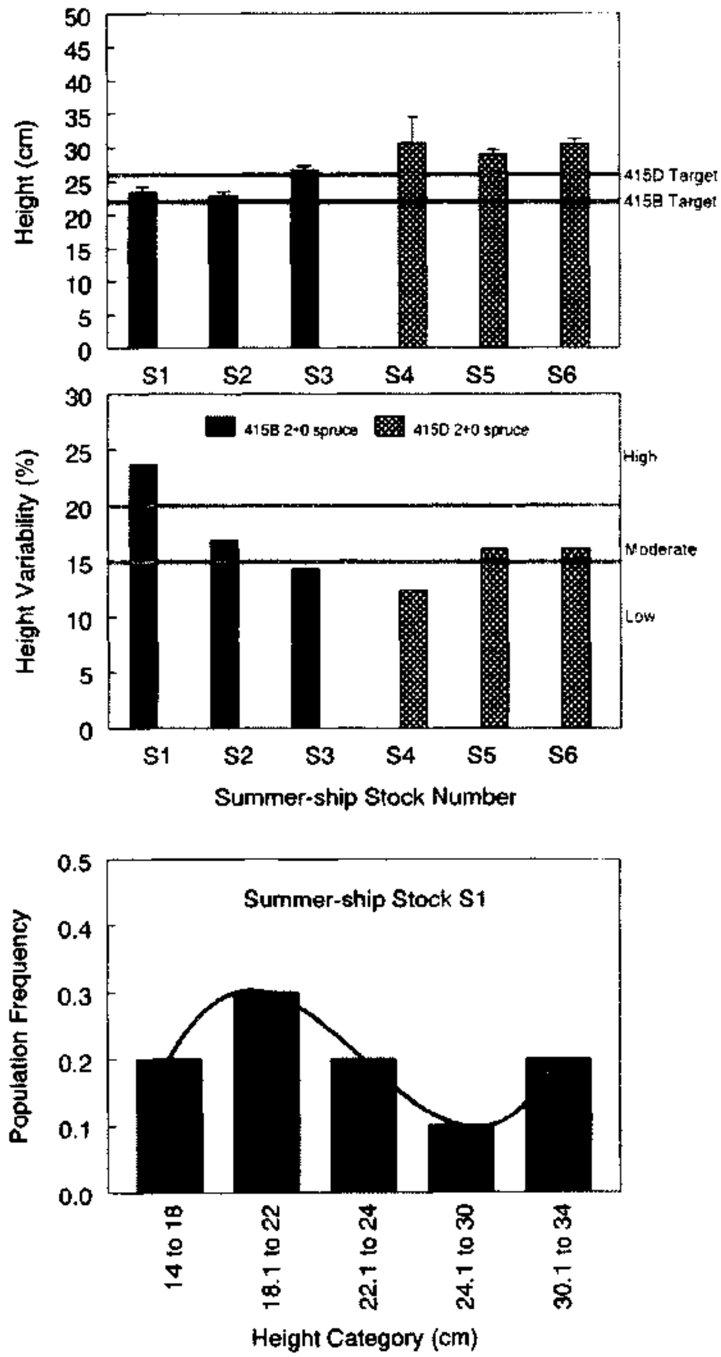

Figure 1. **Assessment of: 1) height and 2) height variability (coefficient of variation in %) of six summer-ship interior spruce seedling populations, and 3) distribution of 4-cm height classes in the S1 population at one week before the scheduled planting date.**

of stock at 14 to 22 cm and 50% at 22.1 to 34 cm), and planting on two sites differing in degree of competing vegetation.

MONITORING DEVELOPMENT IN THE NURSERY

Adequate assessment of stock during the nursery phase requires the quantification of both visual observations and hidden attributes. Frozen-stored seedlings are often chosen as a stock type because they are ready for planting in the early spring and will grow in shoot height during the first year, compared to summer-ship stock which is planted after shoot growth in the nursery. Thus, it is important to determine the viability of the terminal bud in frozen-stored seedlings, and the developmental stage of terminal buds in summer-ship stock. This attribute should be assessed at the end of the storage period for frozen-stored stock, and after dormancy induction in summer ship stock.

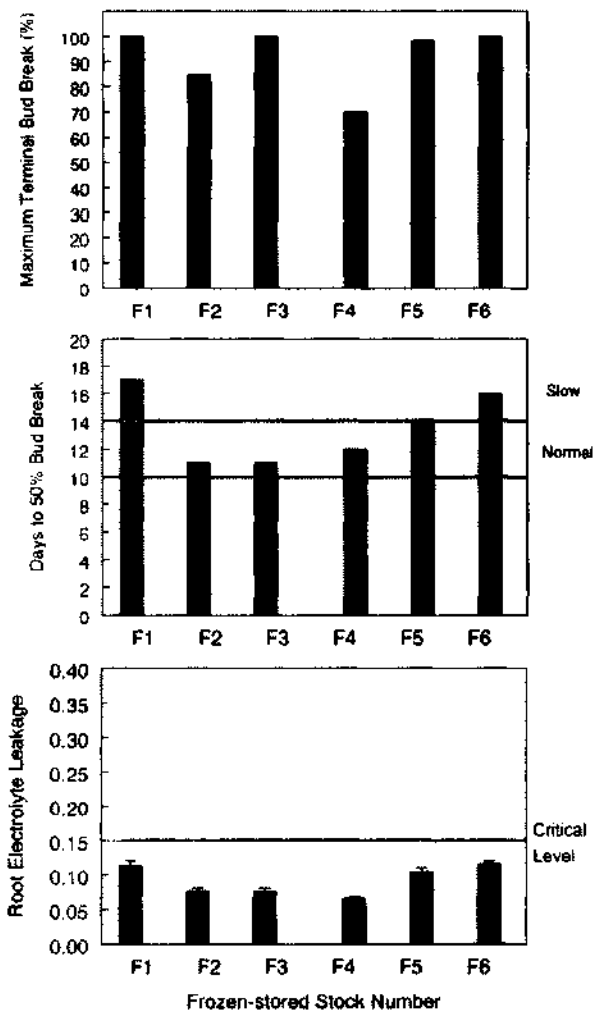

Figure 2. Six frozen-stored stored interior spruce seedling populations one month before the scheduled planting date: 1) percent maximum terminal bud break, 2) number of days require for 50% of seedlings to break bud, and 3) root electrolyte leakage.

Bud break characteristics of six frozen-stored stock types one month before the scheduled plant-date are described in Figure 2. Results indicated that only 70% of the F4 population broke their terminal bud. Reduced terminal bud viability indicated that the stock should not be planted on sites where first year height growth was important (i.e., on sites quickly invaded by competing vegetation). Loss of terminal bud viability coupled with the harsh environmental conditions of the planting site (e.g., frost), could result in first-year growth reductions. Tests can also be conducted to determine the rate of bud flush (Figure 2). Seedlings that have achieved an adequate chilling sum, either before lifting or during storage, will break bud rapidly under optimum environmental conditions (i.e., ≤12 days for 50% of interior spruce seedling populations). Seedlings that are slow in their bud break have been either lifted too soon for frozen-storage (i.e., not phenologically ready for lifting), or have been compromised in functional integrity.

Root electrolyte leakage can be measured on both frozen-stored and summer-ship stock at time of lifting. Identification of root damage in frozen-stored stock during fall lifting allows nursery personnel to avoid the cost of lifting and storage of populations, or portions thereof, that have been root damaged. Other tests for functional integrity (i.e., shoot integrity measured by photosynthetic capability, and root integrity plus overall physiological condition of the seedling measured by root growth capacity) can be conducted for similar purposes. Measurements can also be made during storage to ensure that integrity is not reduced due to the storage environment. Testing for changes in seedling quality during lifting and storage allows both nursery personnel and foresters to monitor their seedling inventory for possible reductions in seedling quality that may require changes to their reforestation plans.

Summer-ship stock can be assessed for similar attributes, but in this case terminal bud retention is the useful attribute. Figure 3 is an example of six summer-ship stock populations measured one week before the scheduled plant-date. The S2, S4, and S5 populations had low terminal bud set, partly due to some breaking of previously set buds. As a result, at least half of each of these populations have terminal buds with less than 164 needle primordia. It was recommended that stock types in this condition be left in the nursery for further bud development before lifting, shipping and planting commenced. In contrast, population SI had 100% bud set, 0% bud break, and more than 60% of the terminal buds had greater than 164 needle primordia developed. This stock was ready for the scheduled planting date. In contrast, planting the S2, S4, and S5 populations on their scheduled plant-date may have compromised future shoot development in the field.

During early testing, both frozen-stored and summer-ship stock can be assessed for anomalies, such as multiple leaders, crooked stems, disease, and other pests. Figure 3 provides the results of multiple leader tallies for the six summer-ship populations. Measurements indicated that 5% or more of the S4 and S5 seedlings had multiple leaders. Early detection of high levels of such anomalies allows foresters and nursery personnel to readjust anticipated seedling numbers by predicting cull rates based on attributes other than conventional height and diameter targets.

Forecasting optimum lift-date

Monitoring the development of seedlings is important for determining if stock will be ready for storage or planting. Determining the best time to lift seedlings for frozen-storage is important. Timing of fall lifting has been considered to be crucial for subsequent field performance of frozen-stored stock. A number of review articles have stated that seedlings can have poor field performance when the dormancy cycle has been interrupted (Ritchie and Dunlap 1980; Sutton 1990). Specific research with container interior spruce has found premature fall lifting can result in low root growth capacity and poor field performance after frozen storage (Simpson 1990).

The timing of lifting is even more important for summer-ship stock. This stock is usually lifted, shipped, and planted within a three to six-week period after dormancy induction treatments that are used to stop shoot growth and initiate bud development (short-day or drought). Shortly after this treatment, stock produce a

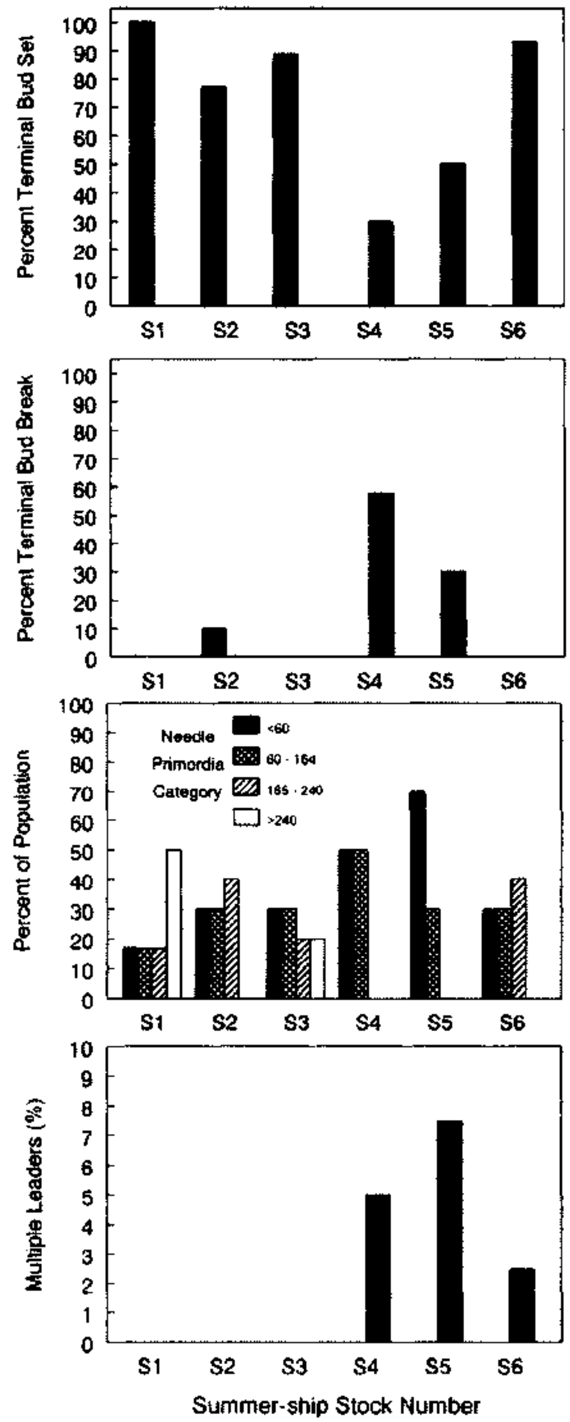

Figure 3 Six summer-ship interior spruce populations at one week before the scheduled planting date; percent of: 1) terminal bud set, 2) terminal bud break after bud set, 3) terminal buds with i) <60, ii) 60 to 164, iii) 165 to 240, and iv) >240 needle primordia, and 4) seedlings with multiple leaders.

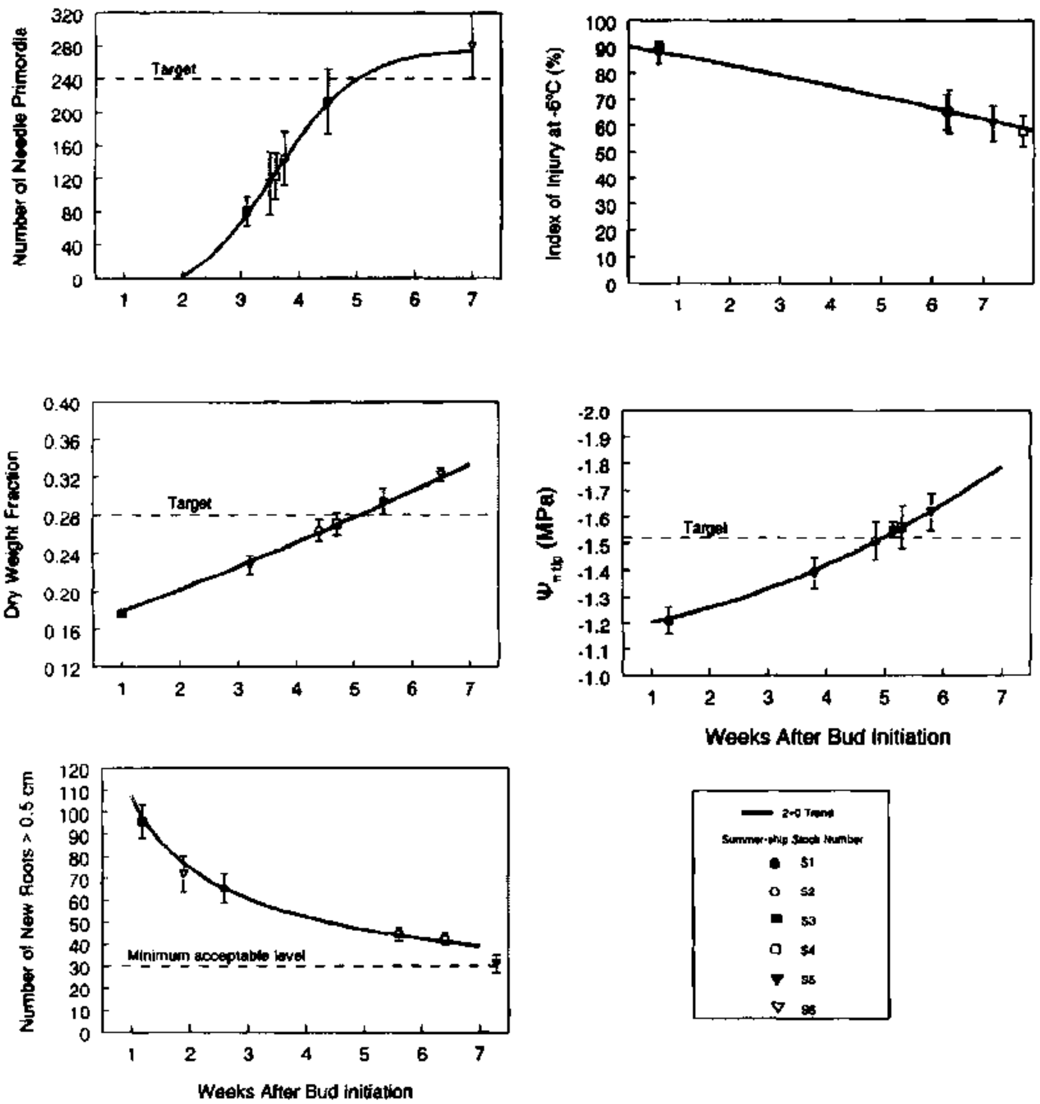

Figure 4 **Forecasting optimum lift-date for six interior spruce seedling populations two weeks before the scheduled plant date: 1) number of needle primordia, 2) dry weight fraction (shoot dry weight divided by saturated weight), 3) index of injury at -6°C (freeze-induced electrolyte leakage), 4) osmotic potential at turgor loss point (Y_{ptlp}), and 5) number of new roots >0.5cm after seven days. Lines are regression models describing the historical trend of these parameters in 2+0 interior spruce seedlings after bud initiation (short-day treatment).**

terminal bud and enter an exponential phase of needle primordia development (Figure 4). This stage is also associated with decreases in root growth capacity, slight increases in frost tolerance, dry weight fraction, and drought tolerance as seedling phenology changes. To forecast an optimum lift-date, these parameters are compared to historical trends. These trends allow an assessment of the approximate time required for stock to reach target levels of needle primordia, frost tolerance, drought tolerance, while maintaining an acceptable level of root growth capacity (i.e., > 30 new roots) (Figure 4).

Targets are still under development, but are currently based on water relation parameters and frost tolerance levels associated with the end of the exponential phase of needle primordia development after dormancy induction. Historically, this has occurred on week 5 after bud initiation. However, the rate of development after dormancy induction may change from year to year according to annual fluctuations in the environmental conditions at the nursery. This can be assessed by comparing mean levels of needle primordia with those predicted by the historical trends. If the time of dormancy induction is known for the stock, an assessment of the rate of development can be made. Seedling populations, or portions thereof, can also set bud before scheduled dormancy induction treatments are to be applied, resulting in populations, or portions thereof, being shipped for planting after seedling dormancy is well advanced. Stock lifted too late will have low levels of root growth capacity, and field establishment capability may be reduced. In contrast, stock that is lifted too early will have low needle primordia development at time of lifting, and further development will have to occur under less than optimum conditions in the field.

In the example given in Figure 4, all populations were tested one week before their scheduled plant-date. The SI and S9 populations are well advanced in needle primordia production, frost and drought tolerance, and cell development (i.e., dry weight fraction), and are ready for planting. In contrast, the S4 and S7 populations require at least two more weeks of development in the nursery before planting should occur.

ASSESSMENT OF SURVIVAL POTENTIAL

Survival potential is a measure of seedling functional integrity (Grossnickle and Folk 1993). Seedlings in good physiological condition should survive in all but the most severe environmental conditions (Sutton 1988; Folk and Grossnickle 1997). Survival potential is determined by material attributes that measure the specific integrity of seedling systems (e.g., root electrolyte leakage (REL) for root system integrity), or by performance attributes measured under optimum conditions (e.g., root growth capacity (RGC), net photosynthesis, etc.) (Folk and Grossnickle 1997). Seedlings that are not compromised in integrity should have acceptable performance attribute levels under non-limiting conditions for their stage of phenological development (i.e., different for actively growing compared to dormant seedlings).

Information on functional integrity allows silviculturists to make effective decisions on stocking levels that will account for possible future losses from mortality. For instance, six summer-ship populations were assessed

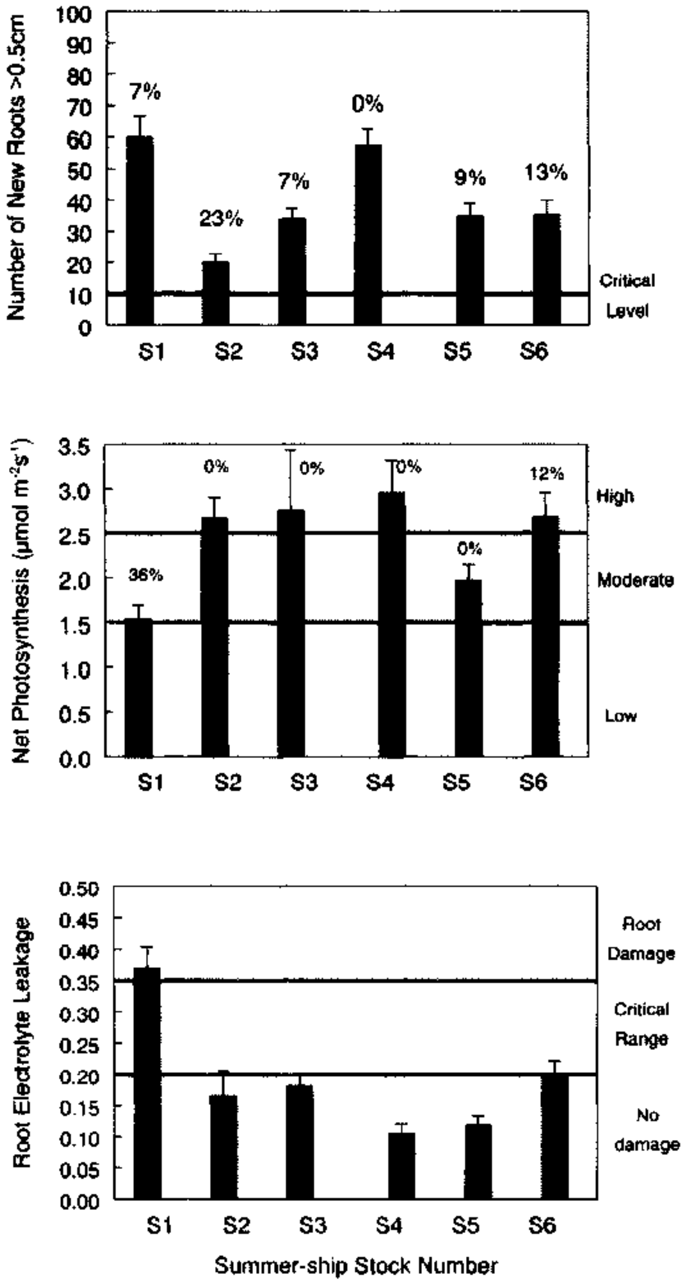

Figure 5 **Survival potential of six summer-ship interior spruce populations at time of planting: 1) number of new roots >0.5cm after seven days under optimum conditions, 2) net photosynthesis after four days under optimum conditions, and 3) root electrolyte leakage. Values above each bar indicate the percent of each population that fell below critical number of roots or moderate net photosynthesis levels.**

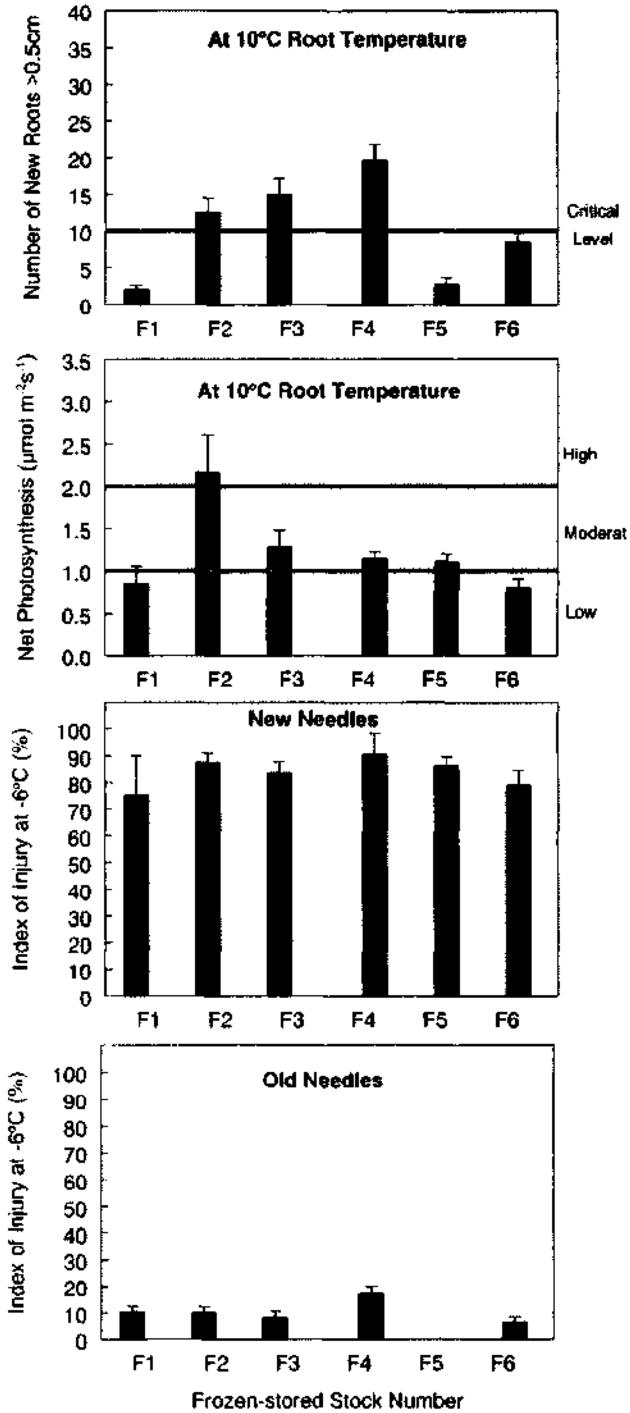

Figure 6 Field performance potential of six frozen-stored interior spruce populations for cold sites, measured one month before planting: 1) number of new roots >0.5cm after fourteen days at 10°C root temperature, and 2) net photosynthesis after seven days at 10°C root temperature, and index of injury at -6°C for 3) new needles of the elongating leader, and 4) old needles produced the previous year in the nursery.

for one material attribute (root electrolyte leakage) and two performance attributes under optimum conditions to determine their functional integrity one week before their scheduled plant-date (Figure 5). Test results indicated that all six populations had acceptable mean levels of RGC (i.e., > 10 roots), and net photosynthesis (i.e., > 1.5 mmol m^{-2} s^{-1}), but portions of SI, S2, and S6 populations had reduced RGC, net photosynthesis, and or high REL. Twenty-three percent of the S2 population, and 13 % of the S6 population had seedlings that were below critical RGC levels. A portion of the SI and S6 populations also had seedlings with low net photosynthesis. Information on reduced survival potential of populations, or a portion thereof, provides the forester with an option to increase stocking levels to account for a high potential rate of mortality. In the long-term, this should reduce the incidence of re-planting to improve stocking levels.

ASSESSMENT OF FIELD PERFORMANCE POTENTIAL

Material attributes that measure stress tolerance, and performance attributes that are measured under conditions that reflect the planting site, provide information about field performance potential (Grossnickle *et. al.* 1991; Grossnickle and Folk 1993; Folk and Grossnickle 1997). Various standard environmental regimes can be used to represent different site conditions. For example, seedlings can be tested under low root temperature conditions for high elevation sites, or sites planted in early spring, where root temperature is low (< 10°C), or under low moisture conditions for dry sites where seedlings will undergo significant planting stress or drought.

Six frozen-stored interior spruce populations were tested under low root temperature (i.e., 10°C) and frost conditions at time of planting (Figure 6). Results indicated that three populations (Fl, F5, and F6) had low RGC, and two (Fl and F6) also had low net photosynthesis under low root temperature conditions. Thus, populations F3, F4, and F5 may be better suited to cold-soil sites. However, sites with cold soils are also likely to experience frost events (e.g., northern ESSFwk subzone in British Columbia, see Farnden 1994). Tests for frost damage at -6°C indicated that all six populations had low frost tolerance (>70% index of injury) in new needles (of the elongating leader), but greater frost tolerance in old needles (developed in the previous season). Differences in the frost tolerance of old and new needles is important when frost events result in severe damage of new shoot growth. The old needles of population F5 had no measurable damage at -6°C, indicating a better ability to survive when new foliage is severely damage by frost. Planting the F5 population on the most frost-prone sites may increase the probability for survival on those sites. However, this would be done at the expense of reduced performance potential, since this population had poor root growth and low net photosynthetic capability under low root temperature conditions.

Field performance potential testing can also be conducted to determine the ability of stock to recover from planting or drought stress. For this testing, seedlings are exposed to drought until they reach -3.0 MPa mid-day shoot water potential, and re-measured for RGC and net photosynthesis under optimum conditions. Testing results of six summer-ship populations indicated that populations S3 and S6 had high RGC after drought, but RGC of S2 was below critical levels (Figure 7). Populations SI, S2, and S6 maintained high levels of net photosynthesis which were 60% or greater of optimum levels. Based on the combined results of RGC and photosynthesis, S3 and S6 appear to be the best suited populations for low-moisture sites. In contrast, the S2 population should not be planted on drought prone sites. A lower RGC for the S2 population also indicated a lower drought avoidance capability.

Under continued low moisture conditions, all populations will eventually experience drought stress. For this reason it is important to also test for the ability to avoid further needle desiccation under severe drought stress. Seedlings with high cuticular transpiration will continue to loose water at greater rates after stomatal closure (severe drought stress) than seedlings with low cuticular transpiration. For the six summer-ship stock tested, S2 and S3 had highest mean levels of cuticular transpiration (Figure 7). Despite a greater ability to recovery from a brief drought stress, S3 may have the lowest ability to avoid further drought stress during a prolonged drought. On sites associated with prolonged droughts, population SI may be more appropriate. This population had an acceptable RGC (>10 roots) and net photosynthesis level after drought, and a lower cuticular transpiration rate than S3.

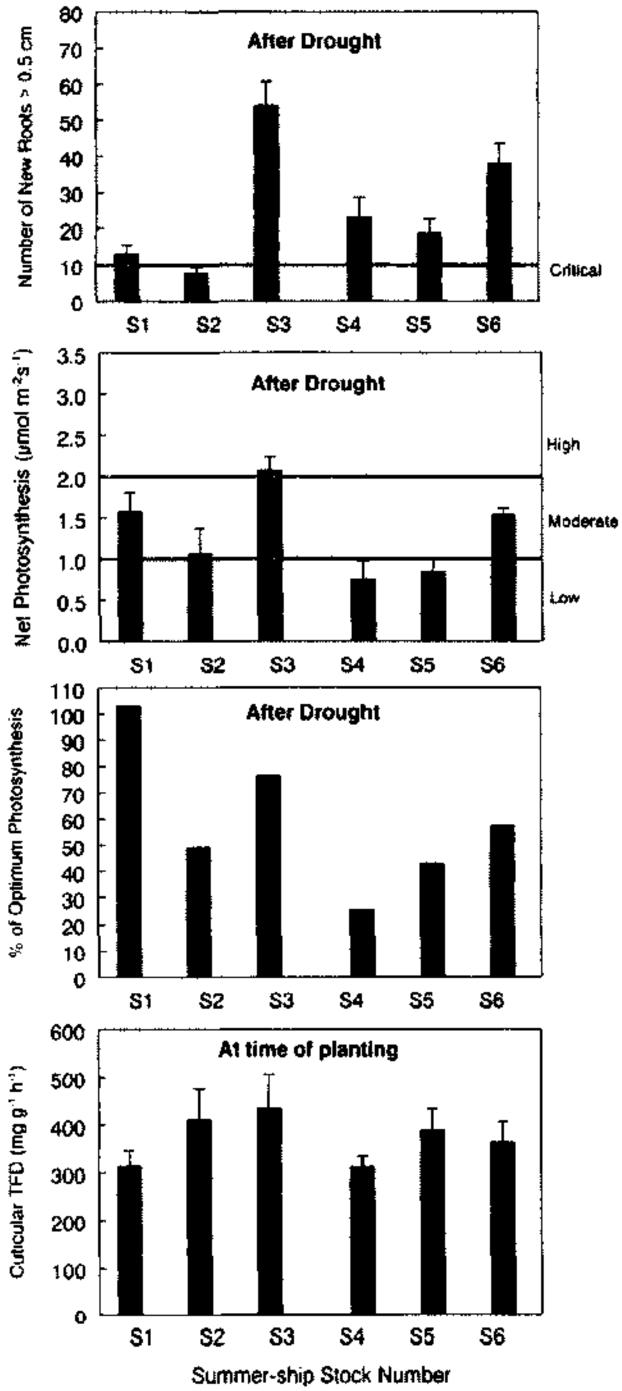

Figure 7 **Field performance potential of six summer-ship interior spruce populations, measured at time of planting and after a drought stress of -3.0 MPa mid-day shoot water potential: 1) number of new roots >0.5cm at seven days after drought stress, 2) net photosynthesis and 3) percent of optimum levels of photosynthesis at four days after drought stress, and 4) cuticular transpiration (TFD) (mg H_2O per g needle dry weight per hour) measured after turgor loss point.**

CONCLUSIONS

Stock quality assessment conducted for monitoring seedlings during the nursery phase, and determining survival and field performance potential, provides valuable information for decision making by both nursery personnel and reforestation silviculturists. Tests conducted to determine optimum lift-date, morphological variability, and performance for specific site conditions can result in decisions that will facilitate greater success in achieving stocking and free-to-grow standards. Costs of providing such information can be less than 3% of the total reforestation budget, and in the long-term, returns on this investment may be realized in terms of lower replanting costs and quicker elimination of free-to-grow liabilities. Stock quality assessment also provides an effective means of quantifying seedling populations for specific site conditions, and evaluates the final product with respect to the client's needs and objectives. This results in more effective communication between buyers (foresters) and producers (nurseries) of forest seedlings.

The tests described in the above case study are only an example of the many assessment procedures that can be used. Grossnickle and Folk (1993) give examples of others that are also useful. Similarly, the results of tests and their implications to nursery cultural practices and operational planting programs described in the case study are not an exhaustive discussion of all of the possible situations that can arise in reforestation programs. Each program will deal with different nursery and site conditions, resulting in different stock quality needs and problems. Stock quality assessment programs must be designed to define seedling performance with specific forest regeneration problems in mind.

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Update On Copper Root Control[1]

Mark A. Crawford[2]

The benefit of using of copper salts in a latex carrier to control root development in containers has been well documented in the literature and has gained widespread use in forestry with the introduction of pretreated styrofoam growing trays in the early 1990's. Using copper to control root growth in containers to eliminate root spiraling first began in forest seedling production in the 1960's and has increased to where greater than 90% of lodgepole pine produced in British Columbia are grown in copper-treated containers. Horticultural researchers who were also looking for ways to eliminate root circling in container landscape trees became interested in this practice. Researchers at Ohio State University demonstrated the benefits of controlling roots in container-grown red oak (*Quercus rubra*) which caught the attention of Griffin Corporation, a major producer of copper fungicides. In 1994, Griffin introduced Spin Out" Root Growth Regulator to ornamental nurseries, the first EPA registered product for controlling plant root growth in containers.

Spin Out was specifically formulated as a stable, ready to use product to be applied to the inner surfaces of growing containers to control undesirable root growth and produce plants with high root regeneration potential. The active ingredient in Spin Out is copper hydroxide. Copper hydroxide has been used for over 30 years for disease control on crops throughout the world and is considered the best source of copper for copper-based fungicides/bactericides. Spin Out has been formulated to adhere to plastic nursery containers and styroblocks and holds the copper hydroxide in place to control root growth only along the container wall. It is easily applied to the inner surfaces of new and used containers using conventional spray paint equipment. It was also formulated to reduce the problems of copper-induced iron chlorosis associated with home brewed mixtures of latex paint and copper carbonate and the Canadian pretreated styrofoam blocks. When root tips reach the sides of the container, the Spin Out coating inhibits root elongation and deflection and stimulates root branching. As the plant produces new roots, they in turn will be pruned, resulting in a very fibrous root system. Spin Out prevents the "cage root" condition where roots are only present on the outside of the root ball. Instead, the roots explore and utilize all the available potting media. An improvement in root distribution can lead to an improvement in the nutrient status and health of the plant which will support quicker growth when upcanned or transplanted. With the absence of circled and matted roots, no mechanical root pruning is required at transplanting resulting in decreased sites where root diseases can enter the plant. Also, root heat stress associated with black nursery containers is reduced in Spin Out-treated containers. In a typical black nursery container, 80% of the roots are within one inch of the container wall. Spin Out will cause the root system to be distributed more evenly through the soil thereby reducing the mass of roots which come in contact with the plastic that are subject to temperature extremes. Better root distribution can also increase the nutrient status of roots since the plant is able to utilize all the available soil in the con-

[1] *Crawford, M.A. 1997. Update On Copper Root Control. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 120-124.*

[2] *Griffin Corporation, PO Box 1847, 2509 Rocky Ford Rd., Valdosta, GA 31602-1847; Tel: 9121249-5271; Fax: 9121244-5978; e-mail: (mark, crawford@griffincorp.com).*

tainer. An increase in flowering has been demonstrated with lantana grown in Spin Out-treated containers during greenhouse production (Table 1). Spin Out also makes removal of plants from containers easier since the roots do not adhere to the plastic or styrofoam.

Most of the research with Spin Out has been on ornamental trees, shrubs, and herbaceous annuals and perennials grown in large containers ranging in size from 1 to 100 gallons. Initially, Spin Out was developed as a user-applied coating where growers apply the product to containers at the nursery. Growers found the product very effective but they were resistant to the time and inconvenience of application. This lead to Griffin and Lerio Corp., a container manufacturer, forming a partnership in 1996 to supply pretreated pots and propagation trays to the market. Pretreated propagation trays are produced by a patented process where flat polystyrene sheet is coated with Spin Out and then formed into a tray. This represents a significant reduction in the cost and time to produce a treated tray and the coating rate is specific to cell size. At this time, plastic trays with cells less than 3 inches deep are available from Lerio and in 1998, Lerio plans to introduce trays with deep cells used for forest and landscape tree seedlings (Figure 1).

In addition to rigid plastic containers, Griffin has developed polybags pretreated with Spin Out (Figure 2). Polybags are currently being tested on numerous forestry and nursery crops in several countries as a cost effective way to solve root problems associated with polybag culture. First year results are very encouraging on *Pinus montezume* (Table 2).

The development of Spin Out has lead to many other uses for root and pest management in nurseries, greenhouses, and in the landscape. Spin Out can be applied to woven and non-woven geotextile fabrics to provide root control for different situations. Weeds growing in a decorative mulch used to cover a fabric groundcover in a landscape are very difficult to remove because the roots grow through the small openings in the fabric. Spin Out-treated geotextile fabric will prevent weeds from becoming established by controlling roots that attach and grow through the fabric. This concept has been modified where Spin Out-treated non-woven fabric is cut into circles or discs and placed on the tops of pots to control weeds as an alternative to herbicides (Figure 3). When weed seeds germinate, the roots are pruned, preventing weed establishment and the seedling dies. Water is able to pass through the fabric since coated fabrics remains porous. Without the coating, weed seed can germinate and roots can grow through the small pores in the fabric. Spin Out-treated geotextile fabrics can also be used to replace air pruning under styroblocks and plastic propagation trays by pruning roots as they emerge from the drain holes. Treated fabrics can also be used to cover capillary sandbeds to control roots growing from the drainage

Table 1. Influence of Spin Out-treated pots used during propagation on root length of *Evolvulus* and *Lantana,* and on the number of flowers 1 month after transplanting from propagation pots into hanging baskets.

Species	Spin Out®	Total root lenath(mm)	Length of longest root	Number Flowers	% Flower Increase
Evolvulus glomeratus	+	0.46	61	26.3	98
	-	0.55	102	13.3	
E. tenuis	+	0.31	54	13	55
	-	0.33	121	8.4	
Lantana camara	+	0.31	55	19.7	56
	-	0.33	119	12.6	
L. montevidensis	+	0.51	66	23.7	160
	-	0.6	109	9.1	
Significant (P>F)		*	**	**	

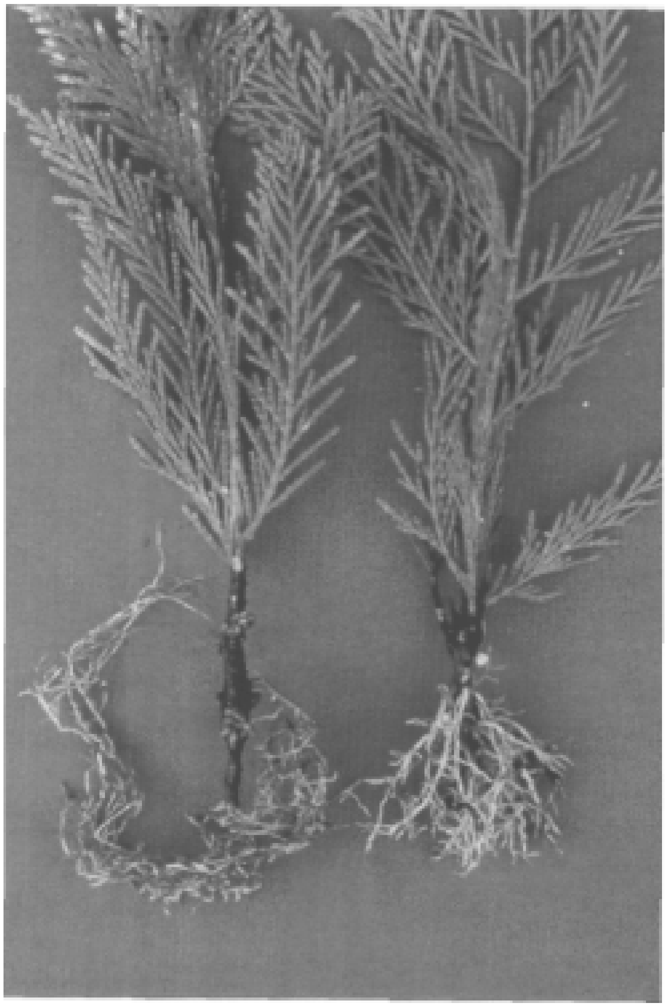

Figure 1. Cuttings of leyeland cypress (XCupressocyparis leylandii) rooted in a Spin Out-treated propagation tray.

Figure 2. Waxmyrtle (*Myrica cerifera*) grown in Spin Out-treated polybags (HDPE) for 11 months

Table 2. Morphological characteristics for *Pinus montezume* and *P. pseudostrobus* nursery produced seedlings grown in polybags with and without Spin Out® treatment.

Species	Treatment	Stem Diameter (mm)	Stem Ht. (cm)	Stem Wt. (g)	Root Wt. (g)	Root: Shoot ratio
P. montezume	Spin Out	9.97		4.36	1.83	0.39
	Untreated	8.29	-	3.49	1.53	0.41
	Significance	***	-	***	**	ns
P. pseudostrobus	Spin Out	4.75	19.41	5.31	1.21	0.22
	Untreated	3.86	17.64	4.10	0.77	0.18
	Significance	***		***	***	

Data provided by R. Phillips, CEFORA, NMSU 1997

Figure 3. Tex-R Geodiscs used for weed control in nursery containers

holes of containers, weeds, liverworts, and several types of algae. In England, the use of sandbeds was declining when herbicides used to control root egress into the sand were discontinued due to groundwater issues. The commercial introduction of two pretreated fabrics, Supercover Plus™ and Tex-R® fabric, have saved the use of sandbeds. Continued research in England has demonstrated that treated fabrics will control zoospores of *Phytophthora crytogea* and reduce the spread of disease from infected to noninfected plants on a sandbed. Capillary mats used for irrigation of greenhouse crops remain free of algae growth when treated with Spin Out. Other research in Oregon, Hawaii and Canada has demonstrated that slugs and snails are repelled by the Spin Out coating on fabrics. It may be possible to keep plants free of slugs and snails by placing containers on treated fabric or by coating the surface under containers. Griffin has teamed up with Texel, Inc. of Quebec, Canada to provide fabrics pretreated with Spin Out.

Spin Out treated fabric (Tex-R) can be used between the socket and growing pots of the pot-in-pot growing system to control rooting-out. This is a problem where roots grow out of the drain holes of the growing pot into the socket pot and then into the surrounding soil, thus preventing the plant from being hand harvested. Spin Out treated fabric provides a physical and chemical barrier to reduce these escaped roots.

Other novel products are Spin Out-treated burlap for control of root growth in beds used to hold field dug trees during summer. This was found be highly effective, but is not commercially available due to the development of treated geotextiles. In Japan, paper sheets are treated with Spin Out and placed under the soil in flats used to grow rice seedlings for transplanting. This treatment eliminates the root mat on the bottom of seed flats and decreases the time to separate the small rice plants. Over 1 million flats of rice will use Spin Out-treated paper in 1998. Spin Out is also registered for use as a tree wound and pruning paint.

Spin Out is also available in a dry formulation for incorporation into fiber pots made from recycled paper. Fiber pots have been used for nursery plant production for many years, but are limited to regions with cool climates like the Pacific Northwest and the northeast. In the southeast, fiber pots cannot be used for plant production because they decompose within 4-6 weeks and become too soft to pick up. When Spin Out is incorporated into fiber pots it extends the life of the pots for up to 2 years by slowing down the decomposition. One of the primary advantages of fiber pots in hot climates is they are porous and provide a cooler root environment compared to standard black plastic nursery pots. Plants sensitive to high root temperatures, like conifers and herbaceous perennials, are more easily grown in fiber pots. Spin Out also prevents root growth into the fiber making it easy to remove the pot for transplanting. Henry Molded Products in Lebanon, Pennsylvania is marketing these containers.

Spin Out is being developed to control undesirable root growth on root control barriers used in the landscape around pavement, foundations, curbing and retaining walls (hardscape). Undesirable root growth is a major problem and expense in the urban environment where arborists try to maintain a healthy urban forest. Rigid plastic barriers are currently used to divert roots under sidewalks and other hardscape to prevent root related damage as the trees grow, but are often ineffective or the effect is short term. Spin Out applied to these rigid barriers modifies the root system along the barrier and prevents large roots from deflecting along the barrier, growing down and then under the base of the barrier. By modifying the root system along the barrier, the life of the barrier is extended and the root system is more effectively redirected under the hardscape. Spin Out treated fabric is also being evaluated as a porous root diversion barrier that will not restrict the movement of water in the landscape.

All of the products discussed so far are for professional growers. Griffin has developed an aerosol formulation of Spin Out for the home gardener. This product is EPA registered and expected to be marketed in the United States in 1999. At this time it is only sold in Japan.

In summary, Spin Out was developed as a ready-to-use copper coating to help nursery growers control root growth in containers, but has been found to provide many other benefits depending on the substrate it is applied to and the problem the grower wants to solve. Providing pretreated pots, propagation trays, fabric and paper has made Spin Out very versatile and easy for the grower to use.

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The Internet: What's Out there For You?[1]

Cassie Rice[2] and Virginia Bruce[3]

ABOUT THE INTERNET

A Network of Networks

Nearly 200 million people using computers worldwide are linked together through the internet, primarily via telephone lines. Each individual user is linked into a small network which in turn is linked to a larger network, and so on until you get to the "backbones" which are actual physical cables which connect major points, or nodes. Each computer on the network has an address, called an IP (Internet Protocol) address.

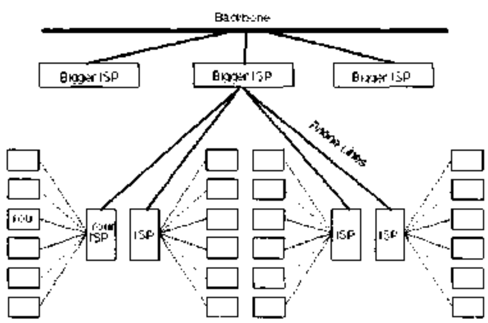


Figure 1. Schematic internet network.

The Internet is based on client/host computing. The host, or server, serves up files at the request of the client computer. The client receives a copy of the information that's on the host computer. All this interchange of information works because of a set of rules-protocol s-that allow the computers to "talk" to each other.

HISTORY OF THE INTERNET

The Internet was conceived during the Cold War to be a "survivable" command and control system – a decentralized system that would work even if part of the system was destroyed. This is accomplished by breaking information up into little pieces, called packets. Each packet carries the address of its destination, but may go by a different route to get there. If it encounters a broken circuit, or a malfunctioning router, it simply takes a different path. The packets are assembled at the other end to form a copy of the original information.

At first, the internet was used only by the military, but soon was extended to research facilities doing military work - universities - where it found great favor among researchers for its ability to serve up research papers to anyone who needed access to them. Through the 70s and 80s the internet grew slowly but steadily as government agencies, the military, and educational institutions connected. During this period of growth Internet protocols, tools, and content were steadily improving and evolving.

In 1986, the National Science Foundation assumed oversight of the Internet infrastructure to better link research organizations and educational institutions. NSF contracted with a consortium of Michigan Universities to manage and significantly upgrade the backbone infrastructure. This move opened the Internet up to wider use. At the same time, NSF provided grants to

[1]Rice, C; Bruce, V. 1997. The Internet: What's Out there For You? In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 125-131.

[2]Information Resources, USDA Forest Service, PO Box 3623, Portland, OR 97208-3623; Tel: 503/326-5132.

[3]Teamweb, 12110 NW West Road, Portland, OR 97229; Tel: 503/629-5799; e-mail: (vrb@teamweb.com).

universities to work with regional providers in developing local portions of the infrastructure. The regional providers became the first commercial Internet Service Providers (ISPs).

At the end of April 1995, ownership of the backbone infrastructure was turned over to a consortium of telecommunications companies, including ANS, Sprint, AT&T, and others. In most other countries, the "backbone" is owned by the government.

THE WEB

In 1992, Tim Berners-Lee, an Englishman working at the Particle Physics Lab in Switzerland (CERN), developed the World Wide Web as an information management tool for local documents. It allowed anyone on a network to "publish" a document that could be viewed by anyone else on the network with the right software, regardless of computer type. It was based on Hypertext Markup Language (HTML) which uses plain text, called ascii text, which is standard on all computers, to "mark up" a document, indicating formatting and other characteristics.

A team at NCSA (National Center for Supercomputing) at the University of Illinois in Champaign, led by undergraduate Marc Andreessen, created the NCSA Mosaic browser. With a friendly, point-and-click method for navigating the Internet and free distribution, this client (browser) could use the resources of the user's machine to display graphic files downloaded from a web server. The addition of graphics really spurred the explosive growth of the web. NCSA Mosaic gained an estimated 2 million users worldwide in just over one year. Andreesen went on to cofound Netscape in 1994. Some people use the words "internet" and "web" interchangeably. Actually, the web is a subset of the internet, it's basically a set of files on the internet that can be viewed with a web browser.

CURRENT SITUATION

The number of host computers connected to the Internet has grown from 100,000 in 1989 to about 10 million today. It is projected that by the year 2001, one billion computers will be connected. It may be that everyone will have some type of access to WWW services. Companies are working hard to create cheaper and easier-to-use computers, and many people are bringing computers into their homes and workplaces primarily to access the net. Some say that the web and internet systems will replace the computer operating systems (such as Macintosh or Microsoft Windows) that we know today.

WHAT'S OUT THERE FOR YOU?

For those involved in the Forest Nursery industry, there's a lot of useful information on the web, and more to come. But with well over twelve million websites on the internet, how can you sort out what's useful? First, we'll decode web addresses for you.

URLs

A URL (Uniform Resource Locator) is the address of a file (sometimes a page) on the web. It is made up of several parts. The first part is standard for all websites – http:// — http stands for HyperText Transfer Protocol, and the colon and slashes are UNIX conventions. (UNIX is a computer operating system that is the basis of web serving.) This simply tells the receiving computer what type of file its dealing with, and how to handle it.

The next part of the address takes you to the domain, which could be thought of as a building address. It usually, but not necessarily, begins with www. This is followed by the domain name, such as usfs for the Forest Service. The final part of an American domain will be one of several three-letter abbreviations standing for the type of site (Table 1). URLs for websites in other countries often end in a two-letter abbreviation such as .ca (Canada), .jp (Japan), .uk (United Kingdom). Some sites can be reached by simply typing in the

Table 1. Site abbreviations

.com	= commercial site
.org	= an organization
.edu	= educational, usually a college or university
.net	= backbone internet provider
.gov	= governmental agency

domain name. To get to a specific page within a site, however, a longer URL may be needed. These are actually "path names" which take you through layers of directories to the file. For example: http://www.domain.com/toplevel/nextlevel/bottom/file.html.

FINDING WHAT YOU WANT

There are several ways to find what you're looking for on the web. Indexes, search engines, and reference sites are some types. The type of searching tool you use depends on what you want to find, and also what seems most comfortable to you.

Indexes

Yahoo (www.yahoo.com) is the best-known internet index, although there are others. An index uses hierarchical organization to refer searchers to sites. An example of the hierarchy of a search on Yahoo is: http://www.yahoo.com/Business_and_Economy/Companies/Home_and_Garden/Lawn_and_Garden/Nurseries/Trees/. This yields up a long list of websites for tree nurseries. You tunnel down through the levels until you (hopefully) find what you need. (Figure 2).

An index search is great if you are reasonably certain there is a whole site devoted to what you're interested in. But an index has to list the site for it to show up there. If the site hasn't caught the attention of the index, it won't be there.

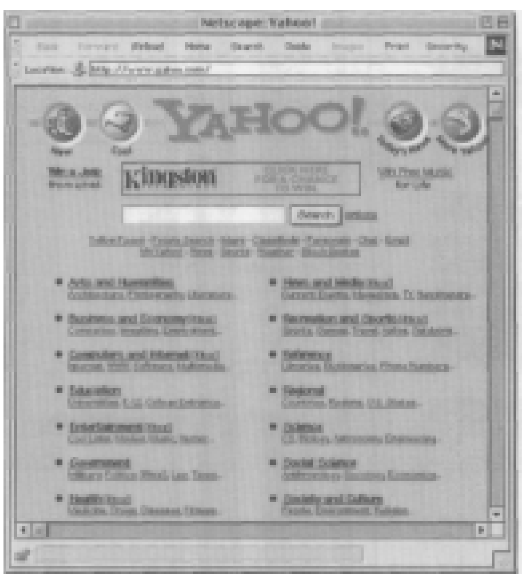


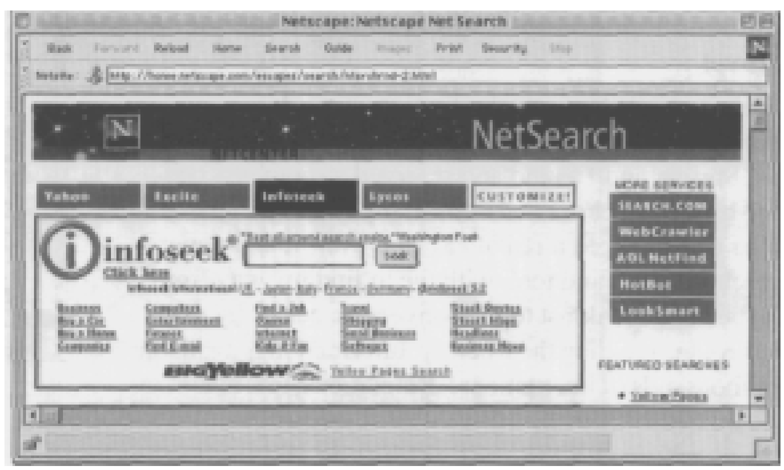
Figure 2. An internet index

Search Engines

A search engine uses any of a variety of technologies to crawl around the web and find and catalog sites. It usually searches all the text on the page, although different search engines use different methods. That way, if a topic is only mentioned as part of a larger site, it will show up on a search engine. Excite, Infoseek, and AltaVista are some of the more popular search engines. Most browsers include a search button which takes you to a page linking to a variety of search engines. If you're looking for something rather obscure, a plant disease, for example, a search engine will often turn up better results.

Many search engines allow "Boolean searches." This allows you to narrow your search, and can make all the difference between frustration and success. For example, if you're looking up oak root rot, if you just type that into a search engine, it will begin by finding all the references to oak, and then to root, and then to rot. Not what you had in mind. However, in a Boolean search, you'd type "oak root rot" inside quote marks, and that tells the engine to find only sites with all three words together. The plus sign and minus sign are useful, too. If you wanted to find references to the climate fluctuations in southeastern Idaho, you'd type in climate +fluctuation + "southeastern Idaho." That way, even if the phrase didn't appear as a whole, the engine would return results with all three phrases. You exclude items from the search with the minus; owls -horned would turn up references to owls other than horned owls. To learn more about this kind of searching, and what works on your favorite engine, read their tutorials (Figure 3).

Figure 3. A web search engine



Reference Sites

Many people and organizations include a list of links, favorite places, etc. on their sites to help you find more information on the topic you're interested in. The Seedlings, Nurseries, and Tree Improvement (SNTI) site (http://willow.ncfes.umn.edu/snti/snti.htm) is a good example. Some of these also solicit relevant links, and offer to list your site if it relates to their topic. Getting around the web by clicking on these links is what is usually referred to as "surfing the web." You may start out with an interest in bats and end up finding out about football in Peru!

Educational Sites

Almost all colleges, universities and research institutions now have websites, many packed with information. Research papers, descriptions of current research projects, plus links are usually found there.

Governmental Sites

Many governmental agencies are finally catching up in the world of information and beginning to actually offer information and in some cases to allow you to transact business with them via their website. In some cities, for example, you can begin an application for a building permit by filling out a form on a website. Some agencies also offer useful information. In Portland, for example, Metro offers hazardous waste disposal information on its website, among other things.

Doing Things On the Web

Websites are increasingly offering more than information. Because of the interactive nature of the web, you can actually do things, such as filling out applications, purchasing, and other transactions.

Travel

There's a wealth of travel information available on the web (Figure 4). 1 went to Los Angeles for a conference last Spring, and I found and reserved a room at a bed-and-breakfast, chose and booked my flight, compared rates and reserved a rental car, and even found a map which I printed and took with me to find my way from the bed and breakfast to the convention center by the best route, avoiding the freeway. Information is available for thousands of international destinations, too.

Banking

Many banks are offering online service these days. My bank has a website which lets me see my balance updated daily and transfer funds from one account to another, by using a password to access my account.

Purchasing

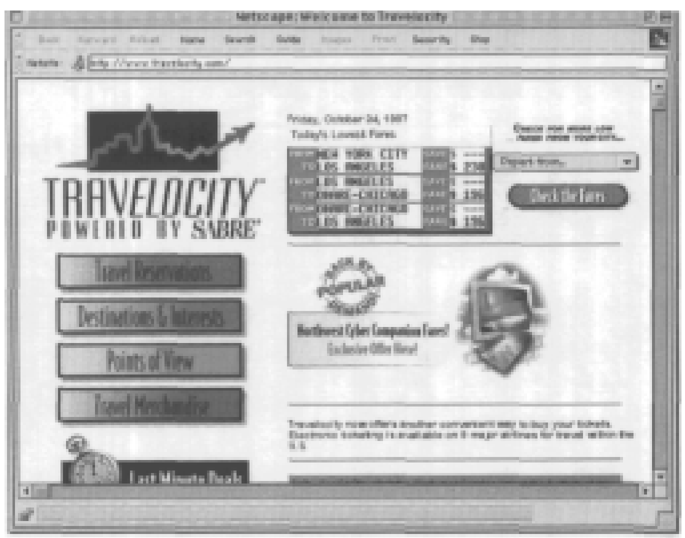
Buying things on the web is a lot like catalog shopping, but faster, easier, and it can be done anytime. And best of all, you don't have to have the catalog. Sometimes you can go straight to the manufacturer. I bought some maple syrup from a small farm in New Hampshire last year. You've probably all heard of the bookstore, Amazon (www.amazon.com) with its two million titles. You can search for a book by subject, author, title, or keywords, and then find a picture of the book, a description, and a usually well-discounted price. I know, it's not as sociable as the corner bookstore, but it's fast, efficient, and their customer service is good.

There are even online stockbrokers, that let you trade stocks after setting up an account. You can research a company, track its stock for a while, and then buy and sell it all online.

Learning

Some organizations including accredited schools are

Figure 4. Travel information available on the web.



offering "distance learning" via website. The instructor puts up pages with course material and reading lists, and then receives homework assignments and tests from students via email.

Directory Services

Looking for a long-lost friend? Want to see if you have cousins in Milwaukee? There are a number of White and Yellow Page directories on the net for finding people and businesses. It's also interesting to see if you're listed, you may be surprised. And if you're not, you can register yourself so your long lost friend can find you.

The Rest of the Internet - Email, Newsgroups, FTP, Archie

There's a lot more to the internet than the web. Most browsers today will let you access all these different types of files. Email, of course, is used to send messages back and forth, and can also be used to transmit formatted documents, such as word processed files, as attachments. FTP (file transfer protocol) is used to transfer files as well, and is used extensively to download software over the net.

Newsgroups are bulletin-board type discussion groups on a particular topic, such as rec.sports.soccer. If you want to find a newsgroup on a topic you're interested in, a good place to start is Deja News (www.dejanews.com), which is an index of past discussions. Search for your topic and you'll probably find it being talked about in one or more groups. It's advisable to "lurk" or hang around and read postings for a few days or weeks to become familiar with the real subject of the group before you post — people who post off-topic often get "flamed," or chewed out in no uncertain terms! And most newsgroups have FAQs (Frequently Asked Questions) which you should read before posting. But once you've got the hang of them, they can be a great way to get information right from the source, or just to hook up with people sharing your interest. You can also start a newsgroup if you think there's a need.

Jargon

Just like any new field, the internet has spawned a whole language of jargon. For an online source of information about all those terms, visit the C|Net Site, which has a wealth of other computer and internet information as well. The glossary is located at http://www.cnet.com/Resources/Info/Glossary/

GETTING CONNECTED

There are three things you need to get on the net (aside from a computer, that is). You need an Internet Service Provider (ISP), a modem, and the right software.

ISPs

Internet Service Providers come in all sizes, from the one my dad uses which is actually a beef jerky factory (really) but the guy got interested in the net, to Sprint and AT&T, have just jumped into the pond recently, but boy did they make a splash.

Finding An ISP

If you know others who are already online in your area, ask them who they like. Otherwise, the phone book lists them under Internet. There are lists online, but if you're not online already, they won't do you much good. Your local computer store may also be a good source of information.

Costs

In general, it costs from $10-$20 per month to get internet access, and usually storage space for your own website as well.

What to Look For

If you have a choice of ISPs, you'll want to ask about customer service (this is the person on the other end of the phone who can help you set things up and tell you why you're not getting connected.) The more the better. Many ISPs provide connection software for most computer platforms. You might want to ask about user-to-modem ratio. This means will you get a busy signal when you dial in. Books can be written about what makes a good ISP, but in rural areas you may have few choices. Good luck.

If you travel a lot, you might want to choose a large ISP that has local numbers in many cities. This will let you carry your laptop and access your email wherever you are. They tend to be a bit more expensive, though. Again, they're usually not available in rural areas. Many of these services advertise in computer magazines.

Modems

A modem (modulator-demodulator) allows your computer to hook up to your ISP via phone lines. You have to get one unless you have a direct connection to the internet through a local network. They're available from computer stores, and also from discount computer catalogs.

Speed

The fastest speed available today is 56K, but there are two different standards and it isn't really recommended yet unless you're sure your ISP will support it. 28.8 or 33.6 are quite acceptable.

Other Things You Can Do With A Modem

If you hook a modem up to your computer, you can also use it to send and receive faxes with the right software. This software is usually bundled with the modem. A modem also will let you access online banking services, get onto bulletin boards, and use telnet, which lets you directly control another computer.

Internet Connection Software

You need two kinds of software to get onto the web. One, TCP/IP (Transmission Control Protocol/Internet Protocol) lets your computer talk to the rest of the network. The other type is the browser that lets you see files on your computer.

The TCP/IP software you need is now included with many operating systems. If you don't already have it you can probably get it from your ISP for free.

The two major browsers are Netscape's Communicator (used to be Navigator) and Microsoft's Internet Explorer. They have both recently been released in version 4.0 (although many people are reporting trouble with IE 4.0). The early versions of browsers just showed graphics and text, lined up along the left margin of the page. Later releases included text wrapped around the pictures, animation, and now there's a veritable multimedia cornucopia of stuff out there. If you have an old slow computer without much RAM (memory) you might want to get an early version of Netscape, say 2.0. (IE wasn't really much of anything before 3.0.) But if you want to experience Java (a whole other subject) and some of the other interactive widgets on the web, you'll need at least the 3.0 version of either.

PUBLISHING

Putting up your own website is known as publishing on the Internet. People publish all kinds of content, from corporate information to pictures of their cat. Tim Berners-Lee, the "father" of the web, envisioned that nearly everyone would have a website one day, and designed html to be easy to learn and use. If you think you have some information that others would be interested in, you might consider becoming an internet publisher.

What to publish

The variety of material available on the net mirrors the variety of humanity - it's vast. Some of the types of information you might want to provide include research papers, product information, newsletters, forums for visitor input, a way for people to contact you, and images of course, including charts, photographs, diagrams and illustrations.

The interactivity of the web, its two-way nature, makes it possible to do a lot more than just post information. You can display your products, but also enable people to buy the product right on the website, by entering their credit card information. You can create a forum, where one visitor can post a question, and other visitors (and/or your own resident expert) can respond. You can put up surveys and then publish the results. One of the best ways to get a sense of what might work for you is to do some surfing, visiting a variety of sites with similar content to see what they have done.

How to publish

There are a sea of books available now with titles such as "Teach Yourself HTML In A Week." And the web is full of self-published sites. If you have adequate writing and graphic skills, it can certainly be a do-it-yourself project. A simple website can be made by anyone who can desktop-publish a newsletter.

You'll need a way to turn your graphics into computer files, by scanning them yourself or having it done. Then the fdes need to be converted to one of the two formats that will show up on a browser – gif or jpeg, with an image-editing program like PhotoShop. You then wrap your text and graphics in the html code that tells the browser how to display the page. There is now some acceptable semi-wysiwyg (what you see is what you get) html editing software. PageMill from Adobe is one I like, and it's not too expensive (around $100, last time I checked). Even Microsoft Word now has a free downloadable plug-in that lets you crank out html.

Then again, I don't try to grow my own trees from seed, so you might consider hiring an expert to do your website. Making good-looking graphics that don't take minutes to load is an art. Html standards are continually changing. All the multimedia and interactive features of websites veer perilously close to full-on computer programming. Java *is* a programming language. And there's a whole art/science of information design, which studies the best ways to present information.

Many newspapers run ads for people offering to do web design, and we're even listed in the yellow pages, along with the ISPs. And you don't need to stick with someone local any more, with the net making long-distance communication cheap and quick, you can even hire someone from as far away as Portland!

INTRANETS

If your organization has a computer network, you can create an intranet to share information and accomplish tasks using browsers to access a set of html files which are only available internally. Many large and small companies are finding this the ideal solution to a number of business problems, including letting people on different platforms (Mac, PC, UNIX) see and use the same files, easily keeping material up-to-date, and making corporate databases available to all those who need to access them.

Many companies use an intranet to make training available "just in time" to both new and continuing employees. When you need to know the standard operating procedure for a new task, you just go to the intranet. Personnel departments can post employee handbooks, handle requests for vacations, let employees access their own IRA and other important files. An intranet can even replace a time clock for tracking hours and also time spent on various tasks. Inventory and all the details of ordering and shipping can be deployed on an intranet. The "mission critical" tasks that businesses and institutions are putting on their intranets are growing every day.

For more information on the topics I've discussed, the web is the best place to start. Using a search engine or an index, just begin to surf around and you'll find answers to questions you didn't even know you had.

This article will be posted on my website, at http://www.teamweb.com. I'll be adding hypertext links to many of the references, so you'll be able to jump directly to them from the site. In addition, I'd be glad to help you with any projects you might have. Just email me at vrb@teamweb.com, or call 503-629-5799.

A Constructed Wetland System for Water Quality Improvement of Nursery Irrigation Wastewater[1]

J. Chris Hoag [2]

Most nurseries use agri-chemicals in their operations to obtain maximum production from their crops. Not all of these chemicals are utilized by the crops. Irrigation wastewater and natural runoff can carry nutrients and agri-chemicals to an off-site waterbody or into the groundwater. This contributes to non-point source pollution and can lead to eutrophication of streams, reservoirs, and other bodies of water. It can also contaminate the groundwater. Eutrophication often results in undesirable aquatic plant growth (Hammer, 1989). However, the nutrient-laden water can be diverted into a relatively small area where a treatment system has been established. The system resembles and functions like a natural wetland to remove nutrients, sediment, and other contaminants before the water returns to surface or ground water (see Figure 1).

A Constructed Wetland System (CWS), sometimes referred to as a nutrient and sediment control system, is both a biological and a physiochemical treatment system that utilizes wetland plants and microbes to assimilate and break down excess nutrients and remove them from the irrigation wastewater (DuPoldt et al., 1993). It is a cost effective way to treat agricultural wastewater before it is returned to surface or groundwater. Few systems of this type that treat nursery wastewater have been built, especially in the arid and semi-arid West. These ecoregions pose special problems for the operation of a year-round constructed wetland system. The first problem is that much of this area receives 10-40 cm (4-16 inches) total annual precipitation, most of which comes in the form of snow. This natural precipitation must be supplemented with irrigation water if crops are to be economically produced. The moisture required for most wetland plants to survive and spread is only available from April through October when water is turned into the irrigation system.

Another problem with the arid and semi-arid west are the temperature extremes. Many of the wetland plants that have been used in Constructed Wetland Systems for water quality improvement in the eastern and southern United States do not grow in the typical weather extremes of the drier West. So, other wetland species must be used to efficiently operate a Constructed Wetland System during the irrigation season and yet survive with almost no water through late fall, winter, and early spring.

A Constructed Wetland System is designed to mimic a natural wetland's purification process by removing a variety of nutrients, sediment, and other contaminants. The actual size of each component is based on contaminant levels (e.g. nitrogen, phosphorous, or total suspended solids) in the water, hydraulic loading rates, and water retention time. The system is not meant to replace proper nursery management, only to supplement it, especially in situations where no other cost effective alternatives are available.

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[1]*Hoag, J.C. 1997. A Constructed Wetland System for Water Quality Imrovement of Nursery Irrigation Wastewater. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 132-135.*

[2]USDA, Aberdeen PMC MCRS, Aberdeen, ID 83210.

Figure 1. The Cedar Draw Water Quality Demonstration and Research Project located in southern Idaho 5 miles Norh of Buhl, ID (near the Snake River). This constructed wetland system is only 2 years old.

A few advantages of a CWS are: only a small area is needed, low construction costs, long life, easy management, and potential economic returns from harvesting green manure. A CWS is inexpensive, usually constructed on site, and mimics the way natural wetlands treat runoff.

A Constructed Wetland System can also be used in a wide variety of situations other than nursery wastewater treatment. For example, dry cropland, irrigated cropland, irrigation wastewater recovery drains, pastures, and animal waste facilities. A properly designed system can remove a significant amount of nitrogen, soluble and insoluble phosphorus, and sediment from wastewater. It can also improve water quality by reducing the total suspended solids, total dissolved solids, turbidity, some heavy metals, bacteria, and several trace elements (Dortch, 1992).

Constructed Wetland Systems for water quality improvement of irrigation wastewater in the arid and semi-arid West are based on a System that was designed and constructed in Maine (Wengrzynek and Terrell, 1990). USDA holds a public patent on this five-component system based on the biological action of the plants and microbes (US Patent Office, 1992). Each component is specifically designed and sized to reduce or remove various contaminants from the wastewater as it makes its way through the system and eventually returns to surface or ground water. The components are also sized to take excess water that a 25-50 year flood event may produce. During flooding events, the retention time will decrease from the 4-5 day rule to as little as 1 day depending upon the storm event. The lowered retention time will not allow as thorough removal of nutrients as would be normally expected, but it will act as a filter and erosion control complex (Wengrzynek and Terrell, 1990). In Maine, it has been reported that even after storm events of 5 cm/hr that occurred on saturated ground, the system was able to remove 94% of Total Phosphorous and 95% of Total Suspended Solids (US Patent Office, 1992).

The 5 components in a Constructed Wetland System are:

1) Sediment basin - wastewater first enters the CWS at the sediment basin. The sediment basin is designed to collect organic matter, larger sediment particles and adsorbed phosphorus from the wastewater before it enters the next component. It regulates flow and acts as a buffer to protect the majority of the other components from abnormal runoff. Nothing is planted in this component. Over time submergent vegetation will establish, but will be removed with periodic cleanout.

2) Primary filter - a level area that receives sheet flow from the sediment basin. It is planted with rhizomatous grasses or wetland plants to establish a dense sod. Species include 'Garrison' Creeping Foxtail (*Alopecurus anmdinaceus*), or a combination of Baltic Rush (*Juncus balticus*), Nebraska Sedge (*Carex nebrascensis*), and Creeping Spikerush (*Eleocharis palustris*) depending upon specific landowner objectives. This component removes fine sediment, nutrients (mainly nitrates), and acts as a buffer to protect the vegetated wetland from abnormal runoff.

3) Shallow wetland - constructed to maintain shallow water and saturated soil conditions. It receives water flow from the primary filter. This component is especially important in the removal of nitrates, ammonia, and bacteria. The conditions are suitable for growth of a dense stand of emergent aquatic plants and habitat for important micro and macro organisms. This component is normally planted to Hardstem Bulrush (*Schoenoplectus acutus*) and Cattails (*Typha latifolia*).

4) Deep water pond - designed to provide a limnetic ecosystem for nutrient (mainly ortho-phosphorous) and fine sediment removal. Water from the shallow wetland flows into the deep water pond. The pond ecosystem is a living filter which provides habitat for a variety of organisms. This component is too deep for emergent vegetation. It is usually planted with Duckweed (*Lemna sp.*), Pondweeds (*Potamogeton sp.*), and other submergent plants.

5) Final filter - relatively level, stable, vegetated area between the deep water pond and the surface or ground water where the cleaned irrigation wastewater is deposited. The final filter will remove algae and nutrients that occasionally might move through the system during spring runoff or flood conditions. This component is planted to a wide variety of native wetland plant species. It can also have woody riparian plant species in it.

Maintenance of the system is necessary on an annual basis. Harvesting above-ground vegetation in the Primary Filter and occasional sediment removal from the sediment basin and deep water pond are critical parts of system maintenance (USDA Soil Conservation Service, 1993). Removal of the above ground biomass in the Primary Filter is necessary to remove assimilated nutrients. This can be accomplished by haying and feeding the harvested plant materials or by chopping the plant materials and applying it on other fields as fertilizer. Decay of unharvested above ground plant materials would release the nutrients back into the water when it reenters the system the next year (Mitsch and Gosselink, 1986). Vegetation in the Shallow Wetland should not be harvested on a regular basis. The living and dead material provide sites for microbial activity that is necessary to break down the excess nutrients in the water. Phosphorous is also removed from the wastewater by attaching itself to the suspended solids. The majority of these solids are removed in the sediment basin (Dortch, 1992). Cleanout of the sediment basin and reapplication of the sediment on fields allows long term removal and reduces fertilizer costs.

Additional benefits can be achieved from the sale of plants from the different components as the system matures. Since most of the nutrient breakdown is accomplished by microbial activity in the rhizosphere, extensive adventitious root growth provides more total area for microbial attachment sites (Brix, 1987). As the plants mature, less adventitious root growth occurs as the plants put more energy into seed production. By removing some of the plants from the colony, the remaining plants tend to put out more adventitious roots again. The plants that are removed can then be sold to help defray the original cost of construction or continued maintenance costs.

Existing systems have produced removal efficiencies of 66 to 95% for nitrogen, total phosphorous, and total

Figure 2. The Prairie habitats' "Prairie Seed Stripper can be used to collect the seeds of all the wetland plants worked with in the Constructed Wetland Systems.

suspended solids (Dortch, 1992). Extensive application of this technology would result in significant improvements in water quality, wildlife habitat, aesthetics, and quality of life. By using this system for nursery wastewater quality improvement, the entire nursery trade can demonstrate its commitment in helping to improve the nation's surface and ground water quality.

Plants necessary to populate the various components are not readily available on the market. This is especially true of performance-tested ecotypes. In order to address this need, the Interagency Riparian/Wetland Plant Development Project, USDA-NRCS Plant Materials Center, Aberdeen, ID recently released 22 performance-tested ecotypes of six different species of wetland plants:

Nebraska Sedge, *Carex nebrascensis* **(CANE2)**
Creeping Spikerush, *Eleocharis palustris* **(ELPA3)**
Baltic Rush, *Juncus balticus* **(JUBA)**
Threesquare Bulrush, *Scirpus pungens* **(SCPU3)**
Alkali Bulrush, *Scirpus maritimus* **(SCMA)**
Hardstem Bulrush, *Scirpus acutus* **(SCAC)**

Plants from each of four different ecoregions (based on Land Resource Regions as defined in Agriculture Handbook 296) located in the Plant Materials Center Service Area of Idaho, eastern Oregon, northeastern California, Nevada, and Utah were selected based on their performance in low precipitation, medium elevation areas of the Intermountain and Great Basin regions. In addition, they were selected based on seed production, spread, and vigor (Figure2). These plants were released under the new alternative plant release procedures defined by AOSCA as Selected Releases (Young, 1995). Release notices are available upon request. Seed can be obtained by collecting at the Selected Release source.

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The Role of the Nursery in Developing a Sustainable Forest Regeneration Program for the Rio Condor Project in Tierra del Fuego, Chile[1]

Richard Phillips[2], R. Moreno[3], and P. Ovalle[4]

One of the cornerstones of a sustainable forestry program is a solid regeneration plan. Bayside Ltd. took the steps to ensure that forest regeneration is a high priority by establishing the Rio Condor Forest Nursery and Regeneration Program prior to any harvesting activities. In 1995, Bayside contracted with New Mexico State University's Centro de Forestacion de las Americas (CEFORA) to develop a nursery and reforestation research, training, and production program. CEFORA, an inter-disciplinary group of forest nursery and regeneration specialists, has been actively involved with training, technology transfer, technical services, and forest nursery and regeneration research in Latin America since 1991. The six-member specialist team assigned to the Rio Condor Project included researchers, seedling production specialists, and technology transfer specialists in the areas of tree improvement, seed management, seedling production, and regeneration. Their career backgrounds include forest industry operations; university, U.S. Forest Service, and industry research programs; university and extension teaching experience; technology transfer and nursery product development; operation of private nurseries; and consulting experiences (Figure 1).

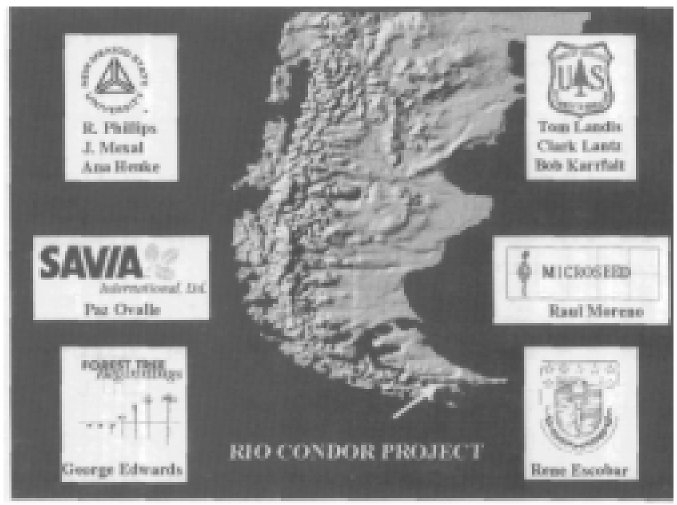

Figure 1. CEFORA's Rio Condor Project nursery and regeneration evaluation and support team.

The overall objective of the Rio Condor Forest Nursery and Regeneration Program is to successfully regenerate the company's *Mothofagus* forests on Tierra del Fuego (Figure 2). Artificial regeneration is the only viable option for the lands that have been degraded by fire, over-grazing, inundation due to beaver damage, and

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[1]*Philips, R., Moreno, R. and Ovalle, P. 1997. The Role of the Nursery in Developing a Sustainable Forest Regeneration Program for the Rio Condor Project in Tierra del Fuego, Chile. In: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 136-139.*

[2]*New Mexico State University, Agronomy and Horticulture PO Box 3Q, Gerald Thomas Hall, Room 254, Las Cruces, NM 88003-0003; Tel: 505/646-2353; Fax: 505/646-6041.*

[3]*MICROSEED, PO Box 35, Ridgefield, WA; TEL 206/887-4477; FAX: 2061887-3721; email (microseed@aol.com)*

[4]*Forestal Trillium Ltd., Avda 21 de Mayo 1688, PuntoAvenas, Chile*

Figure 2. *Nothofagus* forests on Tierra del Fuego.

other poor land use practices in the past. The nursery program will also provide seedlings to meet the silvicultural requirements for optimum stocking on "Protection Cut" harvested lands where natural regeneration is inadequate.

In addition, a research program is being developed to study the biological and economic benefits of artificial vs. natural regeneration. The potential benefits of artificial regeneration include decreased rotation time; increased volume production; and potentially improved timber quality. A successful artificial regeneration program will require careful selection of adapted genotypes; production of quality seedlings; planting appropriate stocking levels; conducting quality plantings; and controlling guanaco and livestock grazing. The company is already taking steps to produce high quality seedlings and to conduct appropriate applied research. Forestal Trillium Ltda. and CEFORA are jointly developing the Rio Condor Nursery and Regeneration Program. The following steps have already been accomplished in the program: 1) assessed current native forest nursery technology in Chile; 2) assessed current natural forest regeneration; 3) determined the extent and condition of degraded lands; 4) developed seed collection strategy; 5) developed and conducted training program; 6) selected appropriate nursery technology; 7) developed a research/production nursery facility at University of Magallanes (UMAG); 8) produced 30,000 *Nothofagus pumilio* seedlings; 9) developed crop tracking system for *N. pumilio;* 10) established regeneration field plots on Tierra del Fuego; 11) identified research priorities.

In October 1995, CEFORA specialists and company project staff visited native forest nurseries in southern Chile and Argentina to evaluate seedling quality and current nursery technology. It was clear that the level of native forest nursery development lagged far behind the Chilean industry's exotic species nurseries. The company program managers and a six-member CEFORA specialist team conducted a second, more extensive evaluation of forest regeneration on Tierra del Fuego in January 1996. Subsequently, a plan was developed for staff training, seed collection, nursery development, seedling production, and forest regeneration.

A seed management program was developed for the 1996 and 1997 *Nothofagus spp.* seed crops for the company's forest on Tierra del Fuego. The objectives of this program included the following: 1) to select seed zones; 2) to develop seed tree selection criteria; 3) to select collection method options; 4) to determine a seed collection time-table; 5) to define storage conditions; 6) to select cleaning methods; 7) to develop seed testing procedures; 8) to select seed cleaning and testing equipment; and 9) to train in-country manager and field staff. In both 1996 and 1997 the company employed UMAG students and Porvenir residents to assist with harvesting, cleaning and testing of the seed.

A seedling production and seed testing training program was developed for the nursery management staff. A two-week intensive training program was conducted at one of CEFORA's associated nurseries, MICROSEED, in Ridgefield, Washington, USA. The company nursery and regeneration program manager and the director of the horticulture center at UMAG attended this training. The training facility, an operational nursery, utilizes the

Figure 3. ITS Grower® uniformly irrigating lenga seedlings at the Rio Condor Nursery, 1996.

Figure 4. 1996 *Nothofagus pumilio* seedling crop at the company's research nursery greenhouse at the University of Magallanes.

same technology selected for the Rio Condor Nursery. The training provided the staff with practical experience in equipment calibration, seedling production, seed testing, and crop tracking systems. Both CEFORA and Forestal Trillium Ltda. conducted follow-up training in Chile for the nursery staff.

The company committed to developing a state-of-the-art nursery facility utilizing the latest nursery technology available to create optimum seedling growing conditions. A 400 m^2 greenhouse was leased from UMAG. Appropriate media, containers, automated irrigation system, fertilizer injector, rolling benches, and bio-therm vegetative propagation system were purchased and installed (Figure 3). In addition, seed cleaning equipment, a seed testing laboratory and seed storage facility were developed.

In October 1996, a pilot crop of 30,000 *Nothofagus pumilio* seedlings was grown at the company's UMAG research/production facility (Figure 4). A seedling production schedule was developed by CEFORA along with a crop tracking system to monitor the development of these seedlings. Figure 5 illustrates the mean height growth for three-seedling container volumes (336 ml, 172 ml, 80 ml styroblocks) for 20-week-old seedlings grown at the company's greenhouse at UMAG. In addition, these seedlings had excellent stem caliper (mean diameter of 4.5 mm for 20-week old seedlings grown in 336ml styroblocks), and a well-developed root system. Irrigation and fertilization response demonstrations and seedling pruning and conditioning trials were also conducted with this experimental seedling crop.

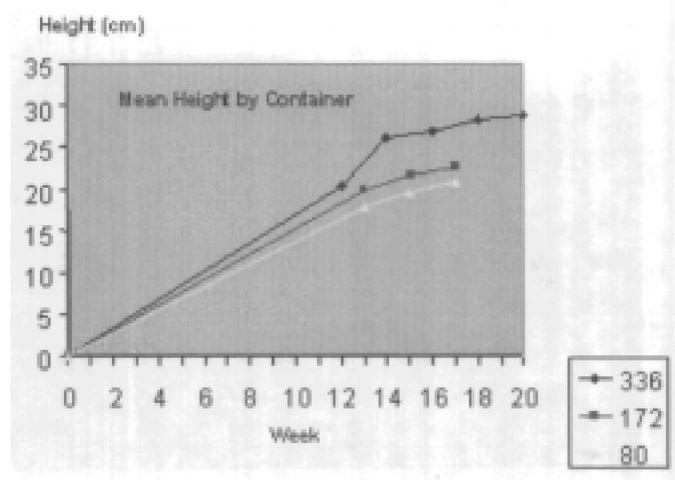

Figure 5. Nothofagus pumilio growth response to three different styroblock cavity volumes (336ml, 172 ml and 80 ml) at Rio Condor Nursery.

Nine different seedling container types were selected that represented a critical range of growing density and cavity volumes. These seedlings will be outplanted in spring 1998 to evaluate the impact of key morphological characteristics on subsequent survival and growth.

Forest regeneration activities have already been initiated. In January 1997, demonstration plantings were established within the company's experimental "Protection Cut" plot in Tierra del Fuego (fig. 6). Additional experimental areas have been selected for planting in spring 1998 on fire damaged areas. The objective of the first planting was to evaluate seedling conditioning, guanaco control, and time of planting trials. The first

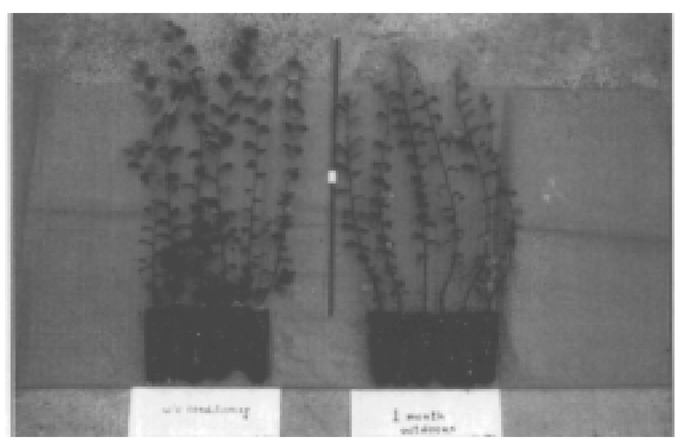

Figure 6. Five month old *Nothofagus pumilio* seedlings grown at the Rio Condor Nursery and used for the initial seedling conditioning trials on Tierra del Fuego.

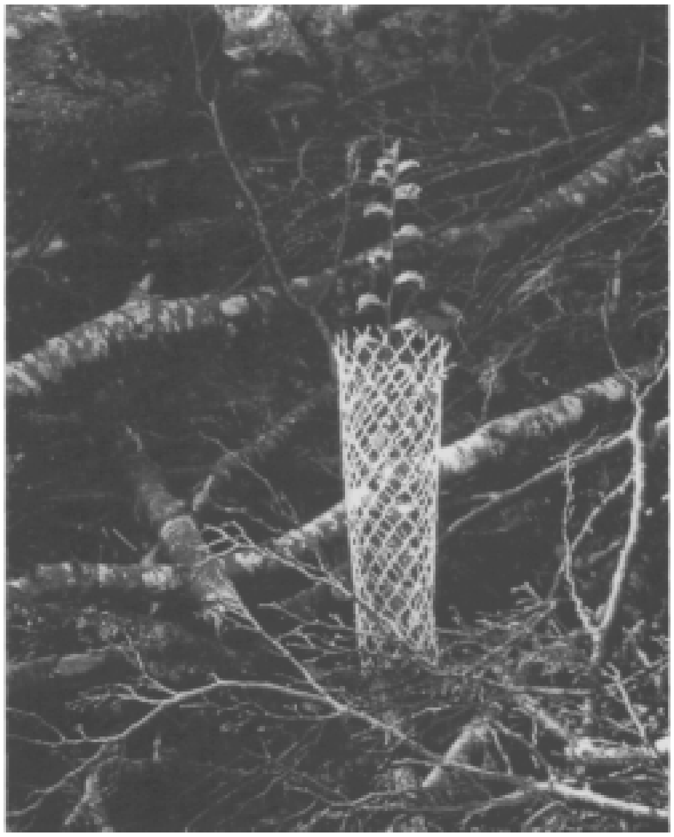

Figure 7. ***N. pumilo*** **seedling plant at the company's regeneration trials on Tierra del Fuego, 1997.**

evaluation of these plantings, conducted one month after planting, demonstrated excellent survival (99%), good vigor, and 100% guanaco browsing damage on non-protected seedlings. Follow-up evaluations for survival, growth, and development will be conducted throughout the early years of establishment of these and subsequent regeneration studies.

During the initial phases of the seed management, seedling production, and regeneration operations, the program has been continuously evaluated and applied research opportunities have been identified. Research is being conducted on seed storage, seed stratification and seed testing. In addition, direct sowing and seedling transplant trials are being conducted in the nursery to improve seed use efficiency prior to sowing a second larger, operational seedling crop in September 1997. Additional regeneration trials are planned including: site preparation; guanaco control; time of planting trial; seedling container type comparison trials; and progeny tests for a wide range of outplanting site conditions.

A successful vegetative propagation trial has been conducted and a second study is currently being designed on the basis of preliminary results. This propagation technique maybe useful in production of seedlings in the event of seed scarcity. Vegetative propagation is a technique that also could be useful in the future development of a tree improvement program.

Forestal Trillium Ltd., CEFORA, and scientists from the Instituto Forestal, are currently pursuing collaborative research opportunities on artificial regeneration and seedling production. The results of these proposed research activities will be available to regional nursery managers and regeneration specialists in order to help improve the level of native forest management.

The Rio Condor Forest Nursery and Regeneration Program has made significant progress by demonstrating the application of forest science to nursery and regeneration opportunities. The growth and quality of Rio Condor Nursery-produced seedlings have greatly exceeded the expectations of regional foresters, nursery managers and forest researchers (Figure 7). Future gains from the company's nursery and regeneration research and development program will continue to benefit all those interested in the professional forest management of the *Nothofagus* forests on Tierra del Fuego.

Business Meetings

Western Forest and Conservation Nursery Association

The business meeting was called to order by Tom Landis at noon on Thursday, August 21 at the Red Lion Riverside Motor Inn in Boise, ID. Tom explained that the WFCNA charter states that anyone who attends the business meeting is considered a member and has full voting privileges.

OLD BUSINESS

1. Minutes from 1996 meeting. Tom noted that the minutes are published on pages 255-258 in the National Proceedings: Forest and Conservation Nursery Associations-1996 (USD A Forest Service, General Technical Report PNW-GTR-389). The minutes were approved by a unanimous voice vote.

2. Budget. Tom presented the following accounting for the WFCNA budget. The base WFCNA account is managed as a money market account by the Western Forestry and Conservation Association (WFC A) in Portland, OR. All receipts are from meeting registrations and exhibitors fees. The balance of $2,687.33 from the 1996 meeting was not deposited to this account but instead was forwarded to the Lucky Peak Nursery in Boise as "seed money". The 1997 meeting netted an ending balance of $3,121.53, and so now this account has a balance of $ 11,750.25

There was no other Old Business.

NEWBUSINESS

1. Funding for Proceedings. Tom mentioned that the technical papers from this meeting would be included in a National Nursery Proceedings as has been done in previous years. In the past, the layout and printing of these Proceedings has been funded by State and Private Forestry (S&PF) of the USDA-Forest Service. Tom explained that, starting this year, the cost of publishing the Proceedings will have to be approved as a National Investment by an S&PF review team. This year's review raised some questions about why the Forest Service should fund this publication, but eventually the team agreed that the Proceedings was an excellent example of how the federal government can provide technology transfer to State and private nurseries.

   There was some discussion over the merits of the Proceedings and the group voiced their support and hoped that they could be continued.

2. Location of Future Meetings. Tom reported that results of the ballot for the location of the 1998 meeting were published in last year's Proceedings - 59% voting for British Columbia and 41 % for Hawaii. Several attendees expressed concern about the loss of the opportunity to visit Hawaii and so a discussion ensued. Tom explained that the concern of many

1997 Budget for WFCNA Account

Year	Meetinq Location/Host	Expenses	Receipts	Balance	WFCA Account
1996	Salem, OR / Mark Triebwasser WEYCO Aurora Nursery: Mark Triebwasser	$14,337.67	$17,025.00 (Registration)	$2,687.33	$8,628.72
1997	Boise, ID/Dick Thatcher USDA-FS, Lucky Peak Nursery: Dick Thatcher/Kay Beall	$11,565.80	$2,687,33 (from 1996 Meeting)	$3,121.53	$11,750,25

people at the Salem, OR meeting the previous year was that they would not be able to receive approval for the trip. Someone requested another voice vote for the WFCN A meeting in the year 2000, and Hawaii received unanimous approval.

Therefore, the next three meetings will be held as follows:

1998—A joint meeting of the WFCN A and the Forest Nursery Association of British Columbia will be held in Victoria, BC on Aug. 10-13 at the Dunsmuir Lodge.

1999—This will be a joint meeting of the WFCN A and the Northeastern Forest Nursery Conference and is being planned for Ames, IA. Our host will be the State Forest Nursery of the Iowa Department of Natural Resources and the meeting will be held in early August. Exact dates and location will be announced at next year's business meeting.

2000—The special millennium meeting of the WFCNA will be held in Hawaii where our host will be the Hawaii Division of Forestry and Wildlife. The meeting probably will be held on the Big Island where we will be able to visit the Kamuela Tree Nursery and the Hilo District Nursery. Exact dates and location will be announced at next year's business meeting.

Western Forest and Conservation Nursery Association Record of Past Meetings

(A complete summary of past meetings of the Intermountain Forest Nursery Association for 1960 to 1989 is contained in the GTR- RM-184).

Year	Dates	Location	Host Nursery	Joint/Special Meetings	Proceedings
1997	Aug. 18-21	Boise, ID	USDA Forest Service Lucky Peak Richard Thatcher, Kay Beall		USDA Forest Service GTR-PNW-419
1996	Aug. 21-23	Salem, OR	Weyerhaeuser Company Aurora Forest Nursery Mark Triebwasser		USDA Forest Service GTR-PNW-389
1995	Aug. 7-11	Kearney, NE	USDA Forest Service Bessey Nursery Clark Fleege		USDA Forest Service GTR-PNW-365
1994	Aug. 14-18	Moscow, ID	Forest Research Nursery University of Idaho Kas Dumroese, Dave Wenny	Forest Nursery Assoc. of British Columbia	USDA Forest Service GTR RM-257
1993	Aug. 2-5	St. Louis, MO	G.O. White State Nursery Licking, MO BillYoder	NE Forest Nursery Association	USDA-Forest Service GTR RM-243
1992	Sept. 14-18	Fallen Leaf Lake, CA	L.A. Moran Refor. Ctr. Davis, CA Laurie Lippitt		USDA-Forest Service GTRRM-221
1991	Aug. 12-16	Park City, UT Draper, UT	Lone Peak State Nursery Glenn Beagle, John Justin		USDA-Forest Service GTRRM-211
1990	Aug. 13-17	Roseburg, OR	D.L. Phipps State Nursery Elkton, OR Paul Morgan	Target Seedling Symposium	USDA-Forest Service GTR RM-200
1989	Aug. 14-18	Bismarck, ND	Lincoln-Oakes Nurseries Bismarck, ND Greg Morgenson		USDA-Forest Service GTRRM-184

Western Forest and Conservation Nursery Association Record of Past Meetings

Year	Dates	Location	Host Nursery		Proceedings
1988	Aug. 8-11	Vernon, BC	BC Ministry of Forests Victoria, BC Ralph Huber	Forest Nursery Assoc. of British Columbia	USDA-Forest Service GTRRM-167
1987	Aug. 10-14	Oklahoma City, OK	Forest Regeneration Center Washington, OK Al Myatt, Clark Fleege		USDA-Forest Service GTRRM-151
1986	Aug. 12-15	Olympia, WA	Webster State Forest Nursery Ken Curtis IFA-Toledo Kevin O'Hara Weyerhaeuser-Mima Jim Bryan		USDA-Forest Service GTRRM-137
1985	Aug. 13-15	Ft. Collins, CO	Colorado State FS Nursery Marvin Strachan		USDA-Forest Service GTRRM-125
1984	Aug. 14-16	Coeurd' Alene, ID	USDA-FS Coeurd' Alene Nursery Joe Myers		USDA-Forest Service GTRINT-185
1983	Aug. 8-11	Las Vegas, NV	Tule Springs State Nursery Pat Murphy, Steve Dericco		USDA-Forest Service GTRINT-168
1982	Aug. 10-12	Medford, OR	USDA-FS J.H. Stone Nursery Medford.OR Frank Morby		S. OR Community College Unnumbered Pub.
1981	Aug. 11-13	Edmonton, ALB	Alberta Tree Nursery Edmonton, ALB Ralph Huber		Canadian Forest Service N. Forest Res. Centre Info. Rep. NOR-X-241
1980	Aug. 12-14	Boise, ID	USDA-FS, Lone Peak Nursery Dick Thatcher		USDA-Forest Service GTRINT-109
1979	Aug. 13-16	Aspen, CO	USDA-FS, Mt. Sopris Nursery Carbondale,CO John Scholtes		USDA Forest Service, S&PF Unnumbered Publication
1978	Aug. 7-11	Eureka, CA	USDA-FS, Humboldt Nursery McKinleyville, CA Don Perry		USDA-Forest Service, S&PF Unnumbered Publication
1977	Aug. 9-11	Manhattan, KS	Kansas State FS Nursery Bill Loucks		USDA-Forest Service, S&PF Unnumbered Publication
1976	Aug. 10-12	Richmond, BC	BC Ministry of Forests Surrey Nursery Bayne Vance		BC Ministry of Forests of BC

Western Forest and Conservation Nursery Association Record of Past Meetings

Year	Dates	Location	Host Nursery		Proceedings
1975	Aug. 5-7	Missoula, MT	Montana State FS Nursery Willis Heron		USDA-Forest Service, S&PF Unumbered Publication
1974	Aug. 26-29	Denver, CO	Denver, CO	North American Containerized Forest Tree Seedling Symposium	Great Plains Ag. Council Publication No. 68
1974	Aug. 5-7	Portland, OR	USDA-FS, Wind River Nursery Jim Betts		Unnumbered Publication
1973	Aug. 7-9	Watertown,SD	Big Sioux State Nursery Don Townsend		Unnumbered Publication
1972	Aug. 8-10	Olympia, WA	Webster State Forest Nursery/ H. Anderson IFA-Toledo/R.Eide Weyerhaeuser-Mima/ J. Bryan		Unnumbered Publication
1971	Aug. 3-5	Edmonton, ALB	Northern Forest Research Center, D. Hillson		Unnumbered Publication
1970	Aug. 4-6	Coeurd' Alene, ID	USDA Forest Service Bud Mason		USDA Forest Service Unnumbered Publication
1969	Aug. 5-7	Bismarck, ND	Lincoln-Oakes Nurseries Lee Hinds/Jerry Liddle		Unnumbered Publication
1968	Aug. 6-8	Salt Lake City, UT	Green Canyon Tree Nursery Clyn Bishop		Unnumbered Publication
1967	Aug. 1-4	Indian Head, SAS	PFRA Tree Nursery Sandy Patterson		Unnumbered Publication
1966	Aug. 30-Sept. 1	Ft. Collins, CO	Colorado State FS Nursery John Ellis		Unnumbered Publication
1965	Sept. 14-16	Carbondale, CO	USDA FS, Mt. Sopris Nursery Sidney H. Hanks		Unnumbered Publication
1964	Aug. 19-20	Boise, ID	USDA-FS, Lucky Peak Nursery Leroy Sprague		Unnumbered Publication
1963	Sept. 11-13	Missoula, MT	Montata State FS Nursery Don Baldwin		Unnumbered Publication
1962	Sept. 13-14	Monument, CO	USDA FS, Monument Nursery Ed Palpant		Unnumbered Publication
1961	Sept. 14-15	Halsey, NE	USDA-FS, Bessey Nursery Red Meines		Unnumbered Publication
1960	Aug. 20	Watertown, SD	Big Sioux Nursery Marvin Strachan		Unnumbered Publication

Western Meeting Review

Report of the Annual General Meeting of the Western Forest and Conservation Nursery Association—Boise, Idaho August 19-21,1997

Carole Leadem[1]

This excellent meeting was organized by Dr. Tom Landis, USDA-FS, Portland, OR; and Kay Beall, Nursery Culturalist, Lucky Peak Nursery, Boise, ID. The theme of the meeting was "Propagating native plants for fire rehabilitation, forest health, and streambank revegetation". The attached agenda and technical summaries provide only a brief synopsis of the papers presented at the meeting.

There were a number of recurring themes relating to forest nurseries, technology transfer, and government and community involvement in forestry, which are summarized below. For me, the "take-home message" was the number of parallels (and differences) between what is happening in the American and the Canadian forest community today, plus the glimpses of what we might expect in the near future and beyond. (Numbers in parentheses refer to the technical summaries).

Forest Nurseries

Less US federal government support for nurseries (1,2)
Increased involvement of the private sector (1)

Propagation of native species for conservation and restoration

A wide range of trees, shrubs, forbs, and grasses are being grown and (5,7,8,12,13) used for fire rehabilitation, streambank stabilization, wildlife forage, improving water quality (3,8). Seeds of native species are often in short supply (3,12). Lack of knowledge on how to propagate native species (4,5,6,9,10,11).

Technology Co-operatives

USA: Nursery Technol. Coop., Oregon State Univ. (14,15,22) Canada: LUSTR Cooperative, Thunder Bay, Ontario (16)

Community involvement in restoration activities

Coalition of federal, state, and citizen groups in rehabilitation projects (3) Volunteers growing and planting trees for city streets and parks (20)

Environmental Protection

Tighter water quality standards for nursery effluents (21) Phasing out of methyl bromide (damage to human health and ozone layer) and other potentially hazardous substances (15,18).

I compliment both Tom Landis and Kay Beall (and all the behind-the-scenes helpers) on a very successful meeting. Everything ran seamlessly, primarily due to the attention paid to the small details. Tom attends a LOT of meetings as an extension officer for the USDA-FS, so he has some definite ideas about how meetings should be run (he's a pretty big guy, too, so usually no one argues with him). Tom's meeting tips were field-tested at Boise, and I can verify that they are 100% effective!

Meeting tip #1. Use the "Yaker-Saker" to ensure your speakers finish on time. No meeting should be without one! The Yaker Saker is constructed from a lawn watering timer and has three lights. The green light is lit for about 20 minutes, and the yellow light is on for about 10 minutes. When the red light comes up, you're done! The enforcer is the session moderator, who sits in the

[1]*B.C. Ministry of Forests, Glyn Road Research Station, PO Box 9536 Stn. Prov. Govt., Victoria, B.C. V8W9C4 CANADA; Tel: 25019524130; FAX: 250/9524119; Email: (cleadem@gems2.gov.bc.ca).*

front row equipped with a water canon.

Meeting tip #2. Have trouble getting the audience back from the breaks? Offer them door prizes such baseball caps, gift certificates, etc. When attendees register for the meeting, print their registration numbers on the back of their name tag. At the meeting, 4 to 5 winning numbers are drawn *promptly* at the end of each break. You must be present in the meeting room to win.

Meeting tip #3. Have plenty of variety. Present technical sessions in the morning, and plan stimulating field trips for the afternoon. This helps keep audience attention and interest up for the technical sessions. Good food and BBQs don't hurt either.

SUMMARIES OF TECHNICAL PRESENTATIONS

Meeting theme: "Propagating native plants for fire rehabilitation, forest health, and streambank revegetation"

Technical sessions Day One: August 19, 1997

(1) Jack Troyer, Deputy—Regional Forester, USDA-FS (Region 4, Ogden, UT)—New Demands on Forest & Conservation Nurseries in the West. Present forestry trends in the U.S. show an increased investment in small private woodlots, mostly driven by increased lumber prices. The establishment of private seedling nurseries is also increasing, but this is primarily due to reduced commitment by the USDA-FS to federal forest nurseries. Future projections by the Federal government show only one major nursery per Region (the USDA-FS currently has 8 regions in the continental US and Pacific Islands). These two trends are not acting independently; rising timber prices may once again increase the demand for seedling nurseries, but probably not in the near future.

(2) Frank Burch, National Co-ordinator, Forest Nursery Operations—Nursery trends in USDA-FS nurseries in the West. Frank briefly reviewed the history of Forest Service nurseries, then explained why the USDA-FS is closing many of them. The operation of seedling nurseries depends on National Forest timber sales, which have been steadily decreasing during the last decade. In 1987, 12 billion board ft. were sold, compared to only 3.8 billion board-ft. in 1995. Another factor is the reduction in reforestation backlog. In 1980, 180 million seedlings nation-wide were produced in FS nurseries; in 1995, this was reduced to 60 million. 1995 was also the first year that the number of seedlings from natural regeneration exceeded the number of seedlings planted.

Another important trend in FS is the shift away from an exclusive focus on fast-growing seedling stock (with heavy emphasis on growth and yield) to prescriptions based on long-term suitability of planted seedlings, e.g., adaptability to climate change, greater disease resistance, etc. The responsibility for making such prescriptions depends upon the judgement of certified silviculturists.

(3) **John Thorton, Boise National Firefighters—Boise NF Fire Rehabilitation.** Fire is a major problem in the dry interior climate of Boise. Major fires in the grasscovered mountains surrounding Boise in the late 50's and in 1995 were followed by sudden, heavy rainfall. This resulted in major mud and debris slides into the center of Boise. In an effort to prevent such reoccurrences, a major coalition of government agencies and citizen groups organized to rehabilitate the grasslands and institute other measures to prevent erosion. The afternoon field trip visited an area of rehabilitation and erosion control efforts.

In the Boise area, fire rehabilitation depends primarily on the re-establishment of grasses and forbs. A major constraint is the availability of seeds of native species. Seeds are either in short supply, or not available at all. In such cases, non-native seed mixes must be used until supplies of native species are obtainable. Other researchers in restoration biology are attempting to meet this demand.

(4) Carole Leadem, B.C. Ministry of Forests, Victoria, BC—Overview of seed dormancy and treatments. It is difficult, if not impossible, to know *a priori* what type of treatment is needed to break seed dormancy. However, the reason(s) that seeds are dormant may offer clues regarding the treatment required to release seeds from the dormant state. Dormancy may be due to: unfavourable climatic conditions, immaturity, a light requirement, genetic variation, or protection against predation. Depending upon the type of dormancy, stratification, light, leaching, scarification, growth regulators, or high O_2 concentrations may be used to promote germination. Treatments such as stratification may have to be modified to meet the particular physiological requirements of different species. Five different types of stratification are presently used to release dormancy of forest trees. An evaluation of the habitat in which a particular species is found also may point to the most effective dormancy treatment if the requirements for a particular species are unknown.

(5) **Bob Karrfalt, National Tree Seed Laboratory, Macon, GA—Considerations for processing native plants.** Little is known about reproductive cycles of native plants. Extraction and storage protocols are also largely unknown. (With some plant material, it sometimes difficult to determine which parts are the seeds.) It is often necessary to rely on knowledge gained from other species that possess similar seed characteristics. Fortunately, many extraction and processing techniques used for agricultural seeds can be applied to the seeds of native plants.

The National Tree Seed Laboratory has a continuing Quality Assurance Program, which is subject to third-party review. One issue currently under consideration is how to name local varieties of native species, since protocols have not been established (e.g., should it be Ada County bitterbrush or Ada County germplasm of bitterbrush?)

(6)Victor Vankus, National Tree Seed Laboratory, Macon, GA—Tetrazolium (TZ) testing of native plant seeds. Victor explained the use of the TZ test, an useful assay technique when used in combination with germination tests. It may also been employed when species germination requirements are unknown.

Technical Sessions Day Two: August 20, 1997

(7) David Steinfeld, J.H. Stone Nursery—Oregon Propagating diverse species at Forest Service nurseries. Forest nurseries don't look the same as they used to. Today you are as likely to see fields of grasses and shrubs as you are to see rows of conifer seedlings. In 1997, 24 species of grasses were sown from 24,000 lbs. of seeds. Blue wildrye *(Elymus glaucas),* Idaho and California fescue *(Festuca spp.)* are among the variety of species sown. 45 acres were in production in 1997, and 58 acres are planned for 1998. Hydroseeding or hand seeding are used to sow seeds into bareroot beds or containers. Seeds are covered with netting after sowing.

A number of shrubs are grown for restoration and wildlife forage, such as bitterbrush, Oregon grape, *Ribes* spp. (gooseberry, currant, etc.), and manzanita. Forbs include penstemon, aster and *Brendilla.* Deciduous trees such as willows and poplars are grown for riparian areas. Some sites have special stock requirements, e.g., pines grown for the Dunes Recreation Area, Oregon, must be grown in large containers for the plants to establish successfully. Considering the large number of species about which little is known, propagation of native plants in the nursery can be a real challenge!

(8) Scott Lambert, USDA-National Resource Conservation Service, Pullman, WA—Native Plants in the Pacific Northwest. The National Resource Conservation Service consists of 26 plant materials centers across the U.S. which produce plants for riparian zones in public lands and national parks. In the past, introduced species were used for rangelands, many of which came from Europe, Central Asia, and Russia. Today at Pullman, they are growing native wheat grasses, bluegrass, needle-and-thread grass, fescue, junegrass, and wild rye. Such large quantities of grass seeds are grown that agricultural harvesting equipment such as combines are required.

A variety of shrubs and trees are grown for forage, cover, ornamental use, streambanks: chokecherry, mock orange, w. serviceberry, vine maple, oceanspray, w. hazelnut (for disease resistant rootstock), red osier dogwood, blue elderberry, snowberry, and Sitka alder (soil erosion control). They grow a variety of forbs such as balsamroot, pine lupine, elkshorn, as well as mosses, ferns, and fungi. The propagation of some native species can be very difficult. Manzanita seeds, for example, are very dormant, and even cuttings are hard to grow.

(9) Kas Dumroese, University of Idaho, Forest Research Nursery, Moscow, ID—Propagation of woody riparian plants for streamside restoration projects. Plants are propagated from root cuttings (trembling aspen), softwood cuttings, and hardwood cuttings. Propagation from seeds is problematic because seed supplies are often unavailable, seed quality is poor, proper seed treatments are unknown, and seed responses are quite variable.

Culturally, seedlings are usually grown in 10 to 20 cu.in. containers in a 1:1 peat: vermiculite mix. Nitrogen fertilization varies from 22 to 100 ppm. Shrubs generally must be top pruned. Stock of most species is sown in larger container sizes because seedlings with larger calliper have much better survival in the field.

(10) Dave Dreesen, Los Lunas PMC—Propagation of native plants for restoration projects in the Southwest. A variety of dormancy-release treatments are required for breaking the seed dormancy of southwestern species. Tumbler scarification (60 rpm with carborundum for 1 to 30 days) and metal brushes are often used for mechanical scarification of seedcoats. Steeping seeds in hot water (90 °C) for 4 hours is also effective for seedcoat dormancy.

Plant growth regulators have been used for some species. A soak in 1% bleach solution followed by gibberellin (250 mg/1 GA) treatment can stimulate the germination of *Rubus* (salmonberry, blackberry, etc.) seeds. Germination of *Alnus is* enhanced by treatment by 60-125 mg/1 GA3, followed by stratification at 2-5°C.

(11) Scott Zeidler, Lone Peak Conservation Center, Draper, UT—Propagation of wetland plants in the Intermountain Area. A number of wetland plants have been successfully propagated from seeds e.g., sedges *(Carex* spp.), rushes *(Juncus* spp.), and bulrush *(Scirpus).* Propagation is very labour intensive so they are glad of the access to inmate labour. Propagation techniques used for wetland species can differ substantially from familiar tree nursery practice. *Juncus* seeds become very gelatinous in water and must be planted by pipette. Germination regimes are 110°F, with light and high humidity. The seeds do not require mulching as long as humidity is high. To control the growth of weeds, paper matting soaked in copper hydroxide solution is placed under containers on greenhouse benches.

Carex seeds are soaked in 33% bleach solution to reduce the microbial growth on seeds. The seeds are imbibed at 20 to 25°C for 24 h, and then stratified. The seeds are so buoyant they must be kept submerged by covering the seeds with a disk. Hydrogen peroxide treatment is sometimes substituted for stratification (1 day H_20_2 can substitute for 1 wk stratification at 2-5°C).

(12) Tom Jones, USDA-ARS, Logan, UT—The expanding potential for native grass seed production in W. North America. Native grasses can be separated into two general groups: C_3 cold season grasses and C_4 warm season grasses (biochemically, C_3 and C_4 refers to the first products of photosynthesis being a 3-carbon or 4-carbon compound, respectively). For breeding purposes, it is important to understand the physiological adaptations of the two types. The C_3 cold season grasses require vernalization (cold conditions) and long-day conditions to flower; C_4 warm season grasses requires short days for flowering.

Tom is studying the natural distribution of the two types, and what occurs when grasses are moved either north or south. In general:

C_3 grasses	moved N flower earlier	moved S flower later
C_4 grasses	moved N flower later	moved S flower earlier

He is also studying other environmental effects such as soil texture, snow accumulation, and rainfall, and has found that the timing of precipitation is more important than the amount of precipitation. There is now enough data to separate the natural occurrence of C_3 and C_4 grasses into seed zones; the maximum movement of seed sources is 300 mi. north or 200 mi. south. Seed sources moved beyond these ranges are likely to suffer from winter kill and reproductive failure.

(13) Betsy Carroll, USDA-FS, Nat. For. Genet. Electrophoresis Lab., Placerville, CA—Application of genetic analyses to native plant propagation. Betsy outlined the techniques that are being used to characterize the genetic makeup of native plant species. These include isozyme analysis, RFLP (Restriction Fragment Length Polymorphic DNA), RAPD (Random Amplified Polymorphic DNA), and PCR (Polymerase Chain Reaction). The techniques are used in support of both tree improvement activities and conservation studies. Some of the practical applications of these methods are: in species that form mats, to distinguish one individual from another; to determine whether closely related species should be considered a distinct species; to assess the degree of diversity existing in natural communities; and to re-identify various clones in a southern pine seed orchard that was heavily damaged by a hurricane.

(14) Ben Lowman, USDA-FS, MTDC, Missoula, MT— Nursery equipment project at the Missoula Technology and Development Center. An impressive array of nursery equipment is being developed at the center. Just a partial list of the projects are: ultrasonic detection of seedling heights in nursery beds; using machine vision to automatically measure morphological characteristics of seedlings (at the rate of 10 seedlings/ minute); improved devices for pollen collection and wet or dry pollen application; use of a reciprocating beater for cone collection; development of a granular applicator for herbicides; improved mesh for protecting planted seedlings; a safer Hawk Power Scalper (modified chainsaw attachment mfg. in Canada); new methods for girdling trees; use of garlic and other substances as game repellents.

(15) Dick Karrsky, USDA-FS, MTDC, Missoula, MT— Steam pasteurization of soil. Under the Clean Air Act, the US must halt production and importation of methyl bromide by the year 2001. This has prompted the development of alternate methods such as steam pasteurization for the fumigation of nursery soils. Pasteurization of soil with steam is not a new technique. It was first used in Germany and the U.S. around 1890, but was discontinued when nurseries started using methyl bromide in the 1950s. The unit currently being tested in nurseries (the Steam Plow) uses a portable diesel boiler which can generate one million BTU per hour; an undercutter blade helps to inject the steam into the soil. Some difficulties are the slow travel speed, and uneven temperature distribution. They are trying to rectify this by dragging a tarp behind the tractor to retain the heat longer in the soil. Another approach being tested at the University of California, Davis is soil fumigation with microwaves.

Technical Sessions Day Three: August 21, 1997

(16) Irwin Smith, LUSTR Co-op, Inc., Thunder Bay, ON—The nursery situation in Canada and the LUSTR Nursery Cooperative. The mission of the LUSTR Co-op, Inc. is to determine and execute research priorities and provide technical guidance, scientific liaison and support services for those involved in container seedling production and plantation establishment. This research and extension cooperative was originally funded by the Ontario government in late 1980's to provide technical services to Ontario seedling growers. By 1992, funding was no longer available, and with government downsizing, seedling research and technology was eliminated. The closure of the Angus seed plant closed left eastern Canada with no seed processing and storage facilities. To fill these continuing needs, the LUSTR Co-op Inc. was founded in 1993 as a registered, non-profit, self-funded organization to provide research and extension services to its members. LUSTR Co-op is Canada-wide and has 19 members, consisting of seedling growers, timber companies, tree planting contractors, and allied supply companies.

The co-op acts as a distribution center for information. A bi-monthly newsletter summarizes research results, co-op business, conference proceedings and upcoming meetings. A January conference and summer workshop are held annually. They have also published a greenhouse safety manual, and have given workshops on growing media, seeds, and other topics. [See recent article published in USDA-FS Forest Nursery Notes, July 1997.]

(17) Steve Grossnickle, BC Research, Vancouver, BC—Application of stock quality testing within an operational forest regeneration program. Steve described how BC Research applied stock quality testing in an actual operational field season. At the beginning of the planting season, seedlings underwent a series of intensive morphological and physiological tests to determine "fitness for purpose" for a variety of outplanting sites in B.C. Based on the results from "command central" seedlings were shipped to the most suitable sites for planting. The size of the workload and immediacy of the operation was a scheduling and transportation challenge. However, it was satisfying to demonstrate that that stock quality testing could work in an operational forestry regeneration program. Lessons from conducting a stock quality program: more automation and training are needed.

(18) Mark Crawford, Griffin Corp., Valdosta, GA—Update on chemical root pruning SpinOut is an improved user-applied copper (Cu) compound which was registered in 1993 for chemical root pruning. It has been successfully used for oak, coffee, flowering plants (e.g., *Lantana, Evolvulus*), *Acer, Pistacia,* and strawberry. When sprayed on pots its 'Teflon effect" allows for clean, easy removal of bedding plants such as *Impatiens* from containers. Cu-imprinted paper is used in Japan to line the bottoms of trays for root pruning of greenhouse stock. Nonwoven fabric impregnated with Cu and covering the soil effectively controls weeds in containers, and doesn't leach out.

Other applications are for lining large containers sunk into the ground, which prevents root egress into the soil. The fabric is used on sandbeds in England and Oregon; it prevents tree growth into culverts or houses, and acts as weed barrier around street trees. Cu controls algal and fungal growth, and is avoided by slugs. The control of microbial growth provided by SpinOut preserves paper pots up to a year. Different formulations are available—user applied, spray, or fibre pots.

(19) Virginia Bruce, Team Web, Portland OR—The Internet and World Wide Web-basics and nursery applications. Using a computer with a projection screen, Virginia demonstrated how to access the Internet with a browser and how to use a Search Engine (Yahoo) to explore the Word Wide Web (WWW). The internet is a network of networked computers. The backbone of the WWW is maintained by a consortium of telecommunications corporations. When someone requests a web page, the information is broken up into addressed packets which find a path along the network, and get back to the client.

A modem and an account with an internet service provider (ISP) are needed to get online. Web pages are accessed by entering the Web page address. Web page files are in HTTP (Hyper Text Transfer Protocol), and usually have the form:

http://host name/Unix path/filename, htm

The USFS Seedling, Nursery, and Tree Improvement program has a website with a variety of useful information. To access, enter the path name:
HTTP://willow. ncfes. umn. edu/snti/snti. htm

(20) Jerry Stallsmith, Boise City Forester, Boise, ID—Boise: The City of Trees. Boise is known as The City of Trees, and the city is responsible for planting and maintaining all the trees in Boise. They have a central facility where they grow the trees until they are large enough to be planted along streets and in parks. Street trees must be 1 " to 1 1/2" caliper and park trees must be a minimum of 4" calliper. Species used for street trees must be able to withstand mechanical and drought stress; the usual life of a street tree is about 20 years, after which it must be replaced. A catalogue of species and their most appropriate use is available.

The nursery budget is only $6,000 per year, so volunteer help is essential to grow, plant and maintain the trees. Volunteers vary from private citizens to youth groups and service clubs.

(21) Chris Hoag, Aberdeen Plant Materials Center, ID—Use of constructed wetlands for water treatment. To help meet the stricter environmental standards in the U.S., constructed wetlands are used to enhance the quality of irrigation waste water. In addition to their role as purification sites, constructed wetlands create habitat essential for many wildlife species, add to food chain production, shield adjacent land, and create storage ponds. The field trip to the Lucky Peak Nursery outside Boise included a tour of a constructed wetland.

5-Step Plan for Constructed Wetlands (USDA public patent).

1. Heavy sediment basin removes most of phosphorus-containing compounds
2a. Sheet flow over rocks removes nitrogen and phosphorus

2b. Primary filter using plants (grass, sedges, rushes)
3. Shallow wetland with 12-15" water (cattails, bulrushes)
4. Deep pond 8-10 ft. (water lily and *Lemna)*
5. Natural wetland with willows (free of nitrates and phosphorus).

Constructed wetlands need a minimum linear run to work properly. Once that requirement is satisfied, you can adjust the various components according to nitrogen and phosphorus concentrations flowing into the system. It generally takes about 4 to 5 years for all components to become established and work effectively. Note, however, it is essential to have complete control of all components moving IN and OUT of the system.

An important aspect of creating a constructed wetland is the procurement of the plants needed for the system. Rush *(Juncus* spp.), bulrush (*Scirpus* spp.), and sedge *(Carex* spp.) are very effective in absorbing metals and other compounds from the wetland system. Rush seeds are relatively easy to germinate and require no stratification. Bulrush seeds are collected using a weed eater with special collection device (mfg. in Canada). They need light, heat, and plenty of water for establishment. For sedge, you must remove the husk and stratify the seeds. At least a 5" root system is needed before transplanting. A variety of species may be planted at different water levels. One system for establishing wetland species is to plant the seedlings in fibrelogs made of coconut When the plants are well established the entire log is transferred to the site. With the larger econolog system, it is possible to transplant an entire plant community. Bioengineering manual on this topic will be published soon.

(22) **Robin Rose, OSU, Nursery Cooperative, Corvallis, OR—Nurseries and reforestation in Thailand.** Robin described the planning and operation of a very successful two-year project to improve nursery and reforestation practices. They recognized that materials and equipment would be difficult to obtain once they left North America, so packed *everything* for a nursery operation, including greenhouse, automatic irrigation system, fertilizers, styroblocks, etc. into a sealed shipping container and sent it to Thailand. One of the elements contributing to the success of the project was the blessing of the Queen, who had proclaimed the reforestation project to celebrate the 50th year of the King's reign. In addition to the improvements made in production and planting of nursery stock, the project provided training in physiological assessment such as use of pressure bomb (a very popular technique!). Unfortunately, despite its success, the project ended abruptly when U.S. governmental support was withdrawn by declaring that Thailand did not qualify for assistance because it is no longer a developing country.

(23) **Rich Phillips, and Raul Moreno, CEFORA, New Mexico State University—How nurseries fit into sustainable forestry in the Trillium Project, Tierra del Fuego, Chile** This was a forestry aid project to demonstrate the feasibility of utilizing *Nothofagus* as a source of timber production in southern Chile. In this instance, very little was known about the seed production cycle, the processing, storage, and treatment of *Nothofagus* seeds. However, the team members were able to successfully establish greenhouse facilities and grow seedlings. Knowing the tendency for local governments to politicize such projects, the team purposely chose to remain apolitical. In spite of these efforts, however, the project has been delayed as a result of political interference.

List of Participants

Northeastern Forest Nursery Association Conference; Bemidji,MN (August 11-14, 1997)—Speakers

Bob Brittain
USDA Forest Service
Chippewa National Forest
Rt. 3, Box 244
Cass Lake, MN 56633
Tel: 218/335-8600

Susan B. Brokl
PO Box 1171
Bemidji,MN 56619

Mike Fasteland
Potlatch Corp.
Nursery and Greenhouses
PO Box 503
Cloquet,MN 55720
Tel: 218/879-2362

Dan Jordan
IRRRB
Mineland Reclamation Div.
PO Box 392
Highway 169 W
Chisholm,MN 55719
Tel: 218/254-3369
Fax: 218/254-5539

Jennifer Juzwik
USDA Forest Service
North Central Forest Experiment Station
1992 Folwell Ave.
St. Paul, MN 55108
Tel: 612/649-5114
Fax: 612/649-5285

Gary Lee
Lee Nursery
Route 2, Box 20
Fertile, MN 56540
Tel: 218/574-2237

Thorn McDonough
Ministry of Natural Resources
Forest Renewal Section
70 Foster Drive
Sault Ste. Marie, ON P6A 6V5
CANADA

Thomas P. Murn
Potlatch Corporation
MN Wood Products Division
PO Box 504
105 Arch Street
Cloquet,MN 55720

Ron Overton
USDA Forest Service
North Central Forest Experiment Station
1992 Folwell Ave.
Saint Paul, MN 55108
Tel: 612/649-5241

Bob Pajala
MN DNR-Forestry
500 Lafayette Rd.
St. Paul, MN 55155-4044
Tel: 612/297-3513
Fax: 612/296-5954

Jill Pokorny
USDA Forest Service
State & Private Forestry
1992 Folwell Ave.
St. Paul, MN 55108
Tel: 612/649-5247

Mark Reed
Beltrami County Land Commissioner
315 5th St., NW
Bemidji, MN 56601
Tel: 218/759-4210

Don Riemenschneider
USDA Forest Service
Forestry Sciences Laboratory
5985 Hwy. K
Rhinelander, WI 54501
Tel: 715/362-7474

Dwayne L. Stenlund
Minnesota Dept. of Transportation
Environmental Services Division
3485 Hadley Ave. N
Oakdale,MN 55128
Tel: 612/779-5638
Fax: 612/779-5109

Robert A. Stine
University of Minnesota
Cloquet Forestry Center
175 University Road
Cloquet, MN 55720-9594

Dick Tinus
USDA Forest Service
Forestry Sciences Laboratory
2500 S. Pine Knoll
Flagstaff, AZ 86001
Tel: 520/556-2104
Fax: 520/556-2130

Northeastern Forest Nursery Association Conference; Bemidji, MN (August 11-14, 1997)—Attendees

Annette Anderson
MN Dept. Natural Resources
Gen. Andrews State Nursery
PO Box 95
Willow River, MN 55795
Tel: 218/372-3183

James K. Bailey
PA Dept. Conservation & Natural Res.
PO Box 8552
Harrisburg, PA 17105-8552

Charles Bathrick
Ohio Dept. Natural Resources
Zanesville State Nursery
5880 Memory Rd.
Zanesville, OH 43701
Tel: 614/453-9472

Michael R. Carroll
MN Dept. Natural Resources
Badoura State Forest Nursery
RR2,Box 210
Akeley,MN 56433
Tel: 218/652-2385

Gordon Christians
Hayward State Nursery
Rte. 8, Box 8213
Hayward, WI 54843

Steve Copeland
MN DOT Office Environ. Services
3485 Hadley Ave. N
Oakdale,MN 55128

R. Alexander Day
PA Dept. Conservation & Natural Res.
PO Box 8552
Harrisburg, PA 17105-8552

Gary Dinkel
USDA Forest Service
J.W. Towmey Nursery
Box 445
Watersmeet, MI 49969

Darlyne Ekstrand
MN Dept. Natural Resources
Gen. Andrews State Nursery
PO Box 95
Willow River, MN 55795
Tel: 218/372-3182

Jerry Grebasch
State Forest Nursery
2404 S. Duff
Ames, IA 50010
Tel: 515/233-1161

Kenny Hanson
Red Lake Band of Chippewa Indians
Red Lake Agency
Red Lake, MN 56671
Tel: 218/679-3361

Bob Hawkins
IN Dept. Natural Resources
Vallonia Tree Nursery
2782 West County Rd., 540 S.
Vallonia, IN 47281
Tel: 812/358-3621

Larry Hegstad
MN DNR Forestry Region I
615 Anne Street, NW
Bemidji,MN 56601
Tel: 218/755-2891

Greg Hoss
MO Dept. of Conservation
George O. White State Nursery
14027 Shafer Rd.
Licking, MO 65542
Tel: 573/674-3229

Donald Houseman
Illinois Dept. Natural Resources
Union State Nursery
3240 State Forest Rd.
Jonesboro, IL 62952

Cynthia Johnson
MN Dept. Natural Resources
Badoura State Forest Nursery
RR2,Box 210
Akeley, MN 56433
Tel: 218/652-2385

Phyllis Juarez
Red Lake Band of Chippewa Indians
Red Lake Agency
Red Lake, MN 56671
Tel: 218/679-3361

John Karstens
Jasper-Pulaski Tree Nursery
RR 1, Box 241
Medaryville, IN 47957

Rick Klevorn
MN Dept. Natural Resources
Gen. Andrews State Nursery
PO Box 95
Willow River, MN 55795
Tel: 218/372-3182

Ross Korpela
Potlatch Corporation
PO Box 504
Cloquet,MN 55720

Rick Kruger
Terra Industries
1313 Sixth Street SW
Grand Rapids, MN 55744
Tel: 218/327-3049

Roy LaFramboise
Towner State Nursery
878 Nursery Rd.
Towner, ND 58788-9500
Tel: 701/537-5636

Becky Lein
MN DNR Forestry Area
PO Box 43
Warroad, MN 56763-2407
Tel: 218/386-1304

Brett Leschinsky
Northwood Panelboard
Rte. 1, Box 2650
Solway, MN 56678

Fred Lundeby
Lundeby Manufacturing
RRl,Box l36
Tolna,ND 58380
Tel: 701/262-4721

Steve Maniak
MN Dept. Natural Resources
Gen. Andrews State Nursery
PO Box 95
Willow River, MN 55795
Tel: 218/372-3182

Trenten Marty
WI Dept. Natural Resources
Box 7921
Madison, WI 53707
Tel: 608/266-7891

John Mathweg
MN DNR Forestry Area
2220 Bemidji Ave.
Bemidji, MN 56601
Tel: 218/755-2890

David K. McCurdy
Clements State Tree Nursery
101 Allison Dr., PO Box 8
West Columbia, WV 25287
Tel: 304/675-1820

Richard "Duke" Merrion
Fresh Air Farm Implements
2283 South County Road, 300E
Danville, IN 46122-8598
Tel: 317/745-6195

Andrew Monk
U. W-Madison Forestry Dept.
1630 Linden Dr.
Madison, WI 53706

Dan Myklebust
Rainbow Treecare
5105 West 35th Street
St. Louis Park, MN 55416
Tel: 612/922-3810

Greg Nolan
Snowy Pines Reforestation
Rt. 3, Box 95
Browerville, MN 56438
Tel: 320/594-6317

Dave Olsen
Chippewa Farms
10295 Nursery Lane NW
Brandon, MN 56315
Tel: 320/834-2651

Alan Peaslee
NJ Forest Tree Nursery
370 East Veterns Hwy.
Jackson, NJ 08527

JeffRengo
MN DNR Forestry Area
PO Box 432
Tower, MN 55790
Tel: 218/753-4500

Fred S. Rice
Mead Corp.
Woodlands Greenhouse
PO Box 1008
Escanaba, MI 49829
Tel: 906/786-1660, ext. 2120

Jerry Rose
MN DNR Forestry Director
500 Lafayette Rd.
St. Paul, MN 55155-4044
Tel: 612/296-4484

William Sayward
Itasca Greenhouse, Inc.
PO Box 273
Cohasset,MN 55721

Bill Schnell
MN DNR Forestry Station
Box 339
Side Lake, MN 55781
Tel: 218/254-2370

Trent Schumacher
Schumacher's Tree Nursery
RR#2,Box 10
Heron Lake, MN 56137
Tel: 507/793-2288

Steven Shimek
MN Dept. of Agriculture
90 West Plato Blvd.
Saint Paul, MN 55107-2094

John Solan
NYS Dept. Environmental Conser.
Saratoga Tree Nursery
431 Rte. 50 S
Saratoga Springs, NY 12866
Tel: 518/581-1439

Gloria Spears
Red Lake Band of Chippewa Indians
Red Lake Agency
Red Lake, MN 56671
Tel: 218/679-3361

Spencer Stone
MN Dept. Natural Resources
Gen. Andrews State Nursery
PO Box 95
Willow River, MN 55795
Tel: 218/372-3182

Jim Storandt
WI Dept. Natural Resources
711 Nepco Lake Rd.
Wisconsin Rapids, WI 54494
Tel: 715/424-3700

John Tornes
MN DNR Forestry Area
PO Box 157
Deer River, MN 56636
Tel: 218/246-8343

Craig A. Van Sickle
MN Dept. Natural Resources
Badoura State Forest Nursery
RR2,Box 210
Akeley, MN 56433
Tel: 218/652-2385

Paul Walvatne
MN DOT Office Enron. Services
3485 Hadley Ave. N
Oakdale,MN 55128

John Wizik
MN Dept. Natural Resources
Badoura State Forest Nursery
RR2,Box 210
Akeley, MN 56433
Tel: 218/652-2385

Richard S. Wojciak
WI Dept. Natural Resources
3911 Fish Hatchery Road
Madison, WI 53711

Western Forest and Conservation Nursery Association Meeting; Boise, ID (August 19-21, 1997)—Speakers

Virginia Bruce
Teamwebb
12110NWW. Road
Portland, OR 97229
Tel: 503/629-5799

Frank Burch
USDA Forest Service
Auditors Bldg., 201 14th St., SW
Washington, DC 20250

Betsy Carroll
USDA Forest Service
NFGEL Laboratory
2375 Fruitridge Road
Camino,CA 95709
Tel: 916/642-
Fax: 916/642-5099

Mark Crawford
Griffin Corporation
PO Box 1847
2509 Rocky Ford Rd.
Valdosta,GA 31603
Tel: 912/249-5271
Fax: 912/244-5978

David Dreesen
USDA-NRCS
Plant Materials Center
1036 Miller Street, SW
Las Lunas,NM 87031
Tel: 505/865-4684
Fax: 505/865-5163

Kas Dumroese
University of Idaho
Forest Research Nursery
Moscow, ID 83844-1137
Tel: 208/885-3509
Fax: 208/885-6226

Steve Grossnickle
BC Research Corporation
Forest Biotechnology Centre
3650 Wesbrook Mall
Vancouver, BC V6S 2L2
CANADA
Tel: 604/224-4331
Fax: 604/224-0540

J. Chris Hoag
USDA Forest Service
NRCS-Aberdeen Plant Materials Center
PO Box 296
Aberdeen, ID 83210
Tel: 208/397-4133
Fax: 208/397-4311

Thomas A. Jones
USDA-ARS
Forage & Range
Utah State University
Logan, UT 84322-6300
Tel: 801/797-3082
Fax: 801/797-3082

Bob Karrfalt
USDA Forest Service
National Tree Seed Laboratory
Route l,Box 182B
Dry Branch, GA 31020-9696
Tel: 912/751-3553
Fax: 912/751-3554

Dick Karrsky
USDA Forest Service
MTDC
Ft. Missoula, Bldg. 1
Missoula,MT 59801
Tel: 406/329-3958
Fax: 406/329-3719

Scott Lambert
USDA-NRCS
Washington State University
127 Johnson, NATRS
Pullman, WA 99164
Tel: 509/335-7093
Fax: 509/335-2940

Tom Landis
USDA Forest Service
Cooperative Programs
PO Box 3623
Portland, OR 97208-3623
Tel: 503/808-2344
Fax: 503/808-2339

Carole L. Leadem
BC Ministry of Forests
1320 Glyn Road
Victoria, BC V8W 3E7
CANADA
Tel: 250/952-4130
Fax: 250/952-4119

Ben Lowman
USDA Forest Service
MTDC
Ft. Missoula, Bldg. 1
Missoula, MT 59801
Tel: 406/329-3958
Fax: 406/329-3719

Rich Phillips
New Mexico State University
PO Box 3Q
Gerald Thomas Hall, Room 254
Las Cruces, NM 88003-0003
Tel: 505/646-2729
Fax: 505/646-6041

Robin Rose
Oregon State University
Nursery Technology Cooperative
Peavy Hall 154, FSL-020
Corvallis, OR 97331-5705
Tel: 541/737-6580
Fax: 541/737-2668

Jerry Stallsmith
City of Boise
1104 Royal Blvd.
Boise, ID 83706

David Steinfeld
USDA Forest Service
Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502
Tel: 503/776-4281
Fax: 503/776-3764

John Thornton
USDA Forest Service
Boise NF
1249 S.Vinnell Way
Boise, ID 83709

Victor Vankus
USDA Forest Service
National Tree Seed Laboratory
Route 1, Box 182B
Dry Branch, GA 31020-9696
Tel: 912/751-3552
Fax: 912/751-3554

Scott Zeidler
Lone Peak Conservation Center
14650 Prison Road
Draper, UT 84020-9599
Tel: 801/571-0900
Fax: 801/571-0468

Western Forest and Conservation Nursery Association Meeting; Boise, ID (August 19-21, 1997)—Attendees

Ruth Ball
A-A-A Hyway 21 Tree Farm
22556 TWP Rd. 511
Sherwood Park, AB T8C 1H1
CANADA

Kay Beall
USDA Forest Service
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706

Jim Brown
WACD Plant Materials Center
1410 Bradley Rd.
Bow, WA 98232

Derek Carby
ESI Environmental Sensors
100-4243 Glanford Ave.
Victoria, BCV8Z4B9
CANADA

Carol Carter
USDA Forest Service
Wind River Nursery
1262 Hemlock Rd.
Carson, WA 98610

Caryn Chachulski
OSU Nursery Technology Coop
Peavy Hall 154,FSL-020
Corvallis, OR 97331-5705

Lee Charleson
PRT-Reed Collins Nursery
PO Box 430
Aldergrove, BC V4W 2TP
CANADA

Cleve Chatterton
USDA Forest Service
Coeur D'Alene Nursery
CD A Nursery, 3600 Nursery
Coeurd' Alene,ID 83814

Cathy Covington
Colville Tribal Greenhouse
PO Box 72
Nespelem,WA 99155

Barbara Delbol
Althouse Nursery
5410 Dick George Rd.
Cave Junction, OR 97523

Graig Delbol
Althouse Nursery
5410 Dick George Rd.
Cave Junction, OR 97523

Dan Dolata
USDA Forest Service
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706

David Dreeson
USDANCRS
1036 Miller St., 8W
Las Lunas,NM 87301

Robin Durham
Natural Resource Science
PO Box 646410, 187 Johnson
Pullman, WA 99164-6410

Vic Elniski
A-A-A Hyway 21 Tree Farm
22556 TWP Rd. 511
Sherwood Park, AB T8C 1H1
CANADA

Susan Ford
USDA Forest Service
PO Box 25127
Lakewood, CO 80225

Diane Gano
OSU Dept. of Forest Science
OSU
FSL-20
Corvallis, OR 97331

Ken Gano
Betchel Hanford, Inc.
3350 George Washington
Richland,WA 99352

Terry Garren
BLM
Horning Seed Orchard
27004 S. Scheckly Rd.
Colton,OR 97017

Beat Hauenstein
Bartschi Fobro Ag.
1715 Airpark Drive, PO Box 651
Grand Haven, MI 49417

Diane Hildebrand
USDA Forest Service
Natural Resources Dept.
PO Box 3623
Portland, OR 97208-3623

Gary Hileman
USDA Forest Service
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706

John Hinz
USDA Forest Service
Tonto National Forest
2325 E. McDowell Rd.
Phoenix, AZ 85010

Michelle Houghton-Cook
BLM
Sprague Seed Orchard
1980 Russell Rd.
Merlin, OR 97532

Robert James
USDA Forest Service
3815 Schreiber Way
Coeurd'Alene, ID 83814

Tammy Jebb
Bureau of Land Management
1980 Russell Rd.
Merlin, OR 97532

John Justin
Montana Seedling Nursery
3815 Sourgin Rd.
Missoula, MT 59804

Chris Kemp
Betchel Hanford, Inc.
3350 George Washington Way
Richland,WA 99352

Richard Kenton
Plant Works Native Nursery
1805 UAve.
LaGrande, OR 97850

Harvey Koester
Bureau of Land Management
3040 Biddle Rd.
Medford, OR 97504

Pete Laird
USDA Forest Service
Federal Building
PO Box 7669
Missoula, MT 59807

Jennifer Lewinshon
Environmental Careers Organization
3350 George Washington Way
Richland,WA 99352

Rosemary Mallory
USDA Forest Service
J. Herbert Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502

Doug McCreary
UC Coop Extension
8279 Scott Forbes
Browns Valley, CA 95918

James McGrath
USDA Forest Service
Wind River Nursery
1161 Hemlock Rd.
Carson, WA 98610

Greg Morganson
ND Assoc. of Soil Conservation Dist.
Lincoln-Oakes Nurseries
Box 1601

Karla Murphy
Lawyer Nursery
950 Highway 200 W.
Plains, MT 59859

Jacek Paczuski
USDA Forest Service
Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502

Eric Pederson
Agrium, Inc.
402-15 Innovation Blvd.
Saskatoon, SK S7N 2X8

Malcolm Quillan
Silvaseed
317 James St., PO Box 118
Roy, WA 98580

Tony Ramirez
Washington Dept. Natural Resources
Webster Nursery
PO Box 47017
Olympia,WA 98504-7017

Nita Rauch
USDA Forest Service
Bend Pine Nursery
63095 Deschutes Market Rd.
Bend, OR 97701

Glenn Roloff
USDA Forest Service
PO Box 7669
Missoula, MT 59807

Sandy Roth
Plant Works Native Nursery
1805 UAve.
LaGrande, OR 97850

Janice Schaefer
Western Forest Systems
1509 Ripon Ave.
Lewiston, ID 83501

John Scholtes
USDA Forest Service
J. Herbert Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502

Robyn Scibilio
USDA Forest Service
Genetic Resource Center
2741 Cramer Lane
Chico, CA 95928

Jerry Stallsmith
Urban Forestry City of Boise
1104 Royal Blvd.
Boise, ID 83706

James Storms
JE Love Company
PO Box 188
Garfield,WA 99130

Hank Switzer
USDA Forest Service
Genetic Resource Center
2741 Cramer Lane
Chico, CA 95926

David Thames
USDA Forest Service
J. Herbert Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502

Richard Thatcher
USDA Forest Service
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706

Pat Trimble
USDA Forest Service
Placerville Nursery
2375 Fruitridge Rd.
Camino,CA 95709

Jack Troyer
USDA Forest Service
S&PF
324 25th Street
Ogden,UT 84401

Gary Wakefield
Miller Chemical
327 Center St.
Slippery Rock, PA

Sharlene Wanichek
USD A Forest Service
Bend Nursery
63095 Deschutes Market Rd.
Bend, OR 97701

David Wenny
University of Idaho
Forest Research Nursery
Moscow, ID 83844-1137

Don Wermlinger
Lucky Peak Nursery
20895 Arbor Grove Rd., NE
St. Paul, OR 97137-9728

Jay Wyatt
USDA Forest Service
J. Herbert Stone Nursery
2606 Old Stage Rd.
Central Point, OR 97502

Ben Zamora
Natural Resource Science
PO Box 646410, 187 Johnson
Pullman, WA 99164-6410

Alvin deHaas
USDA Forest Service
Placerville Nursery
2375 Fruitridge Rd.
Camino,CA 95709

Landis, T.D.; Thompson, J.R., tech. coords. 1997. National proceedings: Forestand Conservation Nursery Associations—1997. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 163 p.

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Keywords: Barerootseedlings, containerseedlings, nursery practices, reforestation.

The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

Pacific Northwest Research Station
333 SW First Avenue
PO Box 3890
Portland, OR 97208-3890