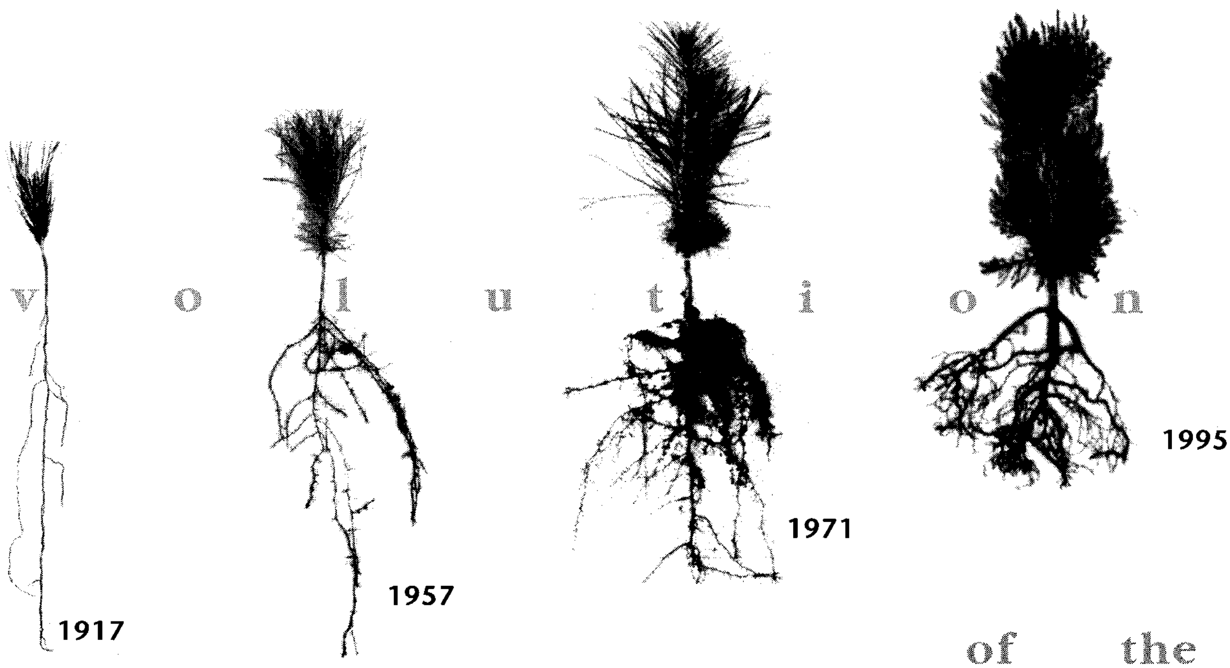
United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research
Station

General Technical
Report
PNW-GTR-389
January 1997

National Proceedings: Forest and Conservation Nursery Associations—1996



Evolution of the Target Seedling

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Funding for this publication was provided as a technology transfer service by State and Private Forestry, USDA Forest Service.

Cover: The "Target Seedling" produced by forest and consevation nurseries has improved dramatically over the past century.

National Proceedings:
Forest and Conservation Nursery Associations

1996

Thomas D. Landis and David B. South,
Technical Coordinators

U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, OR 97208
General Technical Report PNW-GTR-389
January 1997

This publication was published as a cooperative effort by the
Pacific Northwest Research Station and the
Pacific Northwest Region.

Abstract-Landis, T.D.; South, D.B., tech. coords. 1997. National proceedings: Forest and Conservation Nursery Associations-1996. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 282 p.

This proceedings is a compilation of 51 papers that were presented at the regional meetings of the forest and conservation nursery associations in the United States in 1996. The Southern Forest Nursery Association meeting was held in Gatlinburg, TN, on June 25-27, 1996; the Northeastern Forest Nursery Association Conference was held in New England, CT, on August 19-22, 1996; and the Western Forest and Conservation Nursery Association meeting was held in Salem, OR, on August 20-22, 1996. 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 CONSERVATION NURSERY ASSOCIATION MEETING

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BUSINESS MEETINGS

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Southern Forest Nursery Association Meeting

Gatlinburg, Tennessee

June 25-27, 1996

Reforestation in Tennessee’

Hart W. Applegate[2] and Paul Ensminger[3]

Good moming! I appreciate the opporhmity to speak to you today. 1 want to extend you an extra welcome to Tennessee as you get down to serious discussions of nursery management and seedling production. If you can escape the delights and seductions of Dollywood, the gift shops, and outlet malls while you’re here, I urge you to spend a few hours walking a trail in the Park, visiting the Cherokee National Forest, or taking a day’s tour in “God’s County,” as the East Tennessee Region is affectionately known to the natives.

As you have no doubt noticed, Tennessee is abundantly blessed with forests that support an impressive variety of plants and animals. It has been said that the biological diversity in the Southem Appalachians is as rich as any region on earth outside the tropics. Tennessee is located in that in-between land where the central hardwood forests to the north merge with the pines farther south. Unlike most of the other Southeastem states, dominated by southem pine types, almost 90 percent of Tennessee’s forests are composed of hardwood and pine-hardwood types.

Arrayed from east to west, we also have a diversity of physiography and forest types, ranging from the spruce-fir and northem hardwood forests of the Smoky Mountains . . . to the cove hardwoods of the Cumberland Plateau . . . to the oak-hickory forests on the Highland Rim and Central Basin of Middle Tennessee . . . to the bottomland hardwood and cypress-tupelo forests in the floodplains of the Mississippi and other rivers in West Tennessee.

Timber and wood products have been a mainstay of the State’s economy for almost two centuries. Long known for production of fine hardwoods, Tennessee has been for many years among the top 2 or 3 hardwood lumber-producing states. In recent years, increased demand for paper and other fiber products has created a greatly expanded market for low grade hardwoods, a product with which we are amply blessed. In addition, the State produces impressive amounts of hardwood veneer, cooperage, and crossties. Although forest industry utilizes significant volumes of pine, mainly for pulpwood, hardwoods still provide the bulk of raw material for the primary wood-using industries.

Most forest regeneration in the State, especially regeneration of hardwoods, is accomplished through natural means. Primarily for this reason, artificial regeneration does not receive as much attention as it does in the states of the Coastal Plain.

To be sure, the productivity of hundreds of thousands of acres of low-grade hardwood sites could be dramatically increased if converted to pine. In the years ahead, more hardwood-to-pine conversion is sure to occur, but until very recently the lucrative markets for

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[1]*Applegate H. W. and Ensminger, P. 1996.* **Reforestation** *in Tennessee. In: Landis, 7.0.; South, DB., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1-5.*

[2]*Author: Forest Management Chief, Tennessee Division of Forestry.*

[3]*Speaker: Reforestation Forester, Tennessee Division of Forestty.*

pine, enjoyed by the states to the south, were not available to us.

The birth of artificial reforestation in Tennessee began during the 1920s soon after creation of a Bureau of Forestry and establishment of a rudimentary fire control organization. In those days, new land was cleared when old farm land was "worn out," and the "worn out" fields produced millions of tons of eroded sediment.

Farmland erosion was widespread throughout the State, but nowhere was it as severe as in West Tennessee where silty loess soil overlies Coastal Plain sands and gravels. Althouglh highly productive for agricultural crops, the fertile loess erodes like sugar when unprotected by cover. Countless fields were reduced to useless moonscapes by such erosion. Up to 200 tons of soil per acre per year may be lost on these bare loess sites, depositing unwanted silt in the lowlands, polluting streams, and leaving the land barren for decades.

The State's first seedling nursery was established near Jackson in the late 1920s to furnish planting stock for stabilizing eroding lands. Planting records from those early days are lost; but oral tradition and the existence of some of the older pine stands throughout the State, especially in the West Tennessee area, suggest that loblolly pine was the main species produced.

One of the agencies established to get America back on its feet during the Great Depression was the Civilian Conservation Corps, which also ushered in the State's first signiticant tree planting initiative. A number of CCC camps were established across the State, and tree planting, primarily for erosion control, was a major CCC activity. According to a former state forester, something over half a million acres were severely eroded in the mid-thirties; yet less than 1,500 acres had been reforested.

In addition to the State's West Tennessee nursery, a nursery was established by the Tennessee Valley Authority during the mid-30s at Clinton near Knoxville. The Clinton Nursery furnished seedlings to CCC camps in East Tennessee both for reforestation of old fields on its reservoir properties and for erosion control plantings on private lands.

Small, on-site nurseries were also established on at least three, and probably more, Resettlement Administration Project areas in the State. Later, these areas were turned over to the State of Tennessee and now exist as state forests.

Records show that many native and non-native species were planted. Most were apparently trial plantings, established to determine how various species survived and developed under various soil and site conditions. Judging from the appearance of these lands today, few of the species planted survived and grew as intended. Among the hardwoods, only a few black walnut and yellow poplar plantings survived and grew. In most cases, the reason for failure was unsuitable site conditions.

Among the softwoods, loblolly, shortleaf, and white pines were generally successful. Severa1 thousand acres of CCC-planted loblolly sawtimber still exist on Natchez Trace and Chickasaw State Forests in West Tennessee. Much of it has been thinned two or three times. Now 60 years old and of high qualilty, this timber is being sold for the highest prices ever seen for pine sawtimber in Tennessee.

The work of the CCC was cut short by the Second World War when suddenly plenty of jobs were available for everyone. We are greatly indebted to the CCC for the pioneering work they did under some of the most difficult economic conditions Americans have ever lived through. From 1935 to 1942, the CCC planted more than 130,000 acres in Tennessee.

After the War, it was apparent that the 38-acre nursery site near Jackson was inadequate for the State's seedling needs. In 1947 a 3 19-acre site, located at Pinson about 10 miles South of Jackson, was purchased by the State. Approximately 100 acres were suitable for seedling production. The smaller nursery was closed, and in 1948 the first seedlings were grown at the newer Pinson nursery.

Until the late 1980s, al1 planting stock was produced at Pinson with the exception of white pine. The hot summers experienced in West Tennessee made production of white pine seedlings, a 2-year crop, extremely difficult. An arrangement was made with TVA to produce white pine seedling stock for distribution to private landowners by the Division of Forestry. TVA continued to supply State needs for white pine until the Clinton nursery was closed in the mid-60s.

Beginning in the eauly 1950s, the pulp and paper industry became interested in Tennessee as a raw material source for its products. In addition to the native hardwoods, Tennessee had abundant natural shortleaf and Virginia pine resources from the Cumberland Plateau east to the North Carolina line.

The first big industry was Bowater Southern Paper Company, which built one of the world's largest newsprint mills in the Tennessee River Valley at Calhoun, northeast of Chattanooga. Bowater also acquired numerous forested tracts on the Cumberland Plateau and in the Valley to supplement purchases of pine grown on non-ind.ustrial private lands mostly in Tennessee, Georgia, and Alabama.

Bowater soon established a state-of-the-art nursery and seed orchard on Rose Island, a beautiful site in the Little Tennessee River about 35 miles northeast of the mill. Pine seed and seedlings were produced at this site until the late 1960s when the site was vacated to make way for impoundment of the River by TVA's Tellico Dam. Nursery improvements were moved to a North Georgia site 50 miles to the south, and the entire seed orchard, severa1 hundred 25 to 40-foot trees which had just begun to produce seed, was moved to a nearby upland site. Beginning in the early 1950s, Bowater planted severa1 thousand acres of loblolly and Virginia pine on its company lands each year, greatly improving the productivity of tens of thousands of acres of low-grade hardwood sites.

During the 60s, 70.5, 80s, and 90s other pulp and paper interests were also drawn to Tennessee. Tenneco Packaging, Willamette,, Westvaco, Chamption International, and L.M. Huber today control more than 1.1 million acres in Tennessee on which they expect to produce a portion of their raw material needs. Tree planting on company lands by the pulp and paper industry currently exceeds 20,000 acres annually.

Beginning in the mid- 1950s, tree planting soared in Tennessee, boosted by industry's new presence and the new federally funded reforestation programs. In 1955, the Pinson nursery produced 13 million seedlings, many of which were produced for sale to forest industry.

Most of the rest were grown for the new federal programs. The Agricultura1 Conservation Program, the so-called "ACP Program," offered private landowners federal cost-sharing for tree planting beginning in 1936. But when the PL-566 Watershed Protection and Flood Prevention Act was passed in 1954, most ACP cost-share funds for tree planting were utilized for soil stabilization on PL-566 projects, located mainly in the West Tennessee Area. In the decade from the mid-50s to the mid-60s, ACP provided cost-sharing for the reforestation and stabilization of more than 330,000 acres in Tennessee.

Another stimulus to tree planting during this period was the Soil Bank Program. From 1956 to 1962, landowners planted trees on more than 45,000 acres of crop and pasture land in Tennessee.

Seedling production at the Pinson nursery grew from 6.7 million trees in 1954 to 62 million in 1958. In the mid- 1960s, when the Soil Bank Program ended and tree planting in PL-566 watersheds tapered off; seedling production declined. Still, production remained relatively high through the early 1980s as industry accelerated reforestation on company lands and demands for seedlings continued for surface mine reclamation and forestation of private lands, supported largely by the Forestry Incentive Program, created in 1973.

Beginning in the early 80s, industry began to rely less on Tennessee's nursery for seedling production. Most developed company nurseries to produce seedlings with home-grown genetic material. As a result, annual seedling production at the State nursery throughout most of the 80s dipped below 10 million.

In 1986, however, reforestation received another shot-in-the-arm with the introduction of the Conservation Reserve Program. Since 1986, more than 35,000 acres were planted under CRP.

After TVA's Clinton nursery was closed, the Division of Forestry began producing white pine at the Pinson Nursery but was always unable to satisfy demand for the species and furnish high qualilty planting stock due to the warmer climate of West Tennessee. A decision was made to develop a new nursery in East Tennessee; so in 1988, a site was purchased in extreme southeast Tennessee in a bottom-land, of the Hiwassee River, an old Cherokee Indian site, in the shadow of tlhe Smoky Mountains.

Outfitted with al1 new, state-of-the-art buildings and equipment, the new nursery produced its first seedling crop in 1989. The site proved near ideal for white pine production as well as many other species. During the first eight years of operation, the new nursery has produced an average of 6.6 million seedings, 83 percent of which were pines. This year's production is almost 10 million.

In 1992 the first Stewardship Incentive Program funds were allocated to the State. After the fifth program year, landowners have planted more than 12,000 acres of trees under SIP and requests for cost-sharing continue to climb.

The continuing pressure for cuts in State spending forced the Division to close the Pinson nursery earlier this year. The last seedling crop produced at Pinson was 300,000 yellow poplar, the State Tree, grown for this year's Tennessee Bicentennial event.

The Division's Tree: Improvement Program, started in 1964, provides first generation improved seed for al1 loblolly, shortleaf, Virginia, and white pine, including white pine Christmas tree stock, from more than 250 acres of orchards. In addition improved seed is also produced for black walnut, yellow poplar, and Northern red oak seedling stock.

Over the years, Tennessee nurseries have furnished planting stock for a variety of conservation uses, programs, and customers. In addition to the CCC and PL-566 watershed projects, millions of seedlings were produced for erosion control for the Yazoo-Little Tallahatchie Flood Prevention Project in North Mississippi until completion of tree planting in the late 1970s.

Virginia and white pine, black locust, and and severa1 other species were grown for federal and State agencies and coa1 companies for surface mine reclamation work.

The already-mentioned Soil Bank Program of the 50s and 60s and Conservation Reserve Program of the 80s and 90s used significant amounts of seedlings for retirement of agricultura1 lands.

When the Interstate Highway System was built, the Department of Transportation utilized millions of trees for beautification and soil stabilization along rights-of-way throughout the State.

Oaks, pecan, persimmon, autumn olive, bicolor lespedeza, and indigo bush have been produced for planting on Wildlife Resources Agency lands, as well as for sale to landowners, for improvement of wildlife habitat.

In addition, Tennessee's State nurseries have produced seedling stock for forest industry, the Forest Service, TVA, Corps of Engineers, Army Ammunition Plants, Department of Energy, and many municipal and corporate owners for a variety of projects and purposes for more than half a century.

Turning now to the future, severa1 realistic opportunities exist both for increasing regeneration of natural stands and for artificial regeneration in the Volunteer State during the next few years. Probably the greatest opportunity for forest regeneration in the foreseeable future is, of course, natural regeneration of the fine hardwoods for which Tennessee is famous. With more complete utilization of lower grade trees and the cutting or deadening of unusable trees, we are confident that hardwoods can be cost-effectively regenerated by natural means on the better sites. The key to the success of natural regeneration on private lands, however, is the ability of our agency to furnish information and close technical assistance to the huge number of forest landowners in the State.

Considerable opportunity also exists for producing pine on forest sites unsuitable for high grade hardwoods. Although more expensive than natural regeneration, conversion to pines will produce greater volumes and more profit than native hardwoods on these poorer sites. With the growth of the pulp and paper industry and Tennessee's geographic location, such investments are becoming more obvious to landowners, and we see more of them planting trees without federal cost-share program subsidies.

Although the Soil Bank and Conservation Reserve Programs were responsible for changing thousands of acres of agricultura1 lands to forest land, great potential still exists for reforesting marginal crop and pasture lands in Tennessee. According to the SCS's National Resource Inventory of 1992, there are 1.8 million acres of Class VI, VII, and VIII lands in the State. These lands are unsuitable for crop and forage production due to steepness of slope, shallowness of soil, and or eroded condition. These lands could be reforested at low cost and provide enormous economic and environmental benefits to both landowners and the public.

Recent new emphasis on wetland protection and restoration offers new opportunities to plant bottomland hardwoods on tens of thousands of acres of cleared wetland sites, located mostly in West Tennessee. During the 1960s and 1970s, wholesale clearing of bottomland hardwoods was conducted to make way for soybeans and other crops. In many cases, farmers have been lucky to make a crop one or two years in five due to seasonal flooding, high water table, or other factors. Through the corporate efforts of the Division of Forestry, the Wildlife Resources Agency, NRCS, Fish and Wildlife Service, and others, a number of wetland restoration projects are now getting underway.

In addition to hardwood restoration in West Tennessee under the Natural Resource Conservation Service-administered Wetlands Reserve Program, the Wildlife Resources Agency has begun restoring bottomland hardwoods on severa1 Agency-managed lands, and the Division of Forestry, having received a three-year federal grant from EPA, recently hired a Wetlands Project Forester who is stationed at the old nursery site near Jackson. In addition to working with NRCS on WRP cases, the forester provides assistance to private landowners in managing existing bottomland hardwoods and restoring the resource on suitable wetland sites. This new activity in wetlands will generate considerable new demand for hardwood planting stock and provide us much-needed experience in hardwood reforestation.

We think these opportunities can also yield huge benefits in terms of improving wildlife habitat, water quality, soil protection, outdoor recreation and natural beauty.

To summarize the main points:

- Most forest regeneration is achieved in Tennessee's predominatly hardwood forests through natural means. Artificial regeneration plays a relatively minor role.
- The bulk of artificial regeneration in the State is carried out by pulp and paper companies.
- Historically, the relatively modest amount of reforestation performed on non-industrial private lands has been driven mainly by federal agricultura1 lands retirement and cost-share incentive programs.
- Reforestation in Tennessee would benefit greatly from a state-funded incentive program as it has elsewhere.
- The recent acceleration of timber prices shows that market conditions may be the most effective incentive for reforestation on non-industrial forest lands.
- Significant opportunities exist for increasing forest regeneration in Tennessee through natural means; conversion of low-grade hardwoods to pine; reforestation of marginal crop and pasture lands; and restoration of bottomland hardwoods on wetland sites.

In closing, 1 want to thank you again for the opportunity to speak to a group which has served the South and the Nation so well during the past half century. The fruits of your efforts will be the economic prosperity of the people and the sustainability of the land for many generations.

Best wishes for a productive meeting.

Nursery Soil Management-Organic Amendments

C. B. Davey[1]

Abstract—In von Carlowitz' book of 1713 on economic silviculture, he devotes a full chapter to nurseries. He discusses the best soil for a nursery, how the soil is treated and prepared for sowing, and the favorability of using lots of organic matter. Thus, our present topic is hardly new. However, there is considerable new information that will help us to a better understanding of the dynamics of organic matter in soil. Recently it has been shown that some of the most active and important organic matter is soluble. It breaks down very rapidly, however, so it must be continuously replaced. Organic matter maintenance is a bother but it is essential to the production of high quality grade one seedlings. It even makes economic sense.

The roles of organic matter in the physical, chemical, and biological aspects of nursery soil management are discussed in this review. The impact of soil organic matter on air and water movement into and out of the soil, the water-holding capacity, soil compaction and bulk density, and ease of root penetration are all physical aspects. The dynamics of nutrients in the soil, both immobilization and mineralization, the components of acidity (both the pH value and exchangeable aluminum), and the cation exchange capacity are the important chemical aspects. The enhancement of mycorrhiza formation and function and the suppression of soil-borne pests, including disease organisms, nematodes, insects, and some weeds are parts of the biological factors. These are all discussed in terms of improved seedling quality.

INTRODUCTION

Forest nurseries are hardly a new idea and stressing the importance of organic matter management in nursery soil is almost as old. In von Carlowitz' book of 1713 on economic silviculture, he devotes a full1 chapter to nurseries. In it he discusses the best soil for a nursery, how the soil is treated and prepared for sowing, and the use of lots of organic matter is favored. He discusses what to take into account when planting hardwoods rather than conifers. However, we have progressed some since 1713. Evidence of this is contained in his discussion of planting seeds of mixed species together in the seedbed. The final section in the chapter is called "The great benefit of nurseries." Certainly, we can al1 relate to that idea.

After the development of mineral fertilizers, the use of organic matter in soil management was considered unnecessary for a few years. Then it became apparent that organic matter is responsible for numerous functions in the soil other than simply serving as a source of nutrients. This was cause for a redefining of the role of organic matter and its value in soil management.

Fifty years ago, S. A. Wilde (1946) called organic matter the soul of the soil. That may be a bit flowery but it does suggest the importance of organic matter. However, we must be aware that organic matter is not the only important constituent of soil. This was called to our attention by Phil Wakeley (1954) who said, "So

[1]*Davey, C. B. 1996. Nursery Soil Management-Organic Amendments. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 6-18.*

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enthusiastically is soil organic matter regarded by many that there is danger of its being expected to cure ills with which it has no connection....."

Very recently, Fisher (1995) posed some important questions regarding soil organic matter. They included; "..is soil organic matter an important determinant of soil quality, and if it is, why are formal relationships between soil organic matter and soil quality so poor?"

There is only a poor relationship between total soil organic carbon and tree growth (Fisher 1995). This is probably because of a large difference between total and active C. "In mineral soils, the amount of active organic C, that which is in solution or exchangeable at any one time.....is less than 1% of the total organic C...." Thus, large changes can take place in the active fraction without being detectable in the total organic C. "There may be a statistically signiticant relation between tree growth and some particular fraction of soil C, but we are yet to explain that relationship" (Fisher 1995).

After posing these and other tough questions, Fisher discusses them at length. Finally, after looking at some of what is known, as well as what is not known, he concludes that "Soil organic matter is the fuel that runs the soil's engine" (Fisher 1995). With this cautious but optimistic background, we will undertake a discussion of nursery soil organic matter management and its impact on important soil properties and eventually, of course, on seedling growth and quality.

Before we get down to the particulars, we need to define soil organic matter. This can be done from the philosophical to the very practica1 point of view. There is a lack of complete unanimity of definition, but in general, ideas are quite close. There are three basic components to soil organic matter. They include:

1) live plant and animal tissues and microbes in soil which are easily identifiable and are starting to be humified,
2) plant, animal, and microbial tissues in various stages of decomposition and which are difficult to identify, and
3) fully humified material whose origin is essentially impossible to detect (Davey and Krause 1980, Davey 1984).

From the totally practica1 point of view, soil organic matter is any organic material in a soil sample that we submit for analysis which will pass through the sieve that the lab uses [commonly the holes in the sieve are about 1/8th inch (2 mm)]. Anything larger than that ends up in the trash. Because of this fact, recently-applied bark or sawdust frequently does not appear to have had an effect the soil organic matter content.

The study of organic.matter decomposition and humification was first quantitied by S. A. Waksman and associates (Waksman 1929; 1936; Waksman and Tenney 1927). The 1927 report discussed in detail the decomposition of our favorite winter cover crop— rye.

On a world-wide basis the amount of C in decaying organic mater and fully humified soil organic matter appears to exceed the amount of C in live vegetation by at least factor of two (Bouman and Leemans 1995).

The addition of organic matter to soils can affect the cycling of nutrients through its effects on the physical, chemical, and biological properties of those soils (Johnson 1995). Thus, organic matter is shown to be involved in nearly all aspects of soil processes.

In these introductor-y remarks, we have seen soil organic matter go from a position of being overly important to being of little importance to the present middle ground where we realize that it is important in soil management but it is only one of severa1 important aspects in nursery soil management. With these thoughts in mind, we will now undertake a discussion of the various roles and effects of soil organic matter.

PHYSICAL PROPERTIES AND EFFECTS

Soil organic matter occurs in the solid, colloidal, and soluble states. The surface area of the colloidal material is extremely large and many important reactions occur at the solid-liquid interface. (Stevenson, 1985).

The organic matter affects aeration, structure, drainage, moisture-holding capacity, and nutrient availability. The last represents organic matter as both a source of some nutrients and cation exchange capacity (CEC) to hold others against leaching. This fact demonstrates that the physical and chemical aspects of soil organic matter management are completely intertwined.

Organic matter helps hold water (Hollis 1977). It accounted for over 73% of the variation in water held over a range of soils. This was expanded by Krause (personal communication) to show that the sandier the soil, the more important was the organic matter in water retention.

Soil with ample organic matter allows good air and water movement. This is important for both movement in and out of the soil. Any impediment of air movement in both directions results in a shortage of oxygen for root respiration. This results in impeded root growth and eventually top growth as well.

One basic physical property of soil that does not receive much attention is soil temperature. However, it is the most important factor in determining the appropriate amount of organic matter that we might seek to maintain in our soils. Temperature affects al1 reactions similarly. That is, a rise in temperature by 10 ° C (18 ° F) doubles the rates of reaction. Conversely, a temperature drop of that same amount cuts the rates in half. For example, if a soil starts the growing season at 40 ° F and warms to 58 °, the rate of organic matter decomposition doubles. In the middle of the summer it can easily increase to 76 ° F. That will double the decomposition rate again. The rate will remain high until fa11 when the soil cools again. Thus the warmer the soil, the more difficult it is to maintain a high organic matter content. Soil texture also affects this relationship with sandy soils losing organic matter faster than finer textured soils. Many of us in the South are on soils that are sandy and very warm. Thus, we cannot hope to maintain levels much above 2 % organic matter. Those on the north edge of the range (e.g., in Virginia), may maintain about 3 %. With altitude, such as at the fraser fir nursery in North Carolina, we might work for 4 %. In the cooler and finer textured nursery soils of the PNW, levels of 5 to 8 % are not unreasonable.

Regardless of soil texture, erosion is always a worry. The maintenance of a good organic matter leve1 in the soil will reduce the rate of erosion. Thus, it is a form of insurance.

Lack of control of traffic across nursery fields can result in increased soil bulk density, a measure of compaction. This easily results in 15%, or more, reduction in seedling production. This process can be partly reversed by proper soil organic matter maintenance. However, traffic control is still necessary. Eventually, subsoiling will also be needed. The reverse should also be noted. A significant reduction in soil organic matter results in more damaging soil compaction.

Soil bulk density is related to severa1 other soil properties. These include porosity, aeration, interna1 drainage, and mechanical impedance. Collectively, these properties strongly affect both root and top growth. Nearly al1 nursery soil management operations result in some soil compaction. The degree of compaction varies with the type of operation and especially the care with which it is practiced. This is true both in the nursery and in the forest (Froehlich and McNabb 1984). The loss of organic matter and compaction lead to a decrease in water infiltration and water-holding capacity, a reduction of air movement into and out of the soil, and an impedance in root penetration of the soil. Above a certain compaction level, roots are no longer able to expand at al1 and seedling growth stagnates (Mitchell et al. 1982).

CHEMICAL PROPERTIES AND EFFECTS

Soil chemical properties that are affected by organic matter include, acidity, nutrition, and CEC relationships. To keep us humble, let's refer to Fisher (1995) again.

"Despite al1 our efforts, . . . our understanding of the ecological role of humus is very poor." (Fisher 1995). "A second area in which we lack sufficient understanding is the role of C in soil solution . . . in soil fertility" (Fisher 1995).

We know that the soluble C can chelate metallic ions, enhance nutrient availability, and reduce the toxic effects of Al (Fox and Comerford 1992). These soluble organic compounds are probably very short-lived. Thus, to be effective they must be continuously produced. Some estimates have suggested replacement every three days during the growing season.

Fresh plant material decomposes, releasing C, H, 0, N, S, P and cations such as Ca, Mg, and K. Nutrient elements are recycled by microorganisms in the soil and in the organic matter, and are often made available for plant uptake (McColl and Gressel 1995). Interactions between inorganic elements and the organic material can have important effects on nutrient availability. For example, soluble organic acids can affect P availability through chelation. Organic acids can also prevent precipitation of P by Fe and Al oxides (Fox et al. 1990).

The topic of disolved organic matter and its importance to soil management is quite new (Hebert and Bertsch 1995). These authors have provided a review of our current understamding of this topic. This is probably the most dynamic part of organic matter management because of the rapidity with which changes occur.

Organic matter and phosphorus (P) have a complicated relationship. The organic matter contains P and its decomposition requires P. Partly humified organic matter can solubilize both Fe and Al P compounds. Thus, P dynamics during organic matter decomposition are very complex. Some P is being mineralized while other P is being immobilized continually. Usually, between 30 and 80 percent of the P in soil is associated with the organic matter.

Soil organic compounds bind metallic ions and increase the availability of some and decrease that of others (Stevenson 1982). This is especially involved in the case of iron (Fe). The Fe is often chelated in the soil by low molecular weight organic acids. This reduces the likelihood of Fe chlorosis (Stumm 1986). Iron that is free in a well aerated soil (suitable for root growth) is usually highly oxidized and thus not available for uptake by plants. There are microbes in the soil that tend to oxidize Fe and make it less available. They are a major cause of our common mid-summer Fe chlorosis. There are other microbes that tend to reduce Fe and increase its availability. There are still others that chelate the Fe. They chelate it for their own benefit. That is so they will have Fe when they need it. In some of the chelates, the Fe is in a form that the seedlings can get and that is helpful. However, in other chelates, the Fe is not available to the seedlings at all. We must remember that these microbes are working for their own benefit. The seedling is just a bystander—sometimes a winner and sometimes a toser.

The boron (B) that plants frequently use comes from the organic matter. Thus, decomposition of the organic matter is required to maintain a supply of B in the soil. This means that a dry soil can be deficient while that same soil when moist may not be defícient without any change in the total amount of B in the soil at all. Sands that are low in organic matter are prone to B deficiency. Many nursery managers are well aware of that.

The minor elements, copper, manganese, and zinc are chelated by low molecular weight organic matter, some of which is soluble (Fox 1995). It is possible that the small molecule including these elements is taken up directly by seedling roots. The important thing is that with ample organic matter, minor element availability is enhanced.

In addition to the direct effects of organic matter on seedling nutrition, there are some less direct effects as well. These involve the soil acidity and the cation exchange capacity (CEC). In nearly all nursery soils, the CEC is highly affected by the organic matter content. This is because the two principal sources of CEC are organic matter and clay. Hopefully, very few of us manage nurseries with clay soils. The CEC of organic matter is different from that associated with clays. The difference is that the clay-CEC is independent of acidity (pH) while the CEC from organic matter is highly pH-dependent. Roughly, the pH-dependent CEC will about double as a sandy soil goes from pH 3.5 to pH 7.0. Obviously, we don't want our soil to be at either extreme but it does show that if our soil becomes increasing acidic, its ability to hold nutrients on the CEC is diminished. Under very acidic conditions both the CEC lowers and lots of H is produced which further induces nutrient cation displacement. At pH 5.5 we hit a happy medium of lots of things and nutrient retention is good.

The more organic matter there is in a soil, the higher is its CEC. This, in tum, buffers the soil against rapid changes in pH value. Sandy soil that is low in organic matter and thus has a low CEC is prone to experience large and rapid shifts in pH value. Seedling development is adversely affected by such shifts in acidity.

BIOLOGICAL PROPERTIES AND EFFECTS

In this section, we finally get the organic matter and the organisms together. The constituents of the organic materials that we may add to our soil are comprised of carbohydrates, amino acids and proteins, nucleic acids, lipids, lignins, and hurnus. These are listed in approximate order of increasing resistance to decay. There are sometimes other materials such as waxes in some materials that also decay slowly, but they usually constitute a small part of the whole.

The study of constituents of soil organic matter was established by Waksman and Tenney (1927). They showed that pine organic matter had a higher content of lignin and a lower content of protein than crops such as our cover crops. Pines have a relatively high content of fats, waxes, and resins. Consequently, they take a relatively long time to decompose. From the standpoint of nursery soil management, those are al1 in favor of adding sawdust, bark, etc. to our soils. Not only do those materials contain the constituents that we want, especially lignin and its derivatives, but those last in the soil relatively long times.

The loss of organic matter from soil occurs principally as a result of respiration by microbes in the process of building their own tissues. Mostly, it is C that is lost while other elements are conserved. This process is affected by temperature, aeration, water, and nutrients. These have been discussed above. The soil must also contain microbes that are capable of doing the decomposition. This is not usually a problem. Soil fumigation will temporarily reduce the numbers and diversity of such organisms (Danielson and Davey 1969). Fungi were found to be more severely impacted than bacteria.

Some microbes can convert one class of substances into another class. For example, Haider and Martin (1977) showed that a soil fungus could transform simple carbohydrates to a group of 24 different phenolic compounds. The carbohydrates used are typical of those in cellulosic materials while the phenolics would normally be thought of as being derivatives of lignin. This further complicates our understanding of how the various original organic constituents are altered during the processes of humification.

One concept that is sometimes misunderstood is known as "priming." In this case, fresh organic material is added to soil. This food source stimulates the growth of many microbes. They attack the added organic matter and break it down. Eventually, the new material is gone but the population of decomposers is still high in the soil. In order to survive, the microflora then attack the native soil organic matter. The end result of this process is that there is less total organic matter in the soil than there was before the new organic material was added to the soil. This happens most often when easily decomposable materials, such as an immature cover crop, are added to the soil (Arsjad and Giddens 1966; Broadbent 1948).

Nearly al1 C loss that occurs after forested land is cleared (such as is frequently the case when a new nursery is established) happens within 20 years and most of that happens in the first 5 years (Davidson and Ackerman 1993). When tilled land is abandoned, it has been estimated that it takes about a century for the soil organic matter leve1 to reach the pre-clearing leve1 (Van Veen and Paul 1981).

Organic residues added to soil, ranging from cover crops to wood waste (sawdust, bark, etc.) decompose over a long period of time. However, there are very short-lived fractions that decompose over periods of hours to days. These are followed by materials that decompose over increasingly long times: days to years, years to decades, decades to centuries, and centuries to millennia (Ellert and Gregorich 1995). Thus, some organic residues remain in the soil for a very long time.

"Proportions of total C in actively cycling fractions typically range from 1 to 20% for mineralizable C, 1 to 5% for microbial biomass C, and 3 to 50% for..." other constituents (Ellert and Gregorich 1995).

About one-third of the added organic C will remain in the soil at the end of the first growing season. Different methods have given rise to somewhat different estimates of just how long added C remains in soil, but it is longer than most expect. Using C-14 dating, the mean residence time in undisturbed forest soils is about 800 years while that in tilled soil is closer to 1200 years. The reason for this difference is that the more easily decomposed C is exposed by tilling and is lost while the most resistant C remains. Thus, the average age of soil C is actually increased by tilling.

Richter et al. (1995), used the ratios of C- 14 to C- 12 to estimate the mean residence time of organic matter in the soil. They estimated that in the South, the most passive C in the soil has a turnover time of about 2300 years while the active C turns over in about 12 years. This suggests that fresh organic matter, such as cover crop material, will decompose rapidly and make little if any long term contribution to the stable ("passive") organic material. It is material that contains significant amounts of lignin that will remain and actually increase the soil organic matter content.

Many people refer to the ratio of C to N in organic matter and try to relate it to seedling production. Severa1 years ago, it was reported that a better indicator was the lignin to N ratio. That ratio at least ignores the mass of cellulose that figures into the C to N ratio but has only a small effect on productivity. More recently Palm (1988) has shown that the ratio of polyphenols to N ratio is an even better predictor of productivity. This is because the polyphenols reflect only the most active part of the lignin and other heterocyclic compounds.

Various materials have been added to nursery soils as sources of organic matter. They range from fresh wood wastes such as bark or sawdust to nutrient-containing fresh materials such as municipal leaves and manures to true composts. Most manures (horse, cow, pig) are safe. Poultry manure has to be handled carefully because the N is present in it as uric acid and this can damage roots. Composting poultry manure with sawdust produces excellent compost that is quite safe to use (Davey 1953; 1955; Galler et al. 1978).

Composts are sufficiently stable for use ahead of the seedling crop. Also, the volume needed is about one-half that of sawdust, etc. Purchased material must be evaluated carefully. For example, mushroom compost was found to receive sufficient additives that a salt build-up in the nursery soil occurred (Davey, unpublished).

There are at least 20 low molecular weight (LMW) organic acids that are part of the soil organic matter. They al1 have molecular weights below 200 (Fox 1995). Oxalic, citric, and malic acids are the most common, but many others do occur. Fungi, including mycorrhizal fungi produce considerable oxalic acid. The average longevity of LMW acids is about 3 days. Thus the amount present at any given time is a balance between formation and degradation (Fox et al. 1990). Since the breakdown occurs so quickly, the formation of these LMW acids must also be rapid and constant.

A factorial experiment involving mycorrhizae, phosphorus, and organic matter added to a soil in which *Erythrina americana* was grown for six months showed that al1 three treatments produced significant favorable effects on seedling growth (Gardezi et al. 1995). Interestingly, the organic matter addition produced the largest effect. The seedlings associated with the main effect of the organic matter were the tallest, had greatest root volume, had a large leaf area, and the greatest above-ground weight. The only caution 1 would add is that the rate of organic matter addition was rather high (0, 2.5, 5.0, and 10%). Also, it was fully humified material.

In addition to the physical and chemical effects of added organic matter (either as cover crops or material transported to the soil) there have been reported biological control of various soil-borne pests such as diseases, insects, nematodes, weeds, and some small animals. Disease and nematode control have received the most attention (Davey and Papavizas 1959; 1960; 1963; Papavizas and Davey 1960; Sayre et al. 1965).

SOIL MANAGEMENT CONSIDERATIONS

It is interesting to consider the soil requirements for organic matter decomposition and seedling root growth. They are almost identical. Both require suitable levels of oxygen, water, acidity, temperature, and nutrients (especially N), and suitable microorganisms. The only real difference is in the suitable microorganisms. For organic matter decomposition we need the decomposer microbes while for seedling growth we need the mycorrhizal fungi and for N-fixing trees we need either the rhizobia for leguminous species or the frankia for actinorhizal species.

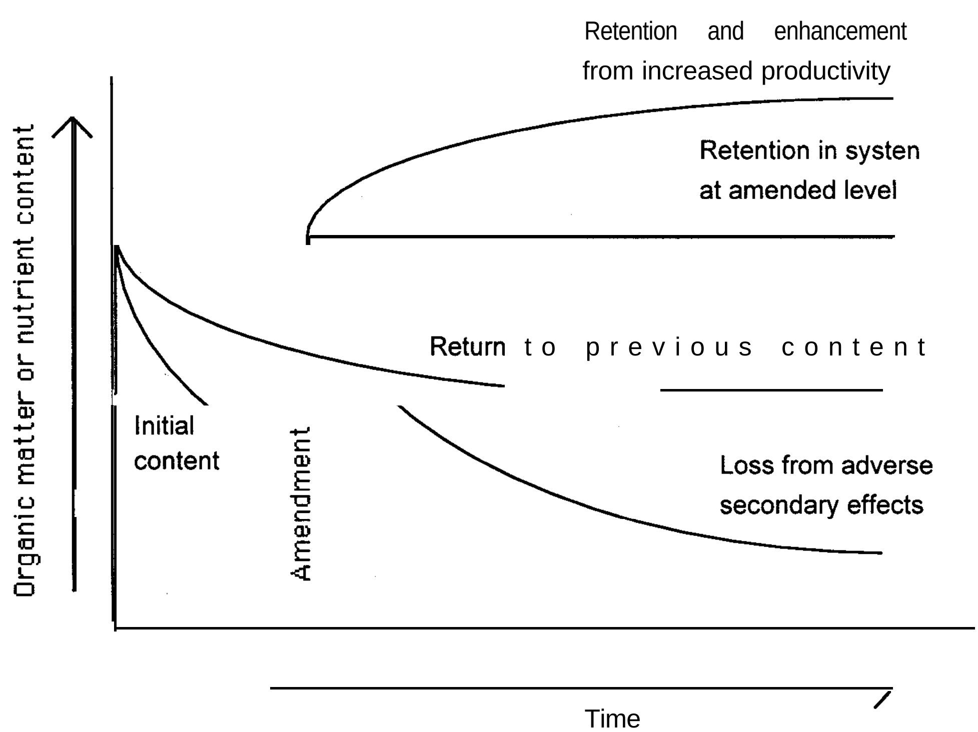
When organic residues such as cover crops are incorporated with the soil, there are about four different outcomes that are possible. There may be an immediate increase in the organic matter and nutrient contents which is followed by vigorous decomposition and leaching which leads to an actual reduction in both organic matter content and nutrient supply. This is the priming effect discussed above. There may be an immediate increase in the organic matter and nutrient contents which is followed by a return to the pre-addition condition. There may be an immediate increase in the organic matter and nutrient contents which is followed by a retention of the elevated state of both. There may be an immediate increase in the organic matter and nutrient contents which is followed by an increase in productivity and the eventual actual increase in both components. Figure 1 illustrates these possible outcomes.

When woody materials (sawdust, bark ,chips, shavings, etc.) are added to soil, supplemental N is needed to avoid serious N shortage in the soil. The period of N immobilization varies with species of wood but generally runs from about 20 days for some hardwoods to 80 days for most conifers. Interestingly, the amount of extra N required is about the same (Allison et al. 1963). It is more strongly related to the amount of the material added to the soil than to the length of time required for its initial decomposition. After the time periods mentioned, the N begins to be re-mineralized and return to the soil in forms that are available to plants. Thus, it acts like a slow-release fertilizer.

Other materials added to nursery soil have included peat and municipal and industrial sludges. These are already nearly stable and require only minimal extra N. However, they also have less effect on the soil biology than sawdust, etc. Conversely, they have a very high CEC. Where available at a reasonable price, these are useful sources of organic matter. The only precaution is that they must be tested for levels of heavy metals to be sure that they are safe to use.

We must differentiate between organic matter that is incorporated with the soil and that which is used as a mulch. Sawdust is the most common material that is used for both purposes. Mulch lies on the soil surface where it has ample oxygen but limited moisture. More importantly, the decomposer microbes have very limited access to the energy in the mulch. The consequence of these factors is that the mulch decomposes very slowly and has very limited effect on the N status of the soil or seedling roots. It does slowly decompose on the soil surface but it poses little if any problem for the trees.

Figure 1. Potential paths of change over time following soil amendment. (Adapted from Harrison et al. 1995).



There are three names given to crops that we grow on nursery land between seedling crops. They are called "cover crops", "catch crops", and "green manure." Cover crops are grown to protect (cover) the soil. Catch crops are grown to catch and hold nutrients from leaching out of the soil. Green manures are grown for the purpose of producing some organic matter for the soil. In actuality, we usually want to do al1 three things with one crop. At the present time most people just use the name "cover crop," but we need to be aware that there actually are the three functions. In some situations, we would change the crop being grown if we wanted to stress one function over the others.

For cover crops, in the South, we tend to use grasses rather than legumes. These range from sudangrass to sudex, to sorghum to millet to milo, depending mostly on the local rainfall. In some places corn is planted. In winter, rye is the most common cover. In the coolest locations, some people use buckwheat - but it has had a history of being associated with fusarium root rots in subsequent seedling crops. When a 2-year cover rotation is used, some woodier materials can be planted, such as pigeon pea, in the first year.

Nutrients that are immediately available to seedlings or cover crops are located in the soil solution. The soil solution is considered a bottleneck through which organic matter in the solid phase must pass before it is converted to available nutrients and other soluble or gaseous constituents (Ellert and Gregorich 1995). The influence of soil management on the amount of soluble organic matter results from differences in soil climate, water fluxes, and the quantity, composition, and placement of the organic residues in the soil.

The presence of low molecular weight (LMW) organic acids strongly affects both chemical and biological processes in soil (Fox 1995). They play an important role in mineral weathering. The availability of nutrients such as P and K increases in the presence of LMW organic acids and thus improves plant nutrition (Marschner 1995). They may also complex Al and reduce Al toxicity. Conversely, the very early or incomplete decomposition of organic matter may lead to detrimental effects on seed germination and plant growth (Papavizas and Davey 1960).

PRACTICAL IMPLICATIONS

Bare root seedling production is a mining operation, as far as soil organic matter goes. Not only does frequent tilling increase organic matter oxidation and expose the soil to wind and water erosion, but lifting and shipping exports much organic matter adhering to the roots.

The organic matter content of nursery soil is usually less than in the forest. There are severa1 possible causes for this: (1) much of the biomass produced in cultivated land is removed in the harvest and that is very true in a crop where the roots as well as the tops are harvested, (2) decomposition rates are higher in cultivated soil because of higher soil temperature during the growing season, (3) the organic substances produced by seedlings or cover crops are less resistant to decomposition than are woody residues in the forest and cultivation increases the exposure of organic materials to microbial attack by soil mixing, (4) reduced rain interception by the crop canopy increases water infiltration into the soil and results in increased leaching of soluble C, and (5) the microbial species composition may change and affect the rate of decomposition (Bouman and Leemans 1995). This last point is especially true following fumigation (Danielson and Davey 1969).

The systems in nursery soil management, organic matter maintenance, and seedling quality represent a bio-feedback system. For this to occur, the influences must work in both directions. Figure 2 illustrates these relations.

In a study of organic matter maintenance in nursery soil, Sumner and Bouton (198 1) reported that the soil organic matter leve1 could be increased with summer cover crops. They showed that after two years, of continuous cover crops the organic matter content increased from 1.1% to 1.4% while the fallow area decreased from 1.1% to 0.9%. These conclusions, while valid, do not really reflect reality. The only true test would have been to complete a ful1 rotation, including one or two seedling crops, and then determine whether the organic matter leve1 remained elevated. 1 doubt that there would have been any real gain. Certainly, at the moment a cover crop is turned under, the soil organic matter level is increased by the amount incorporated with the soil. Then, however, decomposition is very rapid, as discussed above, and the increase is short-lived. The problem is that there is insufficient lignin in most cover crops to produce anything other than a very temporary boost. We must hasten to add, however, that cover crops serve several valuable purposes. Increasing soil organic matter level in a meaningful way, however, is not one of them.

In a recent study of the decomposition rates of soil organic matter particles of differing sizes, it was found that the larger particles decomposed most rapidly while the very fine particles were the slowest to decay (Hassink 1995). The reason for this reversal of expected results can be explained by the fact that the larger particles still contain some easily decomposable materials. Once those materials are gone, the resulting particle is both smaller and more resistant to decay. Finally, the smallest particles are very stable and decay only very slowly. This conclusion was valid in soils from sands to clays. It should be cautioned that in the soil, the age and particle size of the organic matter are inversely related. That is that the older the particle, the smaller it is. When we add fresh materials such as sawdust or bark, the reverse conclusion is reached. That is, that the larger particles are slower to decompose than the smaller one. That is because they are all the same material and age and the smaller particles have more surface area available for microbial attack. These conclusions are both correct and do not contradict each other.

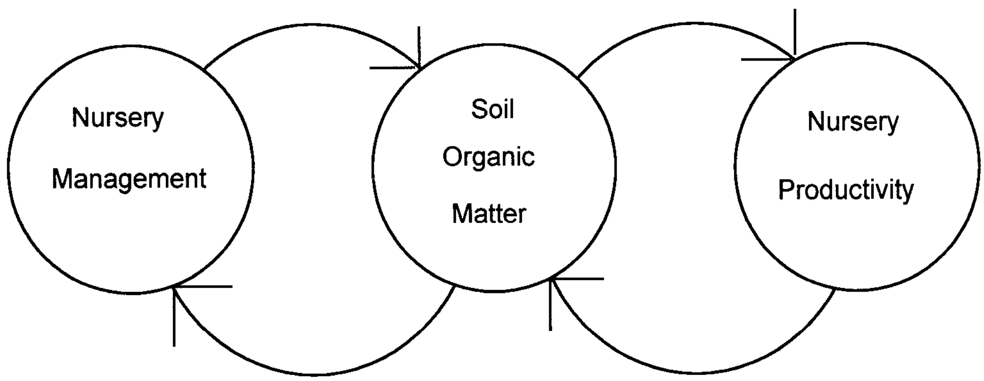
Earlier this year, Jastrow et al. (1996) showed that C associated with small soil aggregates averages 4 12 years in age and for C in large aggregates it is 140 years. This agrees with the work of Hassink (1995) who showed that smaller organic matter particles are more stable and less prone to decomposition than larger particles.

Many nursery managers complain, justifiably, that obtaining organic material to apply to the soil, such as sawdust, bark, chips, shavings, etc., is both time-consuming and expensive. The expense is often due to the distance that these bulky materials must be hauled to the nursery. There is an alternative which solves most of the problems and simultaneously saves money. However, it is rarely used. The idea is to grow your own organic matter in rapidly growing coppice plantations of species such as willow, cottonwood, or paulonia. Then harvest and chip the woody biomass during slow seasons of the year. This provides both organic matter on demand and a use for labor when other operations are not pressing. Transportation should be of very low cost since the wood is grown on or near the nursery. One nursery manager was actually cleaning up small, local woodlots of their "green junk" as a favor to the land owners. It was a win-win situation.

In addition to the various topics discussed so far, we find that soil organic matter level impacts other management practices as well. It has been established that pesticide effectivity is affected by organic matter (Upchurch 1966). Generally, the dose needs to be increased a little where organic matter is in abundance. In fact some people say that this fact is the principal reason they are interested in the organic matter level in the soil.

Organic matter ser-ves as a source of C and energy for many beneficial soil microbes. For example, rapidly decomposing organic matter increases the soil

Figure 2. Linkage among forest nursery soil management, soil organic matter, and nursery productivity. (Adapted from Henderson 1995).



atmosphere leve1 of CO,. This, in turn, is a strong suppressant of the damping-off activity of *Rhizoctonia* (Davey and Papavizas 1960; Papavizas and Davey 1960).

There is a concept that ample soil organic matter and good mycorrhiza development go hand-in-hand. That is true, but it must be understood that organic matter does not usually serve as inoculum for mycorrhiza formation. However, it does enhance formation and activity of mycorrhizae. Table 1 (Davey and Krause 1980) illustrates this point. It is useful to note that both soils were approximately the same texture (a fine sand).

Table 1. Influence of composted sawdust on pine seedling growth and mycorrhiza development.

Soil	Composted Sawdust (m^3/h^a)	Seedling Ht. (cm)	Seedling Wt. (mg)	Mycorrhizal Short roots (Number/plant)
Washed river sand	0	7.9	211	0
Washed river sand	40	20.2	369	0
Sandy nursery soil	0	17.1	216	20
Sandy nursery soil	40	22.9	382	31

Finally, it is informative to understand how the leve1 of organic matter is determined by various laboratories. Nearly all labs sieve soil samples before analysis. Consequently, the comment made earlier concerning organic matter that does not even become part of the sample is general. Beyond that, there are three distinct methods of analysis of samples, once they have been prepared for analysis. Probably the oldest method is called "loss on ignition." In this method a sample is oven-dried, weighed, placed in a furnace (±550° C) until it loses no more weight. At that point it is assumed that all of the organic matter in the sample has burned and any weight loss can be called "organic matter." Unfortunately, the temperature required to burn al1 of the organic matter also begins to break down some minerals. The result is that loss on ignition nearly always over-estimates the actual amount of organic matter in soil. The other two methods were developed at about the same time. One is called "acid hydrolysis" and the second is called "alkaline hydrolysis." Acid hydrolysis is the most commonly used method. In that method a weighed sample of soil is digested in a mixture of concentrated sulfuric acid and potassium dichromate. This method detects most organic matter from the most fresh to most humified. It does not detect charred carbon. Thus, if you were interested in past fire history, this method would miss all the fine charcoal in the soil. It also underestimates the amount of organic matter in the soil. The method has a second, and serious problem. Following the test, the lab is left with a residue that is ver-y strongly acidic and contains lots of the heavy metal, chromium. Some labs have simply been told by their State EPA to stop using the method. The alkaline hydrolysis method is much more "environmentally friendly." It involves soaking the soil sample overnight in a weak sodium hydroxide solution. In the morning the solution is an "iced tea" color and the intensity of the color is measured against a standard to determine the amount of organic matter in the sample. The problem with this method is that the organic materials must be at least partly humified in order to be detected. Thus, this method misses both the non-humified carbon and the charred carbon. If you really want to know the amount of organic matter in the soil, the alkaline hydrolysis method underestimates it the most. The bad news is that a single soil sample analysed by the three methods will give three distinct results. Thus, we always need to know the method used in order to interpret the results. This, of course is also true for nearly al1 soil test results.

SUMMARY AND CONCLUSION

Over the last half-century, emphasis on soil organic matter in forest soils has been continuous (Chandler 1995). The techniques used and the points of emphasis, such as the importance of soluble organic matter, have changed but the importance of organic matter has not (Chandler 1939; Heiberg and Chandler 194 1).

How much organic matter is enough? The answer to this, as we have seen, depends mostly on climate and soil texture. Note that the native leve1 of organic matter in soil is an equilibrium between natural additions and losses. The organic matter does not accumulate indefinitely. The situation in the nursery is the same. We add organic matter to the soil, either as cover crop or materials brought to the nursery such as sawdust or bark. The organic matter decomposes according to the temperature, moisture, and available nutrients, and we export organic matter on the roots of shipped seedlings. If the soil is managed properly, this will lead to an equilibrium, depending on location, somewhere between two and eight percent. The other side of this coin is to ask, can there be too much organic matter? That is easy to answer. NO. Plenty of work has shown that plants grow very well in 1 OO percent compost (Galler et al. 1978; Meyer, 1977). Also, many container mixes are nearly all organic. The reasons for that situation are quite different from the present discussion and will not be pursued further in this discussion.

Increased organic matter in soil will increase efficiency of water and fertilizer use. It will reduce the risk of disease and enhance mycorrhiza formation. Probably the largest benefit, however, will come from improved stock quality. Many nurseries these days are striving mightily to increase their proportion of grade one seedlings. Organic matter will help in this effort. The elusive short-fat seedling can be raised more easily on soil with ample organic matter than on one that is low in organic matter. Many people are lowering seedbed density (almost drastically) in order to increase seedling quality. Think about a decrease from 35 to 17 per square foot. The amount of water and fertilizer needed per seedling are each about doubled. Adequate organic matter may permit a somewhat less drastic decrease in bed density. This translates into less cost for water, fertilizer, and pesticides. This is true since these are all applied on a per acre basis - not a per seedling basis. Even lifting is less time and energy demanding if seedbed density can be maintained at a more moderate leve1 and still produce those grade one seedlings.

The soil needs to contain both dynamic and stable organic matter. They are both important but serve different purposes. The processes of decomposition are hastened by nursery soil management. Consequently, we are always running out of organic matter and must be involved in its restoration. The modern nursery manager is in about the same situation as Sisyphus, that king of ancient Corinth who got in trouble with the Gods. We don't know what angered the Gods but we do know what the punishment was for Sisyphus. He was directed to rol1 a large boulder to the top of a hill. Of course at some point the boulder always slipped and rolled back to the bottom of the hill. As far as we know, Sisyphus is still struggling with that boulder. Nursery soil organic matter maintenance is a similar struggle. We can never really reach a permanent solution to the problem because the organic matter always decomposes or is shipped out of the nursery on the seedlings. Consequently, we and Sisyphus must always keep trying.

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Surwey of Southern Forest Nurseries: Fumigation Practices and Pest Management Concerns[1]

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Abstract-The proposed ban on methyl bromide by the Environmental Protection Agency in 2001 is anticipated to have an adverse impact on forest tree nurseries in the southern region. Surveys in the past have indicated that methyl bromide was the fumigant of choice for southern nurseries. A recent survey of southern nursery managers was conducted to determine what type of alternatives to methyl bromide fumigation are in use or have been attempted, and what pest problems have occurred as a result of these other methods of pest control.

The majority of nursery managers routinely use MBC (methyl bromide with chloropicrin) fumigation for control of pest problems (89%). The most impottant pest problems that currently concern nursery managers are nutsedge followed by post-emergence damping-off. Forty-two percent of nursery managers have used fumigants other than MBC. Dazomet was the most common fumigant tested by nurseries, and only 5 out of 17 nurseries reported that dazomet had the same effectiveness as MBC. Inability to control weeds was cited as the most common problem with the use of dazomet.

Twenty out of 45 nursery managers have attempted to manage a portion of their nursery without the benefit of fumigants. Six of these nurseries were just in the process of establishing studies, while 14 nurseries have been managed for 2 years to more than 10 years without fumigation. Again, weeds were the most frequently listed problem (9 out of 14), followed by diseases (5 out of 14) in unfumigated beds. Only two nurseríes continue to manage their entire nursery without the use of fumigation.

If fumigants were not available, 67% of nursery managers responded that weeds would be a problem and 62% cited pathogens would be a problem in their nursery. When managers were asked what the greatest needs were for management of pest problems, they rated the development of herbicides for control of specific weed problems (80%), and better information on prevention and control of specific disease problems (60%) as high priority needs.

INTRODUCTION

Southern nursery managers are faced with many challenges in their efforts to provide the South with quality seedlings for reforestation. Pests that cause damage to their crops are of great concern. These agents can include diseases, nematodes, insects, competing weeds, chemicals, environmental conditions, and animals. Management of damaging agents is an important part of any nursery's program. The soil fumigant MBC (methyl bromide with chloropicrin) is a broad spectrum fumigant that is used to control soilborne pests. In the South, methyl bromide is an integral par-t of nursery pest management (Boyer and South 1984; Fraedrich 1994). The Environmental Protection Agency has planned to phase out production and use of methyl bromide by the year 2001, which could have an adverse effect on the production of seedlings for reforestation.

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A survey of southern nursery managers was initiated by the USDA Forest Service, Forest Health Unit (R-S), in cooperation with the Southern Research Station to provide specific information on nursery fumigation practices, current pest problems, alternative fumigants, and anticipated pest problems if no fumigant were available. The survey was also designed to gain information on pest problems that nurseries may have had when they managed seedbeds without fumigation.

METHODS

In January 1995, a survey was mailed to 87 managers of state, forest industry, and other private nurseries that produce tree seedlings in the South. The source of the nursery addresses was obtained from the October 1992 issue of Forest Farmer (Anonymous 1992). The survey consisted of a series of questions that required respondents to check the appropriate response or provided a short answer.

Survey responses were summarized and responses to questions were reported as a percentage of respondents. Short answer responses were grouped into major categories and then divided by the total number of respondents.

RESULTS

A total of 45 (52%) of the nursery managers responded to the survey. The percentage of state, industry and private nurseries that answered the survey was 94%, 66%, and 12% respectively. The 45 responses consisted of 25 (56%) from forest industry, 16 (36%) from state agencies, and 4 (9%) from private nurseries.

All of the nursery managers reported that they produce conifers, while only 28% of the respondents grow hardwoods. The species most commonly produced was loblolly pine (table 1). The second most common species grown was slash pine. Hardwoods were often grouped by genus due to the great variety of hardwood species grown by nurseries. Oaks were listed most frequently as a crop produced at nurseries, followed by ash species.

Nursery managers were asked to provide information regarding the pest problems that occur in their nurseries under their current nursery pest management practices. They were also asked to rate the severity of these problems, and indicate whether these problems occurred on a yearly or periodic basis (table 2). The most severe pest problem reported was nutsedge with 18% of managers listing it as a severe-yearly problem, and 33% listing it as a moderate-yearly problem. Some managers also added prostrate spurge under "other" pest problems (9% severe-yearly, 9% moderate-yearly). Pre-emergence and post-emergence damping-off were primarily considered as slight-periodic problems, but 18% of managers listed post-emergence damping-off as a moderate-yearly problem.

Insect pest problems, such as cutworms (Family: *Noctuidae)* and white grubs *(Phyllophaga* spp.), were reported most frequently as a slight-periodic problem. In the "other" category, 4% of nursery managers indicated that lygus bugs cause a severe-periodic problem, and 7% indicated it was a slight-periodic problem. Specific disease problems such as Rhizoctonia blight and Cylindrocladium root rot were reported primarily as slight-periodic pest problems by a small percentage of managers. Most managers did not regard these diseases as problems, or were unsure if they were a problem in their nursery. It is noteworthy that 40%

Table 1. The percentage of nurseries that are producing a particular pine species or hardwood genus

Types of trees produced	Percentage of nurseries (n=45)
Loblolly pine	87
Slash pine	58
Longleaf pine	33
Virginia pine	20
White pine	16
Sand pine	9
Oak	35
Ash	16
Sweetgum	I I
Walnut	9
Sycamore	9

Table 2—Percentage of southern nurseries reporting a pest problem in their nurseries as severe, moderate, or slight on a yearly or periodic basis under current nursery practices (n = 45)

	Severe		Moderate		Slight				
Pest	Y[1]	P[1]	Y[1]	P[1]	Y[1]	P[1]	Unsure	None	N/R[2]
Pre-damping-off		2	7	4	20	38	9	11	9
Post-damping-off		2	18	2	18	53		2	4
Charcoal root rot	2	-	2	4	-	24	13	47	7
Cylindrocladium	9	-	-	-	2	13	20	49	7
Rhizoctonia	2	-	7	4	7	27	13	27	13
Pitch canker	4	-	-		2	20	7	51	13
Fusiform Rust	2	-		2	11*	20		47	16
Seedborne fungi				-	4	13	40	33	9
Cutworms			7	4	13*	29	2	24	16
White grubs		4	4	-	9*	38	2	29	9
Nematodes					11*	22	24	29	11
Nutsedge	18	2	33	4	20	7	2	11	2
Other: Spurge	9	-	9	-	-	-			
Other: lygus bug		4	-	-	-	7			

[1] Y = a yearly problem in the nursery; P = a periodic problem in the nursery.
[2] N/R = no response.
*2 - 4% of nursery managers in this severity rating failed to indicate whether the pest was a yearly or periodic problem.

of managers were unsure whether they had a problem with seedborne fungi, and 24% of managers were unsure if nematodes were a problem in their nursery.

Eighty-nine percent of nursery managers reported that they routinely use MBC in their nursery (Figure 1). Three managers indicated they rely upon other fumigants and two indicated that they did not routinely fumigate their nursery beds. Forty-five percent of nurseries that applied MBC use the formulation with 2% chloropicrin (18 out of 40). MBC with 33% chloropicrin was applied by 30% of the nursery managers. Both formulations were utilized by 25% of those nurseries that use MBC.

Fumigation after every other crop was conducted by 58% of nurseries that rely on MBC. Fumigation with MBC before every crop was reported by 25% of nurseries. Another 8% of the nursery managers reported fumigation before every other crop of pines and before every crop of hardwoods. Only 5% of nursery managers reported fumigation before every third to fifth crop, and another 5% were not fumigating their nursery.

Fumigants other than MBC were used or tested by 19 of the 45 nursery managers (42%); most of these (17 of 45) use or had tested dazomet (Basimid®). Dazomet was reported to be less effective than MBC by ll of the 17 managers. Only 5 managers that applied dazomet reported that its effectiveness was the same as MBC. Chloropicrin is currently being tested by 2 of the responding nurseries; no rating was reported by these managers. Metam-sodium (Busan 1020®) was the only other fumigant listed by a manager to have the same effectiveness as MBC. One nursery manager had tested vorlex (discontinued 199 1 by NOR-AM) and reported it to be less effective than MBC. A new fumigant, consisting of 70% dichloropropene and 30% chloropicrin (Triforme), was tested by one manager and he reported it to be less effective than MBC. When managers were asked what were the problems with other fumigants, al1 answers but one were aimed at dazomet. Poor weed control was the most common problem cited by 7 out of 17 nursery managers who used dazomet. Other problems reported by managers were poor seedling growth, poor mixing with soil , and no benefit (2 out of 17, each category). One manager

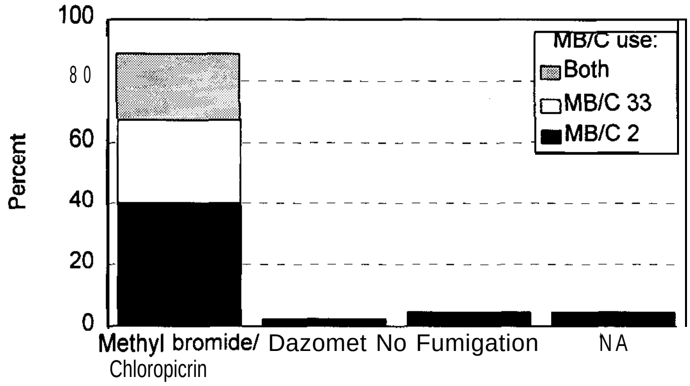

Figure 1. The percentage of southern nurseries that utilize a particular fumigant operationally (n=45).

had difficulty finding a contractor to apply the fumigant and another manager reported the fumigant remained in the soil after it should have dissipated.

Forty-four percent of nursery managers indicated that they have managed areas of their nursery without the benefit of fumigants. Seventy percent of these nurseries (14 out of 20) have had unfumigated areas ranging from 1 acre for 2 years, up to the entire nursery for more than 10 years. The primary pest problem identified by managers that had unfumigated beds were weeds (9 out of 14). Nutsedge was mentioned as a severe to moderate problem in these unfumigated areas by 6 out of 8 nursery managers. Diseases caused by fungi were the second category of pests cited by 5 out of 14 managers as problems in non-fumigated beds. The two disease problems cited were damping-off (3 out of 5) and root rots (2 out of 5). Managers rated these disease problems as moderate to severe. Only one nursery mentioned nematode damage as a problem in non-fumigated beds. Although 44% of managers have managed some portion of their nurseries without fumigation, only 16% of nurseries routinely leave small areas in their nursery unfumigated to determine the effectiveness of fumigation for the prevention of pest problems.

A profile of 6 nurseries that have managed unfumigated areas for 5 years or more is outlined in table 3. The most common pest problems reported by these nurseries were weeds and damping-off. The current fumigation practice at 4 of the 6 nurseries is the use of MBC before every crop, or every other crop. Only 2 nurseries are continuing to manage their seedling crops without fumigation. In both cases the soil texture of these nurseries was sandy clay loam, and the soil was managed for an average of 3% organic matter.

Table 3. Profile of nurseries that have managed areas without fumigation for 5 years or greater

Area	Species		Soil texture	Pest problems	Current fumigation
1/10th acre	5	Loblolly pine	Loam	moderate-slight damping-off	MBC 33 before every other crop.
18 beds	5	Slash pine	Sand	severe nutsedge	MBC 33 before every other crop
Entire nursery	7	Loblolly pine	Sand	poor crop quality; nematodes & root rots were major concerns.	MBC 33 before evety other crop— if they had problems in an area since the last fumigation.
Entire nursery	10	White pine, oaks, poplar, alder	Sandy loam	severe weeds and damping-off.	MBC 2 before every crop
Entire nursery	8+	Loblolly pine, Virginia pine	Sandy clay loam	moderate nutsedge & sicklepod; slight-periodic damping-off & cutworms.	no fumigation-organic matter 2.6-3.9%.
Entire nursery	10+	Loblolly,	Sandy clay loam	severe prostrate spurge; periodically other pests: moderate charcoal root rot; slight damping-off, *Rhizoctonia*, cutworms, and nematodes.	no fumigation; plants longleaf and hardwoods in the fall; organic matter 3%.

Both managers believed that maintaining a high leve1 of organic matter has helped reduce soilborne diseases. One of these nursery managers believed that planting longleaf pine and hardwoods in the fa11 also helped to reduce seedling losses. Both nurseries have had slight-periodic problems with damping-off and cutworm damage. One nursery has a severe problem with prostrate spurge, and the other has moderate problems with nutsedge and sicklepod.

Managers were asked which pests they anticipated to be a problem in their nursery if al1 fumigants were withdrawn from the market. Sixty-seven percent of the nursery managers responded that weeds would be a problem in their nursery (30 out of 45). Nutsedge was the most common weed listed (15 out of 45), followed by spurge (5 out of 45). Sixty-two percent of managers listed diseases as potential problems (28 out of 45). The disease problems listed most often were root rots (14 out of 45), damping-off (7 out of 45), and nematodes (7 out of 45). Specific disease problems reported by nursery managers were charcoal root rot (3 out of 45), Rhizoctonia blight (3 out of 45), and Fusarium diseases (3 out of 45). Other soilborne organisms listed were white grubs (5 out of 45) and cutworms (2 out of 45).

In view of the decision by the Environmental Protection Agency to ban the use of methyl bromide by the year 200 1, nursery managers were asked what they considered to be their greatest needs for the management of pest problems. Managers identified the development of herbicides for control of specific weed problems as their greatest need (Table 4). The second greatest need identified was better information on the prevention and control of specific diseases. Development of systems to forecast insect and disease problems was third in importance.

DISCUSSION

Currently the majority of nursery managers (89%) routinely use MBC formulations to manage pest problems. The number of southern nurseries that use MBC has not significantly changed since Boyer and South (1984) surveyed southern nursery managers in 198 1. However, the frequency of fumigation use has dropped from 60% (Boyer and South 1984) to 25% of nurseries fumigating before every crop. The drop in frequency of fumigation was probably due in part to the development of herbicides that provide adequate control of many weeds in pine seedbeds at one tenth the cost of fumigation (South 1980; South and Gjerstad 1980). Also, there is evidence that fumigation can provide good control of root diseases for up to 3-4 years after fumigation (Hodges 1962).

The use of fumigants by nursery managers for weed control has been well documented throughout the United States (Boyer and South 1984; Fraedrich 1994; South 1980; South and Gjerstad 1980). In 1980, South and Gjerstad reported that the use of MBC fumigation in pine seedbeds for weed control was justified when the incidence of perennial weeds was severe; otherwise herbicides could provide effective control of weeds. They stated further that nursery managers could reduce their fumigation costs by as much as two-thirds, if they used fumigation as needed for nutsedge and disease control. Only in hardwood seedbeds was routine fumigation economically justified for weed control (South and Gjerstad 1980).

Table 4. The greatest needs of nursery managers for management of pest problems in view of the expected ban of methyl bromide in 2001.

Needs for the future	Priorities high	medium	low	NR[1]
Development of herbicides for control of specific weeds	80	18	0	2
Information on prevention and control of specific diseases	60	33	2	4
Development of systems to forecast pest problems	44	36	16	4
Information on prevention and control of specific insects	27	60	11	2
Better information on control of seedborne diseases	29	27	40	4
Better practices for the production of high quality seedlots	29	24	40	7

[1] NR = No Response.

Why did nursery managers report that weed control was still the primary reason for application of MBC? In a 1993 survey, over half of southern nursery man-gers indicated that herbicides were not an effective alternative to soil fumigation for weed control (Fraedrich 1994). The lack of selective herbicides for control of weeds in hardwood seedbeds, and the ineffective control of nutsedge and spurges in conifer beds, were the primary reasons for the belief that herbicides would not be an adequate substitute for fumigation (Fraedrich 1994). Dazomet, the most common alternative fumigant currently used, has been reported to be less effective than MBC in controlling weeds such as nutsedge or prostrate spurge (Alspach 1989; Carey 1995; Chapman 1992; Hildebrand 1991; Hildebrand and Dinkel 1989). In this survey, nutsedge was reported to be the greatest problem in nurseries and is expected to be the greatest future problem if fumigants were not available. This expectation was realized at 6 of 14 nurseries that found nutsedge to be a severe to moderate problem when fumigation was not used for more than two consecutive crops. The lack of effective weed control by available herbicides and alternate fumigants helps to explain the emphasis that managers place on technology development of herbicides for control of specific weeds.

In addition to controlling weeds, fumigation with MBC has been used by nursery managers to prevent soilbome diseases (Boyer and South 1984). Southem nursery managers rated fumigation for disease control as moderate to high in importance in a 1993 survey (Fraedrich 1994). This perception may be due to the view that fungicides are not an effective control of diseases when compared to fumigation (Fraedrich 1994). The results from this survey, compared to the 198 1 survey by Boyer and South (1984), showed an increase in the nurseries who reported pre- and post-emergence damping-off, however, the severity of the problem was classified as slight in both surveys. The reduction in the use of MBC from 1981 to 1994 may account for the reported increase in the occurrence of damping-off. One reason that many managers maintained a reduced fumigation schedule may be because the expense of fumigation was not warranted if the damage was slight (Hodges 1962).

Only a few nurseries listed specific root diseases as the cause of severe-yearly problems. The majority of nursery managers who reported root disease problems rated the severity as slight, as did nursery managers in 198 1 (Boyer and South 1984). Results of the present survey indicated that many managers were unsure of whether they had root disease, seedbome disease, or nematodes in their nursery. The regular use of fumigation by the majority of nurseries would reduce the potential for a severe outbreak of any soilbome pathogen. If no fumigants were available, two-thirds of managers believed that soilbome pathogens would become a problem. Comparatively, only a third of the managers who left part of their nursery without fumigation, reported moderate to severe losses from damping-off and root rot.

Seventeen nursery managers have used dazomet and none indicated that damping-off or root rot was a problem when this fumigant was used. The results of severa1 studies in the westem United States have shown that dazomet was as effective as MBC at controlling damping-off and root disease on conifers (Alspach 1989; Campbell and Kelpsas 1988; Hildebrand 199 1; McElory 1986; Tanaka *et al.* 1986) Other studies have shown that areas treated with dazomet had higher populations of potential pathogen in the soil, however, seedling survival and size surpassed or equaled those treated with MBC (Campbell and Kelpsas 1988; Tanaka *et al.* 1986). These survey results, coupled with past research, indicate that dazomet is a possible altemative fumigant for controlling damping-off and root diseases in pine nurseries.

Parasitic nematodes were reported to be a slight problem in about a third of the nurseries. However, almost as many managers were not sure if nematodes were a problem in their nursery. Only a few managers believed nematodes would be a problem if fumigants were not available. These results correspond to a 1993 survey that found over half of managers surveyed considered the use of fumigation for nematodes as low or not important (Fraedrich 1994). The low concem of managers towards nematode control is perhaps justified considering that effective nematicides are available.

Insect pests, such as cutworms and white grubs, were considered a slight problem in nurseries. In fact, none of the nurseries that managed without fumigation listed insects as a problem. In 1935, Wakeley stated that white grubs were a persistent and destructive nursery pest, and that even a light infestation of grubs could reduce stocking by 10-20%. Wakeley (1935) also reported that cutworms were considered less serious, except when populations were high. The present routine use of fumigation has probably helped to maintain low populations of grubs and cutworms. Insecticides can also provide effective control when fumigation is not used (Bacon and South 1989), therefore, few nursery managers have anticipated that cutworms or grubs to be a problem if al1 fumigants were withdrawn from the market.

Alternate fumigants are being tested in many nurseries in the South (Carey 1995). Whether any of these fumigants will replace MBC in effectiveness as a biocide is unknown at this time. Nursery managers may have to use a more comprehensive IPM program to control soilborne pests when methyl bromide is no longer available. The primary problem with alternate fumigants is the poor control of nutsedge and spurge. Until more selective herbicides are developed, nurseries that do not have access to selective herbicides will have to be more aggressive in their sanitation efforts

The use of alternative fumigants and other pesticides to replace MBC may be short-term solutions (Civerolo et *al.* 1993; Fraedrich 1994; Kannwischer-Mitchell *et al.* 1995). Public concern over environmental quality, and human health and safety, has continued to increase over time, therefore, altemative fumigants to MBC may be challenged by environmental regulations in the future (Civerolo *et al.* 1993). Long-term research priorities, outlined at the USDA Workshop on Alternatives to Methyl Bromide, were to develop new cultural/crop production systems, and integrate existing cultural practices that are appropriate (Civerolo *et al.* 1993). Nationwide studies are being conducted in public and private nurseries to evaluated altemative soil and crop management systems and their effect on soilbome diseases (James *et al.* 1994; Littke 1994). Initial results are promising (Bamard *el al.* 1996; Hildebrand 1996; Stone *et al.* 1996), however, this may be due to a lack of disease pressure. Significant disease pressure may not occur in the first couple of years for many nurseries that have been using fumigation for decades.

The future management of southem nurseries depends on exploration of various methods to manage nursery pest problems including altemate fumigants, selective herbicides, and cultural practices. Nurseries may be able to maintain quality seedling production with the integration of these altemate methods into their current pest management. The more information and management options that a nursery has available, the more readily a nursery can adjust to changes in pesticide availability.

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Testing Alternatives to Methyl Bromide Fumigation in Southern Forest Tree Nurseries[1]

William A. Carey[2]

In the southern United States, most bareroot forest tree seedlings are produced in nurseries with average annual productions of over 2 1 million seedlings. Just two species of southern pine, Loblolly *(Pinus taeda)* and Slash (P. *elliottii)* account for more than 90% of these seedlings (Carey and Kelley 1993). Most of these nurseries regularly use soil fumigation with methyl bromide (MBr) to control specific, persistent, disease and insect pests, weeds, and a spectrum of usually unidentified agents that otherwise reduce seed efficiency and seedling size in non-fumigated beds.

The Auburn University Southern Forestry Nursery Management Cooperative, with the cooperation of Hendrix & Dail Inc., has over the last three years installed ll trials in which the efficacies of registered, alternative, fumigants were compared. Our primary concern has been to determine which alternatives most economically enhance production of seedlings with characteristics correlated with good survival and growth after outplanting. Because larger seedlings consistently survive and grow better after outplanting (South and Mexal 1984) both numbers and the size distribution of seedlings should be evaluated. Populations of selected soil microorganisms were also evaluated as indicators of the possible causes for differences in seedling growth among treatments.

In al1 trials, alternative fumigants were compared to beds fumigated with 235 lbs/ac MBr plus 115 lbs/ac chloropicrin (350 lbs/ac MC33) and to non-fumigated beds. The treatments evaluated, with the number of comparisons in parentheses, are as follows; chloropicrin (8), metham sodium (2), dazomet (6), 1,3 dichloropropene plus chloropicrin (6), metham sodium plus chloropicrin (3), and dazomet plus chloropicrin (1). Seedbeds fumigated with chloropicrin or with 1,3 dichloropropene plus chloropicrin yielded similar sizes and numbers of seedlings and also generally effected the populations of the surveyed soil fungi (primarily *Trichoderma* and *Fusarium)* similarly to beds fumigated with MC33. None of the tested treatments controlled *weeds* as well as MBr.

There was little post-germination mortality in either fumigated or not fumigated beds in our trials. However, because these trials have been in soils fumigated few rotations ago with MBr, these results could underestimate potential differences over a longer term. Nevertheless, even without differences in mortality, the better fumigants increased seedling sizes enough to have been cost effective (based on the expected differences for growth and survival after outplanting).

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Growing Bareroot Seedlings without Fumigation at the Bowater Nursery[1]

Mike Williford[2]

Abstract-The Bowater Newsprint Carters Nursery has been producing bareroot pine seedlings without soil fumigation for many years. Practices contributing to this success include soil organic matter amendments, good water drainage, chemical and hand weed control and quick response to pest problems. Crops are grown on a 1 :1 rotation with cover crops managed intensively on areas not growing seedlings. Operating without soil fumigation increases the risk of disease and pest invasion and requires a higher tolerance for early season weed populations.

BACKGROUND

The Bowater Newsprint Carters Nursery has been in operation since 1975. It was created to replace the original nursery near Vonore, Tennessee, which had been in use since the mid 1950's. That nursery was flooded by the TVA in the Tellico Lake project. The combined production of both nurseries to date has been nearly 800 million seedlings.

The primary purpose of Carters Nursery is to supply seedlings for reforestation of lands supporting the Calhoun, Tennessee newsprint mill. The predominant species grown is loblolly pine from either piedmont or mountain provenances. Small numbers of Virginia pine seedlings are grown each year for Christmas tree growers and reclamation work. Other minor pine species are occasionally grown to meet special needs or requests. Approximately 40% of the yearly crop is currently sold to outside customers.

SOILS

Soils of the Carters Nursery are predominantly classified as Sullivan series; deep alluvials described as dystric fluventic eutrochrepts, fine-loamy, siliceous, thermic. Texturally, the soil ranges from a silty clay loam to a sandy clay loam. With pH values between 5.0 and 6.0 and inherently good fertility, these soils are highly productive and produce excellent seedlings. Operational drawbacks include limited ability to manipulate seedling growth through nutrient or water management and equipment access limitations during wet weather.

FUMIGATION

Soil fumigation of bareroot pine seedling nurseries has been practiced for many years and is acknowledged to provide severa1 benefits. Among these are the control of soil borne fungi and nematodes and some control of certain weed species. Additional benefits attributed to fumigation include improved seed efficiency and increased seedling size (usually reported as increased biomass per unit of growing space) when compared to unfumigated crops. In essence, individual cultural practices are substituted for fumigation in the Bowater nursery to achieve each of these benefits.

Carters Nursery was fumigated before the initial crop was planted. Records indicate that eight acres were fumigated in 198 1 to control a Pythium root rot

[1] *Williford, M. 1996. Growing Bareroot Seedlings without Fumigation at the Bowater Nursery. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 29-31.*

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problem and two acres were fumigated in 1987 prior to installation of a mycorrhizae study. Both treatments were made with 400 pounds per acre of MC-2. Other than these noted exceptions, the nursery has been operated without fumigation to date. The decision to manage without fumigation has not been based simply on cost avoidance or environmental concerns, but rather on the belief that it has not been necessary. Calculated seed efficiencies have consistently exceeded 0.70, targeted seedbed densities are routinely realized and field performance of the seedlings has been good.

Operating a bareroot seedling nursery without fumigation is acknowledged to carry an element of risk. In the spring of 1996, a section of the nursery that had been cover-cropped for five consecutive years was sown with loblolly pine seed. Weather conditions at time of germination allowed damping-off fungi to proliferate and cause failure of nearly one-half acre of a particular seedlot. Interestingly, adjacent beds of the same seedlot sown three days later were essentially unaffected. This occurrence serves as a reminder that each nursery manager should make their own risk-vs-cost assessment to determine whether they can afford the occasional problem that might be prevented with regular fumigation.

CULTURAL PRACTICES

Successful crops of seedlings have been produced from the Bowater nursery through a disciplined cultural regime. Essentially, there are three components to the program: soil management, intensive weed control and prompt response to problem areas.

One of the most critical aspects of producing seedlings in fine textured soils is maintaining organic matter levels. The Bowater nursery is nominally on a 1: 1 rotation. Areas not in seedlings receive an application of approximately 65 cubic yards per acre of sawdust prior to planting cover crops. Corn and grain sorghum are the primary cover crops grown and are managed intensively. After grain harvest the stalks are chopped with a silage cutter, lightly disked in and overseeded with winter wheat to reduce soil erosion. Bark mulch used on the seedbeds retains its integrity for up to a year and supplements the sawdust and cover crop organic amendments. Benefits derived from elevated soil organic matter levels include enhanced soil microbial activity, better soil porosity and improved soil drainage.

Complementing management of soil organic matter has been attention to both surface and subsurface water drainage. Particular emphasis is placed on moving water off the site quickly. Fields are leveled with a land plane prior to shaping beds to eliminate any low spots. After shaping the raised beds, bed ends are graded to open the aisles and allow release of water. Internal soil drainage is enhanced by deep chisel-plowing (18 - 24") on two foot centers before shaping beds. Subterranean drains have been installed in areas that were poorly drained to move subsurface water.

WEED CONTROL

Weed control requires an intensive regime of sanitation, hand weeding and herbicides. The two most persistent problem weeds in this nursery are sicklepod and yellow nutsedge. Coincidentally, fumigation does not effectively control either species. Other common but less intrusive weed species present include morning-glory, crabgrass, carpetweed, chickweed, eclipta, prostrate surge, johnsongrass and evening primrose. Most of these minor weeds are easily controlled by herbicides. Weed control in the seedbeds begins with sanitation in the cover crops. An effort is made to eliminate weeds before they reach maturity in cover crops, along irrigation lines and in adjacent non-crop areas.

Weed control in the seedlings consists of the accepted standards of pregermination oxyfluorfen application at sowing followed by alternating treatments or tank mixes of oxyfluorfen, sethoxydim and lactofen. Two tenets of weed control in an unfumigated nursery should be understood:

1) early season weed populations will be higher and

2) the amount of hand weeding necessary will be greater than in fumigated nurseries. Hand weeding of Carters Nursery averaged 29 man-hours per acre last year.

NEMATODES AND FUNGI

One of the obvious benefits from soil fumigation is control of nematode and fungal populations. At Carters Nursery, a nematicide (ethoprop) is soil incorporated prior to planting cover crops. Pre-plant drenches and post-emergent sprays of captan are applied to control damping-off fungi. In addition, spot sprays of metalaxyl are used to control any small problem areas that might occur. While not as effective as soil fumigation, these prophylactic and remedia1 sprays have kept the organisms under reasonable control.

SUMMARY

The Bowater nursery has produced quality bareroot pine seedlings without fumigation for many years. The key elements of this success have been soil organic matter management, intensive weed control and attention to water drainage. Managing an unfumigated nursery requires precise prescription and timing of herbicide applications. It also requires a tolerance for high early season weed populations until seedlings have reached the growth stage where herbicides can be applied.

Fumigation has been used at Carters Nursery in the past to correct specific problems and will remain a management option as long as it is available. Alternate management practices will continue to be developed as well. Trials of alternative cover crops, rate and timing refinement of herbicide applications and evaluating substitutes for methyl bromide fumigation will continue.

Development and Field Performance of Slash and Loblolly Pine Seedlings Produced in Fumigated Nursery Seedbeds and Seedbeds Amended with Organic Residues[1,2]

E. L. Barnard[3], M. E. Kannwischer-Mitchell[3], D. J. Mitchell[4], and S. W. Fraedrich[5]

The Montreal Protocol assessment of 199 1 identifying methyl bromide as a chemical contributing to the depletion of the stratospheric zone layer and the U.S. Environmental Protection Agency's (EPA) proposal to eliminate the production and use of methyl bromide pursuant to the U.S. Clean Air Act of 1990 (Civerolo, et al.; Smith and Fraedrich 1993) have generated a flurry of activity to identify and assess alternatives to methyl bromide for the control of pests in forest tree nurseries. As part of a national initiative funded by the United States Forest Service (James, et al. 1993), we have grown southern pine seedlings (*Pinus elliottii* Engelm., *P. taeda* L. and *P. palustris* Mill.) in southern forest nurseries in successive years in seedbeds amended with pine bark or composted organic residues, or treated with methyl bromide. Project objectives include the following:

1) assess effects of organic soil amendments on disease suppression and seedling production/quality;

2) evaluate the field outplant performance of treated seedlings;

3) assess comparative costs and benefits;

4) develop methods and baseline data for nursery disease forecasting and/or risk assessment.

Progress reports have been provided periodically (Barnard, et al. 1994; Barnard et al. 1996; Kannwischer-Mitchell, et al. 1994), and this paper updates our results in anticipation of a final report as we enter our fourth, and likely final, project year. The focus of this paper is on seedling development and field performance. Microbiological data and nutrient data for seedlings and soil, collected primarily for analytical purposes, are still being developed and will be published in detail upon completion of the project.

Three nurseries are involved in this project. However, the following unanticipated problems have limited the value of information from longleaf pine at the U.S. Forest Service's Ashe Nursery in Brooklyn, Mississippi.: major infestations of nutsedge (*Cyperus* spp.); 1.5-year as opposed to annual crop rotations; a confounding influence of a possibly seedborne infec-

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[1]*Barnard, E.L.; Kannwischer-Mitchell, M. E.; Mitchell, D. J.; and Fraedrich, S. W. 1996. Development and Field Performance of Slash and Loblolly Pine Seedlings Produced in Fumigated Nursery Seedbeds and Seedbeds Amended with Organic Residues. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 32-37.*

[2]*This paper also appears in the Proceedings of the third Meeting of the International Union of Forest Research Organizations' Working Party on Diseases & Insects in Forest Nurseries. Gainesville, FL. May 19-24, 1996*

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tion by *Fusarium subglutinans* (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun, & Marasas; and necessary mid-study plot relocations. Accordingly, this paper includes data for only slash pine at the Florida Division of Forestry's Andrews Nursery in Chiefland, Florida, and loblolly pine at International Paper Company's Supertree Nursery in Blenheim, South Carolina.

MATERIALS AND METHODS

Field trials began in the Division of Forestry's Andrews Nursery in 1993 and in International Paper Company's Supertree Nursery in 1994. Fumigated study plots received standard operational treatment with methyl bromide prior to the sowing of each seedling crop. Plots amended with organic residue received annual applications of either pine bark or composted organic materials. Composted organic residues consisted of composted yard waste at Andrews Nursery in 1993 and 1994, aged hardwood bark at International Paper Company's Supertree Nursery in 1994, and a commercially available composted municipal waste from Tennessee (Bedminster, Inc.) in both nurseries in 1995 and 1996. These materials were applied at 1X (2.5 cm layer) or 2X (5.0 cm layer) rates and mechanically incorporated into seedbed soils to a depth of 15-20 cm prior to the sowing of each seedling crop. Check plots received no treatment other than routine soil tillage and seedbed preparation, which was standard across all treatments. All plots were operationally irrigated, fertilized, and treated with topically applied herbicides. No special treatments were applied to any particular plots, with the exception of the, 1996 compost plots at Andrews Nursery which received an additional 560 kg per hectare of sulfur to ameliorate a treatment-induced pH problem. Plots were installed as indicated in figures 1 and 2.

Seedling stand counts were performed periodically in three permanent subplots in the center of each treatment plot. In addition, seedlings from each treatment plot were systematically sampled at early season, mid-season, and end of season for comparative morphology measurements, nutrient analyses, and rhizosphere microbe assays. Soil samples collected simultaneously with seedling samples were subjected to standard nutrient and nematological assays. Also, soils from the Andrews Nursery plots periodically were assayed for qualitative and quantitative comparisons of soil microbe and pathogen populations.

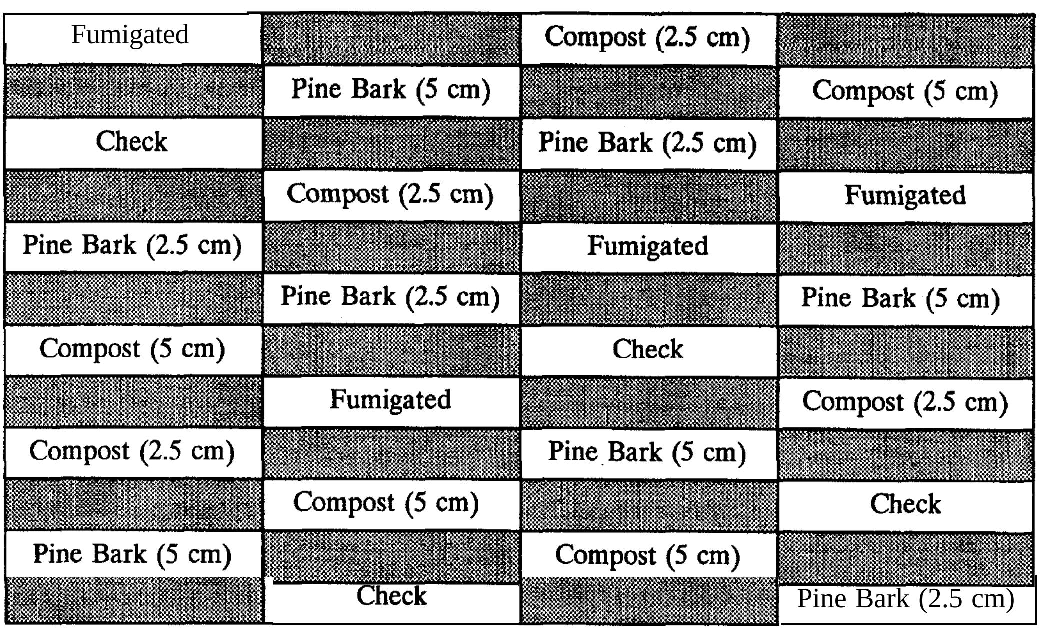

Figure 1. Field layout of study plots at the Florida Division of Forestry's Andrews Nursery in Chiefland, FL. Individual treatment plots are three seedbeds wide (3.7 m) by 36.6 m long. Fumigated borders are indicated by shaded areas.

Fum		Ch		Ch		Fum		Com		Fum
Com		Com		PB		PB		Ch		
PB		Fum		Com		Ch		PB		

Figure 2. Field layout of study plots at International Paper Company's Supertree Nursery in Blenheim, SC. Individual treatment plots are three seedbeds wide (3.7 m) by 12.2 m long. Fumigated borders are indicated by shaded areas (Fum=fumigated, Com=compost 2.5 cm, PB=pine bark 2.5 cm, Ch=check).

At the end of each nursery year, seedlings from each treatment plot were outplanted onto operationally prepared reforestation sites in three replicate 50-seedling row plots in a randomized complete block design. Survival and growth of these seedlings were periodically monitored and measurements were taken at the end of the first growing season following outplanting.

RESULTS AND DISCUSSION

Treatment effects thus far have not been large. Although interesting and sometimes subtle treatment differences with respect to rhizosphere microorganisms, seedling nutrition, and seedling size, are apparent, few statistically signilicant differences were consistent among treatments across study years. Organic residue amendments have clearly influenced soil organic matter and pH. For example, soil organic matter in composted yard waste-amended soils (2X rate) in the Andrews Nursery were above 2.0% after two seedling crops, while that in al1 other soils was between 0.5 and 1 .O%. Similarly, seedbed soil pH values in the Andrews Nursery were well above 6.5 after 2 years of amending with composted yard waste, whereas pH values in al1 other treatments were approximately 5.0. However, across the board, differences in seedling quality and field performance have been minimal. Tables l-4 provide a summary of our seedling quality and performance data to date. Field performance data for the 1995 nursery seedling crops will be collected during the winter of 1996-97, and 1996 crop data are still being collected.

Of interest is the fact that serious root disease problems have not occurred in our study plots, despite the fact that plots at the Andrews Nursery were purposely located in a compartment with a history of charcoal root rot caused by *Macrophominaphaseolina* (Tassi) Goid. In fact, the only indication of any root disease present in our plots, and this has been relatively inconsequential, has been scattered damping-off, apparently caused by species of *Fusarium, Pythium, Rhizoctonia* (or *Rhizoctonia-like* fungi), and possibly other fungi. In the 1993 seedling crop at Andrews Nursery, damping-off, apparently due in large measure to *Pythium myriotylum* Drechs., resulted in a statistically significant reduction in seedling numbers in our check plots as compared to methyl bromide-treated plots (table 1). This difference was not maintained in the 1994 and 1995 seedling crops, however, even though treatment plots have been maintained in the same locations throughout the study.

Organic residues used as soil amendments in this study were not selected because of their particular perfection or demonstrated utility. Instead, they were selected because of their ready availability and potential utility with respect to suppression of soilborne pathogens (Hoitink and Fahy 1986; Pokorny 1982). Rates of application have been arbitrar-y, but one of our objectives has been to sufficiently load soils typically deficient in organic matter to induce over time beneficial changes in soil microflora. Data are still being collected and analyzed with respect to soil microbial responses, but on a macro level1 it appears that pine bark is generally preferable as an amendment to the composted materials used in our studies.

Table 1. Slash pine seedling production and morphology at the Division of Forestry's Andrews Nursery in Chiefland, Florida.=

Measurement	Check	Methvl Bromide	Pine Bark (2.5 cm)	Pine Bark (5.0 cm)	"Compost" (2.5 cm)	"Compost" (5.0 cm)
		1993 Crop Year				
Seedlings per 929 cm² (1 ft²)	15.3 b	20.0 a	17.6 ab	17.7 ab	18.0 ab	18.2 ab
Height	19.5 c	25.2 a	21.8 bc	22.5 ab	23.6 ab	21.1 bc
Root Collar Diameter (mm)	4.6 a	4.9 a	4.5 a	4.4 a	4.7 a	4.6 a
Shoot/Root Ratio	2.4 a	2.9 a	2.8 a	2.4 a	2.9 a	2.5 a
		1994 Crop Year				
Seedlings per 929 cm² (1 ft²)	20.9 a	22.1 a	22.2 a	22.1 a	21.4 a	20.4 a
Height (cm)	24.6 c	29.1 a	26.2 bc	24.9 bc	29.3 ab	27.9 bc
Root Collar Diameter (mm)	5.2 a	4.8 a	4.8 a	5.2 a	5.1 a	5.4 a
Shoot/Root Ratio	3.1 ab	3.6 a	3.3 ab	3.0 bc	3.6 a	3.4 ab
		7995 Crop Year				
Seedlings per 929 cm² (1 ft²)	24.3 bc	26.2 ab	27.3 a	25.2 abc	23.4 bc	22.7 c
Height (cm)	23.9 b	28.6 a	25.7 b	23.6 b	28.4 a	25.7 b
Root Collar Diameter (mm)	4.7 bc	4.7 abc	4.4 cd	4.2 d	5.2 a	4.9 ab
Shoot/Root Ratio	3.6 ab	4.3 a	3.5 b	3.4 b	3.8 ab	3.5 b

ᶻ Mean seedling counts based on twelve subplot counts per treatment. All other means based on measurements of 160 seedlings per treatment. Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 2. Loblolly pine seedling production and morphology at International Paper Company's Supertree Nursery in Blenheim, South Carolina.ᶻ

Measurement	Check	Methvl Bromide	Pine Bark (2.5 cm)	"Compost" (2.5 cm)
	1994 Crop Year			
Seedlings per 929 cm² (1 ft²)	28.8 a	26.4 ab	24.7 ab	23.8 ab
Height	33.6 ab	35.3 a	33.3 ab	31.7 ab
Root Collar Diameter (mm)	5.0 ab	5.1 ab	5.4 a	4.6 a
Shoot/Root Ratio	3.9 a	4.1 a	3.5 b	3.6 b
	1995 Crop Year			
Seedlings per 929 cm² (1 ft²)	23.3 ab	23.9 a	21.4 b	24 a
Height (cm)	28.7 b	28.6 b	27.2 b	31.5 a
Root Collar Diameter (mm)	4.2 a	4.1 a	4.2 a	4.4 a
Shoot/Root Ratio	3.2 b	3.3 b	3.5 b	4.2 a

ᶻ Mean seedling counts based on twelve subplot counts per treatment. All other means based on measurements of 160 seedlings per treatment. Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 3. First-year field outplant performance of slash pine seedlings from the Division of Forestry's Andrews Nursery in Chiefland, Florida.[z]

	Treatment					
			Pine Bark		"Compost"	
Measurement	Check	Methvl Bromide	(2.5 cm)	(5.0 cm)	(2.5 cm)	(5.0 cm)
		1993 Seedling Crop				
Survival (%)	100 a	99.2 a	99.3 a	99.2 a	99.3 a	99.7 a
Height (cm)	*56.7* ab	*53.4* b	59.4 ab	*60.7* ab	59.9 ab	*62.6* a
Fioot Collar Diameter (mm)	*20.7* a	19.1 a	*20.3* a	21.9 a	*20.8* a	*22.2* a
Plot Voiume Index[x]	121.7 ab	100.0 b	123.6 ab	146.1 ab	129.5 ab	157.0 a
		1994 Seedling Crop				
Survival (%)	99.6 a	98.8 a	100.0 a	99.0 a	99.2 a	99.4 a
Height (cm)	51.1 a	52.9 a	*55.4* a	*53.3* a	55.1 a	*55.8* a
Root Collar Diameter (mm)	15.1 a	14.6 a	15.9 a	16.4 a	16.1 a	*17.3* a
Plot Volume Index	58.9 a	59.5 a	*72.7* a	71.6 a	*72.2* a	*83.6* a

[z] Survival means based on twelve, 50-tree plots per treatment. Mean heights based on 25 seedlings per plot (=300 seedlings per treatment). Mean root collar diameters based on 15 seedlings per plot (1=180 seedlings per treatment). Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 4. First-year field outplant performance of loblolly pine seedlings from International Paper Company's Supertree Nursery in Blenheim, South Carolina.[z]

	Treatment			
Measurement	Check	Methyl Bromide	Pine Bark ((2.5 cm)	"Compost" m)
		1994 Seedling Crop		
Survival (%)	97.0 a	97.5 a	95.5 ab	97 a
Height (cm)	52.9 a	*53.4* a	51.4 ab	*48.8* b
Root Collar Diameter (mm)	*8.6* ab	9.0 a	*8.2* b	8.1 b
Plot Volume Index	19.0 ab	21.3 a	16.5 b	15.7 b

[z] Survival means based on twelve, 50-tree plots per treatment. Mean heights based on 25 seedlings per plot (=300 seedlings per treatment). Mean root collar diameters based on 15 seedlings per plot (=180 seedlings per treatment). Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

The lack of root disease development to date has pretty much precluded meaningful evaluation of our organic residue amendments with the respect to suppression of disease development. Nonetheless, the lack of disease development and the failure of seedlings in fumigated soils to develop or perform better than those in unfumigated soils even those soils not receiving any amendment, raises legitimate questions regarding the need for and cost-effectiveness of the routine use of methyl bromide for root disease control in these two test nurseries.

Much more can (and will) be said regarding the issue of methyl bromide fumigation in forest tree nurseries. To date our data are inconclusive, discouraging, or encouraging depending upon one's point of view and the particular data being considered. At the least, our data, to be summarized in detail upon project completion, will provide a substantial and useful baseline from which to continue discussions and consider new approaches.

ACKNOWLEDGEMENTS

The authors express their appreciation to Charles Affeltranger, Ernie Ash, Steve Gilly, Michelle Cram, Chuck Gramling, International Paper Co. and Jefferson Smurfit Corporation for invaluable support rendered to this effort. Funding for this work has been provided by the U.S.D.A. Forest Service, Region 8, Forest Health.

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Bottom-Land Hardwoods for Today's Market[1]

Randy Rentz[2]

Abstract-Columbia Nursery, of the Louisiana Department of Agriculture and Forestry, has been producing seedlings both pine and hardwood since 1956. We currently grow 5 - 6 million loblolly pine and 3.5 - 5.5 million hardwoods annually. The demand for hardwoods in the market today has far exceeded the research in managing and growing these species. Therefore, most nursery men and women have been left to manage on their own.

When we say bottom-land hardwood for today's market, it is very important that we first define the market. In most cases, it is bottom-lands which were once in some type of agriculture production or cut-over wetlands, being either machine or hand planted, at a minimum cost to the landowner, and not necessarily for timber production but for multiple uses. It also, in many instances, has a tendency to be inundated with water at some point in its cycle, therefore, species selection for specific sites can be critical. In the nursery setting, hardwood performance can be quite erratic between species, and each species, even though they are grown under the same general conditions, must be handled separately.

SOIL MANAGEMENT

Columbia Nursery has a silt loam soil, which is a very fertile soil with a high capacity for retaining moisture. By today's standards, most would consider this a poor nursery site. But its capacity for growing high quality hardwood and pine seedlings cannot be overlooked. Working in this soil type, like another site, is not difficult if you maintain a high organic matter content, have good interna1 drainage, and good overa11 field drainage.

Organic matter is currently maintained between two and three percent through the use of cover crops of corn, winter wheat, sudex, and outside sources. Outside sources include: gin trash, bedding material from a local horse farm, chips from the town of Columbia, Louisiana, and sawdust from local mills. Ph is maintain at about 5.6, and soil samples are taken annually and adjusted as needed.

Hardwood seedlings are rotated one year in cover crop and one year in seedlings. With the high demand for bottom-land hardwood, however, about one-third of the crop is planted two years in seedlings and one year in cover crops. Without the addition of organic matter from outside sources, it would be impossible to maintain good soil quality. Cover crops of sudex are planted in the spring, and cut down before heading. Following this, two inches or more of gin trash is spread over the entire area. The sudex is then allowed to grow four feet in height, then cut down and disc under.

The cover crops of sudex and gin trash are cut-under around the end of July to insure good decomposition before fall fumigation. Outside sources of organic matter are always followed by fa11 fumigation to control any introduced weed seed. Fumigation is performed each year over about two thirds of our hardwood ground with about a third of the crop being grown on ground two years out of fumigation. On the

[1] *Rentz, R.* 1996. Bottom-Land Hardwoods for Today's Market. *In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Depattment of Agriculture, Forest Service, Pacific Northwest Research Station: 38-40.*

[2] *Louisiana Department of Agriculture and Forestry, PO Box 1388, Columbia, LA 71418; Tel: 318/649-7463.*

second year ground, we try to plant species which germinate readily and exhibit fast initial growth to help with weed control. These species include, but are not necessarily limited to, Nuttall oak, overcup oak, Shumard oak, and baldcypress.

PLANTING

One very important thing to consider in preparation for planting is planning species location in the nursery. Many species exhibit extremely fast growth in the nursery environment, while many species tend to have slower initial growth patterns. These slower species will need a little extra push during the growing season. Species such as green ash, Nuttall oak, and baldcypress, which tend to have faster growth patterns, do not need to be planted next to species such as water oak and sweet pecan, which tend to exhibit slower patterns of growth.

Fa11 planting is done as much as possible, but for the most part, planting begins around the first of March and continues until the middle of May. Timing planting can help control the uniformity of the crop. If they can't be fa11 planted, slower germinating species, such as water and willow oak, should be planted first; the faster species, such as green ash and cypress, should be planted last. After planting, be sure to maintain adequate moisture to insure uniform germination. Most bottom-land species are planted four drills to a bed for six seedlings per square foot. By planting four drills this allows for the easy use of a dril1 sprayer for weed control during the critica1 time before the seedlings close. Most seed is planted one to two inches deep and a soil stabilizer mixed with pre-emerge herbicide and fungicide is applied in one pass immediately following planting. With fa11 planting, rye grass instead of soil stabilizer is broadcast over the beds after planting. In February before germination the rye grass is killed. In some cases the seedlings may have already begun to germinate, and on these we simply use Fusilaide or Poast.

THE GROWING SEASON

Following germination, after the seedlings have reached about ten inches, a shielded sprayer can be used to eliminate any emerging weeds. This sprayer, along with one or two men goose picking, can keep the entire crop practically weed-free. A good weed control program with a zero tolerance for weeds is essential in maintaining a clean nursery.

A flush of growth can be stimulated at practically any time during the growing season. This is done by applying 15-20 units of nitrogen per acre and watering thoroughly. By the same token, seedlings may be held back by withholding water and nutrients. Care must be taken to maintain enough soil moisture to sustain a healthy seedling.

Though uniformity in hardwood is not quite as critica1 as pine, it does make for easier packing and shipping. There are a number of ways to work towards a fairly uniform stand of hardwoods. Top pruning, fertilization, and undercutting to name a few. Before any method is used, parameters for seedlings sizes must first be established. With bottom-land hardwoods we like a 16" - 30" seedling. If planted at the proper density, seedling caliper in hardwood should not present a problem with a 16" seedling. There are many times seedling heights and calipers must be adjusted for specific conditions and individual cooperators; therefore, it is important to understand the growth characteristics for individual species and plan their management accordingly.

Top pruning begins when the seedlings reach 18"-20" in height. At this point, the seedlings are pruned back to 12"-14". This will help release some slower germinating seedlings that have been suppressed, and can also help increase the caliper of seedlings that may have a higher density than anticipated. The second top pruning is done when seedlings reach about 24"-26", and these are pruned back to 18"-20". This second pruning is usually around the first of August. This is about as late as we like to prune hardwood.

Undercutting the seedlings can be used to control seedlings size and stimulate a more fibrous root system with more first order laterals if needed. Undercutting before seedlings reach target heights is not recommended. It is also important to make sure root rot problems, if present in an area, are not spread into other areas of the nursery. Undercutting can be very beneficial, if needed and done properly. It can also be very detrimental if not done properly.

In many instances, certain areas of the nursery, or even within each bed may show different pattems of growth. By fertilizing during the growing season, either with a gandy, for granular, or a spray rig for liquid fertilize, specific problems areas can be treated individually, regardless of how small.

There will always be conflicting circumstances between species and market conditions which must be addressed and each must be handled separately. An open line of communication between the cooperator and the nursery must be maintained. Many times site conditions, planting methods, and time of planting must be considered when regulating seedling size. It is because of these many varied conditions that one specific target seedling in hardwood cannot and should not be maintained.

CONCLUSION

With hardwoods it is important to understand that what works for one species may not necessarily work for another. Sometimes it is best to let nature take its course and watch and try to leam. We as nursery people can only manipulate the environment to a certain degree without having adverse effects on the seedlings. In many instances today there is a tendency to over exaggerate the role we play in growing what we call a target seedling. For the most part nature plays a much more important role. In many cases a hands-off approach in growing seedlings is the best approach. In other words, provide a good clean bed, enough food, enough water, and watch them grow.

Problems of Hardwood Seed and Planting Hardwood Seed[1]

Floyd Hickam[2]

The problems of hardwood seed will be covered by better qualified speakers than myself. I will keep my discussion confined to planting problems and touch on seed only as a planting problem. Many planting problems are caused by seed conditions. These problems are compounded when the planting supervisor or nursery manager are left out of the seed process. The nursery manager or employee in charge of planting should be involved in setting seed procurement standards. Total seed processing should be delayed if seed is to be stored for extended time. The rate of deterioration of stored seed will be very high in first few weeks of storage. This damage is from insect-disease and other defects that are very hard to detect at time of harvesting.

PLANTING PROBLEMS RELATED TO SEED QUALITY, SEED CONDITION, SEED SIZE AND OTHER SEED CHARACTERISTICS

Seed lots containing mixed sizes are hard to plant with some planters. Seed lots with mixed sizes are hard to obtain uniform bed density.

Seed that has started the germination process will be a problem to plant regardless of planting method.

Seed lots that contain high percentages of ti.111 nonviable seed need not be discarded as a total loss.

To prevent or minimize these losses we have developed three planting systems or methods.

The plate (drop) planter with revolving plates with control of plate revolutions plate hole size, and ground speed.

The plate revolutions are controlled by a restriction valve in hydraulic power supply. The ground speed is controlled by equipment operator. The hole size in plates can be changed by installing different plates five to ten minutes to change plates.

This unit is completely shop made and has the capability to:

1. Open planting slit
2. Drop acorns of any desired density
3. Cover slit after acorns are dropped
4. Requires two employees
5. Plant in eight hours the equivalent of a large hand crew (15 man days)

The sprouted or poor germination potential seed is planted using a shop made seeder attached to rear of an old Ford manure spreader.

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[1]*Hickam, F. 1996. Problems of Hardwood Seed and Planting Hardwood Seed. In: Landis, T.D.; South, D.B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 4 l-42.*

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The manure spreader serves as a supply wagon for large volumes of seed that will be applied to seed beds.

This seeding device has four basic components:

1. Hydraulic controlled agitator to move seed over
2. Drop gate (restricted hydraulic valve) for agitator
3. Adjustable drop gate opening
4. Drop gate closure for on and off positions

The seed can be broadcast through drop gate then covered with mulch if desired.

The last method is a combination of al1 the methods with the addition of an old bed shaper.

The bed is tilled, then leveled with a bed shaper and slits opened with the plate planter. The seed is applied with the manure spreader unit. Bed shaper is used to move seed on surface of bed to slit opening made with plate planter. The nursery manager has the option of covering bed with mulch or rolling bed to close slits.

Seed Handling and Propagation of Hardwood Trees and Shrubs at Oklahoma Forestry Services' Forest Regeneration Center[1]

Gregory R. Huffman[2]

Abstract-The information presented in this paper describes some of the seed handling and propagation procedures used at the Oklahoma Forestry Services' Forest Regeneration Center. Specific pregermination treatments are stressed as important techniques to evaluate and adapt to local needs. Modifications to the Oyjord seeder are also discussed and are aimed at increasing the versatility and effectiveness of this sower.

INTRODUCTION

The Oklahoma Department of Agriculture - Forestry Services has had an ongoing regeneration program since 1926. The Forest Regeneration Center (FRC) in Washington, Oklahoma has been in continuous seedling production since 1946. This paper will review some of the most recent advances in techniques used at the FRC particularly in regards to seed treatments and sowing.

Approximately 40 species of bareroot trees and shrubs are grown at the FRC. Since Oklahoma is centrally located, the species grown range from southern pines and oaks to Great Plains species, and extending to western tree types. This wide diversity of species dictates the development of seed handling techniques that are often not in the mainstream of forest tree nursery research and publications. The techniques and results reviewed here were developed over time in response to specific problems encountered at the FRC. Our findings are based on field trials and operational observations made at the Center. Personnel at other nurseries should use our experience as a general guide, but are encouraged to experiment in their environment before committing to operational programs involving the techniques presented.

It is vital to apply the proper handling and pregermination treatments to each species being propagated. In particular, the techniques used in stratification, aeration, and ripening can have significant impacts on propagation efforts.

STRATIFICATION FOR *PRUNUS* SPECIES

Heat stratification is a technique that has been very successful in treatment of severa1 *Prunus* species at the FRC, including American plum (*Prunus* americana), chokecherry (*Prunus* virginiana), and sand plum (*Prunus angustifolia*). Early work with ***Prunus*** suggests that the seeds have embryo dormancy and require a period of after-ripening in the presence of moisture and oxygen in order to overcome it (Grisez 1974). ***Prunus*** species are not truly hard seeded, but do have a hard

[1]Huffman, G.R. 1996. Seed Handling and Propagation of Hardwood Jrees and Shrubs at Oklahoma Forestry Services' Forest Regeneration Cenfer. In: Landis, J. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Jech. Rep. PNW-GJR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 43-48.

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endocarp. The Woody Plant Seed Manual does not recommend heat stratification for the *Prunus* species in question, but our experience has shown a significant improvement in seed germination by utilizing this treatment.

The techniques employed are as follows:

1. Seed is mixed on a 2: 1 volume basis with course vermiculite with American and sand plum and 4: 1 with fine vermiculite on chokecherry. The vermiculite should be moistened to the point that you can barely squeeze a small amount of free water from the media. Generally, this can be approximated by 8 parts vermiculite: 4 parts seed: 2.25 parts water.

2. The seed/vermiculite mixture is placed in polypropylene bags which are fairly tight woven, but are not air or water tight. These bags are permeable enough to allow for "adequate" air exchange without excessive drying of the vermiculite. The bags can be ordered from Forestry Suppliers (item #58066).

3. The bags of seed/vermiculite are placed on a pallet with the bags stacked no more than 2.5 feet in height. Additional pallets are used to separate layers ensuring the bags are not stacked too deep. The palleted piles of bags are then covered with 4 mil plastic sheeting. The bags are totally enclosed by the plastic covering, but no effort is made to make a tight seal. The covering is simply used to retard moisture loss from the bags.

4. The bags are kept in our seed extractory which normally is in the temperature range of 60 to 90 degrees F. No attempt has ever been made to precisely control temperatures that the heat stratifying seed are being subjected to.

Our experience with chokecherry exemplifies the integration of heat and cold stratification strategies. The standard procedure was to heat stratify the seed for 30 days, and then to plant in the late fall. This technique gave variable results often with inadequate germination. For example in 199 1, this technique yielded very poor results. In 1992, chokecherry received the standard 30 day heat stratification, but poor soil conditions prevented sowing so the seed received a cold, moist (34-36 degrees F) stratification for 45 days. The crop was then sown in early winter. Germination of this crop was quite satisfactory. Based on these field observations, it was concluded that mild and/or dry winter conditions lacked the needed elements to provide a "good" cold stratification for the chokecherry.

Similar observations were made with American plum. Sand plum appears to be less sensitive to mild winter conditions, but for simplicity purposes, we now subject al1 three *Prunus* species to 30 days heat and 30-45 days cold stratification prior to early winter sowing.

Caution should be exercised when utilizing a heat/cold stratification followed by early winter sowing. Although al1 of our comparisons have shown the treatment to be beneficial, there is one potential drawback. Our experience has shown that chokecherry seed receiving both a heat and cold stratitication will generally germinate about 10- 14 days earlier than seed receiving only a heat treatment followed by immediate sowing. We desire the more complete and rapid germination with the heat/cold treated seed, but hard spring freezes can kill these germinants easily. Seed that has not had the artificial cold stratification is slower to germinate, and can potentially "miss" a spring freeze due to the germination delay.

In Oklahoma, we have seen either method get caught in the freeze. One year the heat/cold treatment germinated early in February and was sufficiently large and hardened before any extreme freezes occurred. A couple weeks later the seed that was only heat stratified germinated, and was shortly thereafter severely damaged by freezing conditions. The heat/cold treatment had sufficient time to develop hardier stems and leaves, and showed much less freeze damage. The advantage of the heat/cold treatment appear to outweigh potential freeze problems since either method can result in seed germinating during dangerous cold periods. Under an optima1 "safe" strategy, it might be best to use both treatments and risk only one-half of the crop to any one treatment. We tried this one year and had no spring freezes affect either treatment.

An alternative that we have not tried is to heat stratify the seed for 30 days, and then "hold" in cold stratification until the danger of late spring freezes has passed. At least three potential problems would be associated with this strategy, including:

1. Soil conditions often prevent sowing when desired and the seed may "miss" the best germination and early growing conditions.

2. It can be difficult to accurately predict when the danger of late spring freezes has passed.

3. The totally artificial stratitication strategy could be used as a backup to sow in the event that the winter sown crop was a failure. An experiment would need to be initiated to ascertain if the seed would tolerate redrying and subsequent sowing the following year, if the backup seed was not used.

In summary, we have found heat stratification to be very useful particularly with *Prunus* species. This technique allows for a slow breakdown of the seedcoat within an environment promoting moisture absorption and ample air exchange. When used in conjunction with artificial cold stratification followed by early winter sowing, chokecherry, American and sand plum germinate more completely and rapidly in comparison to either treatment when used alone.

AERATION

Seed needs to breathe, and this is particularly important during pregermination treatments. Common suggestions with cold stratified seed are to periodically turn the bags, use poly bags that hold moisture but allow some air exchange, fold the bag opening but do not sea1 tight (oaks), etc. These concerns are greatly dependent on the initial quality of the seed, species, quantity of seed being treated, duration of treatment, and many other factors. In Oklahoma, our experience has shown that aeration control can have significant impacts on seed germination and crop development.

The air exchange requirements for tree seeds in various stages of pregermination treatments is not well defined. Our limited research in this area has led to one conclusion-namely that various aeration treatments appear to hasten physiological processes that promote germination. Discussions citing examples in this area follow.

The goal of every nursery manager is to have very rapid and complete germination. Steve Hallgren with Oklahoma State University has utilized osmotic seed priming in severa1 pine species (Hallgren 1987). In general, his studies showed that priming significantly increased speed of germination particularly for loblolly and shortleaf pine. A tendency to increase the final germination of unstratified loblolly seed was also observed. These results have led us to the postulation that the primary benefit of priming may simply be increased air exchange. This concomitant increase in seed metabolism may allow the hastening of physiological processes that are needed to help break dormancy, or otherwise "pu11 the germination trigger."

In the spring of 1992 a hard freeze killed most of the germinating hackberry crop. This is a fa11 sown species at the FRC, and generally would require a 60 to 90 day cold stratification if sown in the spring. Faced with a freeze killed crop and no stratified seed, we decided to try a short, cold stratification (30 days) followed by severa1 treatments including aeration in cold and room temperature water, and polyethylene glycol. Aeration treatments continued for approximately 15 days.

Germination was similar for al1 treatments with lab germination ranging from 36 to 41%. Approximately 75% of this germination occurred in the first 3 1 days following sowing. Similar results were seen in the field plots. Although the germination was poor in comparison to normal hackberry germination, the aeration treatments did produce marginally acceptable germination in a situation where there was insufficient time to undergo a full cold stratification. No non-aerated comparisons were made as our goal was to maximize germination as quickly as possible. It was felt that a short, cold stratification without aeration would be futile. From an experimental view, this presents a problem as we can not claim that aeration was better than simply extending the cold stratification 15 days (vs. aeration for 15 days). In any event, al1 aeration treatments "worked" and resulted in an acceptable crop in a situation that looked rather hopeless.

Similar experiences have been observed in the treatment of honeysuckle (*Lonicera maackii*) and euonymous (*Euonymous bungeanus*). These species, like hackberry, generally exhibit moderate seed dormancy, and require up to 90 days of cold stratilication for adequate germination. These species respond rapidly to aeration treatments when used in conjunction with shorter cold stratitication.

In 1995, after spring freezes damaged these fa11 sown crops, the seed was stratified for 60 days and then put into aeration. Surprisingly, the euonymous began germinating in the aeration chambers within one day. Honeysuckle was germinating the same day as aeration began. Apparently, 60 days of cold stratification was sufficient, and the favorable conditions of aeration quickly promoted the seed to begin to germinate.

Although it appears that the aeration treatment did nothing in terms of helping meet stratification requirements, it did demonstrate how quickly the treatment could aid in the initiation of germination. Bringing seed to a state that it is ready to "hit the ground running" is a very desirable quality. The basic premise of osmotic priming is to bring seed to the point that it is ready to germinate, but is held back due to the effect of the negative water potential osmotic solutions. Our aeration treatments were in water so negative osmotic potentials were not present to prevent radical emergence. Perhaps, we could have brought the seed to a greater state of "germination readiness" if polyethylene glycol had been used. In any event, aeration in water resulted in very rapid germination. The seed was immediately sown and approximately sixteen trees per square foot was realized for both species. This compares to about two trees per square foot in the fa11 sown freeze damaged beds. The seed was not sown until Apri127 for species that normally germinate in early to mid March. Our concern was the loss of about 45 days of potential growing days. However, with rapid germination and a little luck (co01 weather in May), the crop developed well. The aeration treatment provided the extra "push" that was needed to grow an acceptable crop.

RIPENING

For many species, well documented procedures are available to guide seed collection and processing efforts. Also, in many instances considerable latitude is allowed in collection timing, after-ripening, etc. However, for some species more exact procedures need to be followed. Often, as nursery managers, we assume that we are performing collection and processing procedures in the "correct" manner each year. This was the case in our experience with red mulberry (*Morus rubra*). Unfortunately, seed germination in recent years began showing poor results.

Mulberry seed handling procedures were suspected as possible problem areas due to a lack of well defined handling parameters. The standard procedure was to collect fruits as they fe11 onto tarps spread below target trees. "Occasionally," the fruits would be gathered from the tarp and soaked for a "day or so." It is very apparent that these procedures were quite loose, and needed to be better defined.

A study to evaluate the impact of various treatments confirmed the importance of proper handling procedures. Seed germination was best (89%) for seed collected within 4 to 5 days after falling. Waiting for 1 to 2 weeks reduced germination to 73% and lower. Germination was further reduced for seed fermented in water for 48 hours (56%) and 72 hours (33%). We now make sure that fruits are promptly removed from tarps (by the third day) and ferment the fruit for no longer than 24 hours.

STRATIFICATION MEDIUM

Stratification techniques usually employ either a medium such as sand, peat moss, vermiculite, etc., or may be done without media (naked). The naked method is generally more desirable due to its' ease of technique. However, naked methods are not universally applicable to al1 species.

1 have previously described the use of vermiculite in heat stratification techniques. We also use vermiculite for cold stratification treatments with severa1 species including autumn olive (*Elaegnus umbellata*), Cotoneaster (*Cotoneaster acutifolia*), soapberry (*Sapindus drummondii*), and Vitex (*Vitex agnus-castus*).

General observations of various seeds during naked cold stratification have led us to use vermiculite media in severa1 situations. The most obvious benefit of using media is the "forgiving" nature of this method. It is difficult to get the seed too wet or too dry as the vermiculite has very good moisture holding capacity with a wide range of acceptable moisture regimes. This allows for a much better moisture balance. In short, use of the medium allows for good aeration while still providing ample moisture for seed uptake. This lessens mold problems on seed during stratification. Ultimately, utilizing a medium can provide a safer, more uniform stratification environment. Nursery managers should evaluate the technique on species which are not giving satisfactory results with naked methodology.

OYJORD SOWING TECHNIQUES

The Oyjord seed sower by Love Industries is the mainstay at the FRC. Though designed for smaller seeds, we have found it to be a very versatile sower, needing only minor modifications to sow larger seed. Modifications we have employed are discussed.

The spokes (vanes) in the seed metering wheel are too close together to allow larger seed to drop clear. As we attempted to sow larger seed, they would get crushed or would bend or break a spoke. Removing every other spoke eliminated this problem. We now use two metering wheels. One is kept in original condition with al1 spokes intact. This configuration is used for small seeded species (> 5000 seed per pound). For larger seeds, the alternate wheel is used.

When sowing large seed, larger drop tubes are needed. We have installed clear tubes which are approximately 1.25 inches in diameter. The use of clear tubes is very helpful in order to view seed movement. This allows rapid recognition of seed bridging. Using large drop tubes also dictates that the drop tubes be positioned further to the rear between the seed furrow coulters. This change in drop tube position can be done very quickly, and can be attached easily using standard cable ties. When sowing larger seed, replace the small nozzle (part # S 10 109) with the larger orifice nozzle (part # S10110).

We have successfully sowed seed as large as 540 seed per pound. This year we attempted to sow willow oak (415 seed per pound) via the large seed setup. Although we did not achieve the sowing density that was desired, it may be possible to achieve higher densities if very slow tractor speeds can be tolerated.

Lastly, we have begun experimenting with fine tuning the seed distribution pattern via the Oyjord seeder. The seed spinner within the distribution chamber is normally controlled by the ground speed of the tractor. We wanted to see if independent speed control of the spinner could be used to increase the uniformity between the number of seed applied per dril1 row.

A hydraulically operated motor was mounted on the Oyjord to allow independent control of the spinner. RPMs were measured at the spinner driveshaft. Actual spinner RPMs are approximately 25% greater than the driveshaft readings which are presented and discussed. Seven spinner speeds (driveshaft readings) were tested ranging from 350 to 1850 RPMs at 250 RPM intervals. Tests were successfully run on *two* species. *Lespedeza bicolor* at 55,996 seed per pound and Redbud (*Cercis canadensis*) at 10,933 seed per pound were evaluated. Larger seeded Soapberry (*Sapindus drummondii*) was also tested, but at 728 seed per pound al1 spinner speeds produced unacceptable results.

The results appear fairly consistent, but we are not sure if the differences seen are biologically significant in terms of increasing seed density uniformity. The best results for Lespedeza were obtained at 600 RPMs. At this spinner speed the coefficient of variation between dril1 rows ranged from 2.35 to 4.18 percent (mean 3.42). This compares to the worst variation at 1600 RPMs with 4.33 to 5.63 coefficient of variation values (mean 5.04). The tractor speed still slightly influenced the pattern as the upper seed distribution wheel directly works in tandem with ground speed and primarily impacts the quantity of seed dumped into the distribution chamber.

Note that our intent was to increase the uniformity of seed dropped between dril1 rows. The theory was that any increase in uniformity of distribution within the chamber would result in increased uniformity between dril1 rows and possibly within dril1 rows (better equidistance between seeds). Our preliminary results indicate that some improvement can be gained between dril1 rows. The next step is to evaluate the impact of spinner speed control on uniformity within a dril1 row. Although we never expect the Oyjord to be a "precision" sower, we do want to optimize its' performance.

SUMMARY

Nursery managers desire maximum efficiency from each species sown. Experiences at Oklahoma's Forest Regeneration Center help exemplify the importance of severa1 pregermination treatments. In particular, the role of heat stratification, seed aeration, ripening, and stratification media can greatly impact the ability of seed to promptly germinate and grow. Seed handlers should realize that seemingly small variations in seed treatment technique can potentially impact success in significant ways. A review of Oyjord seeder modifications shows that this machine can handle considerably larger seed with fairly simple changes. The uniformity of seed sown between dril1 rows can also be improved and is dependent on the species in question, particularly as related to seed size. Where applicable, future efforts to increase seed efficiency should include evaluation of the techniques presented.

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Role of State Nurseries in Southern Reforestation—An Historical Perspective[1]

Clark W. Lantz[2]

THE AGE OF UNCERTAINTY

Right now we are living with a great deal of uncertainty. Private property rights are being questioned. Does a landowner have the right to cut his timber if it affects threatened or endangered species? Does a landowner have the right to use pesticides on his own land if these T & E species may be affected? Salvage logging has been questioned in the West. Environmental organizations challenge the logging of beetle- or fire-killed timber, even when it presents a serious fire hazard. Reinvention, down-sizing, out-sourcing are al1 part of our "new age" vocabulary. Perhaps the most serious of al1 is that the politicians are re-ordering our priorities. Often science is replaced with political expedients. The short-term "fix" has taken the place of the long-term, scientitically based strategy. We may not live to see the results of these short-term "fixes" but our children and grandchildren certainly will.

PLANTING AND SEEDING IN THE SOUTH

A brief look at the historical record will show the accomplishments of the major federal planting programs (Figure 1). In 1930, 33 thousand acres were planted southwide in 1987 more than 2 million acres were planted, most as part of the Conservation Reserve Program (CRP). In the 1950's the Soil Bank program resulted in many acres removed from agriculture and planted with trees. Non-industrial private forest (NIPF) landowners planted 1.4 million acres in 1988 as part of the Conservation Reserve Program to retire marginal agricultura1 land. Forest industry has increased planting on their lands since the 1950's. The peak planting on company land was in 1986 with over 1.2 million acres planted.

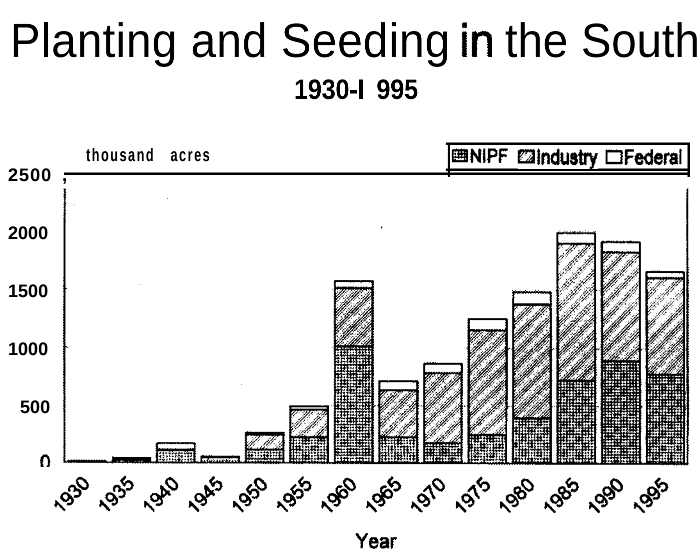

Figure 1. Planting and Seeding in the South. 1930-1995.

[1] *Lantz, C. 7996. Role of State Nurseries in Southern Reforestation—An Historical Perspective. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 49-52.*

[2] *Cooperative Forestry, Southern Region, USDA Forest Service, 7720 Peachtree Rd., W., Atlanta, GA 30367; Tel: 404/347-3554.*

FOREST NURSERIES IN THE SOUTH

The number of forest nurseries in the South has gone through an interesting evolution. In 1956 there were 5 federal nurseries, currently there is only one (Figure 2). Forest industries started building nurseries in the 1970's and by 1986 there were 37. Many of the state nurseries were built during the SoilBank and were maintained through the 1970's and 1980's. Some new state nurseries were built during the CRP, and others were expanded. Only in the last few years have the number of state nurseries declined. Competition from industrial and private nurseries and reduced state budgets have resulted in 10 state nurseries closing since 1986. The most dramatic change has occurred with the opening of 23 private nurseries in the last 10 years. Some of these have been employee buyouts of company nurseries, some have been the results of corporate mergers, and some have been new organizations, formed to serve a specific clientelle.

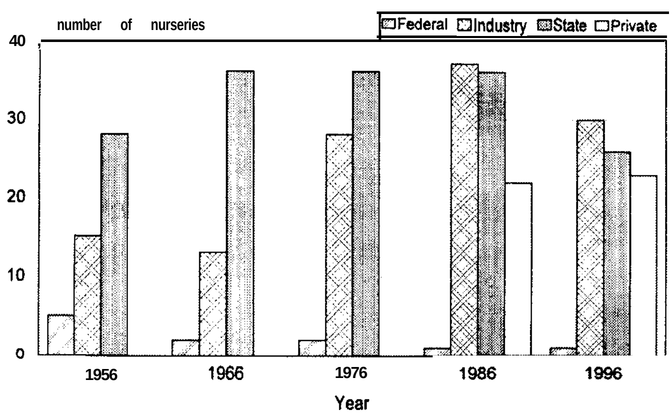

Figure 2. Forest Nurseries in the South:1956-1996.

NURSERY PRODUCTION

Nursery production has been a response to the major federal planting programs, reaching a peak in the CRP with a total of about 2 billion seedlings. This represented about 82% of the total seedling production in the US (USDA 1988). The number of genetically improved seedlings grown in the South has increased from 27% in 1976 to 99% in 1994. Currently the only seedlings produced from woods-run (non-improved) seed are some longleaf pines, some hardwoods, and a few non-timber species.

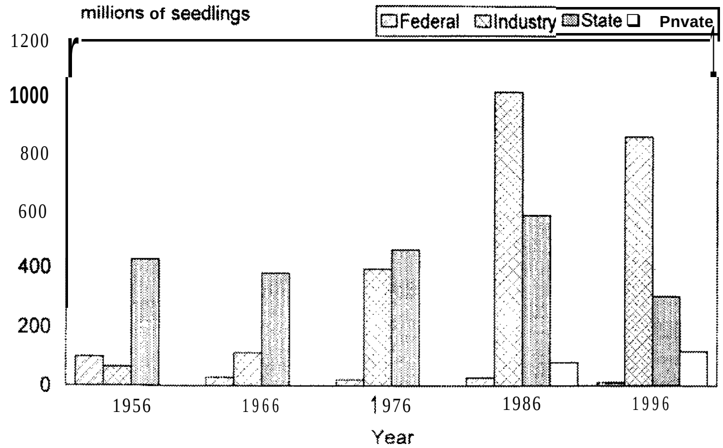

Figure 3. Nursery Production in the South:1956-1996.

HARVESTING VS PLANTING

In the last 5 years the number of acres harvested has steadily increased in the South in response to rising stumpage prices. As more federal land is restricted from logging in the West, the large acreage of private land in the South is under pressure to supply more and more wood. Unfortunately, as the harvested acreage has increased, planting has not kept pace. Since 1989 the acreage planted (on al1 ownerships) has steadily decreased from about 60% to about 40% of the area harvested (Southern Group of State Foresters 1996) (Figure 4). Unless this trend is reversed there may be a serious shortage of wood in the future. Certainly some of the acres logged will be naturally regenerated. Unfortunately however, many of these areas will never reach their ful1 potential. Natural seeding often results in low quality trees, while planting genetically improved seedlings would result in 10 to 15% more high quality wood per acre per year than these natural stands.

In areas where there is an inadequate seed source left after logging, low quality hardwoods, greenbriar, kudzu and honeysuckle will often take over, requiring substantial site preparation costs and the loss of one or more years before productive trees can be established.

In the South we currently have about 23% of the softwood growing stock in the US and about 44% of the hardwood growing stock (Cubbage et al. 1995). The annual growth exceeds the harvest with the hardwoods but unfortunately we are cutting more than the annual growth with the softwoods. To quote Cubbage et al. (1995):" Environmental protection, urbanization, fragmentation, and landowner preferences al1 suggest that our balance between growth and removals is tenuous. . . sustainably increasing both southern timber harvests and inventories will be difficult".

Intensive management of genetically improved trees on our most productive sites will provide more high quality wood on the same number of acres of commercial forest land.

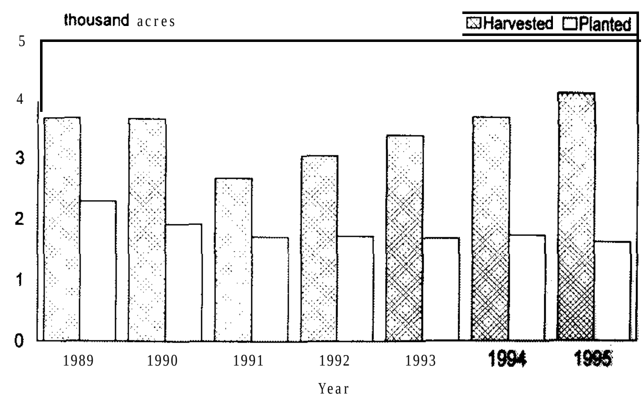

Figure 4. Harvesting vs Planting in the South:1989-1995.

SEEDLING PRODUCTION SURVEY

Seedling shortages occurred across the South during the 1995-6 planting season. In an effort to avoid the same shortages in 1996-7 the Southern Group of State Foresters requested that the USDA Forest Service conduct a survey of Southern nursery production. The results of this survey are presented ín Table 1. The general conclusions of the survey indicate that seedling demand is likely to continue to increase in the future. Even though cost-share funds are not as widely available as in the past, seedling demand appears to be largely a response to elevated stumpage prices. (See table 1).

PREDICTIONS FOR THE FUTURE

It looks to me that the South is in a very favorable position to continue as the leading timber market in the US. Federal timber in the West is likely to continue to be tied-up due to "environmental restrictions". Private land in the South will have the opportunity to supply a major part of the timber market if we manage the land properly.

It also appears that seedling demand will continue to increase and that there will be more demand for hardwoods and other "native species".

What can we do to ensure that the South continues to be the "Wood Basket" of the US?

- Develop and utilize procedures for better utilization of hardwoods.
- Intensively manage our most productive sites for pine timber, including the planting of genetically improved seedlings on harvested land.
- Continue to improve the seedling quality of al1 species.
- Continue to work with the small, private, non-industrial landowner who owns the bulk of our southern timberland.
- Develop procedures to motivate landowners without using cost-share dollars.
- Continue to educate the public on the proper way to care for and plant seedlings.
- Be more aggressive in educating the public about good forestry practices. They need to understand that paper and other wood products come from trees and that trees are a renewable natural resource.

Table 1. Bareroot Seedlings available for NIPF landowners:1996-7 season.

1996-I 997 Season (Million Seedlings-Estimated)

	Nursery Ownership				Total	
	State		Industry & Private			
State	Pine	Hardwoods	Pine	Hardwoods	Pine	Hardwoods
Alabama	36	4	77	1	107	5
Arkansas	7	3	50	2	57	5
Florida	23		87	3	110	3
Georgia	48	2	110	•	158	2+
Kentucky	3	4			3	4
Louisiana	43	5	21	*	64	5+
Mississippi	38	2	31		69	2
North Carolina	25	3	53		78	3
Oklahoma	5	2	4		9	2
South Carolina	19	1	71	2	90	3
Tennessee	8	2			8	2
Texas	12	1	51	*	63	1+
Virginia	38	3	2		40	3
Total	305	32	557	9	862	41

Note: These numbers are predictions of future seedling production. Extreme weather conditions and nursery crop failures may occur. Seedlings are shippped across state lines, are resold, and sometimes lose seed source identity. For these reasons these data should be considered as estimates only.

*Less than 1 million

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Cultural Practices to Improve Survival and Growth of Loblolly and White Pine Seedlings[1]

Tom Dierauf[2]

INTRODUCTION

This is a broad subject for thirty minutes, so to save time 1 will skip the routine cultural practices that al1 nurseries do and spend my time on a few optional cultural practices that some nurseries do and some don't. By routine practices, 1 mean such things as good soil management, accurate seeding, and insect and disease control. 1 will discuss top-clipping, root pruning, and irrigation rates. Al1 three of these affect growth in the seedbed, and can also affect survival and growth in the field. Many nurseries use top-clipping and/or root pruning to control seedling size, especially top length. My comments will be based on research 1 was involved in over a thirty year period. 1 want to offer a couple of precautions about the applicability of this research. First, things that work in Virginia may not work in the deep South. There is risk in extrapolating to areas of different climate. Second, things that work in one nursery may not work in another, even in the same geographic area. Soil differences, in particular, and also differences in cultural practices may result in different responses to a treatment.

SEEDLING SIZE

Because the practices 1 will discuss al1 affect seedling size, 1 want to discuss first how seedling size is related to survival and growth in the field, and what size seedlings, consequently, we should be trying to produce. We installed 14 different studies over a period of more than twenty years that were either exclusively seedling grade studies, or included seedling size as a treatment. From these studies we have concluded that in Virginia we prefer Grade 2 seedlings over Grade 1 seedlings, at least the larger Grade 1 seedlings (larger than about 7/32 inch root-collar-diameter). Grade 1 seedlings are larger than 6/32 inch root collar diameter. This is an example of a geographic difference 1 just cautioned about, because in much of the deep South, large, Grade 1 seedlings are preferred. In our studies, Grade 1 seedlings have usually not survived as well as Grade 2 and have not exhibited enough growth advantage to justify the added expense of growing, lifting, handling, and planting them.

At the other end of the scale, we don't want Grade 3 seedlings either (seedlings below 4/32 root-collar-diameter). They don't survive as well as Grade 2 seedlings, especially when planted early (in December and January).

Larger seedlings grow faster than smaller seedlings, at least for the first few years after planting. Of the 14 Studies I've mentioned, 9 were measured between 17 and 26 years after planting. It seems that in Virginia, most of the height growth advantage of large seedlings occurs in about the first five years. After that, differences increase very little, or may even decrease.

'Dierauf, T. 1996. Cultural Practices to Improve Survival and Growth of Loblolly and White Pine Seedlings. In: Landis, T. D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 53-58.

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Our earliest grade studies were installed in 1966 and 1977. They were planted in March, the safest time to plant in Virginia, and survival was excellent, even for 2/32 and 3/32 inch seedlings. The largest size, 7/32 inch, didn't sur-vive as well (Figure 1). These studies were planted at a 3 by 3 foot spacing, because we planned to measure them for only 3 years. However, they were still in good shape at age 25 and 26 — there had been no problems with ice, wind, bark beetles, etc. — so we remeasured them. Competition-induced mortality had been heavy, but about equal in al1 seedling diameter classes (Figure 1). At age three the larger seedlings were about a foot taller, larger in diameter, and considerably more robust, but by age 25 and 26 the early height differences had disappeared (Figure 2), and larger seedlings were no larger in diameter at breast height.

Two additional studies were installed in 1969-70 and 197 l-72, planting small (2/32 and 3/32), average (4/32), and large (5/32 and 6/32) seedlings in December, March, and April in 8 different locations. In the 197 1-72 study, the small diameter class included only 3/32 inch seedlings. Survival of large seedlings was only slightly better than average seedlings, but small seedlings did not survive nearly as well, especially with December planting (Figure 3). We measured these studies each year for 5 years, and then again at age 20 or 2 1 for the 1969-70 study and age 18 or 19 for the 197 l-72 study. The height growth advantage of large seedlings seemed to peak by or soon after age 5 (Figures 4 and 5).

The five other studies, measured at age 17, 18, or 20, had height growth trends similar to the last two studies, with differences between 4/32 inch and larger diameter seedlings of about a foot or less at the final measurement.

Al1 9 of these studies involved seed bed densities that were high by today's standards 40 to 50 per square foot. David South recommends densities of about 15 per square foot in order to grow a high proportion of Grade 1 seedlings. More recently, we installed two studies in which the seedlings were grown at lower seedbed densities.

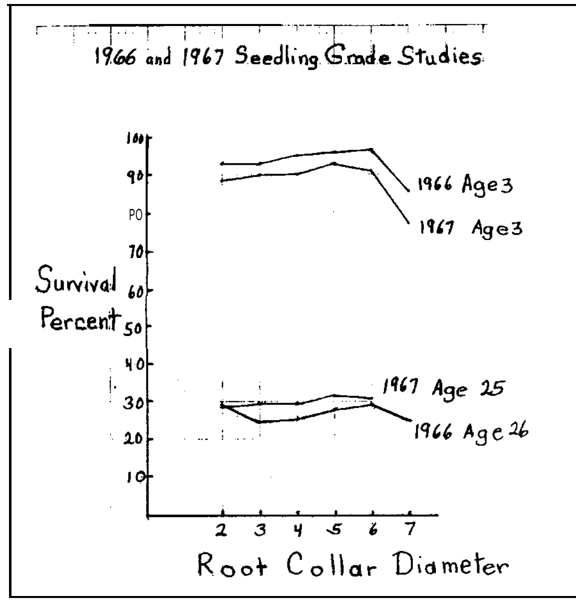

Figure 1. Survival by initial root-collar diameter, at age 3 and 25 or 26.

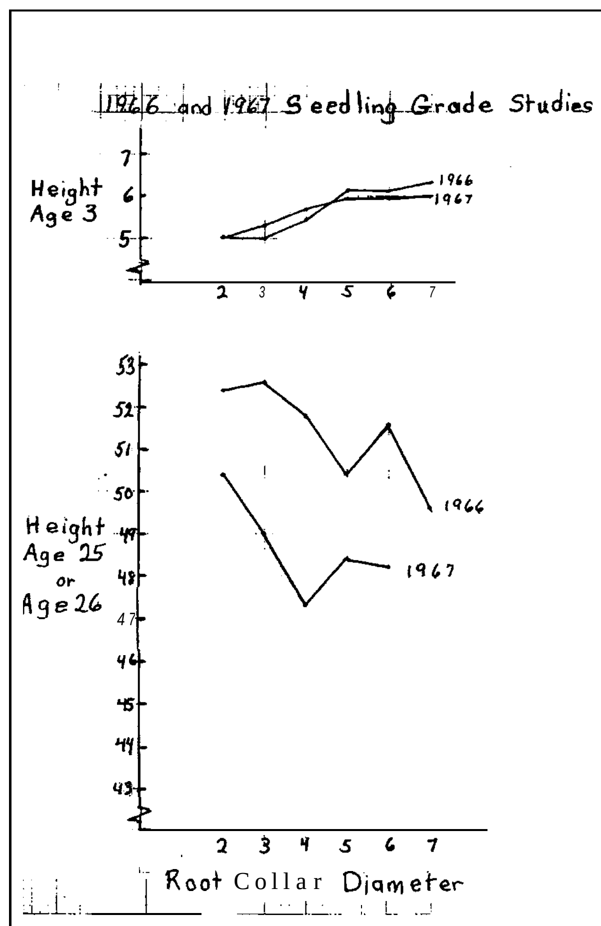

Figure 2. Height by initial root-collar diameter, at age 3 and 25 or 26.

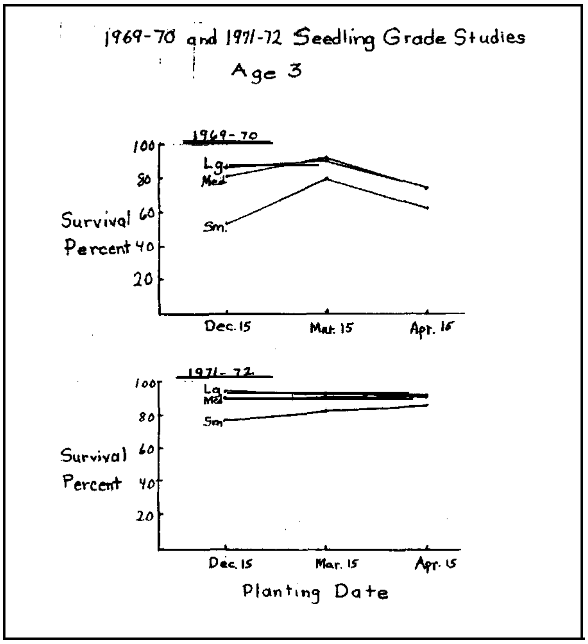

Figure 3. Survival by initial root-collar dimater class and planting date at age 3.

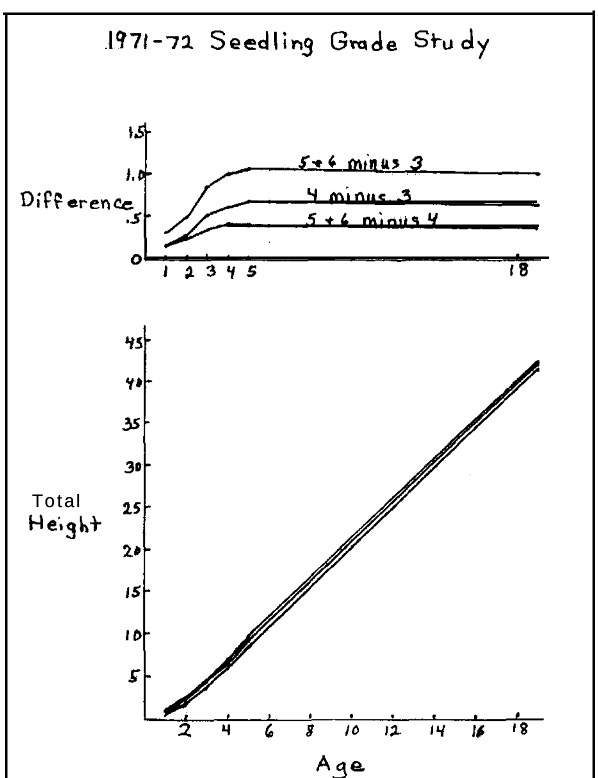

Figure 5. Height differences between initial root-collar diameter classes (above) and total height by initial diameter class (below), at ages 1, 2, 3, 4, 5, and 19 for the 1971-72 study.

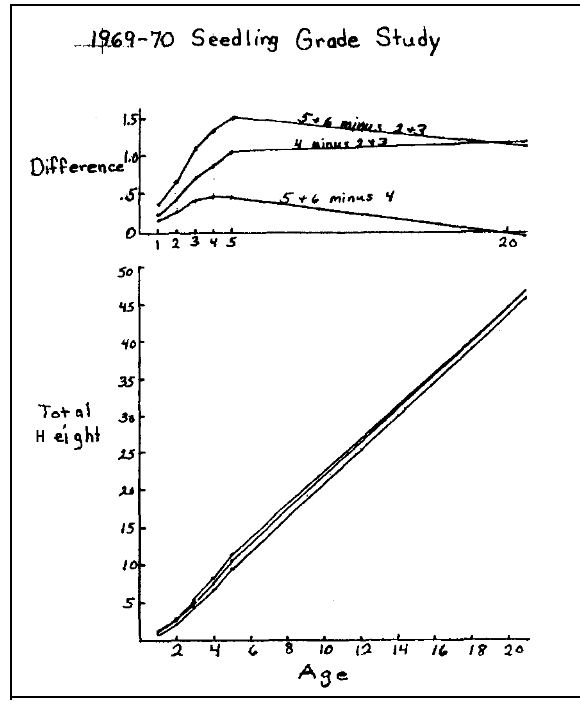

Figure 4. Height differences between inital root-collar diameter classes (above) and total height by initial diameter class (below), at ages 1, 2, 3, 4, 5, and 21 for the 1969-70 study.

In 1987 the Auburn Nursery Co-op installed a nitrogen rate study at our New Kent Nursery which they later abandoned because the precision seeder malfunctioned. We planted a portion of the study to compare 6/32 and 7/32 inch seedlings that had been grown at a bed density of 18 per square foot. At age seven the results were:

Auburn Study-Results at Age 7

Size	Survival	Height (Feet)	H (Inches)
6/32	89.6	20.5	3.9
7/32	87.1	20.6	3.9
DIFF.	2.5	.1	.0

In 1988, we installed a top clipping study that compared the ful1 range of Grade 1 and 2 seedlings that had been grown at a bed density of 27 per square foot. At age 6 the results were:

Top Clipping Study—Results at Age 6

Size	Survival	Heiaht (Feet)	DBH (Inches)
Grade 2	88.2	15.9	3.0
Grade 1	85.0	16.1	3.1
DIFF.	3.2	.2	.1

Today we seed for 30 per square foot, which in conjunction with our top-clipping schedule produces about 2/3 Grade 2 seedlings and 1/3 Grade 1 seedlings (with very few larger than 7/32 inch). In addition to having a target root collar diameter distribution, we try to keep seedlings from getting too tall. We prefer seedling tops of 8 inches or less, and not over 10 inches. Our top-clipping schedule does a good jobs of controlling top length.

TOP CLIPPING

Loblolly

Topclipping works well for us at our two sandy nurseries in Virginia. Between 197 1 and 1988, we installed 15 different studies involving topclipping, which 1 summarized at the 1990 Nurseryman's Conference:

1. Clipping improves survival:

a. The improvement is greater for December planting, a risky time to plant in Virginia, than March planting, usually the safest time. This may be at least partly due to an increase in cold resistance, as David South has reported. However, 1 think an important reason for this difference is the shorter tops resulting from clipping that probably provide some protection from desiccation during cold winters when soil temperatures are too low for root growth to occur. On the average, we get about a 15 point improvement in December and about a five point improvement in March, although this will vary greatly from year to year depending on the weather.

b. The taller the unclipped seedlings, the greater the improvement from clipping. Short, relatively-stocky seedlings survive better than tall, relatively-spindly seedlings.

c. Improvement is related to bed density spindly seedlings in dense beds respond more to top clipping.

2. Clipping produces more uniform seedlings:

a. Seedling heights are much more uniform because "tal1 tops" are eliminated.

b. Diameter distributions are tightened with slightly fewer small seedlings and considerably fewer large seedlings.

3. Clipping, following the schedule we have been using for the past 12 years, does not reduce height growth in the field. By age 3, clipped seedlings are as tall as unclipped.

4. More uniform seedlings (fewer small and over-sized seedlings) may result in a better planting job.

We have been following this top-clipping procedure for 12 years now:

1. We clip three times, sometimes four times in a rainy year with unusually rapid growth.

2. The first clipping is done about August first, plus or minus a week, when about 10 to 20 percent of the seedlings are tal1 enough to be cut at a six inch height.

3. The second and third clippings follow at three to four week intervals, at target heights of seven and eight inches. The third clipping is done about mid-September.

4. Only succulent tips are cut, no woody stems, removing usually one to three inches.

5. The first clipping typically cuts about 10 to 20 percent of the seedlings, the second clipping perhaps half, and the third clipping perhaps a third, including many of the seedlings clipped the

first time. On the average, we think that about twenty percent never get clipped, and these benefit from the improved growing conditions resulting from clipping their taller neighbors.

Consequently, the fastest growing seedlings are slowed the most, because they are clipped twice, and the slowest growing seedlings, that are never clipped, are enabled to grow faster.

White Pine

We did only one study with white pine, as part of a root pruning study, clipping either once on July ll or twice on July ll and September 19 at eight and nine inches. Survival of unclipped, once-clipped and twice-clipped seedlings was identical - 56 percent. Height growth, on the other hand, was significantly reduced by top clipping. At age three, average heights were 2.6, 2.2, and 2.0 feet for unclipped, once-clipped, and twice-clipped seedlings respectively, a 23 percent reduction for two clippings.

ROOT PRUNING

Loblolly

We did six studies between 1977 and 1991, which 1 summarized at the 1994 Nurseryman's Conference. Timing, frequency, and depth of undercutting were varied. Up to four undercuttings were made between late July and late October. Depth of cut was about five inches each time, or increased from 3 inches at the first cut to 5 inches at the final cut. Roots were pruned laterally each time undercutting was done in five of the six studies. In one study, wrenching replaced undercutting after an initial undercutting was done.

There was only one statistically significant difference among pruning treatments in the six studies. Combining root pruning treatments, therefore, and comparing them to unpruned seedlings for each study, the survival increase from pruning was + 1, + 1, +2, +2, 0, and - 1 percentage points in the six studies, averaging overa11 about one point. This is hard to explain, at least for the more frequent root pruning, which in some years produced dramatic changes in root morphology - much denser root systems due to many more lateral roots.

A problem with al1 six of these studies is that survival of unpruned seedlings was so high 88, 91, 96, 96, 94, and 97 percent. These high survivals occurred despite the fact that planting was done between December 13 and January 12 in five of the six studies, usually a risky time to plant loblolly seedlings in Virginia. One study was planted on March 22, usually the safest time to plant, but in this study the difference was two points in favor of pruning, 98 versus 96 percent, one of the largest differences.

It seems logical that improvement from root pruning would be greater under more stressful weather conditions. Of al1 the seedling studies we ever installed over a 30 year period, the 1977 studies experienced the coldest weather. The 1977 root pruning study was planted on December 14 and by late winter al1 the seedling tops had turned brown. Despite this severe stress, at age 3 average survival was less than one point better for root-pruned seedlings, 88.0 versus 87.5 percent.

Root pruning improved height growth slightly. Combining root pruning treatments, again, and comparing them with unpruned seedlings, average differences were .4, . 1, .3, . 1, .2, and .2 feet at age three for the six studies, giving an overa11 average improvement of .2 feet for seedlings that averaged 6 feet tal1 at age 3 (about a three percent difference).

Our 6 studies don't provide much support for root pruning. Top-clipping, which is much faster and easier to do than root pruning, improves survival much more than root pruning. Top clipping also does a much better job of controlling top length and produces more uniform seedlings. As already mentioned, top clipping only slows the growth of the taller seedlings that are growing too fast. The shortest seedlings are never clipped and benefit from the reduced competition when their taller neighbors are clipped. Root pruning, on the other hand, reduces the growth of al1 seedlings, large and small, which for us has resulted in greater numbers of undersize, Grade 3 seedlings.

White Pine

Root pruning white pine in the same sandy nursery soils improves survival dramatically. Five studies were installed in 1988, 1989, 1990 and 199 1. Treatments were similar to the loblolly studies, except that in some studies pruning started earlier and more prunings were done during the season. Overa11 survival was much lower than for the loblolly studies (done in the same years) and survival of unpruned seedlings was only 58, 58, 45, 48, and 59 percent, leaving plenty of room for improvement. There were no statistically significant differences between different root pruning treatments. Combining root pruning treatments, therefore, and comparing them with unpruned seedlings for each study, survival was improved 20, 20, 13, 16, and 19 percentage points in the five studies.

Based on these studies, root pruning white pine is now standard practice in our two sandy nurseries. We undercut and lateral prune three times, with the first pruning about the time height growth begins in the spring.

IRRIGATION

We studied irrigation for three years, comparing one inch of water per week with irrigating at from 5 to 30 centibars of moisture tension. Increased moisture stress reduced seedling growth and produced more cull seedlings. Irrigating at 20 to 30 centibars resulted in greater mortality, areas of stunted seedlings, and greatly increased summer chlorosis. The driest treatments had a slight tendency to improve survival, but this could be explained by the considerably shorter tops. Shorter seedlings usually sur-vive better than taller seedlings, but top length is much more easily controlled by top-clipping, and without the undesirable effects of high moisture stress. We concluded that applying one inch of water per week works very well in our sandy nursery soils.

Phosphate Mine Reclamation in Tennessee[1]

E. J. Griffith and H. N. Lyles[2]

Abstract-Throughout the life of the Columbia Tennessee Elemental Phosphorus Plant, it was necessary to beneficiate our phosphate ore by washing illite clay from the ore. The clay was delivered as a 4% slurry to large tailings ponds where the solids were settled and de-watered. The largest talings pond (number 15) was almost 200 feet deep in settled clay and over 400 acres at the surface. When settled and drained, the clay in the ponds have a consistency similar to mayonnaise, but dry to a solid cracked crust on the surface, causing them to appear deceitfully safe. This is particularly true after scrub vegetation covered the surface of an abandoned mud flat. After a few years, men can usually be supported by the dried crust of an abandoned tailings pond, but machinery can break through the crust and sink into the soggy slimes below.

Settled waterlogged clays are thixotropic and can easily be liquified when suddenly stressed. In the event of a dam failure, this could result in a dangerous undesirable event. To render our effete tailings pond system safe and environmentally pleasing, an asset to the state of Tennessee, the decision was made to plant the pond surfaces with 3,500,000 cypress trees. This report is a history of the planting, care for, and maturing of Monsanto's Columbia Tennessee Cypress Garden. Some of our cypress trees are more than 55 feet tall in less than twenty years. A 1,350 year old tennessee cypress tree grew to the amazing height of 175 feet, and is reported to be the largest tree east of the Mississippi River. Our best growth has been *2.75* feet per year. If the growth continued at this rate, the trees will be 175 tall in only 65 years.

INTRODUCTION

An article by George T. Wilson (1995) appeared in the July 1995 issue of *The Tennessee Conservationist.* It illustrates why we chose to plant 3,500,000 cypress trees to stabilize clays left in tailings ponds of the Columbia, Tennessee phosphorus plant, when the plant was decommissioned. The long term prospects of this project are exciting because the ponds have proved to be an ideal environment for the growth of huge cypress trees. The trees are already attracting considerable interest because our trees, supplied by the Tennessee Division Of Forestry, have performed magnificently.

Phosphate ore in Tennessee contains Illite clay. As much as 50% of the weight of the ore can be clay. The clay is encapsulated in very small sheaths of ferric hydroxide. Because the ferric hydroxide is undesirable in furnace operations the clay fraction was removed with either hydroseparators or clones. In either case the clay was suspended as a 4% slurry while the phosphate ore was concentrated, processed, and fed to electric furnaces to manufacture elemental phosphorus, an important item of commerce.

Twenty years ago Columbia, Tennessee was the elemental phosphorus capitol of the world. As a result of environmental concerns no phosphorus has been produced in Tennessee since 1989 costing the state much revenue and hundreds of jobs.

The clay slurry in Tennessee ore had no known uses and created a huge disposal problem. The primary considerations in disposing of 20,000 gal/min. of a

[1]*Griffith, E.J. and Lyles, H. N. 1996. Phosphate Mine Reclamation in Tennessee. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 59-68.*

[2]*Monsanto Company, 800 N. Lindbergh Boulevard, St. Louis, MO 63167; Tel: 314/694-1000.*

creamed coffee colored liquid was economics and safety. During peak productions periods as much as 90,000 dry net tons of tailings solids were processed each month. Without question, the most economical and safe solution to the problem was to pump the slurries into especially designed lakes called ponds. Lakes were formed by building earthen dams across mouths of valleys. As long as the ponds were small and relatively shallow it took little imagination to deactivate a tailings pond in a safe way. Trees and grass grow on the surface of shallow ponds and the vegetation stabilized soil. This is not the case when the lakes are large (400 acres) and very deep (200 feet).

The ore deposits formed along the shoreline of inland seas about two to three hundred million years ago. Much of the phosphate was contained in very small bones of creatures living and dying along the shores of the sea. Millions of these bones are found in the tailings solids, being too small to be captured during the separation of phosphate ore and clay. Illite clay mixed in these ore deposits by glacier action during the last ice age. The clay is believed to have come from Illinois from which it derived its name. It is an extremely fine colloidal clay and settles slowly to about twenty percent solids before it begins compression settling that can take many years to reach fifty percent solids.

Illite clay contains much potassium that is readily available for plant life by ion exchange. Trees planted in the clays have a large supply of phosphate from the very fine particles of bones found in the tailings. There is also a plentiful supply of water al1 year long. With these advantages there is every reason to believe that these trees will become outstanding examples of what can be done with otherwise unproductive land.

It is easily understood how a deep pond might require less initial investment than a large shallow pond. This is particularly true if the shallow pond is built on expensive farming land while the deep pond is built on a rocky hillside. The initial investments are less on the rocky hillside despite the fact that a larger dam is required to retain the settled solids. Too little thought was given to the ultimate reclamation of the pond sites when they were built. Before environmental concerns prohibitively increased the price of electricity and phosphate detergents were banned there was no reason to believe that the Tennessee phosphorus industry would not thrive throughout perpetuity. Conversely, much thought and effort was expended to be certain that the dams and ponds were safe and am-active (Griffith et al. 1992).

Very pure water is returned to the river from which it was taken, but deep ponds built on hillsides present two unique problems. Firstly, water must migrate through many feet of clay before it can be decanted to the river. Migration is a slow diffusional process. The denser settled clays become the slower the escape of water. A second problem is large ponds built on hillsides store enormous potential energy. These issues must be properly prosecuted when filled ponds are to be responsibly abandoned.

The natural process to stabilizes swamps is tree growth when the water becomes shallow enough to support rooted vegetation. Al1 lakes begin to die from the moment of creation, with or without human intervention. They receive runoff silts from surrounding land to become a swamps and ultimately dry land. Deep rooted trees function to de-water deep soil while respirating deep water to the atmosphere. The root structure binds soil to the substrata below it. Cypress trees can drop deep tap roots and they thrive on marshy terrain. It was for this reason cypress was the tree of choice after experiments with pine, oak and other trees.

It was not known for certain that cypress would grow well in Tennessee tailings ponds. Many questions required answers:

How does one plant millions of trees on clay slimes that are too fluid to walk on?

What will be the survival rate of young trees in wet clay?

What will be the primary attacks on young trees?

How rapidly will cypress trees grow on a tailings pond when it is surface is dried and cracked?

On what centers should cypress trees be planted to assure a coverage sufficiently great to stability of a tailings swamp when the trees reach maturity?

How close to a dam can cypress trees be planted?

What will be the contour of a pond surface when it is drained as completely as it can be drained without allowing the drainage to become muddy as it returns to the river?

How much drainage is required?

How deep must a spillways be constructed to allow optimum drainage and safety?

How quickly will runoff silts fill low spots left in a planted pond?

Can cypress compete with vegetation such as grasses and willows?

What can be done to give the cypress trees an advantage?

EXPERIMENTAL

The cypress tree program at Columbia, Tennessee has been active for more than twenty years. The program can be divided into three parts. Firstly, determine what kind of trees should be chosen. Secondly, experiment with smaller ponds to determine if cypress is a good choice. Thirdly, initiate planting of 3,500,000 cypress trees on the drained ponds while correcting for any misconceptions arising from the earlier experiments.

It was not known which animal or diseases might attack the trees. One problem was soon noted. Grasses, weeds and willows grow more rapidly than cypress seedlings. But, cypress seedlings are capable of living under water for periods longer than grasses. To give cypress an advantage ponds were intentionally flooded and re-drain as necessary. This killed weeds and grasses, but not cypress seedlings unless they are submerged too long.

Most of the animals that were expected to attack the trees did not materialize. The only life form found to destroy the young seedlings are birds called coots (*Fulica Americana).* These birds pu11 the young trees from the soft clay and eat the tubers on their roots. This problem was solved with the help of the United States Department of Agriculture-Animal Damage Control Division. They arranged that guns be fired with blanks to frighten the birds away while the trees were small enough to be easily pulled from the soft clay. The Tennessee Division Of Forestry has also been very helpful with the cypress project and did much to make the project a success. We are indeed appreciative of their assistance.

A problem that was most feared during the early stages of the planting was that the grasses might become ignited in some way, either by lightning or by some careless person. It is doubtful that young trees can withstand a prairie fire and severa1 years plantings can be lost. Flooding ponds did much to alleviate this danger.

If a relatively small shallow pond is drained the surface of the water logged mud will be more or less flat and the surface of the mud will slope downward toward the dam which is usually the deepest point in the pond. If most of the water can be drained the surface of the clay will slowly dry and shrink. This will cause the surface to become badly cracked and these cracks may extend severa1 feet into the clay. In time weathering and runoff debris will fill the cracks and the surface will become smooth and fast growing trees and grasses will cover the surface. While this is happening it would appear on casual observation that no additional changes are taking place in the pond. This is not the case. Muds in the lower regions of the pond continue to settle for many years. Water that was trapped in the mud migrates toward the surface while clay continues to contract and settle in the lower pond. The result is a sandwich ten or more feet thick, of very fluid tailings slurry, trapped between the upper crust and the lower condensed muds. This represents a dangerous condition in deep ponds. See Figure 1.

It is possible for both men a equipment to fa11 though the dried crust of a pond and sink into the slimes below the surface. At Columbia Plant two separate events occurred to confirm this conclusion. In one case an operator drove a bulldozer on to an abandoned tailings pond that had been out of service for many years. The surface of the dried clays were not strong enough to support the weight of the heavy equipment. The bulldozer broke through the crust and was lost in the muds below. Fortunately no one was injured.

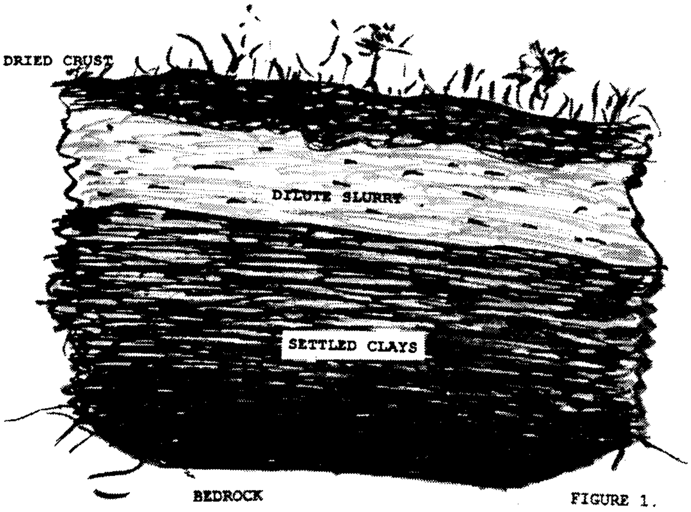

Figure 1.

A worker collected a sample of the slurry where the bulldozer fe11 through the surface crust. It was discovered that the slurry contained only about 12% solids. A misunderstanding of the behavior of the system led to the belief that Illite tailings would not settle to more than 12% solids n-respective of the time given for them to settle and consolidate. This was later shown not to be the case. Many years may be required if the water must leave the clay by diffusing through many feet of clay, but there is no barrier to settling.

It can be seen in Figure 2. how the tap roots of large cypress trees can not only stabilize the pond solids but also eliminate the sandwiching behavior of the settling clays. This occurs because the trees remove water by respirating it from the dilute slurry between the crust and the settled clays as it attempts to form. In the case of No. 15 Pond the planting of the trees began before the crust ever had a chance to dry to any depth. The trees should prevent the dilute slurry from ever forming in the pond while the trees can drop a tap root quickly through the soft uniform clays below.

DRAINING TAILINGS PONDS

The surface of a large drained tailings pond is not leve1 and flat. Even when the clays were covered with water the mud surface varied many feet in elevation from one place in a pond to another. The high point in a pond is usually near the entry point where the tailings enter the pond depositing the courser fractions of solids, while the lowest point is usually at the farthest edges of the pond. Moreover when water is drained from a pond the muds in the pond have a tendency to slide toward the deepest part of the pond and will more or less follow the contour of the original bottom. The deepest point in the pond when the pond is constructed will also be the lowest elevation of the mud surface when the pond is drained, if the mud slides can occur. In very large ponds the distant shores may be far removed from the deepest point and distant mud shores may remain some deeper than the mud surface at the deepest original bottom of the pond.

PREPARING NO. 15 POND FOR PLANTING

Work with smaller ponds had shown that sliding could be significant in larger ponds and it was possible to destroy any young trees that had been planted before a slide took place. This behavior was also a problem in No. 15 Pond during the years electroendosmosis was used to density the settled tailings. The three most important ponds in this work were No.7, No. 12, and No. 15 with Nos. 12 and 15 requiring the most attention because of their dams and their elevation above the Duck River. No.9 Pond was included in the tree planting experiment to learn more about the behavior of trees in shallow ponds. Trees were not planted extensively in No. ll Pond, but some were planted around the pond to give an idea of the rate of growth of trees that were not growing in tailings per se.

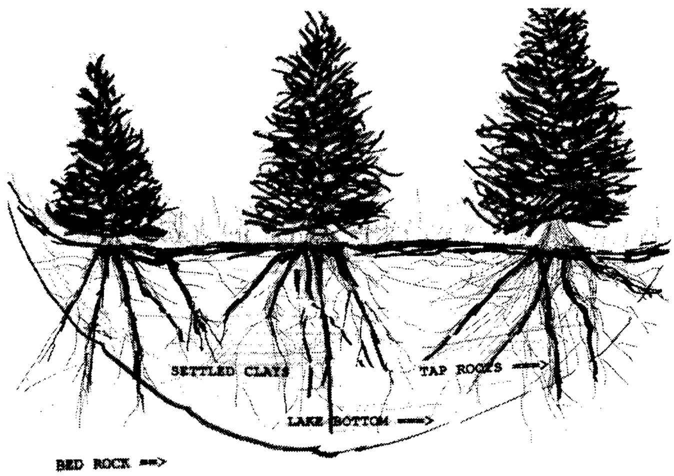

Figure 2.

Mud slides in No. 12 Pond had been intentionally caused during electroendosmosis testing and some slides were intentionally induces in No. 15 pond when the pond was probed to release trapped water. Because of the size of No. 15 it was allowed to lay idle for severa1 years while the electroendosmosis unit continued to compact the bottom of the pond bring the denser muds closer and closer to the surface. When the electroendosmosis unit was decommissioned the dense bottom of the pond was determined to be no more than 90 feet from the surface at the deepest points. The depth was determined with the use of the pond probe to which was attached a mud thief. This depth and concentration is satisfactory for tree planting and roots should easily reach the dense compacted clays.

The first preparation for planting No. 15 Pond was to dredge the pond to remove obvious high spots while filling low spots with the dredgings. The high areas were certain to give troubles when the ponds were drained. The second preparation was to drain the pond as completely as possible. Draining allowed slides to take place and gave an opportunity to observed trouble spots likely to be encountered during planting.

HISTORY

No. 15 Pond was first drained in 1989. Other ponds had been drained much earlier. Figures 3 shows the results of draining No. 15 Pond. It is also worth noting the nature of the clay as is freezes and thaws and dries. Judging from past experience, the concentration of the top lumps are about 30% solids or less. This is another example of the contraction of the clay as water is removed. It points up how much of the volume of an abandoned pond is occupied by water. Figures 4 and 5 show Ponds 15 and 12 before they were drained.

Figure 6 shows No.7 Pond after it was drained to plant trees in the lower end of the pond. Unfortunately the drain pipe for this pond collapsed when the pond was first filled and the drain was grouted closed with concrete. The original drain pipe can be seen as a light colored spot at the end of a short road on the far right side of the picture. This is a road leads from the road on top of the dam. The collapse of the drainage pipe required the construction of a deep drainage ditch to rid the pond of most of its water. This ditch can be seen as a straight line leading from the water's edge to near the top of the picture forming a "V" with the light colored road on top of the dam.

Once a pond had been drained it was allowed to lie dormant for severa1 months as water was collected on the surface as a result of the muds settling and squeezing water from below. Only runoff water could be used to refill a pond because the pumps which had been used to pump water to the ponds had been decommissioned.

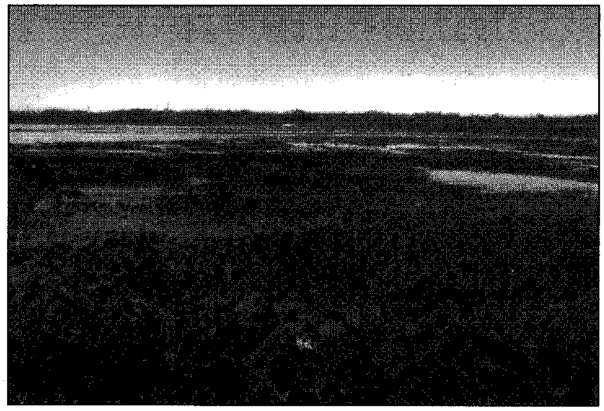

Figure 3. The behavíor of drying clays in No. 15 Pond to prepare it for planting.

Figure 4. No. 15 Pond as an active mountain lake.

Figure 5. No. 12 Pond as an active pond.

Figure 6. No. 7 Pond when it was drained for tree planting experiments. (Note: The large trees to be discussed later were planted on the drained part of No. 7 Pond far to the left of the picture.

Several attempts were made to find ways to plant trees on the sloppy quagmire. A hover craft-air suspension all terrain vehicle- was attempted, but it proved to be too unstable. It was finally decided that the only way that would be reasonable was to flood the pond and plant the trees from a boat. The level of water would be lowered to expose a few feet of clay surface around the edges of the pond during each years's planting. This caused the first trees to be planted where the sub-soil was close to the surface and the new trees should soon be tacking the clays to the bedrock below.

Planting generally started in winter after the pond level had risen far enough to allow planting to begin and the trees had become dormant. The first plantings from the boat was long and very slow. Later, two experienced workers on a fourteen foot Jon boat could plant about 3,000 seedlings per day. After the high survival rate had been established spacing was increased to four feet. The length of the shore line was several miles and trees were planted on one foot centers. This proved to be too close but there was no good way to determine how many trees would survive. It was much more economical to over plant that it would be to replant.

Each year as the previous year's plants became established planting moved toward the center of the pond. The first planting of No. 15 Pond began in the fall of 1989. As can be seen from the photographs most of the surface of No. 15 Pond has been covered by the summer of 1995. It was practice to keep the surface covered with as much water as possible. This was done to control weeds and grass. The fresh surface of the ponds were ideal seeding sites for all manner of trashy undergrowth. Willow trees being one of the more prolific spreaders. The Willow is a short lived, shallow rooted tree and is not desirable on deep muds where respiration from great depths is desired. For this reason it has been necessary to thin the Willows from time to time to assist the cypress.

It should be noted from the photographs trees were intentionally NOT planted near dams. This would violate the Safe Dams Act. It is well known that tree roots are not desirable in dam structures. In the case of No.15 Pond the trees were kept at least fifty feet from the shoreline of the dam. Not only does this protect the dams from invasion by tree roots it places the trees at the very deepest points along the pond side of the dam. The berm that is left at the foot of the dam functions as platform for work and observations of the conditions of the dam. Unfortunately, dams require constant attention and are very costly to maintain. This is a major reason all lakes were not left for recreational use. Those that were considered to be perpetually safe and visible from public roads were left for recreational areas, par-t of the Monsanto Ponds Wildlife Observation Area.

The ponds were beautiful fishing and boating lakes even when they were in full operation killing forever the myth that these tailings killed fish or destroyed their breeding sites.

Although it is a mute question, because the industry is gone forever, it is doubtful that Tennessee tailings ever did any harm to the river in any way. The river contains very large quantities of Illite clay as land runoff every time the river floods, which it does very often. Nevertheless, during the last thirty-five years not one case of river pollution attributable to our pond system was ever recorded. It is an excellent example of remedia1 responsibility and is a record Monsanto employees are justifiably proud!

Most of the photographs were taken of Nos. 15, 12, and 7. No.7 Pond was a large surfaced relatively shallow impoundment with a very steep dam. It is important because it was the first pond to receive experimental trees about 1975. It supports trees of all ages. No. 12 is important because it was a relatively small pond on a steep ridge. It was subject to mild sliding of the muds when drained and had some of the problems anticipated with No. 15 Pond. No. 12 Pond had also been the experimental pond for the demonstration of electroendosmosis which was to be used in No. 15 Pond (Griffith 1978). No. 15 Pond is important because it is the largest of al1 of the ponds and is also on a hillside. No. 15 Pond contains practically al1 of the plant's production from 1967 until the plant closed. Small quantities of tailings were pumped to the remainder of the system during the start up of No. 15 Pond. Nos. 12 and 15 were the ponds of greatest concern and were the primary reason the planting was undertaken.

Figure 7 shows trees planted in No.9 Pond. No.9 Pond is very small and shallow. Trees have grown well in this pond even though many were planted in water and remained in water. The progress of the growth can easily be seen in Figure 8 which is three years growth of the trees from Figure 7. Note the hill in the background for reference.

Figure 8 is almost the same picture of No.9 Pond as was Figure 7. Figure 8 vividly demonstrates what only three years growth can bring to the cypress tree sizes. The trees are performing splendidly. It is expected that the shallow water in No.9 Pond will eventually be replaced with silt and that the cypress trees will seed new growth themselves. At this time there seems to be no need to either plant more trees or to thin those that are currently growing. The process should take cared of itself leaving a grove of cypress trees with perhaps a small stream through it for a few years. Al1 water to this pond is run off from the surrounding land.

Figure 7. No. 9 Pond in the early days of planting in May 7992.

Figure 8. No. 9 Pond in May of 7995 three years after the picture shown in Figure 7.

Figures 9 and 10 compare the growth of trees on No. 12 Pond during the period from May, 1992 through May, 1995. Again the growth has been spectacular. No. 12 Pond also faced a drainage problem. In this case the top water flume could not easily be lowered. A new drainage system was cut through the stones to the left of this picture. The hydrolytic loading of the dam should be diminishing as the trees grow larger and stabilize and dehydrate the waterlogged soils below.

Figure 9. No. 12 Pond in early 1992. Note the small trees at the water's edge and use the hills for reference in the next picture.

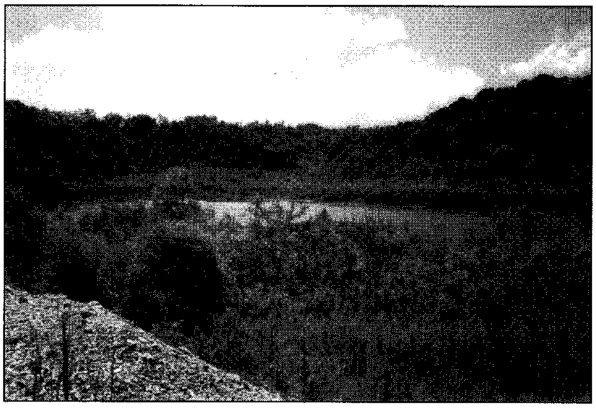

Figure 10. No. 12 Pond in May 1995 showing three years of growth from the picture above.

Figures ll and 12 show the growth of trees on the wet end of No.7 Pond. Tree growth on this pond has far exceeded expectations and is a picture perfect example of what was desired. There was never great concern for stabilizing the soil in this pond for dam protection. There was the concern to dry up the waterlogged slimes in the depths of the pond to prevent the danger of breaking through the dried crust of the pond. As mentioned earlier there was a drainage problem with No.7 Pond also, but it is believed that this problem has been satisfactorily solved. Additional planting as the system dries could be of benefit, but the trees should seed the new growth and silting in should be rapid in this location.

Figures 13 and 14 demonstrate the progress achieved with No. 15 Pond. The pond is much too large to give more than a very selected view. The size of the pond has shrunk dramatically since 1992 until 1995. Note the planting lines as the following years grow is smaller than the year before. The spacing is almost perfect. The water leve1 on this pond has been controlled to keep down grasses that will choke light from young trees.

Planting of No. 15 Pond is almost complete although planting is planned for the winter of 1997. Any areas where there have been tree losses will be planted and a new spillway is being installed to lower the water leve1 of the pond and control what is left in the pond. As the

Figure Il. No. 7 Pond in 1992 showing the planting at the water's edge.

Figure 12. No. 7 Pond three years after the picture above. June 1995.

trees age in this pond there should be only a small stream across the top of the pond. There are know to be subterranean springs buried in the muds of No. 15 Pond. It is difficult to predict which flow path these springs will eventually take. Since the springs are located in the wall of the pond it is likely that they will eventually surface near the old shore line of the pond. It is very unlikely that they should cause any problems once the tap roots of the cypress trees become established and should be helpful to water the large trees.

Figures 15 and 16 te11 the story of Monsanto's Cypress Garden as well as any pictures can tell the story. Figure 15 is one of the test trees planted in a row across the back shallow side of No.7 Pond. To plant these trees the personnel doing the planting lay on big sheets of plywood and were pulled across the wet clay. By the time the picture was made of the tree in Figure 15 one could walk safely across the dried clay.

Figure 16 shows the line of trees planted in 1974 after they have grown for twenty years. Very few if any of the trees were lost.

They are growing rapidly as examples of what can be expected from the 3,500,000 trees planted on our tailings ponds. In the years to come the Cypress Garden will surely become a show place.

Figure 13. The view of No. 15 Pond in May, 1993. The photograph was made from the tower seen in Figure 15.

Figure 14. The view of No. 15 Pond in May, 1995. Note that all water in this part of the pond has been drained.

Figure 15. One of the test trees planted on No. 7 Pond in 1974. This is one of the same trees shown in Figure 16 twenty years later. (The late Joseph Green did much to support the early work with trees.)

Figure 16.

CONCLUSIONS

The tree planting program has been an unqualified success and there is no doubt that the cypress garden will become a show place of much value in the years to come. The garden will be unique and the threat of a dam failure will soon be of no concern. Although it is unlikely that anyone will choose to do so, the dams can probably be removed entirely within a few years with no ill effects. Any hazard initially associated with dams and ponds is diminishing daily.

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Longleaf Pine Seed Quality: Can it be Improved?[1]

James P. Barnett[2]

Abstract-Longleaf pine (*Pinus palustris* Mill.) seeds are sensitive to damage during collecting, processing, storing, and treating activities. High quality seeds are essential for successful regeneration of the species by either direct seeding or planting. Results from recent tests are combined with earlier data to develop recommendations for producing and maintaining longleaf pine seeds of high quality.

Keywords: *Pinus palustris*, southern pines, nursery production, germination, cone and seed production.

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) is a highly desired pine species for reforestation in the southern Coastal Plain of the United States. Vast acreages of virgin longleaf pine previously existed across the South from eastern Texas to North Carolina. However, the species is characterized by a lack of regeneration on sites with extensive amounts of competing vegetation. Longleaf pine has no early epicotyl growth, and its peculiar "grass stage" contributes to its sensitivity to competition and brown-spot needle blight (*Mycosphaerella dearnessii* Barr).

Regeneration of longleaf pine has become more difficult with the advent of fire control, and longleaf has failed to maintain its competitive position because other southern pine species are relatively easier to regenerate. Acreage in longleaf pine is now less than 10 percent of that in the original forests. However, interest in longleaf pine is increasing because it resists insects and diseases and produces high quality solid-wood forest products.

An essential element to improving reforestation success is increasing the quality of longleaf pine planting stock. A number of nursery cultural treatments can be used to improve the quality of seedlings (Barnett 1990; Shipman 1958; Shoulders 1963; Wakeley 1954), but the key to seedling quality is uniform germination and early establishment in the nursery. Developing a uniform nursery crop depends upon the availability of high quality seeds. Cultural practices, either in container or bareroot nurseries, can not effectively overcome the problems resulting from inadequate germination.

Longleaf pine seeds are the most difficult southern pines to collect, process, store, and treat successfully (Wakeley 1954; Barnett and Pesacreta 1993). Because the seeds are large, have thin seedcoats, and are unusually moist when extracted from cones, collecting and processing them without adversely affecting quality requires special handling and unique procedures. Producing longleaf pine seeds to meet the increasing demand in recent years has been plagued by low seed quality. This paper presents results from recent tests, combines these results with other documented findings, and develops recommendations that may improve the potential to produce high quality longleaf pine seeds.

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[1] *Barnett, J. P. 1996. Longleaf Pine Seed Quality: Can it be Improved?. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen, Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 69-74.*

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COLLECTING SEEDS

The greatest early losses in seed quality result from collecting cones before seeds are fully mature. Generally, timing southern pine cone collection is based on Wakeley's (1954) results that indicate cones are mature enough for seed extraction when their specific gravities drop below 0.89. More recent data confirm that collection should be delayed until cones are fully mature, because viability of longleaf seeds from immature cones may decrease during cone storage (Barnett 1976a; McLemore 1975a) if some undetermined stage of ripeness has not been reached (Barnett and Pesacreta 1993).

Tests were conducted in fall 1994 to determine where major losses in seed quality were occurring. Specific gravity (SG) was measured on cones from severa1 clones that were collected on an operational basis in the Stuart Seed Orchard at Pollock, LA. The cones were collected during two collection periods and both lots were divided for shipment to two commercial seed processing plants. Collection 1 (October 5-6) was delayed until average cone specific gravity was below the leve1 that indicated maturity (table 1). In collection 2 (October 20), cone SG was lower. It is important to note that even with an average SG of 0.86, a large portion of the cones had a much higher SG. Wakeley (1954) recommends that cone collection begin when 19 of 20 cones have a SG of less than 0.89. The data from the 1994 tests indicated that average SG must be about 0.81 before Wakeley's criteria are met.

The data also confirmed the previously reported influence of SG on seed yields (figure 1); the lower the SG, the higher the seed yield (table 1). Seed germination was also markedly affected by cone maturity. Average germination of seeds from collection 1 was 5 1 percent compared to 69 percent for collection 2 (table 2).

Ripening immature or holding mature longleaf cones before extraction may or may not improve seed viability (Barnett 1976a; 1976b; Bonner 1987; McLemore 1959; 1975a), but some cone storage is needed to improve seed yields.

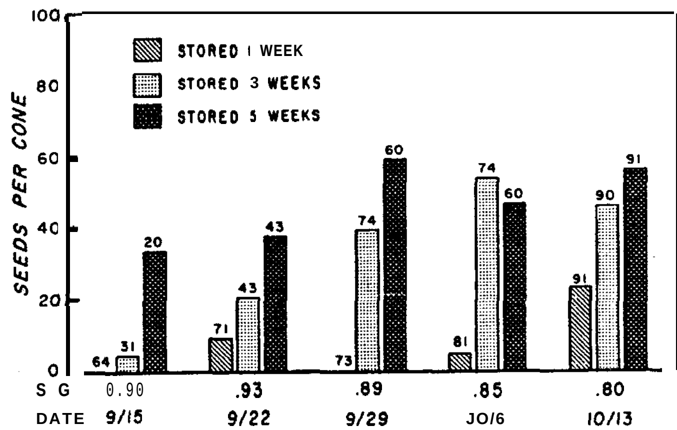

Figure 1. Seed yields and germination (shown above bars) of longleaf pine as affected by date of collection and cone storage (from Barnett 197913).

Table 1-Longleaf pine cone specific gravity[1] and seed yields by collection date.

Collection period	Cone specific gravity: Average	Cone specific gravity: Above 0.89 (percent)	Cone specific gravity: Above 0.87 (percent)	Seed yields (*lbs/bu*)
1 (Oct. 5-6)	0.86	27	44	0.49
2 (Oct. 20)	.81	4	7	0.73

'Values represent an average of 20 replications of 10 cones each per collection period.

Table 2.-Longleaf pine cone and seed exposures during processing and resulting seed germination.

Variables	Collection date 1 Plant A	Collection date 1 Plant B	Collection date 2 Plant A	Collection date 2 Plant B	Avg.
	Cone and seed exposure				
Days of cone storage	44	42	28	20	
Kilning-total hours	96	92	119	94	
Kilning-hours >86°F	66	80	82	80	
Seed drying—total hours	117	21	116	17	
Seed drying-hrs. >86°F	60	19	58	17	
	Seed germination				
After kilning	59	52	76	81	67
After dewinging	46	46	59	65	54
After seed drying	54	47	64	67	58
Average	53	48	6	71	60

After SG's were measured, the cones were shipped to two processing plants. Dataloggers included in the bags of cones recorded hourly temperature exposures during cone storage and processing periods. Duplication of processing provided a greater range of environmental conditions and thus improved the opportunity to identify conditions that might affect seed quality. Table 2 provides a summation of cone and seed exposure.

Information collected on the dataloggers shows differences between processing plants in the length of time the cones were held before kilning and in the temperature exposures during kilning and seed drying (table 2). Delaying cone extraction beyond 30 days may begin to reduce seed quality (figure 2), but the effects of cone storage are difficult to separate from those of exposure to temperature. These two variables may interact. For instance, longer cone storage could improve seed germination (Bonner 1987), but the corresponding longer exposures to high seed drying temperatures might reduce viability.

PROCESSING SEEDS

During the processing stage, dewinging may adversely affect the quality of seeds collected from mature cones. During our 1994 operational tests, dewinging caused germination to drop an average of 13 percentage points. Earlier studies have shown that if longleaf seeds are dewinged carefully, germination is not reduced (Barnett 1969; Belcher and King 1968). Three possible causes of dewinging damage are lack of seed drying, inappropriate dewinging equipment, and large size seeds.

First, processors may dewing seeds before drying for storage. Although this seems to be a logical approach, earlier studies have shown less damage to seeds dried before dewinging (Barnett and McLemore 1970).

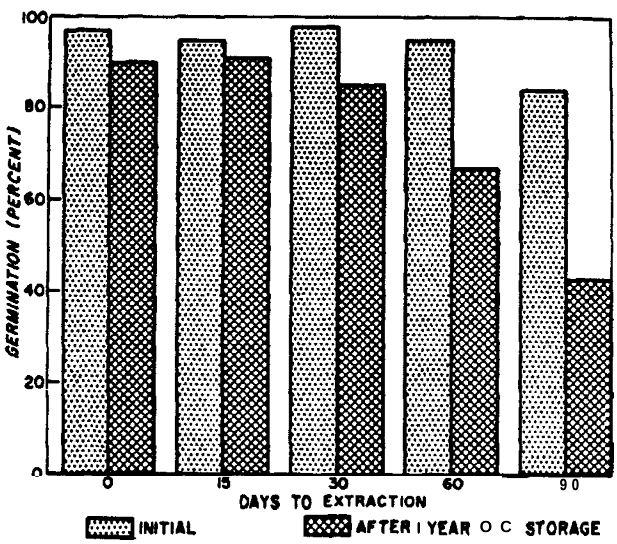

Figure 2. Effect of delayed extraction on longleaf seed germination initially and after one year of seed storage (from McLemore 1961).

Drying results in more brittle wings that are quickly and easily reduced to stubs. However, because longleaf pine seeds are known to be relatively sensitive to high temperatures (Barnett 1979a; Rietz 1941), the length of exposure to high drying temperatures may reduce seed quality.

Second, equipment designed for optimal dewinging of loblolly *(P. taeda* L.) and slash *(P. elliottii* Engelm.) seeds may cause damage to the more sensitive longleaf seeds (Barnett and Pesacreta 1993). Many tests have shown that the harshness and length of dewinging must be minimized. Clearly, equipment must be modified to prevent injury to longleaf pine seeds.

Third, fertilization and other cultural practices in the orchard usually produce relatively large seeds (McLemore 1975b). Larger seeds are more likely to be damaged during processing because the portion of the seedcoat of total seed weight is less than in smaller seeds within the species. Sizing of longleaf seeds may be desirable to improve uniformity of germination in the nursery. A gravity table can be used to size seeds and remove empty or partially developed seeds that have lower viability.

STORING SEEDS

The critical factors affecting storage are seed moisture content and storage temperatures. Results of long-term storage tests with longleaf pine seeds show that seeds must be dried to moisture contents below 10 percent and sealed in airtight containers (Barnett and Jones 1993). Tests have shown that longleaf pine seeds can be satisfactorily stored for 3 years or less at temperatures slightly above freezing (34°F) (Barnett 1969; Jones 1966). For longer periods, storage should be at subfreezing temperatures, preferably near 0°F (figure 3). Longleaf pine seeds have retained their viability for 20 years when held at 0°F temperatures (Barnett and Jones 1993). Seed quality can be maintained for periods to meet all practical needs. In fact, because damaged or less vigorous seeds are best preserved by lowering storage temperatures (Kamra 1967), the lower temperatures are recommended as a routine practice.

TREATING SEEDS

Although early research had suggested that some seedlots might benefit from short periods of stratification (USDA Forest Service 1948; Wakeley 1954), caution was urged because longleaf pine seeds frequently begin to germinate during stratification. As knowledge about how to properly collect, process, and store longleaf seeds increased, most researchers and practitioners felt stratification was unnecessary. In recent years, however, renewed interest in stratification of longleaf pine seeds has occurred-a result of the desire to upgrade or improve performance of seedlots of poor quality. Karrfalt (1988) reported that stratification for 14 days improved both speed and total germination in almost all 54 longleaf pine seedlots tested; most of which had relatively low viability.

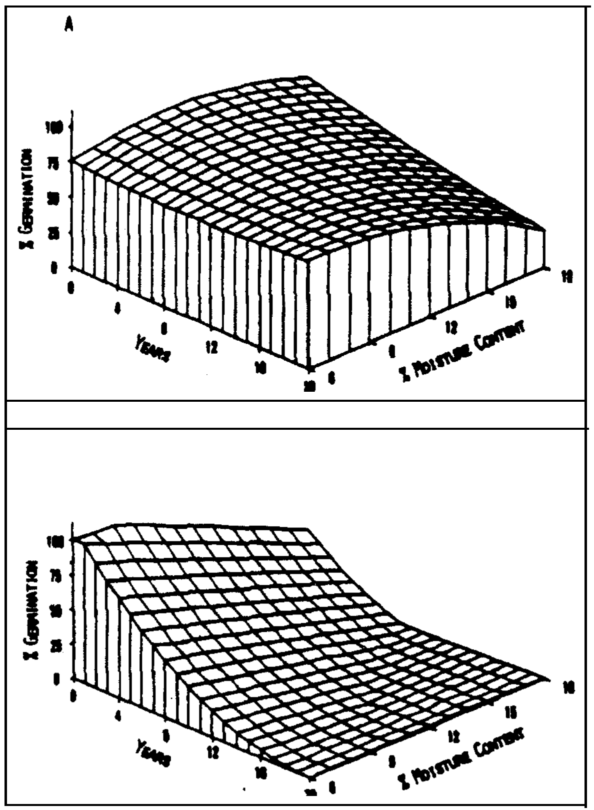

Figure 3. Germination of longleaf pine seeds as influenced by moisture content and years of storage at 0° (top) and 34°F (bottom).

Others provide data showing that stratification, while hastening germination by about 2 days, reduces total germination by about 10 percentage points (Barnett and Jones 1993). The disparity in these results may relate to the method of imbibition needed for stratification. Operationally, seeds are stratified by soaking them overnight in water, draining the water, placing the seeds in polyethylene bags, and holding the bags under refrigeration for an appropriate period. Karrfalt (1988) placed the seeds in germination dishes and imbibed them with the germination medium. Barnett and Jones (1993) soaked the seeds in water alone for 16 hours which reduced germination by 10 percentage points.

Longleaf seedcoats are hosts to significant populations of pathogenic fungi (Barnett and Pesacreta 1993; Pawuk 1978). Germination of less vigorous seeds may be improved by treating with a sterilant, such as hydrogen peroxide (Barnett 1976b), or applying a fungicida1 drench with benomyl (Barnett and Pesacreta 1993). Both treatments are used in southern forest nurseries.

CONCLUSIONS

Longleaf pine seeds are sensitive to injury during collection, processing, storage, and treatment. Because longleaf pine seeds are large, have relatively less dense coats, and are difficult to dewing, the techniques used for processing other southern pines are inadequate. However, when properly handled, high quality longleaf pine seeds can be produced.

RECOMMENDATIONS

The following recommendations include factors essential to maintaining high quality longleaf pine seeds:

1. Collect longleaf p'i.e cones when fully mature (19 of 20 cones have a specific gravity of 0.89 or less) and hold for 3 to 4 weeks before processing. Do not delay processing of cones beyond 4 to 5 weeks.

2. Maintain kiln temperatures between 95°F and 105°F. As soon as the cones open, remove seeds from the kiln. Dry seeds to moisture contents below 10 percent by placing in seed dryers on clear, dry days when the ambient relative humidity is low.

3. Use dewinging equipment designed for longleaf pine to ensure that the wings are reduced to stubs without injury to the seedcoats. Dewing the seeds only after they have been dried to moisture contents of 10 percent or less.

4. Remove trash, wings, and empty seeds carefully in a cleaning mill, on a gravity table, or by flotation in *n*-pentane (Barnett 197 1).

5. Store in sealed containers at moisture contents less than 10 percent and at subfreezing temperatures, preferably near 0°F.

6. Conduct germination tests when seeds are placed in storage and if storage is longer than 1 year, again before use. If stratification is considered, conduct paired germination tests (stratified and control lots). Tests should follow pre-sowing treatments that duplicate operational procedures, i.e., water soaking as used in stratification.

7. Consider control of seed microorganisms if lots are of low quality. The use of sterilants or fungicide soaks will significantly reduce populations of microorganisms on the seedcoats and may improve seed performance, particularly under nursery conditions.

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Seedborne Diseases of Southern Pines and Developing Strategies for Their Control[1]

Stephen Fraedrich[2]

Abstract—Plant pathogenic fungi such as *Lasiodiplodia theobromae* (the black seed rot fungus) and various *Fusarium* spp., most notably *Fusarium subglutinans* (the pitch canker fungus), are the causes of seedborne diseases in southern pines. Seeds contaminated and infected by pathogenic fungi may cause problems that could adversely affect pine seedling production in nurseries. Recent problems with mortality of longleaf pine seedlings caused by *F. subglutinans,* and the association of this fungus with seeds, underscore the importance of developing a better understanding of pathogenic, seedborne fungi and the means to control them. Strategies for the control of various seedborne diseases may differ based on the epidemiology of the diseases, and the biology of the host and pathogen. This paper provides a brief review of seedborne fungal problems that affect southern pine seeds, and discusses established and potential control practices as well as current research efforts.

INTRODUCTION

Pathogenic, seedborne fungi, associated with conifers, can cause seed diseases (Sutherland et al., 1987), as well as pre- and post-emergence damping-off of seedlings (Graham and Linderman 1983; Huang and Kuhlman 1990). Numerous species of fungi are known to be associated with the seeds of southern pines (Anderson 1986; Mason and Van Arsdel 1978; Fraedrich and Miller 1995), but most are probably saprophytes that do not adversely affect seed quality. However, two groups of seedborne fungi are believed to be responsible for seed diseases and seedling disease problems in southern pine orchards and nurseries. These fungal groups include various *Fusarium* spp., such as the pitch canker fungus, *Fusarium subglutinans* (Wollenw. & Reinking) Nelson, Toussoun & Marasas, and Diplodia-like fungi such as *Lasiodiplodia theobromae* (Pat.) Griff. & Maubl.

The detection of seedborne inoculum and the implementation of control practices are important aspects of plant disease management (Irwin 1987). Basic control practices for dealing with seedborne problems include strategies for preventing the establishment of specific fungi with seeds as well as developing remedia1 treatments to control diseases after establishment of seedborne pathogens. This paper provides a brief review of seedborne fungal problems that affect southern pine seeds, and discusses established and potential control practices as well as current research efforts.

BLACK SEED ROT

Some slash pine (*Pinus elliottii* Engelm. var. *elliottii)* seed orchards in the southern United States have experienced severe losses in seed quality and quantity due to black seed rot. The fungi associated with this disease are *Lasiodiplodia theobromae*

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[1] *Fraedrich, S. 1996. Seedborne Diseases of Southern Pines and Developing Strategies for Their Control. In: Landis, T. D.; South, D. B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 75-81.*

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(=*Diplodia gossypina)* and possibly *Sphaeropsis sapinea* (Fr.) Dyko & Sutton (=*Diplodia pinea*). Miller and Bramlett (1979) found that *L. theobromae* was associated with internal seed damage, and poor germination in some slash pine seedlots. Commonly, the embryo and endosperm are destroyed by this fungus in infected seeds. More recent studies have also implicated *S. sapinea* (Fraedrich et al. 1994). In a 1979 survey, Diplodia-like fungi were associated with seeds from 19 of 21 slash pine seed orchards that were examined; a *Sphaeropsis* sp. was also associated with seeds (Anderson et al. 1984). *Lasiodiplodia theobromae* and *S. sapinea* are also known to contaminate and infect the seeds of other pine species such as *P. caribaea* Morelet and *P. oocarpa* Schiede (Rees 1988; Rees and Webber 1988).

Lasiodiplodia theobromae can cause a tip-dieback of loblolly and slash pine seedlings (Rowan 1982). However, no association has been established between seedborne inoculum of this fungus and terminal dieback of seedlings. *Sphaeropsis sapinea* is pathogenic to numerous pine species worldwide and can infect seedlings as well as older trees (Sinclair et al. 1987). This fungus does not appear to cause diseases of pine seedlings or trees indigenous to the southern United States.

Prevention

Studies indicate that black seed rot is primarily a postharvest problem related to the premature collection of cones (Fraedrich et al. 1994). Colonization of slash pine seeds by *L. theobromae* and similar fungi appears to be linked with the time of cone collection and collection practices. In one study, fungus-damaged seeds were not observed at the time that cones were collected from trees (Figure 1; treatment 'NGC/NS'). In contrast, the incidence of fungus-damaged seeds was relatively high in those cones that had been harvested early, and subsequently handled in a manner similar to operational conditions (treatment 'GC/S'). These cones had been dropped from trees, left on the ground for three days, and then stored for five weeks. The incidence of fungus-damaged seeds decreased on later collection dates in the 'GC/S' treatment as cones matured and specific gravities decreased.

Guidelines for the harvest of slash pine cones suggest that collections should begin when cone specific gravity is below 0.89 (Wakeley 1954). Slash pine clones and families can vary greatly in their time of maturation (Fraedrich and Spirek 1991; Fraedrich, et al. 1994) and this should be taken into consideration when establishing proper times to harvest cones. Managers of slash pine seed orchards that have unacceptable seed losses due to *L. theobromae* should evaluate the time of harvest with respect to the relative degree of cone maturation of families or clones in an orchard. Slash pine cones are typically dislodged from trees with a mechanical tree shaker in many orchards and subsequently gathered from the ground. These practices appear to be appropriate provided cones are sufficiently mature when harvested.

Remedial control practices

Techniques are currently available to separate fungus-damaged seeds from healthy, viable seeds in order to increase germination of seedlots. One such

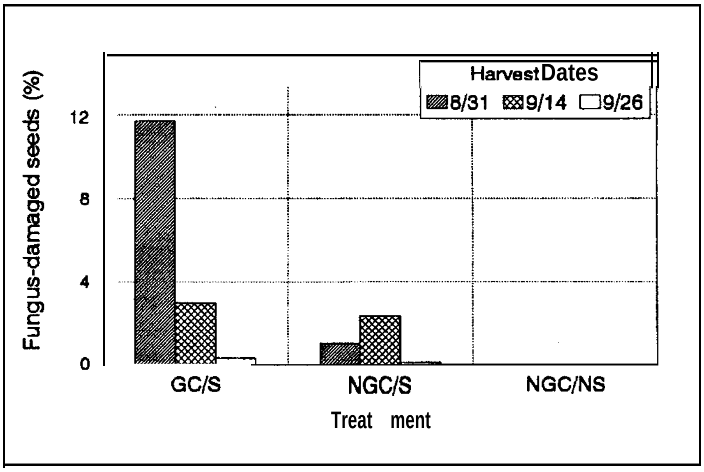

Figure 1. Incidence of fungus-damaged seeds as determined by radiographic evaluation for seeds of slash pine cones collected from four slash pine families on three harvest dates between 30 August and 26 September 1988. Cone treatments included: 'no ground contact/no storage' (NGC/NS), 'no ground contact/storage' (NGC/S) and 'ground contact/storage' (GC/S). The ground contact period was for 3 days; the storage period was for 5 weeks. (Fraedrich et al. 1994)

technique employs a specific gravity table to remove the lighter weight, unsound seeds from seedlots (Karrfalt 1983). This system has been used by severa1 organizations with good results. Another procedure that has shown promise for the separation of viable seeds from filled dead seeds is the IDS-system, and it has been used to remove dead seeds from loblolly (*P. taeda* L.) and slash pine seedlots (McRae 1994). This procedure is based on the differential drying of viable and filled dead seeds, and the subsequent separation of these seeds due to their differences in weight and density.

Seedborne fungi such as *L. theobromae* and *S. sapinea* are apparently not related to any major seedlings diseases that occur in southern pine nurseries. Therefore, the use of surface sterilization agents or fungicides as remedia1 treatments for southern pine seeds infected or contaminated by these fungi does not seem warranted.

DISEASES OF SEEDS AND SEEDLINGS CAUSED BY SEEDBORNE *FUSARIUM* SPP.

Many *Fusarium* spp. can be associated with southern pine seeds (Mason and Van Arsdel 1978; Pawuk 1978; Fraedrich and Miller 1995) and seeds are regarded as a potential inoculum source for Fusarium-related seedling diseases which have occurred in bareroot and container nursery operations (Blakeslee et al.; 1989; Pawuk 1978). In a 1979 survey, *Fusarium* spp. were isolated from seeds of 12 of 21 slash pine seed orchards; in seven of these orchards *F. subglutinans* was isolated from the seeds. However, *Fusarium* spp. are widely distributed, and can be frequently recovered from various sources including air, water and soil samples. Presently, the relationship is not clear between seedbome *Fusarium* spp. and seedling diseases in southem nurseries.

Seedbome inoculum has been suspected to be the source of seedling disease problems in severa1 instances. Root rot and damping-off of container-grown southem pine seedlings in a Louisiana nursery was attributed to *Fusarium* spp. including *F. oxysporum* Schlecht., *F. solani* (Mart.) Sacc. and *F. moniliforme* Sheld. (Pawuk and Bamett 1974; Pawuk 1978). The problem was most prevalent on the longleaf pine (P. *palustris* Mill.) seedlings, although mortality was also observed in loblolly, slash and shortleaf pine (P. *echinata* Mill.) seedlings. The *Fusarium* spp. that were commonly isolated from diseased seedlings were also commonly isolated from the seeds of seedlots sown at the nursery. In another instance, poor germination of longleaf pine seeds and damping-off of seedlings in a North Carolina nursery was caused by *F. subglutinans* (Runion and Bruck 1988). Unlike many other *Fusarium* spp. associated with seeds, *F. subglutinans* can be highly pathogenic to southem pines. *Fusarium subglutinans* can infect various vegetative and reproductive structures, and the fungus is responsible for pitch canker which is particularly damaging to trees in seed orchards and plantations (Dwinell et al. 1985). In addition, the fungus can infect and damage the cones and seeds of slash and loblolly pines (Miller and Bramlett 1979; Barrows-Broaddus 1990), and may also contaminate the seedcoat of otherwise healthy seeds. *Fusarium subglutinans* has also caused mortality of slash pine seedlings in Florida nurseries (Bamard and Blakeslee 1980) and seedbome inoculum has been suspected (Blakeslee et al. 1989). Huang and Kuhlman (1990) demonstrated in greenhouse studies that severa1 *Fusarium* spp. could cause pre- and post-emergence damping-off of slash pine seedlings from seedbome inoeulum. Isolates of *F. subglutinans* caused significant damping-off at 20 and 30 C; however isolates of *F. proliferatum* (Matsushima) Nirenberg and *F. moniliforme* infected seedlings primarily at the higher temperature.

Recent disease problems of longleaf pine seedlings caused by *F. subglutinans* have renewed interest in seedbome fungi and the potential damage they can cause to cones, seeds and developing seedlings. Seed and seedling disease problems caused by *F. subglutinans* have been observed at severa1 longleaf pine nurseries and seed orchards in the southem United States. Carey and Kelley (1994) isolated *F. subglutinans* consistently from diseased seedlings in a North Carolina container nursery and a bareroot nursery in Alabama. In 1995, mortality of longleaf pine in a Florida nursery, caused by *F. subglutinans,* was restricted to seedlings from one particular seed source.

Seedlings in adjacent seedbeds produced from other seed sources were healthy and not affected by the disease (Fraedrich, unpublished data). At a Mississippi nursery, longleaf pine seedling mortality due to *F. subglutinans* has been observed during 1994, 1995, and *1996. Fusarium subglutinans* has been associated with seeds from the longleaf pine seedlots used at this nursery (Fraedrich, unpublished data).

Results of several experiments with longleaf pine seeds used at the Mississippi nursery indicate that *Fusarium* spp., including *F. subglutinans,* were primarily associated with seedcoats, and infections of the endosperm and embryos were rare. In an experiment using one longleaf pine seedlot, *Fusarium* spp. were associated with all seeds that were not treated with surface sterilization agents prior to plating on agar media (Figure 2). No attempt was made to identify individual *Fusarium* spp. in this treatment, but it appeared that more than one species frequently grew from individual seeds. *Fusarium* spp. were isolated from 37% of seeds after treatment with a 1% sodium hypochlorite solution for two minutes, and *F. subglutinans* was isolated from 13% of the seeds in this treatment. We isolated *Fusarium* spp. from only 1% of the seeds after treatment with a 30% hydrogen peroxide solution for 55 minutes as described by Barnett (1976).

In another experiment using three longleaf pine seedlots, *Fusarium* spp. were isolated from 16-22% of the seeds that had been surfaced sterilized with sodium hypochlorite prior to plating on agar media; *F. subglutinans* was isolated from 2-6% of the seeds (Figure 3). When seedcoats were removed from the sodium hypochlorite-treated seeds, and endosperm and embryo plated on an agar medium, *Fusarium* spp. were isolated from only 0-2% of the seeds. Results of these experiments suggest that *Fusarium* spp. were primarily located in the seedcoats of the longleaf pine seeds and were rarely present in the internal portions of these seeds.

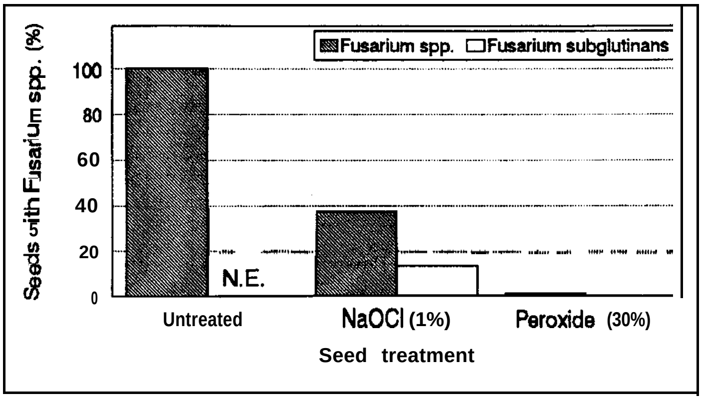

Figure 2. Assessments of *Fusarium* spp. and *F. subglutinans* associated with seeds of a longleaf pine seedlot that were untreated or treated with surface sterilization agents. Surface sterilization agents were 1% sodium hypochlorite (20% Chlorox® for 2 minutes) and hydrogen peroxide (30% for 55 minutes). 'N.E.' indicates that 'No Evaluation' was attempted.

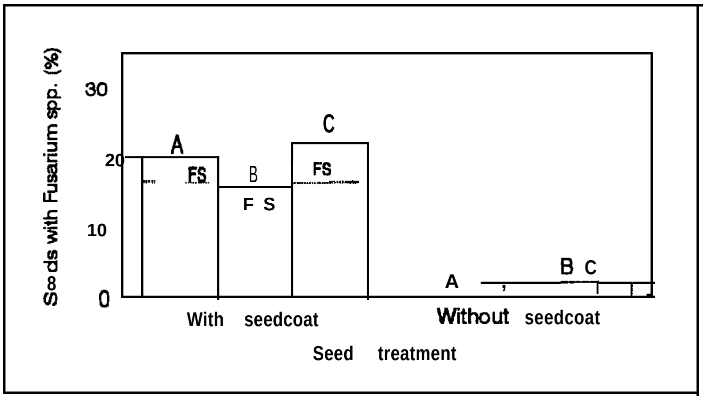

Figure 3. Association of *Fusarium* spp. and *F. subglutinans* with seeds and with embryo and endosperm of seeds from three (A,B,C) longleaf seedlots. Seeds had been treated with a 1% sodium hypochlorite solution (20% Chlorox® for 2 minutes). 'FS' indicates *Fusarium subglutinans.*

Prevention of Seed and Seedling Diseases

Various factors are likely to have an influence on the development of Fusarium-related diseases of seeds and seedlings of southern pines; however, our understanding of the epidemiology of these diseases is presently limited. For instance, susceptibility of some southern pines to pitch canker can vary by pine clone or family (Kelley and Williams 1982; Rockwood et al. 1988), but information is lacking on possible genetic variability in the susceptibility to Fusarium-related seed and seedling diseases. Fertilization also has been linked with pitch canker of slash, loblolly and Virginia (*P. virginiana* Mill.) pines (Fraedrich and Witcher 1982; Wilkerson et al. 1975), but information is not available on possible relationships of fertilization practices in orchards to subsequent seedborne diseases caused by *F. subglutinans*.

Fresh wounds are known to provide infection courts for *F. subglutinans* (Dwinell et al. 1985), and the fungus is regarded as a wound pathogen of severa1 pine species including slash, loblolly and Virginia pine (Hepting and Roth 1946; Kuhlman 1987). Results of inoculation studies indicate that *F. subglutinans* also infects longleaf pine seedlings through wounds (Fraedrich, unpublished data). Entry of this fungus into slash and loblolly pine cones was dependent on wounds that provided an infection court (Miller and Bramlett 1979; Barrows-Broaddus 1990). Various types of agents may be involved in the wounding of seedlings and reproductive structures. These may include insects, and cone handling practices during cone harvest and processing. Infection of longleaf pine seedlings by *F. subglutinans* is thought to be related to insect damage (Carey and Kelley 1994). Contamination and infection of slash pine seeds by *F. solani* has been linked to seedbug damage (Rowan and DeBarr 1974). However, the involvement of insects and other possible causes of wounding in the development of Fusarium-related seedborne diseases requires additional investigation. At present, we have much to learn about the seed and seedling diseases of southern pines in order that specific recommendations and practices can be developed to prevent disease outbreaks caused by *F. subglutinans* and other *Fusarium* spp.

Remedia1 control practices

Numerous techniques have been examined with varying degrees of success for increasing seed germination, and eliminating *Fusarium* spp. and other seedbome fungi. These treatments have included fungicides (Runion and Bruck 1988), surface sterilization agents (Bamett 1976; Wenny and Dumroese 1987), and hot water and microwave treatments (James et al. 1988). One treatment for southem pine seeds that seems to provide excellent control of seedbome problems caused by *F. subglutinans* and other *Fusarium* spp. is surface sterilization with hydrogen peroxide as described by Bamett (1976). The procedure requires soaking seeds in 30% hydrogen peroxide for varying durations depending on the pine species, and then rinsing seeds thoroughly with water. Campbell (1982) indicated that surface sterilization of longleaf seeds with hydrogen peroxide prior to application of a thiram-endrin-latex repellant could not be recommended because better germinating seedlots could be adversely affected by this combination of seed treatments. Nonetheless, in recent experiments, seed germination of longleaf pine seedlots was improved from 29-49% in untreated controls to about 65% for seeds treated with hydrogen peroxide followed by an application of thiram (Fraedrich and Dwinell, unpublished data). In addition, treatment with hydrogen peroxide has the added benefit of virtually eliminating seedbome *Fusarium* spp. associated with the seedcoat. Seed treatment with hydrogen peroxide to increase seed germination has also been tested operationally by one nursery with apparently good success. The procedure can be costly and potentially hazardous when used at a high concentration for large amounts of seeds. In addition, hydrogen peroxide is not registered as a pesticide, although some believe that it may be used legally to stratify seeds. Studies are needed to better define the concentrations of hydrogen peroxide and soaking times required to disinfest seeds. Further research is needed for the development of additional chemical and non-chemical procedures that could be used to control diseases caused by pathogens associated with southem pine seeds.

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This publication reports research involving pesticides. It does not contain recommendations for their uses, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to human, domestic animals, desirable plants, fish or other wildlife-if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Containerized Seedling Longleaf Production[1]

John McRae and Tom Starkey[2]

Abstract—This paper will discuss the production activities and the history of containerized longleaf seedling production in the southeastern United States. Containerized longleaf seedling production began in the mid 1970's. Since the early 1980's production capacity increased approximately 500,000 to 1 ,OOO,OOO seedlings each year. Through 1996 the estimated total production is nearly 30,000,000 seedlings. Most of the containerized longleaf seedling production is in Georgia, where 15 different nurseries are producing seedlings in a variety of containers. But production also occurs in North Carolina, South Carolina, Florida, Alabama, Mississippi, and Louisiana. Production activities from site selection through packaging for shipment are discussed.

Keywords: Longleaf pine, Pinus palustris Mill., containerized seedlings.

INTRODUCTION

Containerized longleaf seedling production dates probably to the mid 1970's in Pineville, Louisiana. Dr. James Barnett, USDA Forest Service Chief Silviculturist began growing longleaf in containers as an alternative to planting bareroot seedlings in silvicultura1 research outplantings. Successful bareroot seedling establishment of longleaf is difficult. It is a widely know fact among foresters that a substantial risk is taken to transport, handle, and plant bareroot longleaf seedlings. It is very common to obtain less than 50 percent survival from planting bareroot longleaf seedlings. To evade the failure, more bareroot seedlings were planted. Resulting stands remained difficult to manage. They were either greatly overstocked or poorly distributed. Frequent success was limited to plantations established close to the nursery. Survival decreased for those seedlings required to be stored and then transported for long distances away from the nursery. Because of these problems with bareroot seedlings, Dr. Barnett was researching new methods to establish longleaf pine seedlings.

The Florida Division of Forestry is probably the first organization that began a significant production of containerized longleaf seedlings. They began in 1982 growing containerized seedlings in Styroblocks in Punta Gorda, Florida. Also, during that time period, Speedling Nurseries Inc. in Tampa, Florida began growing containerized seedlings (Figure 1). Severa1 pulp & paper company personnel in South Georgia recognized the need as well to find a way to plant longleaf pine seedlings and obtain acceptable survival.

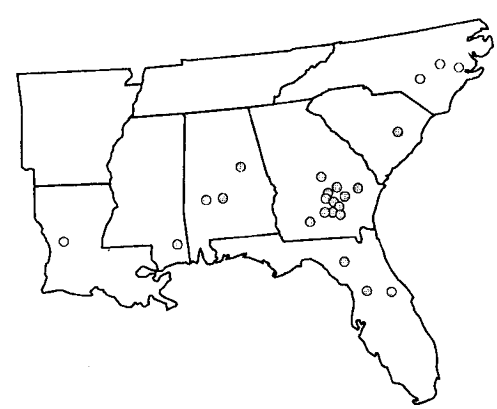

Figure 1. 1996 Production locations of containerized longleaf seedlings.

[1]McRae, J. and Starkey, T. 1996. Containerized Seedling Longleaf Production. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Consetvation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 82-88.

[2]International Forest Seed Company, PO Box 490, Odenville, AL 35120; Tel: I-800-633-4506.

Frank Vande Linde with Brunswick Pulp and Land Company, began some research in cooperation of Howard Waters in Jesup, Georgia. Their objectives were to solve the seed germination problems associated with longleaf and establish the minimum standards to grow containerized longleaf seedlings.

International Forest Seed Company began growing containerized longleaf in 1983 and has increased it's production every year, reaching the current annual production capacity of 9,000,000 seedlings. Other nurseries starting large operations of containerized longleaf during the 1980's include: Southem Seed Company Dublin, Georgia, South Carolina Forestry Commission Wedgefield, South Carolina, U.S. Forest Service Brooklyn, Mississippi and Weyerhaeuser Company Aiken, South Carolina. Howard Waters owner of Waters Plant House Jesup, Georgia, produced severa1 million seedlings and has encouraged other growers in south Georgia to grow seedlings as well (Table 1).

The many successes of plantations established with containerized seedlings have become widely known over the last few years. The results of containerized longleaf technology has instilled new confidence in artificial longleaf regeneration as evidenced in a steady production expansion (Figure 2).

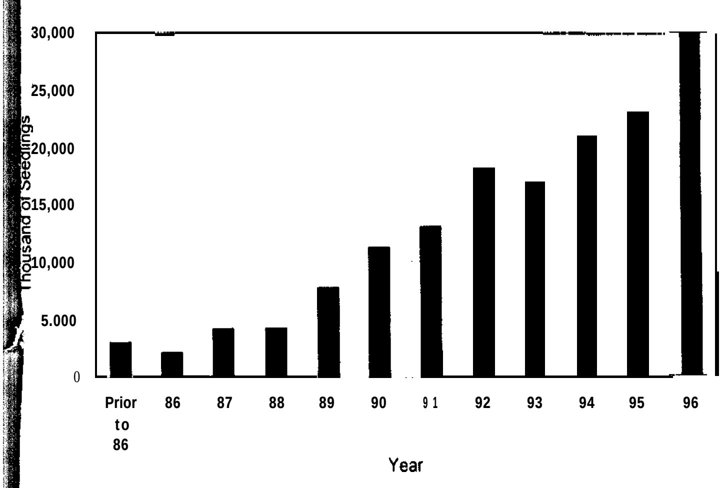

Figure 2. Container longleaf seedling production during the last 10 years.

Table 1. Container Longleaf Production Estimates for the 1996 Growing Season (Millions of Seedlings)

	Government	Private	Total
NC	1.7	2.15	3.85
SC	1.3	0.0	1.2
GA	0.0	13.78	13.78
FL	2.8	0.2	3.0
AL	0.0	5.1	5.1
MS	2.6	0.0	2.6
LA	0.5	0.0	0.5
	8.9	21.23	30.03

PRODUCTION CONSIDERATIONS: NURSERY LOCATION

Selecting a site to grow containerized longleaf seedlings requires thoughtful consideration. The first consideration must be the water quality. It is of course the quality of the irrigation water that will eventually lead to your success or failure over time when growing tree seedlings, whether containerized or bareroot. The source of water is very critica1 and usually determines whether or not you would choose to grow on a particular site. The pH of the water is probably the most important factor. A range of 5.5 to 6.5 is ideal. Also, consider the amount of other minerals and elements in the water. The recommendations of Dr. Charles B. Davey of Zobel Forestry Associates. Inc. is an excellent source to use in establishing water quality thresholds.

When choosing a site, consider the climate in which you plan to grow. Seasonal changes are preferred to help produce quality seedlings. The cool weather in the fall is needed to help push seedlings into dormancy and the cold weather in the winter is needed to maintain dormancy. Of course, a warm spring (temperatures below 85 F) facilities excellent germination. Longleaf thrive in full sunlight. The summer months throughout the longleaf range will be hot regardless of where you establish your nursery. Establish the nursery within the natural range of longleaf, but choose an area where the plants can be exposed to seasonal changes.

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

PRODUCTION CONSIDERATIONS: PRODUCT & SERVICE OBJECTIVES

The container in which you grow is without a doubt the most important decision to be made. The demands of customer requirements and the biological needs to establish a successful plantation drive this decision. A variety of cavity sizes and multipots are available. Experience has shown that a 5.7 cubic inch cavity with a 3.5 inch depth works well. Multipots tend to cost less per cavity and are easier and less costly to manage when growing large quantities of seedlings. Removable cells provide extra flexibility if sorting is necessary but, in general add to production, packaging, and shipping costs. The seedling quality (the product) and customer service is directly effected by the container used.

PRODUCTION CONSIDERATIONS: SEED

Longleaf seed germination still appears to be an enigma to just about al1 nursery managers. It is the most important variable in regards to germination and vigor when considering al1 the Southern pines. It's large size and soft seed coat make it extremely difficult to condition in the seed plant. Methods are in place, however costly, to consistently produce clean seed with germinations of 85% and better. Once again, experience demonstrates that any improvement in seed quality that can be made, should be made, when considering the subsequent compounding effects poor seed quality has on seedling production.

Choose seed with good vigor. That is, seed which germinates fully and quickly. Purities should be higher than 98% since debris slows sowing operations. Stratify the seed 7 to 10 days at 33 F to enhance total germination and vigor. It is also advisable to sterilize the seed coat before sowing, to remove or kill any pathogens that can inhibit germination.

The sowing strategy involves seed use management and how you plan to manage the crop from sowing through shipment. Total estimated germination usually drives the decision as to the number of seeds to sow in each cavity. Considering labor costs to sow seed and to thin unneeded germinates from the cavity, the minimum germination for single sowing (one seed per cavity) is 90%. Less than 90%, usually involves sowing more seed per cavity. Germinations less than 60% are rarely cost effective.

PRODUCTION CONSIDERATIONS: MEDIA

Don't use dirt! Use a soiless media. Commonly equal proportions of peatmoss, coarse vermiculite and perlite are used as a growing media. They must be well blended, but care needs to be taken to avoid destroying the material structure. Equal pore space of air:water:media is desirable for proper drainage. The target cation exchange rate should be 25-35 meg/100cc.

Often, a few to severa1 amendments are incorporated into the media during blending. Controlled release fertilizers and micronutrients are usually incorporated by most growers. The intent is to optimize growth throughout the seedling life cycle, even into the first few months after outplanting. Considerable investigation is recommended before deciding upon products and rates.

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

Mycorrhizae, usually *Pisolithus tinctorius* (PT), is added to the media to improve seedling health. When PT is incorporated in the media, more fibrous roots develop aiding in water and nutrient absorption. It stands to reason that a healthier tree will have a better change at survival in the nursery as well as on the planting site. At the same time, granular fungicides are amended to the mediato control soil borne pathogens. Choose chemicals however that do not inhibit mycorrhizae development.

PRODUCTION ACTIVITIES: MEDIA FILLING AND GERMINATION MANAGEMENT

Filling the containers properly after the media is thoroughly blended is a critica1 operation that should not be taken lightly. First, the containers must be cleaned well enough to prevent weed seeds and/or diseases from significantly affecting seedling growth and development. During filling, careful tamping of the media is extremely important, as subsequent drainage and root growth are greatly influenced by this operation. Tamp each cavity precisely and uniformly. Do not destroy the media structure with "over tamping". Leave a depression on the top in which to place the seed. Mulch the seed lightly with grit, vermiculite, perlite, or peatmoss. Mulching helps maintain seedcoat moisture through the germination phase of seedling growth.

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

Irrigation should be frequent enough during the entire germination phase to maintain seed coat moisture levels that promote germination, but minimizes pathogen development. Over watering as well as under watering can cause severe variation in filled cavity percentages. It is this point in time of the operation that has the greatest influence on the success or failure of the crop. Be sure to have monthlv plant development goals in place before your operation begins, against which you can measure your progress. It is easy to plot on a line graph characteristics such has height, shoot weight, root weight, and root collar caliper.

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

PRODUCTION ACTIVITIES: WATER MANAGEMENT

Water management is the single most important activity the nursery manager must command. Earlier mention of pH and media drainage alluded to the fact that these factors are the two critica1 elements of water management. The pH of the irrigation water and the leachate should be between 5.5 and 6.5. The various fertilizers and chemicals applied throughout the growing season function best in this range. The drainage characteristics of the media also greatly influence water management decisions. Plant/water relations are continually monitored by the nursery manager. By maintaining a consistently drained media, accurate water schedules are easier to establish. A well drain media also aides in fertility and pest management.

PRODUCTION ACTIVITIES: FERTILITY MANAGEMENT

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

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

If you could roughly breakdown the growing season in thirds, apply low levels of nitrogen, and high levels of phosphorus and potassium during the first third of the season. During the second third of the season, apply high nitrogen in the approximate ratio of 20- 1 O-20 or even a balanced fertilizer. As shipping season approaches during the last third of the growing season, back off the nitrogen once again by applying a low nitrogen fertilizer with medium levels of phosphorus and potassium.

PRODUCTION ACTIVITIES: PEST MANAGEMENT

The key to successful control of al1 pests, is daily observation, monitoring and action. Every nursery manager should live by the saying "Don't expect what you don't inspect". Al1 pests, whether they be disease, insect or weeds have the potential to'explosively develop in the nursery environment. It is only through frequent inspection that problems can be diverted.

Just as daily inspection of the nursery crop is imperative, knowledge for al1 nursery workers of what a healthy tree looks like is just as important. A person can never identify the abnormal until they are familiar with what is normal. Bank tellers are trained to identify counterfeit money not by learning what the abnormal looks like but rather by having a thorough knowledge of the genuine.

PRODUCTION ACTIVITIES: WEED CONTROL

Weeds are the perpetua1 nemesis of al1 nursery managers. The question we must answer each year is not "if we have a weed problem" but rather "when the weeds start developing." Although our "bareroot" nursery counterparts may not agree, weeds are more difficult to control in a container nursery than in a bareroot nursery.

The small cavities used to grow container trees necessitates that any herbicides used must be very target specitic. A container nursery manager can not afford to use a herbicide that may potentially cause any root inhibition to the container seedling. Such a chemical may control the weed, but may reduce the growth of the seedling due to root damage.

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

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

We as nursery managers owe it to our customers to be continually looking for not only new chemicals but experimenting with different rates of current herbicides to achieve an economic leve1 of control. We can reduce the cost of container seedlings once we find a method of better controlling weeds in the nursery.

PRODUCTION ACTIVITIES: INSECT CONTROL

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

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

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

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

PRODUCTION ACTIVITIES: DISEASE CONTROL

Water management is the primary factor in control of plant diseases in container nurseries. Al1 nursery managers have noted that in dry years much less fungicides are used than in wetter years. Tied to water management is control of the water pH.

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

Al1 containers used in the industry today have water drainage holes in the bottom of the container. The size and location of these holes or hole can play a part in control of plant pathogens that cause root problems. In general a well designed container set will allow free water to rapidly drain out of the cavity.

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

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

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

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

Regardless of the chemicals chosen, control of the water pH is imperative. Al1 chemicals have an optimum pH range at which the chemical remains active in the water. This information is not readily available for chemical labels. However if you are using water with a pH much outside the recommended range around 6.0, you should check with the manufacturer to determine if the chemical remains active for as long as you require at your pH.

PRODUCTION ACTIVITIES: SHIPPING

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

Perhaps the most common way to ship seedlings is to extract them from the container and ship in a box to the customer. Extraction of al1 the seedlings allows for better quality control than shipping the seedlings to the customer in the container sets. Culls are easily removed before they are shipped to the customer.

Weather conditions are an important consideration during the extraction of seedlings. A wet rootball is more difficult to extract than a rootball that is dry. A seedling that is difficult to extract or has a marginally good rootball may end up as a cull if it must be extracted when very wet.

Container trees are also shipped in the container sets. This is not a preferred method for the nursery manager for severa1 reasons. First, good seedlings and culls that could have been detected by extraction are shipped together. The tree planters seldom remove any culls unless well trained. Second, container sets sent to the customer are frequently not returned or retumed damaged. A deposit can be required, however, it significantly increases the amount of administrative bookkeeping to track them. Thirdly, shipping the trees in the sets is more costly than extracted. More extracted trees can be shipped it the same cubic foot area than can trees shipped in the sets.

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

Container trees do not need to be shipped in refrigerated vans unless they are traveling to a much hotter location. A tree with a rootball of about 80% moisture would ship well in non-refrigerated vans.

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

The other advantage to early planting is the ability to avoid freezing temperatures that are common after mid December in the Southeastem United States. We at Intemational Forest Seed Company are very strong proponents of fa11 or late summer planting of container trees.

SUMMARY

Containerized longleaf seedling production has grown to over 30 million trees during the ten year period through the 1996 growing season. Over 20 growers are producing seedlings in a variety of multipot containers . The keys to successful crops are container choice and the use of quality seed , water and pest management practices. Well trained experienced employees to plan and implement the growing strategy are crucial to the success of any nursery crop, especially containerized longleaf.

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Field Performance of Containerized Longleaf Pine[1]

Dale R. Larson[2]

Abstract—On pine sites Gulf States Paper Corporation's forest management objective is to produce high quality pine sawtimber and poles. Longleaf pine is well suited to fulfill this objective, and longleaf is the most desirable species on about 15% of our pine land. Container seedlings are best suited for our regeneration efforts in establishing longleaf stands. In the early 1980's we established a small container nursery facility for the production of longleaf seedlings. All of our production is outplanted on company-owned land.

Preparation of the planting site involves herbicide application in May and a cool burn in July or August. Our containerized planting season is mid-September to mid-November. Seedlings are extracted and packed into boxes by hand at the nursery. Planting is done by hand with contract labor directly from the boxes. The planting depth must be carefully monitored. Herbaceous vegetation control is used on every tract in the spring following planting.

INTRODUCTION

Gulf States Paper Corporation is a family-owned forest products business with approximately 400 thousand acres of timberland in West Central Alabama. We were founded in the Midwest in 1884, moved to the South about 1900, and located our headquarters in Tuscaloosa, Alabama, in 1929. We were invited to this conference to share some of our experience in regenerating longleaf stands with containerized seedlings.

DESCRIPTION OF GULF STATES PAPER CORPORATION'S CONTAINERIZED SEEDLING REFORESTATION PROGRAM

On pine sites Gulf States's forest management objective is to produce high quality pine sawtimber and poles. Longleaf is the most desirable species on about 15% of the pine site. Container-grown longleaf is best suited for our program.

During the 1970's our efforts to establish longleaf pine with bareroot seedlings were only marginally successful, due in part to seedling quality, planting technique, and a lack of herbaceous control. For severa1 years we suspended our operations. In the early 1980's after the Container Seedling Conference in Savannah, we decided to establish a small container production facility, and we began to produce and plant container longleaf seedlings. After a great deal of trial and error, but learning from our mistakes, we have progressed to a point today, where we feel that we have developed a successful longleaf reforestation program utilizing container seedlings.

My presentation will consist of a brief overview of seedling production and a look at our establishment strategy.

[1]*Larson, D. R. 1996. Field Performance of Containerized Longleaf Pine. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89-90.*

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SEEDLING PRODUCTION

We seed our longleaf crop in early April, usually during the first week. The crop is started out under shade. The shade is removed at about 4 to 6 weeks, and the crop is grown in ful1 sunlight for the rest of the growing season. In about 20 to 24 weeks we will have a seedling with about a one-quarter-inch root collar and a healthy root system. The seedling is extracted from the container and packed in boxes by a contract labor crew.

SITE PREPARATION

Site preparation is accomplished by herbicide application in May and burning in July or August. On longleaf sites, generally imazapyr is applied in liquid form. On tracts where aerial application is a problem, herbicide may be applied by hand with a spot gun. We prefer an aerial broadcast treatment for more effective control. Burning is usually done by hand. We try to have a cool burn to prevent erosion or site degradation problems. During the late summer months, this type of burn can be a real challenge.

PLANTING

Our container planting season is mid-September to mid-November. Starting time will vary due to soil moisture conditions. We have had periods when it has gotten too dry to plant, and we had to shut planting operations down until we got some rainfall. The trees are extracted from the containers and packed into boxes by a contract labor crew. A three-day supply is delivered to the district office from the nursery. Only a one-day supply is taken to the field to be planted. This system allows the majority of the trees to stay on the tables at the nursery where they can be maintained under optimum conditions until the districts are ready for their crews to plant them. Each box contains 260 seedlings. The lid is removed and the box put into an aluminum tray. The seedlings are planted directly out of the box using a standard planting dibble. Planting depth is critica1 as the peat plug must be completely covered to prevent wicking, and the bud position must be exposed. With an experienced crew, the average number planted per man day is about the same as bareroot planting.

VEGETATION CONTROL

Herbaceous vegetation control is used on al1 of our longleaf tracts in the spring following planting. The herbicide is applied as an aerial broadcast treatment. The intent of the herbaceous control is to get the established seedlings out of the grass stage as soon as possible. With the one treatment we are getting our longleaf out of the grass stage at the end of the first growing season or by the start of the second growing season.

CONCLUSION

Our years of effort and experimentation at Gulf States Paper Corporation have resulted in a very satisfactory and successful containerized seedling operation. By carefully monitoring the development of the seedlings in the nursery, we produce hardy seedlings which, when properly planted, have a 90% or better survival potential.

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Mycorrhizal Fungi-Beneficial Tools for Mineland Reclamation and Christmas Trees[1]

Charles E. Cordell[2]

Abstract-Two forestry-related areas where the mycorrhizal fungi have provided consistent benefits have been mineland reclamation and the Christmas tree industry. Selected ectomycorrhizal and endomycorrhizal fungal species have been successfully utilized in the production of tailored higher quality bareroot and container seedlings for these specific applications. A major factor affecting the successful application of this unique biological tool ís the selection of the most favorable and compatible mycorrhizal fungus-host tree seedling species combination for the intended application.

MINELAND RECLAMATION

Both ectomycorrhizal and endomycorrhizal fungi have been successfully utilized during the past severa1 years in the production of high-quality tailored Mycor Tree™ seedlings, shrubs and grasses for mineland reclamation projects in the eastern and western United States. Consistent benefits include increased tree and shrub survival and growth along with increased and better quality native grass establishment. One of the best mineland reclamation success stories involves the Ohio abandoned mineland reforestation project using selective pine and hardwood bareroot seedling species in combination with the ectomycorrhizal fungus, *Pisolithus tinctorius* (PT). During the past 15 years, the Ohio Division of Reclamation has successfully used 3.5 million PT-inoculated pine and oak seedlings to reclaim over 2,000 acres of previously abandoned mineland (AML) sites. Consistent benefits continue to be increased tree survival and early growth on these very harsh stressful planting sites. Typical site characteristics include highly acidic (pH 3 or less), low fertility and soil water storage, high surface soil temperatures, and low rainfall (droughty) conditions. Since 198 1, pine and oak tree seedling survival has averaged over 85% on the PT-tree plantings with less than 5% planting failures. An important consideration is that none of these trees have received any fertilization, amendments, (i.e., sewage sludge) or irrigation. In previous reclamation plantings on these same type sites with nursery-run seedlings of the same tree species but with only natural ectomycorrhizae, tree survival averaged less than 50 % and more than 75% of the plantings were failures and required replanting. The Ohio reforestation AML reclamation program with PT-inoculated seedlings has also significantly reduced reclamation costs. The reforestation cost in 1995 was $354.00/acre with the added PT inoculation costs being $45.00/acre or approximately $.03/seedling. The total cost of the PT reforestation AML reclamation program between 1981 and 1995 has been approximately $800,000. In comparison, using traditional AML reclamation procedures, this program would have cost approximately $14 million. Consequently, the use of PT-inoculated seedlings has represented a 94% savings to the Ohio AML reclamation program.

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[1]*Cordell, C. E. 1996. Mycorrhizal Fungi-Beneficial Tools for Mineland Reclamation and Christmas Trees. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 97-92.*

[2]*Vice-President, Technical Services and Field Operations, Plant Health Care, Inc., 440 William Pitt Way, Pittsburgh, PA 15238; Tel: l-800-42 1-905 1; Fax: 4 12/286-5445.*

CHRISTMAS TREE PRODUCTION

Several selected ectomycorrhizal and endomycorrhizal fungi have been successfully utilized in the production of higher-quality bareroot and container Mycor Tree™ seedlings for Christmas tree production. Specific mycorrhizal fungi-Christmas tree species combinations have been determined to be most compatible and favorable in providing positive tree host responses. These include PT with the pines, a *Hebeloma* sp. with the true firs, a *Laccaria* sp. with Douglas-fir and the spruces and several endomycorrhizal (vescular-arbuscular mycorrhiza) fungi with exotic tree species such as Leyland cypress. Several fungal inoculum types and inoculation techniques are also available including the vegetative and spore inoculants of ectomycorrhizal fungi and endomycorrhizal spore inocula for bareroot and container nursery inoculations. Also, there are root dips containing selected Mycor Tree ectomycorrhizal (PT, Hebeloma, Laccaria) and endomycorrhizal fungi for treating seedling transplants for field planting sites. Christmas tree benefits include increased survival on droughty and substandard planting sites, increased growth for shorter rotations, increased nutrient availability and efficiency for decreased fertilizer requirements, improved tree quality including needle length, density, color, and retention, and increased root disease (i.e., Phytophthora root rot) resistance. Mycorrhizal fungal inoculation costs range from less than $.01/ seedling to $.02-$.03/seedling depending on the inoculum type, inoculation procedure, nursery seedling density, and seedling size.

COMMERCIAL SOURCES

The above along with a variety of additional mycorrhizal, biostimulant, and water management gel products are commercially available from Plant Health Care, Inc., 440 William Pitt Way, Pittsburgh, PA 15238. Requests for a product catalog, price listing, additional information and product orders can be made by calling our toll free number 800-421-9051 or by fax at 412-826-5445.

Northeastern Forest Nursery Association Conference

New England, Connecticut

August 19-22, 1996

USDA Forest Service, Pacific Northwest Research Station and Alaska Region Cooperative Russian Far East Forestry Program[1]

Andrew Youngblood, Peyton Owston, Cynthia Miner,[2] Anne Jeffery,[3] Gary Morrison,[4] and Ron Overton[5]

The Pacific Northwest Research Station and Alaska Region of the USDA Forest Service are participating with the US Agency for International Development in a cooperative program to promote sustainable forestry practices in the Russian Far East, and have formed three working groups to address broad goals. A Forest Planning and Data Management Work Group will help Russian managers and scientists to strengthen policies and incentives to encourage stewardship of forested areas, and develop "Best Management Practices" guidelines. A Forest Fire Protection and Management Work Group will help Russian managers strengthen fire fighting capabilities in mountainous regions, increase the level of training in fire tactics for fire fighters, develop a broad fire prevention and analysis program, and transfer current fire detection and suppression technology. A Reforestation and Timber Stand Improvement Work Group will help Russian managers to summarize knowledge on regeneration and management of local species, develop reforestation priorities and seed zone maps, demonstrate forest regeneration techniques, and design and manage facilities to process and store tree seeds and raise tree seedlings. This program offers a unique opportunity for collaboration and exchange between Russian managers and scientists, and their USDA Forest Service counterparts.

[1] *Youngblood, A.; Owston, P.; Miner, C.; Jeffery, A.; Morrison, G.; Overton, 0. 1996. USDA Forest Service, Pacific Northwest Research Station and Alaska Region Cooperative Russian Far East Forestry Program. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 93.*

[2] *USDA Forest Service, Pacific Northwest Research Station, PO Box 3890, Portland, OR 97208-3890; Tel: 503/326-7135.*

[3] *USDA Forest Service, Chugach National Forest, 3301 C St., Suite 300, Anchorage, AK 99503-3998; Tel: 907/271-2500.*

[4] *USDA Forest Service, Tongass-Chatham National Forest, 204 Siginaka Way, Sitka, AK 99835; Tel: 907/747-6671.*

[5] *USDA Forest Service, State & Private Forestry, Northeast Area, 1992 Folwell Ave., St. Paul, MN 55108; Tel: 612/649-5241*

Prospective Uses of Planting Stock in the Northeast[1]

David M. Smith[2]

Abstract—Public forest-tree nurseries were established in the Northeast decades ago mainly to provide for reforestation and timber production on grassy abandoned farms and old burns. This kind of planting has diminished in importance. Society still needs to plant trees although the kinds of trees and the purposes keep changing. Among the relatively new things now needed are the reforesting of city streets, erosion control along highways, improving the species composition of forests, enrichment planting, wildlife food, and repairing the effects of depredations of insects and diseases.

The role of large-scale planting of coniferous monocultures for wood and timber is likely to be much smaller than that in the South and other regions where hard pines are common in nature. In the Northeast advanced regeneration is very common and the competing pioneer vegetation that appears after site preparation more competitive and persistent than in most other places. There is a place for plantation culture of white pine in mixture with other pines on dry sandy sites. Some paper corporations grow spruce pulpwood in plantations in spite of high costs of establishment as a means of protecting their wood supply. The high production rates available on good northern hardwood soils have also been attractive for intensive plantation management.

There is a role for enrichment planting with fast-growing valuable timber species. We also need to plant trees to forestal1 invasive exotics and to deal with problems caused by the loss of native species to exotic pests. The time may come to plant pest-resistant American chestnuts and eastern hemlocks to re-establish them in our forests. Public nurseries should be become more involved in providing tree and shrub planting stock for erosion control along highways. The use of large seedlings grown in tree shelters should be explored as a low-cost solution to the problem of establishing street and shade trees.

Forest-tree nurseries were established in the Northeast mainly for reforesting abandoned farmland, although replanting after forest fires was a common objective. Large areas of such land were planted before the pace of abandonment of pastures and open fields slowed during recent decades. Now much farmland is being converted to suburban and exurban residences as well as second homes. In some localities, residences are invading the forest. While there will probably always be some grassy areas to plant with trees the old-field stand or plantation of pine or spruce will come to be almost in the category of the museum piece. Providentially burned-over areas in need of planting have also become rare.

IMPEDIMENTS TO PLANTATION SILVICULTURE

The kind of plantation silviculture in which pre-exisiting forest stands are regenerated by planting softwoods has not become common in the Northeast, even on the substantial areas of industrial softwood ownership in northern New York and northem New England. This is because the spruce-fir forests of the region normally have superabundant advanced regeneration. During the 1970s there was a flurry of federally subsidized spruce planting in the adjacent Maritime Provinces of Canada. This program stopped when it was ruefully concluded that it was merely adding to the precommercial thinning problem that is the silvicultural curse of the northeastem spruce-fir forest.

[1]Smith, D.M. 7996. Prospective Uses of Planting Stock in the Northeast. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 94-98.

[2]School of Forestry and Environmental Studies, Yale University, New Haven, CT 06520.

In other parts of the continent, planting to regenerate previous stands of trees has usually gone with industrial forestry on sites where periods of dryness during the growing season tend to favor conifers. Plantation silviculture usually goes with intolerant early-succesional species that grow fast on short rotations.

Most of the important commercial species of the region are not ecological pioneers but species that are adapted to get started as advanced regeneration beneath older stands. They are not adapted to follow fire like the southern pines or coastal Douglas-fir. Generally they are adapted to start beneath old stands and start rapid development after the old trees have blown down or been killed by pests. Species of trees adapted to start as advanced regeneration seldom grow fast in height when they are small even when grown in the open. Probably they divert much carbohydrate into building good root systems. At least they often accellerate in height growth after they are well established and released. These characteristics often discourage their planting even if height growth in the later stages is excellent.

One impediment to forest planting in many localities and sites where hardwoods grow well is that too many different species compete too aggressively. During the summer much of the region has a climate not greatly different from that of the humid tropics. In general only plantations on soils that are too dry or are too wet with poorly aerated water escape the chaos of jungle competition.

The highly successful culture of loblolly and slash pine in the South works on soils where late summer droughts restrict the vigor of hardwood competition. The bareing of mineral soil during site preparation favors annuals during the first growing season and perennial grasses later. The grasses discourage hardwoods enough that hardwood plantations have to be cultivated like corn or soybeans. The reason for the late-summer moisture restrictions is heavy evapotranspiration and the poor soils of the Coastal Plain and the badly eroded Piedmont. It is significant that the pine culture usually fails in the well-watered bottomlands of meandering streams and becomes more difficult with increasing latitude (because of less solar radiation).

Somewhat the same situation applies to the culture of red and jack pines on extensive areas of upland soils in the Great Lakes Region. The late-summer dryness there is probably the result of comparatively low precipitation.

SPRUCE-FIR FORESTS

In the Great Lakes Region, the Northeast, and Atlantic Canada the planting of spruces to regenerate the spruce-fir type on the characteristic poorly drained sites has not been anywhere near as successful. The planted trees grow slowly and southern-style site preparation calls forth not grass but such woody pioneers as raspberries, gray birch, and aspen. Much herbicide treatment is necessary to release small spruces. In the eastern portions of the spruce-fir forest, advanced regeneration in stands old enough to regenerate is usually so abundant that planting ordinarily aggravates a precommerial thinning problem. However, there could be a useful role for the planting of very widely spaced pines and Eurasian larches that are capable of keeping ahead of advanced regeneration of spruce and fir. However, as far as spruce and fir are concerned, precommercial thinning is normally a better investment than planting and doing al1 the release work that is necessary to free planted trees. In fact, on such sites it is very important to avoid the soil disturbance that calls forth pioneer weeds.

The more successful post-harvest plantings of spruces are on the better soils where the northern hardwoods normally grow. Some of the most successful of these have been on industrial free-hold land in New Brunswick. Pulpwood yields have been high. It is, however, not clear how much herbicide treatment has been necessary to keep the plantations from being overwhelmed by hardwood competition.

EASTERN WHITE PINE

There are some possibilities for plantation culture of eastern white pine for timber production but they mostly depend on developing ways of reducing the stem deformities caused by the white pine weevil. Except in the southern Appalachians this insect has turned open-grown plantations into forests of crooked trees covered with dead branches.

Where there are many weevils the only dependable solution involving planting is to start white pines under the shade of taller trees and not release the pines until they are at least one log tall. Weevil-free white pine could be grown in mixed plantings with faster-growing red, pitch, or Scotch pines. These seem to cast enough shade to discourage the weevil. 1 once found, to my sorrow, that Japanese larch does not. European experience indicates that numbers of nurse trees should be restricted to one-quarter of the total number so they will not overwhelm the lower-stratum species. It would be necessary to harvest most of the nurse trees for pulpwood, poles, or small logs when they had served their purpose.

This kind of white pine plantation culture would best be followed on soils dry enough that hardwoods grow poorly but where pines grow comparatively well. Intensive programs of precommercial thinning and pruning are necessary to grow the high-quality white pines needed for lumber . The growing of white pine for sawlogs is best done well or not at all.

On the other hand, at least one paper company has been growing plantations of white pine primarily for pulpwood. With appropriate thinning to rescue straight codominants from weevilled dominants it is also possible to have some trees straight enough to carry on to sawlog size, even in localities where weevilling is common.

NORTHEASTERNHARDWOODS

Under most circumstances it is generally better to learn to understand and live with the complexity of the hardwood forest than to try to fight it by establishing pure plantations. One partial solution that can be borrowed from the tropics involves the "enrichment" planting of so-called emergent species that can either stay ahead or overtake their competition. This usually entails planting a few widely spaced trees and using the typically profuse natural regeneration of other, preferably slower-growing, species to train the stems of the planted trees. In the tropics frequent release cutting is usually necessary and the trees are often planted in lines so that they can be found more easily during the release operations. Honduran mahogany is often planted this way. The basic objective is to produce stands with more of the emergent species, which are often grow large and become valuable, than arise from natural regeneration. In many cases they have been eliminated by high-grading.

Where it will grow satisfactorily, yellow-poplar is the epitome of the emergent. It grows fast in height at virtually al1 stages of life. It is probable that the ill-fated American chestnut grew even faster in height and at al1 stages, at least if it was of stump-sprout origin; it was also an emergent overtopping oaks on many kinds of sites. There are other emergent species, although it is well to note that the height growth of a species relative to others depends heavily on what the other species are and the nature of the site. For example, white ash is an emergent on the best northern hardwood sites but falls behind oaks where oaks are common. White pine can be an emergent in hardwood stands but only after it and its associates get to be about 40 or 50 feet tall. Before then it grows comparatively slowly and usually has to be artificially released unless one is content with the density of about one pine per acre that seems to have prevailed in the original forests. White pine is, however, an emergent right from the beginning in many spruce-fir forests. Eurasian larches develop as emergents in many mixed plantations and could do so if planted after heavy cuttings in more natural stands; they can produce sawlogs on 30-year rotations.

Among the other potential emergents are black walnut on good soils, paper birch at least in the early stages, yellow birch on mediocre sites of the northern hardwood forest, and sweet-gum. Some oaks function as emergents after they have been growing for about 20-40 years. Among these are cherrybark oak on the ridges of southern bottomlands and northem red oak in mixture with black birch and red maple. Sometimes as 30-40 trees of emergent hardwood species can form a solid overstory over an acre. In that case some might argue that they were no longer emergents because they were not isolated trees. With these procedures it would not be necessary to plant many trees per acre because most of them would survive to maturity. If that were the case, the investment per planted tree could be quite high and and tree shelters might be justitied for warding off deer browsing.

REMEDIAL PLANTING

One potential use for forest planting stock is the reestablishment of seed sources and populations of species that have been eliminated by overcutting, tire, or pests. The time will probably come when it will be possible to reestablish the American chestnut or some American-Asian hybrid chestnut in the eastern forest. Past fires have eradicated non-sprouting species over vast areas. There are places formerly cleared for agriculture where not all of the native species have returned. If a control is found for the introduced hemlock adelgid that is eradicating hemlock from the southern part of its range, it will be desirable to underplant it in many hardwood forests. In the spruce-fir forest of Maine there are places where high-grading and the paradoxical effects of the misnamed spruce budworm have eliminated spruce. There is evidence that common natural hybrids of red and black spruce are more resistant to the budworm than pure red spruce.

Planting stock will continue to be needed for erosion control and reforesting burned-over lands and other severely disturbed areas. In fact, it would be useful to grow more non-invasive shrubs for this purpose. Back in the 1930s a forester-ecologist named Hans Bauer was in charge of vegetation management on the Connecticut state highways. He once described to me how he had observed that the native sweet fern *(Comptonia asplenifolia)* was a highly effective colonizer of exposed sub-soils and how he had used it successfully on highway cuts and fills. It does not grow tall and does not require mowing. He also used eastern red-cedar which also grows slowly in thes parts. As 1 drive on Connecticut highways 1 can still detect the roadsides that were revegetated under the aegis of Hans Bauer. It may be noted that, unlike various Asian species once touted by soil conservationists, sweet fern has not become a plant pest in this locality.

There will also remain a place for shrubs as sources of wildlife food. However, the planting of certain invasive exotic woody plants should be totally discouraged or even banned.

In fact, one very important role for forest planting stock is in the replacement of jungles and vine-lands overrun with invasive exotics. Such introduced Asian ornamentals as Oriental bittersweet, Japanese honeysuckle, multiflora rose, giant knotweed, Japanese barberry, winged euonymous, and porcelein-berry are taking over many areas close to human habitations. Many of these seem agressive enough and cast enough shade that they are not likely to be overtopped and shaded out like the native pioneer plants to which we have been accustomed.

The work on the New York City Parks that Anthony Emmerich will tell you about shows that many of the invasive exotics are shade-tolerant enough to overwhelm many late-successional trees that we might plant. We need more experimentation with sophisticated kinds of planting that might overcome these problems. 1 suggest that in the more difficult situations it would be worth following broadcast applications of non-selective herbicides with the planting of combinations of fast-growing hard pines and shade-tolerant lower story species, such as beech, spruce, hemlock, and maple that might cast enough shade to keep the invaders in check. The old-field white pine that once opened the way for stands of native hardwoods to take over are just as hospitable to advance regeneration of the invasive exotics.

OTHER USES OF PLANTING STOCK

Another use for hardwood planting stock might be for low-cost establishment of shade trees done by planting small trees and protecting them with tree shelters. The planting of a sapling costing $150 produces a feeble kind of instant beauty but the trees take a long time getting started and are not as resistant to vandalism as the people who sell them claim. If it cost $10 to plant a large seedling in a tree shelter one could replant the spot 15 times or plant 15 times as many trees for the same cost. Some municipalities in Connecticut show much enthusiasm for planting $150 trees so long as the federal government or some foundation is paying for it but stop completely when the subsidy ceases.

The culture of Christmas trees depends mainly on the planting of nursery stock and is almost sure to continue to do so. The taxol that was initially reputed to come only from the bark of the Pacific yew is more abundant in the foliage of other yews. Some years back 1 learned that in Hungary the honey produced by a plantation of American black locust is worth $80 per acre annually which is equal to the value of the annual production of wood. These uses suggest that it may be well to look at other uses for planted trees and shrubs that do not involve wood production.

Society needs trees worse than it knows but the reasons why trees need to be planted change in time and space. It is up to foresters and the horticulturists who manage nurseries to keep abreast of the changing needs, persuade society to meet them, and have trees and shrubs ready to meet the needs.

Rooting for Environmental Education at the Forest Resource Education Center-Green Side Up![1]

John Benton[2]

Where else in New Jersey can people go to float acorns, bundle tree seedlings, nurture seeds, grow tublings, use a cross cut saw, make resource management decisions and have fun learning about New Jersey's forest resources? These activities and much more are a growing part of the "Seeds to Trees" environmental education programs offered year-round to students of al1 ages at the New Jersey Forest Resource Education Center (FREC) which is located on Route 527 in Jackson, New Jersey.

The Bureau of Forest Management, which is under the Division of Parks and Forestry, New Jersey Department of Environmental Protection, has a healthy, green and growing environmental education facility that uniquely uses hands-on interactive opportunities to learn about trees, seeds and forests. The FREC has over 420 acres of forests, one greenhouse, and thousands of seedlings that will one day be part of the future forests of our state.

"The Center is an outdoor classroom that provides hands-on experiences," explains John Benton, DEP Regional Forester. "It is a place where people of al1 ages can enjoy learning by doing, as well as gain skills and experience the excitement of connecting to our natural world." The FREC promotes the ideal that everyone can make a world of difference and can take the "green" ideas home and try them in their own communities.

Each program at the FREC is designed especially for the specific groups' needs or interests. The staff is trained to use the natural environment as a learning tool, especially in helping teachers feel comfortable and confident to make the outdoors a classroom across curricular boundaries. Visiting groups of students, scouts, youth groups, families and individuals are al1 welcome to visit the FREC, participate in its' programs and experience the wonder of the forest.

Severa1 multi-faceted programs are conducted through the FREC, such as the famous Today's Acorns=Tomorrow's Trees. People are encouraged to collect acorns during the autumn months and bring them to be used to grow oak seedlings at the FREC. Another program that visitors enjoy is Volunteer Conservation Day. Held annually in the spring, groups of volunteers work along with the forestry staff to explore and learn about how trees grow, tree identification, benefits of trees, conservation and stewardship, nonrenewable and renewable resources, natural cycles and systems, wildlife habitat and much more. During every tour and activity, groups actively participate and gain experience to expand their foundation of knowledge in the natural world.

Al1 visitors are encouraged to participate, look, smell and touch. You might be surprised that some tree roots smell like rootbeer, some seeds have wings, and some pine cones need fire to open and release their seeds. You might also imagine that you've become a

[1] *Benton, J. 1996. Rooting for Environmental Education at the Forest Resource Education Center-Green Side Up!. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 99-101.*

[2] *State Forestry Services, 501 E. State St. CN 404, Trenton, NJ 08625-0404; Tel: 609/984-0620; Fax: 609/984-0378.*

tree and experience life as a conifer or a deciduous tree, such as our state tree, the Red Oak. You can feel the chill of a winter day in a cooler which keeps you dormant until ready for planting or feel the heat of a greenhouse to keep you growing year-round. "We make a great effort here to explore the processes in nature," said John enthusiastically.

John also stated the purpose of the center's activities in a matter of fact way. "The power of a seed means a lot to the kids and to the visitors....It's stimulating to watch a seed grow into something, even in your own yard. Visitors get excited here to be able to participate in "greening" New Jersey. These seeds and trees not only have places to go to in terms of being planted, they also maintain environmental quality and are essential to what we, as people, need to live, survive and grow." Seeds of trees and ideas grow equally well here!

Why is the FREC mission so important? About 42% of the state's total land area is occupied by forests, with about 75% of this being privately owned. Though much "green" seems to cover the state's surface, increased rural development and the rate at which open space is disappearing intensifies the need for wise conservation and management practices. Maintaining healthy habitat and water quality and preventing soil erosion are just some of the conservation and stewardship issues that must be effectively communicated to current and future land owners, in order to better protect and preserve the state's diverse forest ecosystems.

As the FREC manager, John Benton has many ideas of how FREC programming will "branch out and take root" in the future. "1 want this center to serve as a place where al1 types of information can be obtained regarding land use, trees, forestry, habitat, forest education and classroom projects. The activities and information shared by our staff are specific to New Jersey, informative for al1 ages, and easy to do, such as planting seeds at home. Because FREC is centrally located in the state and because its facilities are unique, 1 would like this site to become a training center for educators and other professionals, a classroom for al1 ages.

And what about FREC visitors who will one day be able to walk across the entire state in a matter of seconds? FREC recently received grant funds to construct a tree deck in the shape of New Jersey that will provide a platform to connect people to the natural resources of the state. Visitors will be able to easily experience and learn about the state's waterways, forests, and physiographic regions.

Benton would even like his staff to go into the local classrooms to conduct lessons and programs on school property. "Using leaves, acorns and natural systems as fun ways to teach math, science and a connection to the natural world. We need to team up with teachers and help to bring nature into the classroom." John's preferred creative, team-building, problem-solving classroom resource is called Project Learning Tree, PLT. Sponsored by the DEP, this classroom supplement for grades K- 12, has, since the mid- 1980's, set-ved as a popular and effective "window to the natural world" that successfully explores the interactions between nature and people.

John Benton's one wish as a forester is simple. "What if every resident planted just one tree each year...think about it! Seedlings cost as little as $0.25 each and can grow and produce benefits for a lifetime. Trees are beautiful...they help conserve energy and water, they create oxygen, they retain soil, they provide homes for wildlife....They are a renewable natural resource, a "living" resource. What *if* every resident planted one tree each year?"

Volunteers and visitors alike are welcome to the FREC to learn about, enjoy and contribute to its activities that are already "branching out" and "taking root." For information about FREC tours, Project Learning Tree, seedling packets, special events and other information, cal1 (908) 928-0029.

Tree Facts:

- Trees can serve as wind and snow fences. If strategically placed they reduce winds and hold snow away from roadways, thereby reducing winter maintenance costs.

- Trees provide: nutmeats (walnuts, pecans, hickory); fruit (plums, peaches, apples, pears); berries for jams and jellies, and sap for maple syrup.

- Properly placed and maintained trees and shrubs significantly increase residential and commercial property values and conserve energy throughout the state.

- Trees store carbon and clean the atmosphere. In 50 years, one tree generates $30,000 in oxygen, recycles $35,000 of water and removes $60,000 of air pollution.

- Trees help recharge ground water and sustain streamflow. Those planted along rivers, streams and lakes reduce water temperature and prevent or reduce bank erosion and silt. Keeping our forests healthy, green and growing keeps our watersheds clean.

- Trees are renewable resources we use every day of our lives. What if every New Jersey resident planted one tree each year? We would have over 7 million trees planted annually.

FREC Events:

Trees to Seeds—all year

Fall Forestry Festiva/-October 5, 1996

Conservation Volunteer Day—April 1, 1997

Green 'n New Jersey-April 22, 1997 (Eatth Day Celebration)

Arbor Day—last Friday in April , April 28, 1997

Project Learning Tree Workshops—all year

"In the end we will conserve only what we love,
we will love only what we understand,
we will understand only what we are taught."

-BABA DIOUM

Current Issues and the Future of Seed Certification of Trees, Shrubs and Native Plants[1]

Victor Vankus[2]

Abstract-The demand for seed certification by state Crop Improvement Associations of forest tree seed, mainly conifers, has decreased over the past several years because the number of exporl shipments of these species has declined. There continues to be a small but steady number of tree seed lots certified in the northwestern United States under the Organization of Economic Cooperation and Development (OECD) scheme for export to Europe. The demand for seed of tree species other than conifers, shrub and native species by federal and state agencies, conservation groups and the public for a wide range of land management applications is growing. In order to meet market demand, there are now more commercial seed companies and private seed collectors selling these species than ever before. Certification of these species will insure that specific standards are met and this will increase the likelihood of quality seed being offered for sale. Forest tree nurseries need to be aware of and prepared to participate in the seed certificatíon process as warranted.

INTRODUCTION

Seed certification is the process of verifying that seed has been collected or produced according to a known set of standards. Seed certification and state Crop Improvement Associations throughout the country have played a signiticant role in agriculture for the past forty to fifty years. Certification of tree seed was also important because it enabled the forest industry to export seed around the world. The importance of seed certification to agriculture and forestry has changed. Agricultura1 seed is now produced by companies that have strict quality control programs and the certifying agencies are not used to the extent that they were in the past and the forest industry now rarely certifies tree seed because little of it is exported. Seed certilication and the certifying agencies may however provide valuable assistance to seed companies and land managers that are working with hardwood tree species, shrubs and native plants.

SEED CERTIFICATION CLASSES AND STANDARDS

Most states have an association or agency that is responsible for certifying seed. The authority to certify seed is addressed in each states seed law. Most agencies have classes for tree seed certification. The classes developed for tree seed are based on the classes designated for agricultura1 crops. The classes and standards necessary for certifícation are determined by members of the certifying agency, seed producers, extension agents, university research personnel, seed buyers and others, from both the public and private sector, that are knowledgeable and experienced in collecting, processing and producing seed and using seed to produce plants. Standards focus on insuring the production of a quality product. When standards are developed, the agency and the people assisting them need to consider why the species is in demand, what it will be used for, how much will be produced, and the environment in which the demand for the species has developed. What events led to the demand for this species?

[1] *Vankus, V. 1996. Current Issues and the Future of Seed Certification of Trees, Shrubs and Native Plants. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 102-105.*

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In many states, this is the format used to determine which tree species are eligible for certification, the production standards and classes and which processing plants are approved to clean seed. For tree species, the standards of each class of certification may vary slightly from state to state but they are basically the same. Some states have standards and classes for species of plants that other states do not. There are minimum standards for each class. Tree seed can be classitied as either source identitied, selected (phenotypically superior) or improved (genetically superior).

The standards for source identified certitication require that the seed collector keep accurate records of what, where and when the seed was collected. In some states the collectors, either individuals or agencies, may need to be registered with the certifying agency. The agency may or may not certify the collection without an inspection. If the seed is certified on the basis of documentation alone, the agency will reserve the right to make a future inspection. Seeds collected from documented sources can be registered with the certifying agency and can then be used to produce seed in seed production areas. Registered seed can also be bought if there is a supply and then used to produce seed in a production area. Seed produced in a production area can be certified as source identified if accurate records are available to document the origin of the seed used to produce the plants. The seed production area should also be registered with the certifying agency. Species approval for certification is not generally required for source identified certification. These specifications should be addressed in each agencies general standards. Some state certitication agencies are certifying source identified seed of many species, particularly in the western United States. There is little demand for source identified certification in the eastern and southern states at this time. The standards for selected and improved classes for some species are outlined in each certifying agencies scheme. The standards explain the minimum requirements that need to be followed to register, produce, inspect and labe1 lots of tree seed under the scheme. The minimum requirements for seed orchards or plantations and seed processing plants are outlined as well.

HISTORY OF TREE SEED CERTIFICATION

The certification of tree seed by state Crop Improvement Associations has been available for the past thirty to forty years. Certification of tree seed has been directly related to exportation. During the 1960's, seed orchards, particularly in the southern states, began to produce genetically improved seed of conifer species. The demand for seed of species from the western states also developed at this time and tree seed producers in the United States began to use certification to help expedite the exportation of the seed. Seed from the western states was generally source identified and the seed from the seed orchards in the eastern states was certified as genetically improved.

In 1960, the Organization for Economic Cooperation and Development (OECD) was established. This organization has a set of standards that member countries recognize and the establishment of this internationally accepted scheme helped to facilitate the movement of seed between member countries. Member countries included the US, Canada and many European nations. In the Unites States, the authority to certify tree seed lots under the scheme was delegated to the state certitication agencies. Seed companies and state organizations were approved by the certifying agencies to produce or process certified seed and the exportation of conifer seed from these seed orchards drove certification for many years.

The demand from Europe for North American seed sources of conifer seed has diminished and not much of this seed is certified under the OECD scheme at the present time. In 1995, 4000 lbs. were shipped to Europe under the scheme, almost exclusively from the state of Washington. This made up 25% of the overa11 forest reproductive material shipped under the OECD scheme. The seed exported were almost exclusively certified as source identified. The demand from South America and Asia has also diminished and not many state certification agencies are certifying any conifer seed under their own standards either. As a result, private seed companies and state forestry organizations don't really use the certification programs offered by the certification agencies in each state because there isn't really any demand for it.

NEW DEMAND

The area where seed certification is likely to have a significant role in the forest tree nursery industry in the future, is in the production of hardwoods, shrubs and native plants. "Native plants" include grasses, wildflowers, forbs and wetland species endemic to a particular area. The demand for plants and seed of these species has increased dramatically in the past few years. The demand is much greater in the western US at the present time but it is developing quickly in the eastern states. There are more potential users of these species in the eastern states because there are more actual landowners in the east as opposed to the west where public agencies manage a considerable amount of land. Seed certification schemes can be used to help insure that high quality seed and planting stock is produced and made available to the people and groups that need the plants.

The main reason the demand for these species has increased is that federal and state agencies and many environmental and conservation groups and land managers are attempting to use native plants for a wide range of uses and many have or are developing some type of policy to govern the use of both native and non-native plants on their land. Land managers are working with many new plant species to meet both environmental and economic goals. In addition, the public is increasingly interested in how both public and private lands are being managed. There is a leve1 of accountability present for the way land is managed that was not present in the past. Government organizations and private companies are devoting more time and resources to working with the public by providing information for educational purposes and including the public in the decision making process. Maintaining biodiversity, protecting habitats and plant populations and managing land for specific goals are issues the general public is much more knowledgeable about now than in the past. This is another reason that land managers of both public and private land will need to consider using a wide range of plant species in order to address the array of concerns over how land is managed or used.

Some public agency and commercial tree nurseries that used to grow a limited number of tree species are now growing a wide variety of plants, everything from traditional conifer tree species to grasses and wildflowers. Nurseries and land management organizations have to find sources of seed to produce these plants. Individual citizens are also looking for sources of seed of hardwoods, shrubs and native plant species for many different reasons.

To meet the demand for seed of these species, there has been a substantial increase in the number of seed companies selling hardwood, shrub and native plant seed. The seed companies are working with public agencies, conservation groups and individual citizens. To offer the quality of material required by the groups or people that want to purchase the seed, seed companies must keep accurate records that explain in detail the history of the seed being offered for sale. Seed certitication agencies have established schemes of classes and standards that can provide seed companies with guidelines for product development and information management.

In the western United States, source identified seed certification is very common. The importance of seed zones and guidelines for seed movement of many plant species are well established. While we may not know how far seed of some hardwoods, shrubs and native plant species can be moved before they are unable to survive or grow in a vigorous manner, experience dictates that using local seed sources decreases the chance of a crop or planting failure due to local geographic and climatic conditions. In the past, individuals, public agencies and private organizations have al1 bought seed from commercial seed companies that was not source identitied or the source was in question and not had success in establishing plants from the seed to produce the desired outcomes. Using certified source identified seed may help to eliminate some of these failures. This is the reason many seed buyers of these species in the west require seed companies to have their seed certified as source identified. The demand for these types of plants in the eastern US is growing and buyers in the east are likely to follow the lead of buyers in the west.

Some seed companies have their seed certified in order to let prospective buyers know that the seed was collected or produced according to a set of minimum standards. There is a leve1 of quality that is associated with this type of product and as the marketplace becomes more competitive, seed companies may find that offering certifying seed will increase sales. The American Seed Trade Association has organized a Tree, Shrub and Native Plant group at the request of some of the seed companies to look at various issues, including the role of certification.

CONCLUSION

Certification of tree, shrub and native plant species will not ever be in demand unless the end user of the material understands what certification is and is able to perceive or see a real benefit from using certified seed. In states where this leve1 of understanding is present, certification is common. Seed companies and the nurseries, both public agency nurseries and industry and small retail nurseries, are the people with the most direct contact with the end users of the seed or planting stock. As part of this industry, we need to be prepared to educate people about seed certitication and how understanding and using it can be beneficial. Seed certification is not regulation. It is a procedure that can be used to insure that a quality product is placed on the market.

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The Use of Organic Biostimulants to Reduce Fertilizer Use, Increase Stress Resistance, and Promote Growth[1]

Graeme P. Berlyn and Saroj Sivaramakrishnan[2]

Abstract-High quality organic biostimulants can stimulate plant growth, providing excellent growth and yield, with up to a 50% reduction in fertilizer use. These compounds are essentially, a stress vitamin mix for plants. They were developed for use in tissue culture of refractive or sensitive tissue explants. Research and practice has shown that these compounds can work under soil conditions, as well as in tissue culture. They work best on plants under water, cold, nutrient, and/or biotic stress. In well watered and heavily fertilized plants little effect of these compounds may be manifested.

The carrier for most biostimulants is a mix of humic substances and marine algal extracts; the carrier itself has slight activity as an organic biostimulant, however, the most active components are the stress vitamins. Ascorbate is the most active substance, followed by casein hydrolysate. In addition to acting as an antioxidant, ascorbate appears to promotes xylem formation. Under proper conditions, organic biostimulants promote nutrient uptake, acting as both a phosphorus, nitrogen, potassium and micronutrient pump. Thus, seedlings treated with them develop better vascular systems (in the case of pines-more and larger diameter tracheids and thicker walls) to transport water and nutrients, and are more efficient in nutrient uptake dueto a larger root system. Recent results in our laboratory suggest that the biostimulant treated plants are more resistant to insects, possibly because they are more vigorous, and can produce more of the energetically expensive defensive compounds like polyphenols.

Organic biostimulants, a byproduct of biotechnology research, can improve field competitiveness, nutrient use efficiency, and stress resistance of plants (see Berlyn and Beck 1980; Berlyn et al. 1990; Russo and Berlyn 1990; 1992; Russo and Berlyn 1994). Because of these properties, they can decrease reliance on chemicals and tillage, and improve plant health. We do not claim that this approach can completely replace the use of agricultura1 chemicals. It is a truism that where agricultura1 chemicals are used, people have enough to eat, and where they are not used, people do not. The modern agricultura1 practices of developed countries have been highly successful in food production. However, these systems rely on high mechanization, high fertilizer, high herbicide, high fungicide, high pesticide, and high use of fossil fuel energy. Any alternative system that can decrease reliance on fossil fuels and minimize the disturbance of the ecosystem, promotes sustainability and helps preserve the food and fiber supply for future generations. This is increasingly important in view of the limited reserves of fossil fuels that are so necessary in the current high energy agricultural, forestry, and horticultura1 systems. Our approach is to provide one type of alternative that has less reliance on xenobiotic chemical inputs, and more reliance on the inherent physiological capacities of plants and the other organisms of the rhizosphere. This methodology can be used in urban and suburban systems, as well as in nurseries, agriculture and forested ecosystems.

[1]Berlyn, G. P.; Sivaramakrishnan, S. 1996. The Use of Organic Biostimulants to Reduce Fertilizer Use, Increase Stress Resistance, and Promote Growth. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 106-l 12.

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Roots™ is an organic biostimulant developed by this laboratory. It stimulates plant growth, providing optimum yield with up to a 50% reduction in fertilizer use. Essentially, Roots™ is a stress complex for plants. It utilizes many of the organic supplement components developed for use in biotechnology over the past 40 years. These components are used in standard plant tissue culture media where the object is to stimulate fragile tissues and cells to grow in an in vitro (foreign) environment that is stressful to them. These biostimulants alleviate some of the stress, and permit these explants to grow and differentiate depending on the other constituents of the tissue culture media. In the 1970's, the senior author experimented with using these same supplements for stress alleviation in the soil environment. Roots™ and its derivatives are the current result of this research. It is based on long experience in plant tissue culture (cf. Berlyn 1962). Despite their potential autotrophic capacity, plants are seldom situated in optima1 conditions where such capacity can be fully realized. For example, when isolated plant roots are grown in tissue culture, they have to be supplied with B-vitamins because roots do not synthesize the B-vitamins they need for growth. In the intact plant, roots get most, if not all, their B-vitamins from the leaves. In a well watered and fertilized plant growing in a growth room or greenhouse at optima1 temperatures, the leaves are able to supply all the B-vitamins (and other substances) the roots need, but under the multiple stresses usually present in the field, this may not be the case. In such situations we have demonstrated that organic supplements improve plant health (Russo and Berlyn 1990). It is difficult to mimic these multiple stress environments in greenhouses or growth rooms and, in general, potted plant environments are quite different from those in the field. Nevertheless, we have found field data to show fairly good correspondence with our tissue culture, greenhouse, and growth room results over the past decade.

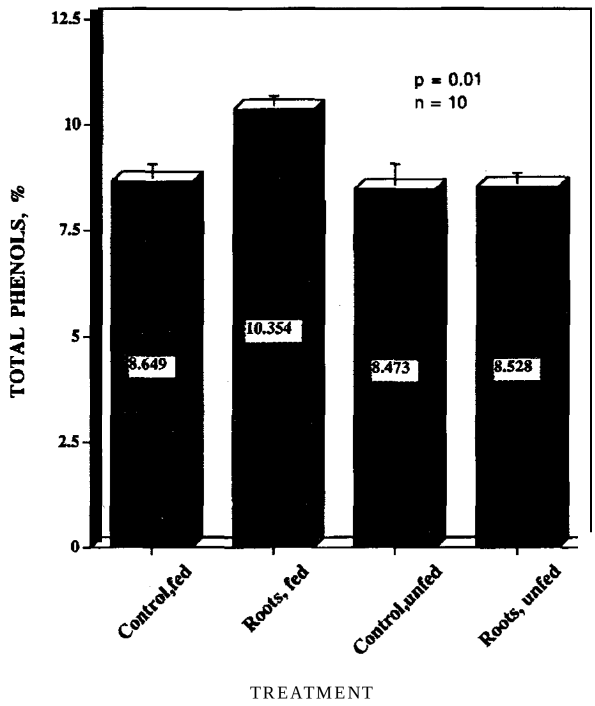
The main active ingredients in the current Roots™ formulae are ascorbic acid (vitamin C), casein hydrolysate, myo-inositol and alpha tocopherol (vitamin E), and thiamin. These substances are combined in an aqueous carrier of humic acid and marine algae extracts. The carrier itself has slight activity as an organic biostimulant. However, the stress vitamin supplements are far more active, even when used alone (Cho and Berlyn, unpublished). The ascorbate is the most active substance followed by casein hydrolysate. In addition to acting as an antioxidant, especially in the glutathione-ascorbate oxidation reduction cycle in the chloroplasts, ascorbate also promotes xylem formation. Roots™ promotes nutrient uptake, acting as both a phosphorus, nitrogen, potassium and micronutrient pump (Russo 1990). Seedlings treated with Roots generally develop better vascular systems (in the case of pines-larger diameter tracheids, larger lumen diameter and thicker walls [under some conditions]) to transport water and nutrients, and are more efficient in nutrient uptake due to a larger root system.

Although the increased efticiency of nutrient uptake might be expected to increase susceptibility to insects, this does not appear to be the case. Recent results in our laboratory suggest just the opposite. Other studies have corroborated this effect and demonstrated that vitamin C and E are active in insect deterrence (Neupane and Norris 199 1). The fact that the biostimulant treated plants are more vigorous may enable them to produce more of the energetically expensive defensive compounds like polyphenols. Results in our laboratory have suggested that this is indeed the case for oaks and eastern hemlock (Sivaramakrishnan et al. 1996). This work involves a comparison of the feeding effects of two important insect pests, the gypsy moth *Lymantria dispar* L. (Lepidoptera: Lymantriidae) and the hemlock woolly adelgid (*Adelges tsugae* Annand, Homoptera: Adelgidae) on white oak Quercus alba L. and eastern hemlock *Tsuga canadensis* (L.) (Carr.) respectively. The hypothesis is: (1) insect feeding alters plant anatomy and physiology, leading to a loss of tree health and vigor, and directly or indirectly to death in extreme cases; and (2) organic biostimulants can increase host plant resistance to insect attack by improving health and vigor through improved ce11 structure and increased production of secondary compounds, such as polyphenols (Sivaramakrishnan, et al. 1996).

We have used a modified solution of Roots2™, and mineral nitrogen to create populations of trees of varying degrees of plant health and vigor by varying nutrient, herbivory and defoliation levels. Anatomical and physiological measurements were made to determine the effect of the different treatments. Physiological status is being determined by measurements of photosynthesis, leaf chlorophyll, chlorophyll fluorescence, total phenolics, starch, and carbohydrates, as well as by measurements of growth and plant leaf area. Anatomical changes (cell numbers, ce11 wall thickness, lumen and tracheid diameters) are being measured using image analysis in conjunction with histological techniques. Secondary chemistry has been measured using the Folin-Denis test. Response of gypsy moth larvae to the experimental treatments is being measured with feeding tests on the leaves. In the case of hemlock fecundity of the hemlock woolly adelgid on the treated and control plants, it is being used to measure the impacts of the treatments on host resistance.

In a preliminary study to measure the effect of organic biostimulants on gypsy moth feeding on red oak seedlings, we found that while no signiticant reduction in feeding was observed, total phenolics in red oak leaves were found to be elevated in foliage treated with organic biostimulants and fed on by gypsy moth larvae. The results were highly significant (Figure 1). Higher levels of total phenolics in oak leaves fed on by gypsy moth larvae have been reported by other workers, and these are negatively correlated with larval growth. In a study conducted on infestation levels of the hemlock woolly adelgid, we found that infestation levels were significantly lower on trees treated with organic biostimulant (Figure 2). This reduction of infestation occurred despite the fact that the trees treated with organic biostimulants grew significantly more in both height and diameter.

Over the past decade, the various versions of the biostimulant have been tested on many species, and it has been beneficial in almost al1 these tests which included pines, beans, peas, lettuce, maples, radishes, oaks, tomatoes, alders, coffee, Gliricidia, Leucaena, orchids, Hypoestes, marigolds, Araucaria, and many others. In coffee we were able to increased photosynthesis and obtain better growth at half fertilization (as recommended by the Costa Rica Coffee Board). In addition, phosphorus, nitrogen and many other nutrients were enhanced in the biostimulant treated plants even with the 50% reduction in fertilization (Russo, 1990). Nitrogen fixation was stimulated in Alnus (Berlyn and Russo 1990). Roots2™ was also beneficial in micropropagation using tissue culture systems. In a recent test, Roots™ with casein hydrolysate far surpassed superabsorbent gels alone in tomato yield. However, the highest yield occurred in plants treated with a combination of Roots2™ and a polyacrylamide



Figurel. Induction of phenols in red oak by gypsy moth feeding.

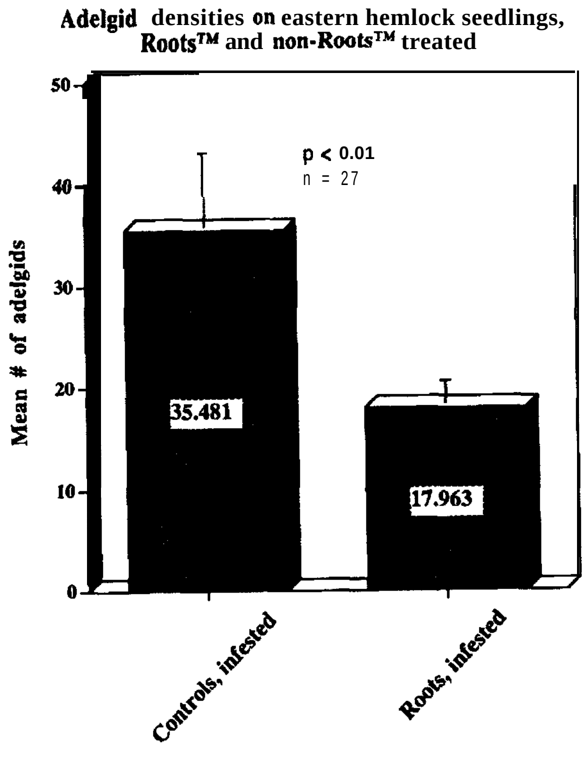


Figure 2. Hemlock woolly adelgid densities on seedlings treated with an organic biostimulant as compared to control.

superabsorbent gel (Figure 3). We are experimenting with these superabsorbent gels, trying to find the most environmentally benign gel for use with Roots™. These gels have potential benefits in arid zone agroforestry, agriculture, and urban horticulture. They may also be useful in reducing irrigation frequency, and even conserving watering in home gardens and lawns, i.e., wherever water is in limited supply.

Roots™ promotes nutrient turnover in soils (reduces thatch in turf), and in another recent test, enhanced the rate of metabolism of ^{13}C-labeled benzene by soil microorganisms (Liptak and Berlyn, unpublished data). We are always trying to improve the product and/or develop new ones. We are also interested in testing its effects in different species, systems, and conditions.

Organic biostimulants improve tree health and vigor in a number of ways. In pines we found Roots™ promoted a large increase in xylem ce11 number, ce11 wall thickness, and lumen diameter. Water flow is proportional to the fourth power of lumen diameter. Thus, a feedback loop is set up whereby the increased root biomass takes up more moisture, and increased hydraulic conductivity of the xylem means that the leaves are provided with reduced water stress. This coupled with enhanced antioxidant capabilities would lead to greater carbon assimilation. This additional photosynthate is allocated to enhancing the roots and the transport system itself, providing even more water and nutrients to the leaves, which in turn leads to greater carbon assimilation. Surplus carbon can be allocated to reserve compartments, and with greater carbon reserves, the trees are able to produce more secondary compounds, such as polyphenols, that may deter herbivory. As this loop cycles around, you get larger roots and stems, and more secondary compounds, as additional carbon becomes available for these functions. This permits a greater harvest of soil resources, and the loop recycles. This is a modified version of the super plant hypothesis (see Arnone 1988).

The biostimulant does not function as a growth regulator in the usual sense. No synthetic plant hormones are added. Roots™ does contain marine alga1 extract and marine algae are known to contain natural cytokinins. However, the cytokinin content of the working solution recommended for Roots™ (1% of the master solution, 10 ml of Roots™ per liter of water) contains at most 0.1 mg/L of cytokinin. This is probably too low to exert a biological effect when added to soil, although it is at the low end of activity in tissue culture and hydroponics. In these systems the recommended concentration of Roots is 0.1% (one milliliter of the master solution per liter of water). We have also tested the ingredients separately and found the vitamin mix and casein hydrolysate to be the main active components.

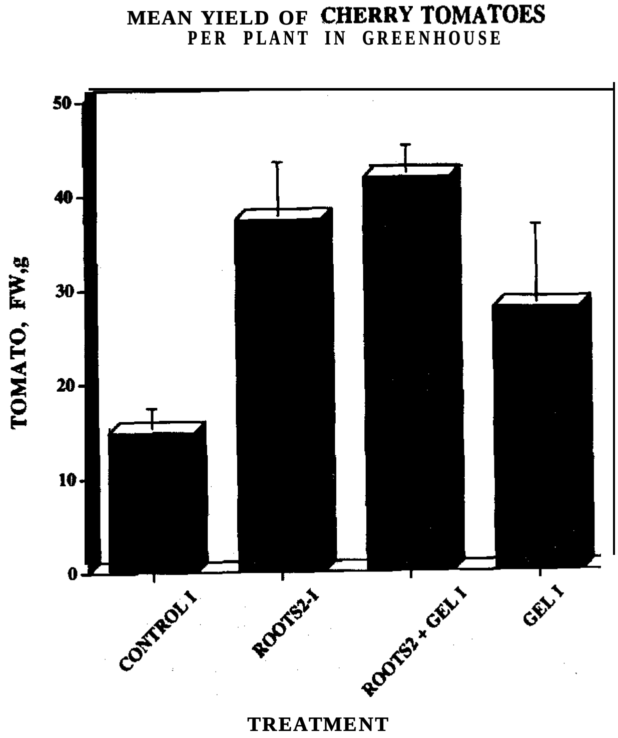


Figure 3. Mean fresh weight yields of tomatoes treated with:control, organic biostimulant (Roots), organic biostimulant plus polyacrylamide superabsorbent gel, and polyacrylamide superabsorbent gel alone.

In many studies, (Coffee, Alnus, Pinus, grasses, Populus) the rate of development was greatly increased as evidenced by the greater number of leaves formed in a given time period (Figure 4). The time between formation of successive leaves is termed the plastochron. This is a useful concept because plant development is more directly keyed to the plastochron than it is to chronological time. The primary vascular system consists of stem bundles (axial, cauline) and the leaf traces that diverge from them and enter the leaves.

These complexes are termed sympodia, and in some species, they develop free in the ground tissue (each leaf is connected to only one axial bundle) and in others they are closed because each leaf is connected to two sympodia. The leaf traces begin development as procambial strands before the leaf primordia to which they will be connected are formed by the shoot apical meristem. At a predictable point in space and developmental time, a vascular cambium is formed, and initiates the secondary plant body in woody plants. Many plants not ordinarily classified as woody plants, such as soybeans, also form a cambium and some secondary tissue. Thus, when the plastochron is shortened by treatment with Roots™, many aspects of development, in addition to the increased number or rate of formation of leaves, are accelerated. However, leaves are the collectors of solar energy and the transducers of solar energy into chemical bonds. Certain useful aggregations of these bonds we humans call food. Thus, making and maturing leaves faster and making more leaves increases the carbon fixing capacity of the plant and the planet.

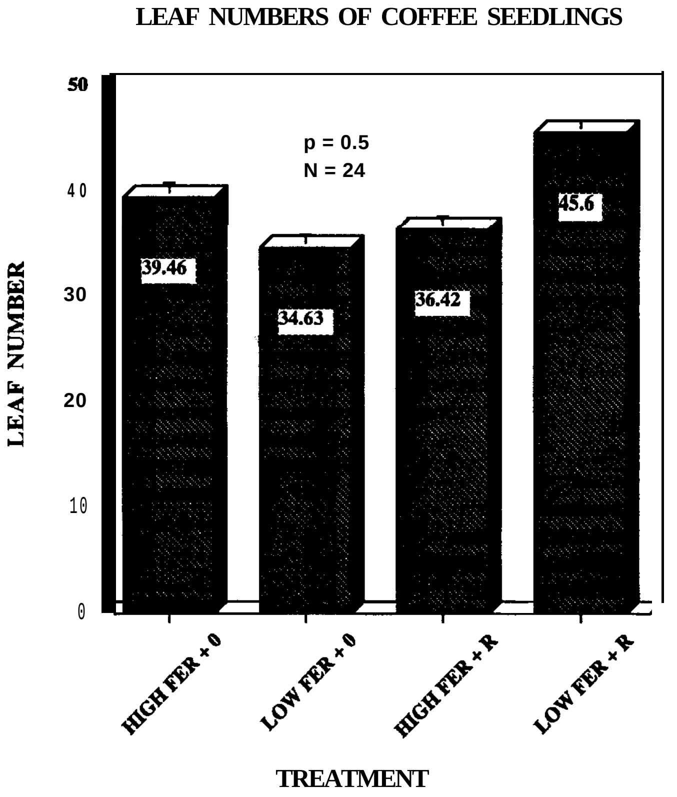


Figure 4. Leaf numbers produced by coffee seedlings overa given time period in response to treatment: HIGH FER=recommended fertilizer rate, LOW FER=half the fertiliter in the HIGH FER treatment, R=plants treated with Roots™, and 0=control plants (Russo 1990).

It has been suggested that biostimulants induce an increase in membrane permeability. Such an increase could arise from several sources. There could be an increase in permeases, specific enzyme protein carrier molecules in the membrane, or an increase in activity of existing carriers. Increase in membrane permeability can also account for increases in cold resistance because increased permeability means less resistance to flow to extracellular ice. As temperatures approach freezing, the viscosity of water increases, and membrane permeability, decreases and flow to extracellular ice is decreased. If temperature change is sufficiently rapid, intracellular ice can form and result in protoplasmic damage in the symplast. If biostimulants can maintain higher membrane permeability at lower temperatures and increase wall storage space, they could decrease cold damage. If biostimulant treatment could effect a 2 degree protection over untreated plants, it would be of considerable importance for citrus and wheat growers.

ANTIOXIDANTS IN GENERAL

Several of the ingredients of Roots™ are antioxidants, and additional antioxidants are being tested for possible use in the product. Plants have special requirements for antioxidant activity because of the nature of the photosynthetic process. Under high light fluxes more energy is absorbed by chlorophyll than can be utilized in photosynthesis. Under these conditions the excess energy may lead to the formation of toxic free radicals. Plants use antioxidants to detoxify these byproducts, and thus prevent severe consequences. Under sufficient stress, plants cannot produce the optimum amount of antioxidants and exogenously applied antioxidants like ascorbate can help in the detoxitication process (Berlyn and Beck 1980).

Free radicals are energetic molecules that have one or several unpaired electrons. They are formed when excess energy is transferred to the abundant oxygen molecules in the chloroplast that are present as a result of the splitting of water and evolution of oxygen during the process of photosynthesis. Free radicals are a serious problem for plant growth and development because they are extremely destructive to chlorophyll and other essential components of the chloroplast, such as: proteins, nucleic acids, lipids, and membranes. While the potential for free radical formation is greatest in the light absorbing and oxygen rich chloroplasts, free radicals can also be formed in many parts of the living cells, such as the mitochondria. These organelles function as an oxygen sink since oxygen is consumed in respiration at these sites.

However, photosynthesis is the most important source of electrons for free radical formation. In photosystem one (PS 1) there are electron acceptors such as ferredoxin. When photoelectron flow is blocked due to lack of oxidized acceptors in the photoelectron transport chain, or due to lack of NADP+, to reduce to NADPH, the electrons can still be transferred to oxygen in the illuminated chloroplast. The superoxide radical, $O^{\bullet}_2$ is one of the destructive free radicals formed in this process. This oxygen derivative can be detoxified through the mediation of superoxide dismutase (SOD) leading (through additional electron donation) to formation of hydrogen peroxide. In turn, this can be reduced to water by the ascorbate/glutathione cycle. If not detoxified, hydrogen peroxide, upon additional electron donation, can lead to the formation of the hydroxyl free radical. The latter has no known biochemical detoxification system in the plant, and is extremely toxic, but further donation of an electron can reduce it to water.

$$0_2 + e^- \rightarrow O^{\bullet}{}_2^- + e^- \rightarrow H_20_2 + e^- \rightarrow OH^{\bullet} + e^- \rightarrow H_20$$

Singlet oxygen is also very destructive and can be formed directly in photosynthesis. After chlorophyll is excited by absorption of a photon, it may decay to the triplet state before returning to the ground state. This triplet state of chlorophyll is relatively long lived, and this increases its probability of donating electrons to oxygen forming the toxic singlet oxygen, ${}^1O^*_2$. The toxic reactions of these activated oxygen species is termed photocatalytic destruction, photooxidation, oxidative photodestruction, or photodynamic effects. They can lead to chain reactions that destroy biological membranes. In the face of all this potential destruction, plants in general thrive and function. This is due to antioxidant pathways. Most celís have an organelle, the peroxisome, that contains the enzyme catalase that can detoxify hydrogen peroxide to water and normal oxygen. However, the chloroplast does not contain catalase, but instead detoxifies hydrogen peroxide through the ascorbic acid glutathione chain. It does this at the expense of NADPH, and is an energy requiring reaction. However, this reaction sequence prevents the formation of the hydroxyl free radical (see Alscher and Hess 1992).

Other important antioxidants in the plant are atocopherol (vitamin E) and the carotenoids. Beta-hydroxy-beta methyl butyric acid (HMB) is another antioxidant that is produced in very small quantities by plants, but its physiological role in detoxification, if any, is not clear as yet. Carotenoids are extremely important in plant growth and development. They absorb harmful UV light, and also in the blue wavelengths. The action curve of photosynthesis of intact leaves shows much more activity in the wavelengths between the blue and red peaks, and a part of this is thought to be due to resonance transfer of light energy from carotenoids to chlorophyll. A key to its protective function may be found in its distribution in the chloroplast. It is high concentration in the chloroplast envelope where it is in a position to protect the chloroplast (Anderson and Beardall 1991; Mohr and Schopfer 1995). It also functions in the thylacoids by the radiationless de-excitation of excess energy absorbed by antennae chlorophyll. The xanthophyll chain of violaxanthin, antheroxanthin, zeaxanthin have been shown to be especially important in this regard (see Salisbury and Ross 1992; Mohr and Schopfer 1995). Any stress whether natural (water, nutrient, excessive light, temperature) or anthropogenic (acid rain, sulfur dioxide, ozone) increases the production of toxic oxygen derivatives (Foyer et al. 1994). The proper use of organic biostimulants provides a means of ameliorating the stress, or its consequences, and therefore improving plant health.

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The Development of Mixed Species Plantations as Successional Analogues to Natural Forests[1]

P. Mark S. Ashton and Mark J. Ducey[2]

Abstract —Moist temperate and tropical forests often regenerate after disturbance regimes (hurricanes, tree falls, pathogens) that promote allogenic processes (initial floristics) of stand development. Disturbance regimes that are more lethal to advance regeneration, such as land clearance for agriculture and subsequent abandonment, promote autogenic processes (relay floristics) of stand development. We propose models for development of mixed plantations that reflect these successional patterns. Initial findings from experiments adopting guidelines that carefully consider the spatial arrangement and timing of mixed plantings can promote the inclusion of late-successional canopy timber species with subcanopy species that provide non-timber forest products (latex, spices, medicinal herbs, fruits). Past experiments have demonstrated poor establishment of subcanopy and late-seral tree species when planted as a single species in open conditions.

We propose experimental mixed plantations that aim to reflect the stand dynamics of natural forests. Using the stand development paradigm of Oliver and Larson (1990) the initiation phase of stand development is represented by the nurse stage of plantation establishment, the stem exclusion phase is reflected during the training period of plantation growth, and the understory initiation and old growth phases can be equated with the tree and crop harvest period at the end of a plantation's rotation. The establishment of experimental mixed plantings requires careful choice for species that are site-specific, shade-tolerant and late-successional. Planted on an appropriate site experiments need to test their survival and establishment within a compatible matrix of faster-growing pioneers that provide partial shade. Preliminary results have shown that initial spacing and differential growth rates can accentuate dynamic canopy stratification. Under-planting trees and shrubs normally of the forest subcanopy can create a more static structural stratification that can increase economic value through yield of non-timber forest products, increase net primary productivity, and enhance wildlife habitat characteristics.

INTRODUCTION

In this paper we first describe the pattems and processes that facilitate the growth of species as compatible mixtures in moist temperate and tropical forests. We then provide a rationale for their simplistic reconstruction as plantation analogues on abandoned agricultura1 lands. Lastly this paper describes models for potential testing and development of mixed plantations and provides preliminary information on experiments that have established them based on our knowledge of moist forest dynamics.

Many studies have documented tree species mixtures to be stratified both over time and in vertical space for natural forests of moist temperate and tropical climates. In these regions soils are moist enough during the growing season to reduce the importance of water acquisition by the plant roots as a limiting process. This has promoted the expansion of below canopy environments within which shade tolerant plants can grow and survive. The complexity of vertical stratification is largely limited by the degree

[1] *Ashton, P.M.S; Ducey, M.J. 1996. The Development of Mixed Species Plantations as Successional Analogues to Natural Forests. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 113-126.*

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to which the availability of water and other edaphic resources to the roots limits the ability of the plant to allocate resources for light capture. The degree of vertical complexity in stratification varies at resource scales that are often based on light-water interactions. Such changes can be seen primarily between different topographic sites within a watershed such as between ridge and valley, or between different soil or geological types such as between a shallow till and deep outwash. Other examples of complexity change can be observed across more regional, physiographically based landscapes, for example between the leeward and windward sides of a mountain range, or between northern and southern aspects of mountain slopes. Watershed infuences on vertical canopy stratification can largely be attributed to below-ground differences in the nature of hydrological flow pathways and storage, and entrained flows and deposition of nutrients and soil structural components. Regional physiographic influences on vertical canopy stratification are often associated with climatic differences in precipitation or incident radiation, but may also be associated with changing water or nutrient availability dueto differing parent material of the soil or dominant surficial geology.

Conceptually, stratification can be characterized in two modes: dynamic and static. Both exist and occur together but vary in their importance depending on the nature and disturbance history of the site. Dynamic stratification can be described as that part of vertical complexity of forest stand structure that is most closely associated with succession. Tree species considered fast-growing pioneers are overtopped by slower-growing but eventually taller and longer-lived tree species. This process has been described as having severa1 phases of stand development which closely parallel changes in the resource use efficiency and therefore the competitive ability of trees to grow and develop (Figure 1). Based primarily on North American literature four phases of development have been proposed by Oliver and Larson (1990). The initiation phase can be considered the first developmental stage of stand reorganization, regeneration site colonization and/or release after disturbance. The stem exclusion phase follows this period and can be regarded as the most active post-establishment period of sorting and self-thinning with growing space totally occupied by the stand. A stand enters into the understory initiation phase of stand development when the maintenance of larger canopy tree sizes promotes less efficient capture and use of resources, and therefore makes growing space available for the re-initiation of groundstory advance regeneration and other often herbaceous plants. This phase also occurs when an increase in the spatial scale of canopy gaps, caused either by increasing tree size or by partial disturbance, exceeds the declining ability of the large canopy trees to reoccupy vacant growing space. The old growth phase is the last period of stand development. Here, the process of understory re-initiation has progressed enough to promote irregular canopy tree death and subsequent patchy release of the groundstory that eventually develops an all-aged tree canopy.

A similar stand development paradigm has been described in the European and old world tropical literature (Watt 1947). Gap phase can be equated to stand initiation; building phase to stem exclusion; and mature phase to the combination of understory re-initiation and old growth. Examples of dynamic stratification of tree mixtures have been reported for

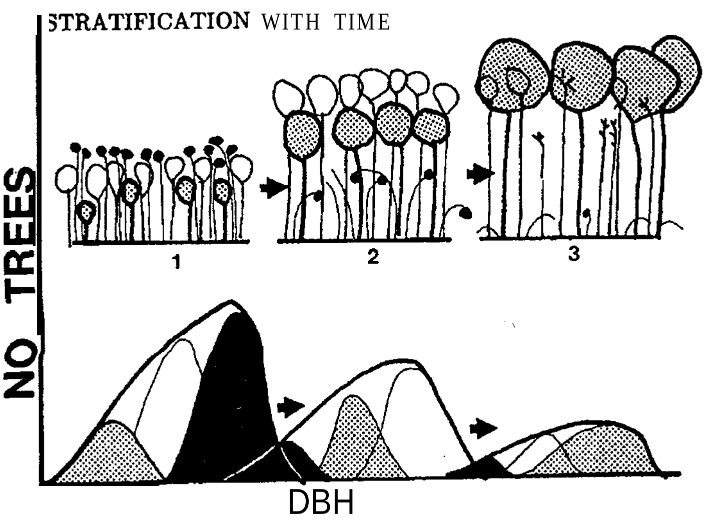

Figure 1. A hypothetical diagram depicting diameter distribution and associated dynamic canopy stratification of an even-aged cohort of mixed-species over different phases of stand development [early successional (1); mid-successional (2); late-successional (3)]. The different shading represents different species crown positions and diameter distributions over time.

birch, oak, maple forests of southern New England (Oliver and Stephens 1977; Oliver 1978); bottomland hardwood of the southern U.S. (Clatterbuck et al. 1987; Oliver et al. 1989); piedmont hardwoods of the Carolinas' (O'Hara 1986); spruce-aspen of the north central states and Canada (Palik & Pregitzer 1993) and coniferous mixtures of the coastal northwest (Stubblefield & Oliver 1978; Wierman & Oliver 1977). The moist tropics have been similarly described particularly with mixtures in the neotropics of central and south America (Uhl et al. 1981; Brokaw 1985; Uhl et al. 1988), and old world tropics of southeast Asia and west Africa (Whitmore 1984; Swaine & Hall 1988; Swaine & Whitmore 1988).

Static stratification can be described as that part of vertical complexity of the forest stand that promotes the permanent existence of a subcanopy and groundstory comprised of plants that never succeed to the canopy. This pattern is most characteristic of moist forest regions with long-term disturbance intervals that allow for the progressive accentuation of vertical habitat strata. Examples of this kind of stratification have been well described in the classical tropical literature (Davis & Richards 1933; 1934; Beard 1944; Black et al. 1950; Ashton 1964; Whitmore 1974). A simple type of static stratification has been described for the southern boreal forest (Cooper 1913; 1928). Many of the more complex temperate forests also have well defined strata particularly in the wet coastal Pacific northwest (Wierman & Oliver 1977) and the cove forests of the southern Appalachians (Braun 1942; Lorimer 1980) (Figure 2). The description of this type of stratification as static is largely one of temporal perspective; some static stratification patterns, such as those of the boreal forest, may be dependent on severe disturbance for long-term maintenance at the landscape scale.

Intermediate between these two types of stratification are examples of long-lived canopy trees that eventually relinquish their canopy space to subcanopy trees that are still longer-lived through gradual canopy disturbances such as ice storms and branch breakage from winds. Depending on the time scale of stand development this can almost be interpreted as part of static forest stratification rather than the last part of dynamic stratification. These intermediate descriptions of forest stratification have been documented for southern New England for hemlock beneath oak (Kelty 1986), and for white oak beneath tulip poplar (O'Hara 1986).

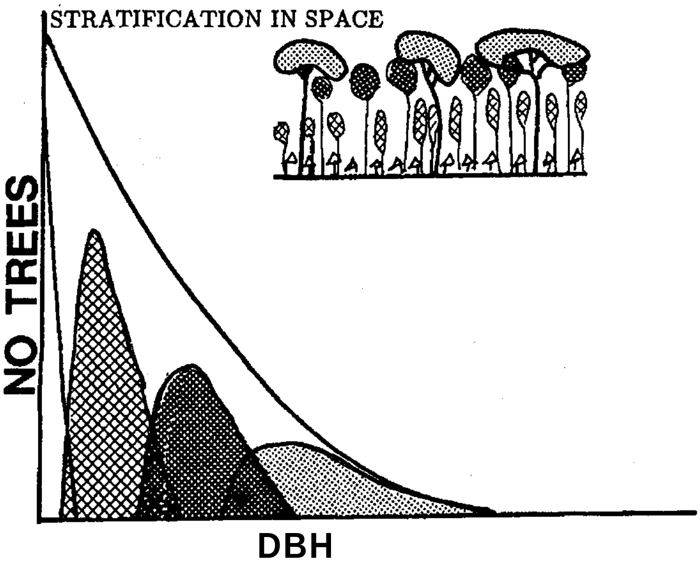

Figure 2. A hypothetical diagram depicting diameter distribution and associated canopy stratification of an even-aged cohort of mixed-species that permananently occupy different canopy strata over time.

The diversity and complexity of both the static and dynamic processes of forest stratification for these regions can largely be attributed to the wide variations in ways that these forests rely upon release of advance regeneration (Figure 3). This indicates the importance of those kinds of disturbance that serve to release regeneration, such as the various kinds and sizes of windthrows, as compared to disturbances that are lethal to the groundstory such as catastrophic wildfires, landslides, or volcanic eruptions. Reliance on release-type disturbances in moist forest regions means all growing space is actually occupied before, or shortly after, a disturbance occurs. The term for this type of regeneration initiation has been called allogenic succession, and is often associated with an initial floristics pathway of development (Egler 1954; Drury & Nisbet 1973; Henry & Swan 1974). Disturbance regimes lethal enough to destroy the groundstory can be considered relatively unusual in these forests, but do occur, in many instances associated with human forest clearance for agriculture, mining, and development. Such disturbance patterns often lead to successional

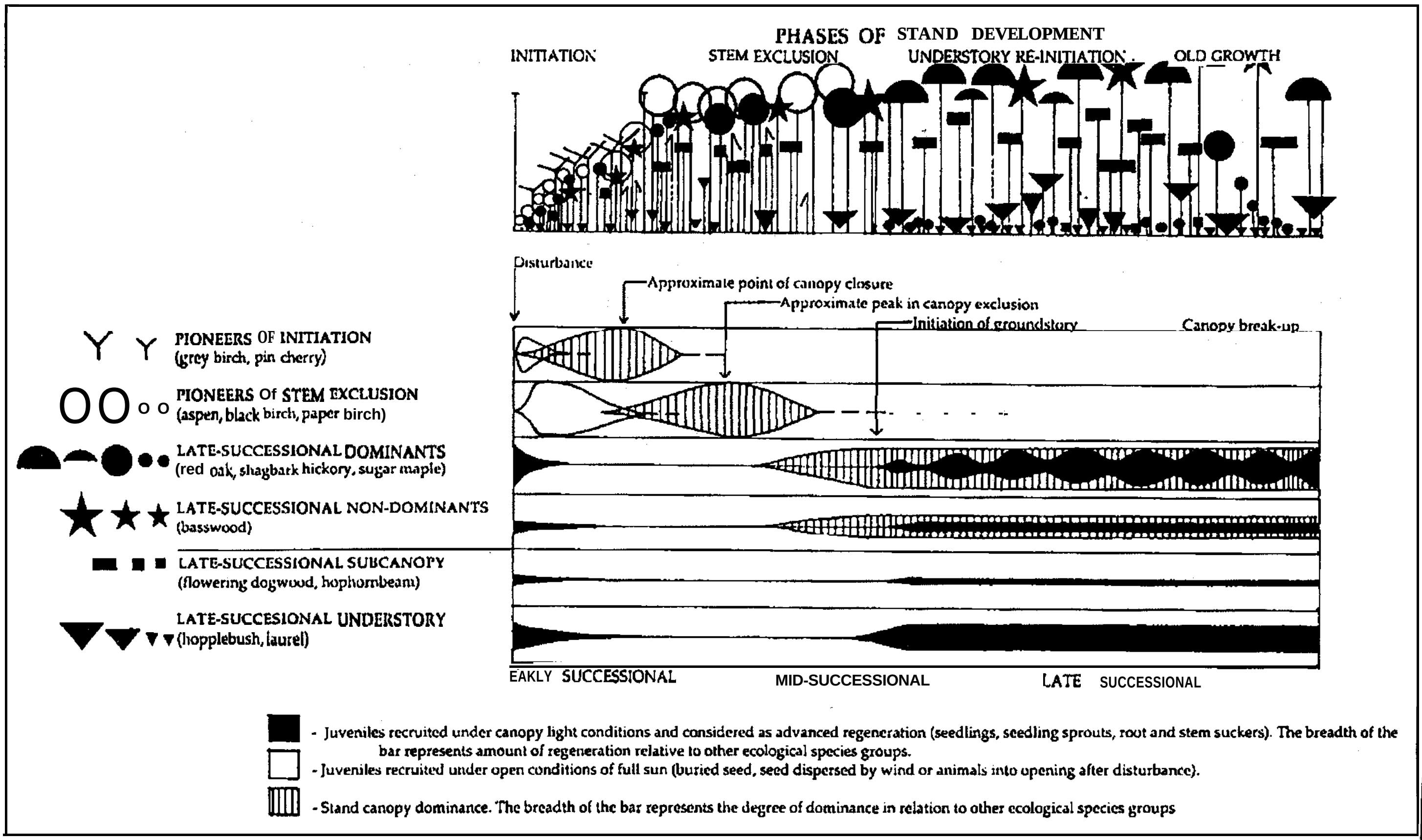

Figure 3. Regeneration recruitment frequency and stand canopy dominance of ecological species groups over different successional stages of stand development for a mixed-hardwood forest of eastern North America. Examples of species are given for each ecological group along with codes denoting their structural position within the stand over time. Note the periodicity recruitment of seedlings for tree species belonging to the late-successional canopy dominants (modified after Ashton 1992).

processes that promote changes in regeneration dominance characterized by sequential recruitment of different species over time, often in pulses as one species modifies the groundstory environment and facilitates the regeneration of another species. Many examples of this kind of successional process existed during the period of agricultura1 abandonment in eastern North America in the form of old-field pine and cedar (Lutz 1928; Billings 1938; Oosting 1942; Bormann 1953; Raup 1966). This kind of sequential regeneration initiation has been termed autogenic succession or relay floristics (Clements 19 16; Daubenmire 1952; MacArthur & Connell1966).

Lastly, site specialization of tree species across below-ground resource gradients that are usually related to variations in topography of the landscape can play an important determining role in the spatial heterogeneity of tree mixtures. In general site specialization is more characteristic of late-successional species that are dependent upon advance regeneration as compared to pioneers. Evidence suggests differences in species composition can exist due to edaphic factors: soil moisture (Bourdeau 1954; Ashton et al. 1995; Ashton & Larson 1996) nutrient status (Denslow et al. 1987; Latham 1992; Burslem et al. 1995; Gunatilleke et al. 1996; Gunatilleke et al. in press); biotic factors including density dependence of host-specific seed predation (Janzen 197 1; Condit et al. 1992; 1994), pathogen mortality (Gilbert et al. 1994), seedling herbivory (Becker et al. 1985), and microfaunal and floral symbioses (Janos 1988; Newberry et al. 1988).

RATIONALE FOR DEVELOPMENT OF MIXED-SPECIES PLANATATIONS

Currently moist mixed-species forests supply much of the world demand for quality timber (furniture, interior panneling, flooring, turnery, veneer, and other speciality woods). In most instances the mode of exploitation has led to a high-graded forest that has no quality timber production capability or value. The majority of species that are desired for quality timber in these forests are canopy tree species that are late-successional site-specialists relying upon advance regeneration for their establishment and growth. Studies have shown that their real price values have dramatically increased compared with other timber values such as fiber, pulp, and production sawlogs (Burgess 1993; Howard 1995; Verissimo et al. 1995). Use of tree species that produce quality timber in conventional plantation systems has thus far been generally poor (Wormald 1992; Ashton et al. 1993). This can be mainly attributed to: i) their inability to compete with weedy competition under full sun conditions; ii) their tendency to stagnate or produce poor bole form when self-thinning amonst themselves; and iii) their poor survival and establishment on soils for which such specialists are not suited.

Once established, mixtures of compatible tree species have been demonstrated to have higher yields than single-species plantation systems. Studies in North America have shown greater yields for mixed plantations of *Alnus rubra* (red alder) and *Pseudotsuga menziesii* (Douglas-f?) (Binkley & Greene 1983; Binkley 1984); *Robiniapseudoacacia* (black locust), *Elaeagnus umbellata* (autumn olive), and *Juglans nigra* (black walnut) (Paschke et al. 1989; Schlesinger & Williams 1984); *Quercus rubra* (red oak) and *Tsuga canadensis* (eastem hemlock) (Kelty 1986). European literature has reported similar findings for mixtures of *Betulapendula* (silver birch) and *Pinus sylvestris* (Scots pine) or *Picea abies* (Norway spruce) (Mielikainen 1985; Tham 1988). Only a few well documented studies have been done in the tropics; notable are those by DeBell et al. (1985; 1989) using different mixtures of *Eucalyptus saligna, Albizia falcataria* and *Acacia melanoxylon.*

Non-timber species are often associated with the same problems in establishment that characterize late-successional canopy trees. They are also solely exploited from these same forests and are quickly depleted. Many of these species are subcanopy trees, lianas, and grounstory shade-demanding herbs that yield a great variety of specialized but highly desirable products (sugars, latex, spices, medicines, and fruits). However, these products are usually ecologically costly for the plant to manufacture, and are often associated with chemical compounds that the plant synthesizes for protection. In certain circumstances the management for these products alone can generate more income and produce an higher net present value for a natural forest than any other use for the land (Peters et al. 1989; Balick & Mendelsohn 1992). Examples of single products that continue to rise dramatically in value are *Calamus* spp. (rattan) and *Taxus* spp. (yew), both of which are now multi-billion dollar industries (Manokaran & Wong 1985).

The more reliable and more frequent the yield of a crop plant, the less financia1 risk, and hence the more desirable for cultivation by landholders. Important examples of such crops are obviously those that are widely grown as intensive single-species plantation systems such as *Camelia sinensis* (tea) or *Hevea brasiliensis* (rubber). Products that produce at infrequent intervals or that take severa1 years to maturity for a one-time harvest are often those plants that are still exploited from natural forests and are most prone to scarcity (Fortmann 1985; DeBeer & McDermott 1989).

We propose that the cultivation of non-timber and quality timber species in mixture, provided the complexities of their autecology are known, can make good economic sense. Mixtures can reduce the downside financia1 risks of crop failure, and potentially provide a crop yield at least once a year for some species (sugars, latex, fruits). At the same time, mixtures can provide for high value through the sequential yield of severa1 one-time crops that mature over the long-term stand development process. The aggregation of multiple products over time is frequently considerably higher in net present value than if each species could be grown alone (Peters et al. 1989).

Lastly, in many instances commercial species that are currently grown in single-species plantation systems can also be incorporated into mixed plantation systems, particularly for reduction of crop failure risk from certain pathogens and insects. Under such circumstances these crops can provide a reliable, early and directly marketable product for income during the early stages of plantation establishment. Certain species have often been planted in mixture with a more commercial plant, to provide shade and to avoid sun scorch (*Milicia excelsa* - Gibson & Jones 1977); to reduce leader weevil damage on *Pinus strobus* (eastern white pine) (Boyce 1954) and *Hypsipyla* spp. stem borer damage to host genera of the Meliaceae (Africa - *Khaya, Entandrophragma;* Asia - *Toona, Chukrasia; S.* America - *Swietenia, Cedrella).*

A MODEL FOR THE DEVELOPMENT OF MIXED-SPECIESPLANTATIONS

Many studies have recorded the establishment and survival of mixed-species plantations (Worwald 1992). Mixtures have been organized in different ways. Mixtures vary in degree of composition dominance, their spatial arrangement and their age structure. Mixtures of plantings often imply intimate, tree by tree, or line by line establishment, but arrangement can be in blocks such as some of the first mixed planting trials in North America (Hawley & Lutz 1943) and conifer-hardwood mixtures in the United Kingdom (Evans 1984). Mixtures need not always be the result of actual planting. Many studies have now measured the recruitment of natural regeneration beneath the canopy of single-species plantations (Guariguata et al. 1995; Parrotta 1995).

The model that we propose is based largely on knowledge gained of moist mixed-species forest dynamics described in the introduction to this paper. It can be condensed into a list of key principles derived from this understanding:

1. Where soil resources have not degraded or diminished beyond a threshold that affects the ability of more site-specific tree species to establish, or where the radiation environment does not exceed the light tolerance of certain tree species, then plantation establishment of species can be completed at approximately the same time (initial floristics). In situations where site-specific species cannot establish on a plantation site because conditions for their establishment are too severe, then plantation establishment should be sequential over time (relay floristics).

2. To obtain satisfactory growth without continuous thinning it is important to select species that are successionally compatible with each other (Table 1).

3. The spatial arrangement of mixtures should be consistent with the differential degree of self-thinning that occurs between tree species that are of different successional status (Table 2). There should

Table 1. Examples of successionally compatible mixtures based on some stand development studies in moist forest regions of North America.

REGION	Successional stages of plantation development: NURSEPHASE	TRAINING PHASE	TREE CROP PHASE
Southern New England[1]		*Acer rubrum* *Betula lenta*	*Quercus rubra*
Piedmont[2]		*Liriodendron tulipifera*	*Quercus alba*
New Hampshire[3]	*Prunus pensylvanica*	*Betula alleghaniensis*	*Acer saccharum* *Fagus grandifolia*
Northern Michigan[4]		*Populus grandidentata*	*Quercus rubra* *Acer rubrum*
Coastal Washington[5]	*Alnus rubra*	*Pseudotsuga menziesii*	*Tsuga heterophylla*

[1]Oliver 1978; [2]O'Hara 1986; [3]Bormann & Likens 1979; [4]Palik & Pregitzer 1993; [5]Stubblefield & Oliver 1978.

be more early-successional species per unit area than late-successional at time of planting. For example this means that in a temperate mixed-species plantation that includes mid-successional Q. *rubra* (red oak) and and early-successional *B. papyrifera* (paper birch) there should be a higher number of B. *papyrifera* planted than Q. *rubra.*

4. The spatial arrangement of trees should be compatible with their crown spatial requirements as they grow (Figure 4).

5. Careful selection of the late-successional more shade tolerant tree species needs to be made to insure their site compatibility.

Our proposed model consists of three phases (Ashton et al. 1993) (Figure 5). These phases of plantation growth represent the same phases described for the natural forest dynamic. The nurse phase can be equated to stand regeneration and initiation; the training phase is the period described as stem exclusion; and the tree crop phase is analogous to the understory initiation and old-growth phase of stand development. Al1 species can be planted simultaneously at establishment, but each species that is selected for the plantation mixture is representative of a different part of the plantation's successional development.

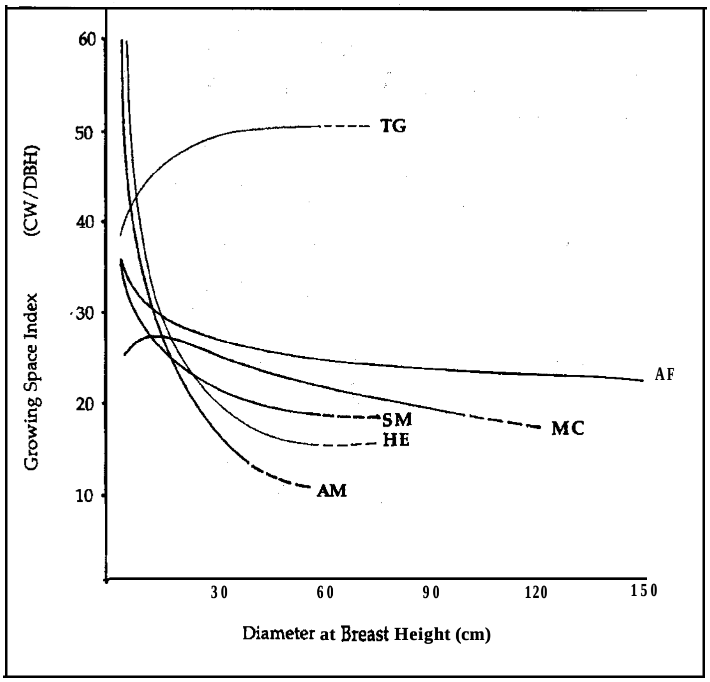

Figure 4. Relationships depicting changes in use efficiency of growing space as measured by the ratio of crown width/ diameter at breast height with increase in diameter at breast height for some tropical tree species of different successional status. [TG - Tectona grandis (mid-successional); AF - Albizia falcataria (mid-successional); MC - Michelia champaca (late-successional); SM - Sweitenia macrophylla (mid-successional); HE - Hibiscus elatus (early-successional); AM - Alstonia macrophylla (early-successional). (Samarasingha et al. 1995).

Table 2. Differences in self thinning over a ten year period (1986 - 1996) for northern hardwood stands on thin till (xeric) and swale till (mesic) sites at the Great Mountain forest in northeastern Connecticut. Both stand are now 27 years old and would be considered within the stem exclusion stage of stand development (unpublished data from Liptzin & Ashton).

SPECIES	TOLERANCE RANK	% STEM MORTALITY		MORTALITY OF STEMS/ha	
		Till	Swale	Till	Swale
Betula populifolia	very intolerant	-65.4	-100.0	-345	-198
Prunus pensylvanica	vety intolerant	-50.0	-46.2	-223	-170
Betula papyrifera	intolerant	-49.1	-47.6	-1704	-694
Betula lenta	intermediate	-40.0	-10.1	-872	-127
Quercus rubra	intermediate	-25.9	-57.9	-609	-992
Fagus grandifolia	tolerant	-13.0	+42.4	-183	+198
Acer rubra	tolerant	-5.9	-6.7	-20	-14
Tsuga canadensis	very tolerant	0.0	0.0	0.0	0.0

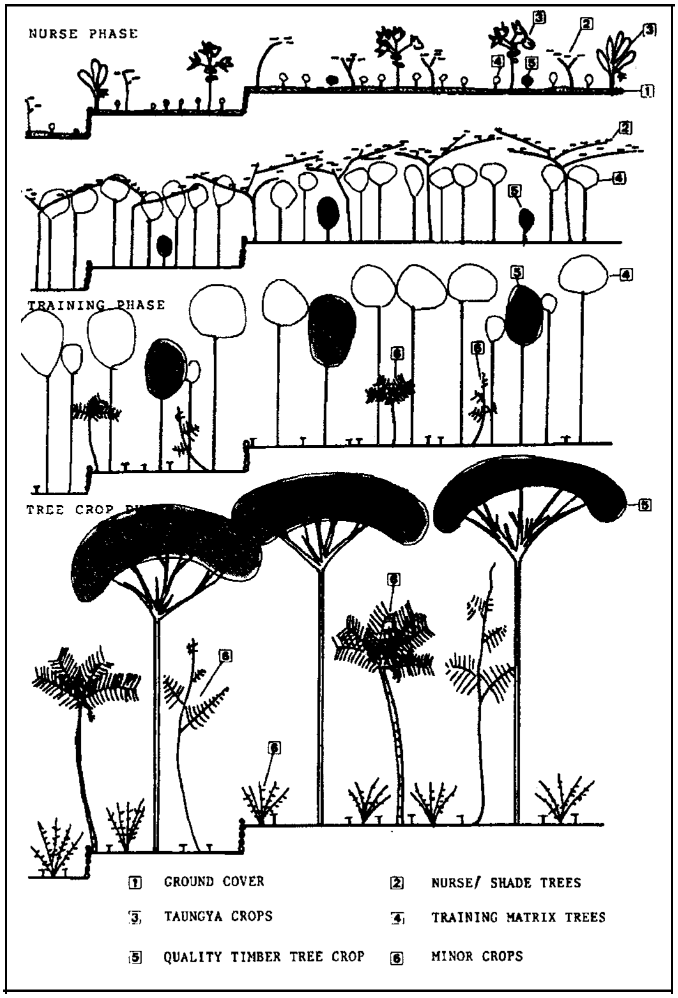

Figure 5. A representation of the progressive development of a mixed-species plantation showing the different phases of development (Ashton et al., 1993).

The Nurse Phase

This period can be considered the most critica1 time of plantation establishment. Where soil conditions merit restoration and then protection of structure and nutrition, the introduction of pioneer nurse tree and herbaceous species can be used to advantage. Many leguminous ground covers can be selected to imitate the invasive but protective roles that have been recorded for certain early sera1 herbaceous forbs and grasses (Safford & Filip 1974; Bormann & Likens 1979). Leguminous ground covers have the added advantage of a low uniform growth habit that can form a compact live mulch. This cover greatly lowers soil surface temperatures, retards soil surface moisture losses from direct evaporation, enriches top soil nitrogen through fixation, and builds soil structure and water holding capacity through increased contributions of organic matter to the soil. Al1 these attributes promote a soil surface cover that is not in direct physical competition for above-ground growing space with the planted tree seedlings.

In certain tropical circumstances where late-successional shade-tolerant tree species are very sensitive to high radiation, early sera1 pioneer tree species can be established to serve as a shade umbrella. In these regions many pioneers have the rapid growth and crown morphology to create this shade environment. Nurse trees can be seeded or planted at a wide spacing to provide as cheaply and as rapidly as biologically possible a shade environment for the slower growing, more shade-tolerant or -demanding trees species planted beneath. Within two years, nurse pioneer trees can develop a spreading but thin mono-layered crown approximately 4-5 meters above the ground surface. Examples of such species are in the genera *Cecropia, Gliricidia, Macaranga, Mussanga* , *Rhus* and *Trema.* Most of these nurse species are very short-lived and die as soon as they are over-topped (Whitmore 1984). Some studies have suggested they may act as temporary nutrient sinks, trapping mineral ions that would otherwise leach out of the soil after a disturbance. As the nurse trees die back they have been suggested to slowly relinquish nutrients back into the soil, making them more available to the other trees (Budowski 196 1; Stark 1970; Marks 1974).

Leaves of nurse tree species often have fewer toxic compounds or protective characteristics such as surface wax, hairs or coriaceousness than slower growing tree species (Ewel 1980). Many of these species also have the capability to coppice or pollard and can have high nitrogen contents because they are able to fix atmospheric nitrogen. Al1 these attributes make them suited to producing arboreal fodder for livestock.

During this period of plantation establishment, other very short-lived species can be inter-planted to bring direct tangible benefits to the local community, as long as this does not interfere with future stand dynamics. A successful example of this type of planting for food crops is the taungya system used to establish teak timber plantations in south Asia (Brandis 1897; Champion & Seth 1968). Use of this system encourages protection and care of the tree species that otherwise could be neglected or under-appreciated by the local community. Examples of species that are often socially desirable for local communities include light-demanding high carbohydrate food/fruit crops (Musa spp., *Maniot esculenta, Carica papaya*). If grown as a commercial crop, the income generated can offset some or all of the costs of plantation establishment.

The Training Phase

When other tree species overtop the shade trees of the nurse phase, fully occupy the plantation canopy, and begin shading out the groundstory cover and crop plants, then the plantation can be considered to have entered the training phase of its development. Tree species that dominate the canopy at this stage typically have autecological characteristics that make them upwardly fast-growing with strong epinastic control. Their crowns are small but compact making them efficient users of growing space. In their native forests they often grow in dense stands and in most circumstances readily self-thin amongst each other. Examples of species that fit this description include many from the genera *Alstonia, Betula* (birches), *Eucalyptus* (eucalypts), *Pinus* (pines), and *Populus* (poplars). Many species in these genera are planted as single-species plantations because they can produce some of the world's highest yields of sawtimber and fiber (Evans 1982; Shepherd 1986).

Species characteristic of this group are usually considered pioneers, and produce abundant seed regularly almost every year. Their regeneration is dependent upon seed that germinates on new growing space that has been created by a forest canopy disturbance. Their purpose in the kind of mixed-species plantation that we propose is to provide the same kind of support, stem training and rapid ability to self-thin that improves yield and quality of the slower growing, longer-lived tree species in moist mixed-species forests. If the trees are planted at a dense spacing, thinning regimes can be adjusted to capture their timber and fiber values, or if no markets are available, reliance can be made on their own self-thinning. During the training period of stand development these species create the matrix within which other more shade-tolerant and late-successional species that eventually create the canopy and subcanopy grow. At this time the plantation, like the stem exclusion stage of a moist mixed-species forest, is undergoing considerable self-thinning in the canopy with little to no growing space available to other plants at the groundstory.

On sites with very moderate environmental conditions, or with planted species mixtures that do not require immediate partial shade for survival, the nurse phase of establishment can be very brief. In many moist temperate regions there are no good examples of large-leaved pioneers that germinate and grow. Instead the ground cover is quickly dominated by forbs such as *Rubus* or species in the Compositae, which do not interfere substantially with seedling growth. However, on other sites species such as ferns or members of the Ericaceae may proliferate rapidly, and can interfere with stand development over long time periods. In these circustances, scarifying the topsoil and then direct seeding pioneer species typically dominant during the training phase along with a temporary ground cover might be a more satisfactory protocol.

Studies have documented the invasive role of many pioneer tree species on abandoned agricultura1 lands. These are also the species that usually dominate the stand canopy of the training phase of our model. In moist temperate circumstances of eastern North America many species of pines have facilitated the understory initiation of late-successional angiosperms (Lutz 1928; Billings 1938; Oosting 1942; Bormann 1953). Plantations of species with similar growth rate have been documented to facilitate secondary rain forest vegetation in the moist tropics (Guariguata et al. 1995; Parrotta 1995). On sites that have soils and aboveground radiation environments that are too extreme for the immediate establishment of site-sensitive, late-successional species, then plantations should be established by the sequential introduction over time. Using species like *Pinus* as an establishment matrix, the site can quickly be occupied, shading out the groundstory. Afterwards more site-sensitive late-successional species can be under planted or line planted beneath the thinned canopy (Ashton et al. in press).

Tree Crop Phase

The initiation of the tree crop phase of plantation development begins when the late-successional tree species begin to overtop the fast-growing pioneers that dominate the canopy of the training phase. The late-successional species, because they are more shade-tolerant, are able to grow steadily through the stratum of training phase pioneers. During this process, the late-successional species often change canopy morphology dramatically from a crown structure that is monopodial and columnar in shape, to one that upon receiving full sun becomes broadly branched and expansive. These species often do not perform well in competition for growing space with each other, but a more shade-intolerant matrix of pioneers allows for their crown expansion. Although diameter increments might prove low during the training phase, increments should increase substantially as these species attain canopy status during the tree crop phase. These are the species that would be harvested at the end of the rotation for high quality timber products (veneer, furniture, interior paneling, flooring, turnery).

Other species that represent true below-canopy strata of older forests can be grown for the production of various non-timber crops. Because they are adapted to relatively poor light environments many of these species have morphological and physiological adapations that make them efficient at "harvesting" light. Their leaves are usually broad and often variegated and arranged in single-layers that are either i) in planar whorls that make crowns deep and monopodial; or ii) shallow crowns that are flat and spreading. Their conservative use of resources promotes greater allocation to production of secondary componds for their protection from pathogens and herbivores. These attributes make them desirable for use as flavorful beverages (obvious commercial examples are the original tea and coffee plants), and medicines. The rotation lengths of these plantations are dependent upon the size and maturity of the canopy late-successional timber trees. The progress of sequentially moving through these phases of planatation development from start to finish could be anywhere between 40 to 100 years depending on the successional dynamic of the mixture chosen for planting and the integrated economic value of the products obtained. Because the subcanopy species, like the late-successional timber species, are slow-growing and site-specific, no satisfactory plantation has been developed to date. However, this aspect of the model deserves testing.

CONCLUSIONS

The growth and development of mixed-species plantations can be understood and managed using an analogue to the development of natural mixed-species stands. Each of the three phases of development corresponds to one the stand development stages of Oliver and Larson (1990): the nurse phase to the stand initiation stage, the training phase to the stem exclusion stage, and the tree crop phase to the understory reinitiation and old-growth stage. Ecologically, each stage is dominated by a different mix of life forms and successional species, while facilitating the regeneration, growth, and development of late-successional or site-sensitive species. Economically, each stage is dominated by a different mix of product yields, offering the possibility of frequent and dependable income compatible with the long-term production of high-quality timber. These features suggest mixed-species plantations can offer a variety of social benefits and considerable silvicultura1 flexibility, while reducing elements of risk often associated with single-species systems.

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Influence of Initial Seedling Size and Browse Protection on Height Growth: 5-Year Results[1]

Jeffrey S. Ward[2]

Abstract: Six plots were established in 1990 to examine the influence of initial seedling size and deer browsing protection on height growth for 5 tree species. Protective devices included plastic mesh and Reemay sleeves (60 cm), and Tubex and Corrulite tree shelters (120 and 180 cm). Species included northern red oak, black walnut, eastern white pine, Norway spruce, and eastern hemlock. Stem length, root length, root collar diameter, and number of twigs and first-order lateral roots were measured prior to planting. After 5 growing seasons, hardwood and white pine seedlings within tree shelters were significantly taller than seedlings protected by plastic mesh and spunbonded polypropylene sleeves. Mortality was lower for seedlings protected by tree shelters. Seedling height after 5 growing seasons was independent of initial seedling size for seedlings protected by tree shelters. Larger seedlings were taller after 5 growing seasons, and had lower mortality, than smaller seedlings. Severe grading may reduce gross nursery production, but would increase planting efficiency by increasing the proportion of seedlings that develop into large saplings.

INTRODUCTION

Ultimately, a nursery is as successful as the number of seedlings that survive and grow into mature trees. In forests with large deer herds, protection from browsing is essential for a successful planting program (Marquis 1977; George and others 199 1). Protecting seedlings from browse damage is expensive, $500/acre or more (Kays 1996). Planting inferior quality seedlings that have little chance of being successful (in dominant or codominant crown class at crown closure) further increases the effective cost ($/successful seedling/acre). A better strategy may be to plant fewer, higher quality seedlings and invest in better browse and vegetation control (Zaczek and others 1995; Schuler and Miller 1996).

Recent studies have indicated the number of first-order lateral roots (FOLR) may be a superior criterion of seedling survival and growth (Kormanik 1986; Kormanik and others 1995; Schultz and Thompson 1990; 1996; but see Kaczmarek and Pope 1993). The objective of this study was to examine the interaction of browse protection and initial seedling characteristics on long-term seedling survival and growth. Both hardwoods and conifers were included because of local interest in increasing the conifer component in the forest. Planting areas were specifically located in areas with large deer herds.

METHODS

Seedlings were planted in 1990 at 6 study sites evenly split between Mohawk State Forest and Lake Gaillard in northern and southern Connecticut, respectively. Because hunting is prohibited on both forests, large deer herds impeded natural regeneration and

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[1] Ward, J.S. 1996. *Influence of Initial Seedling Size and Browse Protection on Height Growth: 5-Year Results. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Setvice, Pacific Northwest Research Station: 127-134.*

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destroyed artificial forest plantations. Deer densities averaged 2 1/km^2 at Lake Gaillard and 18/ km^2 at Mohawk State Forest (Ward and Stephens 1995). Study sites on Mohawk State Forest were recent red pine clearcuts. Lake Gaillard study sites were abandoned agricultura1 fields. Al1 plots were cleaned with chainsaw and machete prior to planting and 2 years after planting.

Northern red oak (*Quercus rubra*), eastern white pine (*Pinus strobus),* and Norway spruce *(Picea abies)* were planted at both forests. Additionally, eastern hemlock (*Tsuga canadensis*) was planted at Mohawk State Forest and black walnut (*Juglans nigra)* was planted at Lake Gaillard. Seedling height (cm), root length (cm), and root collar diameter (mm) were measured prior to planting (Table 1). Numbers of first order twigs and first order lateral roots were counted.

Seedlings were stratified by root collar diameter before assignment to treatments. At each of the six sites 8-20 seedlings received each treatment. Tree heights (nearest cm), browse damage, and any distortions of the terminal leader were measured at the end of each growing season (-15 September). Browse damage was noted at the beginning (-1 December), middle (-15 February), and end of winter (-1 April). Damage to protective devices was noted during each field check.

The 6 treatments included: 60 cm high plastic mesh sleeve supported by a bamboo stake, 60 cm high spunbonded polypropylene (Reemay[3]) sleeve supported by a bamboo stake, 120 cm Tubex tree shelter, 180 cm Tubex tree shelter, 120 cm Corrulite tree shelter, and an unprotected control. Both bamboo and wood stakes were untreated. Mesh caps provided were placed over al1 tree shelters to prevent songbird entry into the tubes.

Table 1. Initial seedling characteristics prior to planting: mean (standard error).

Species	Stem	Twig	RCD	FOLR	Root	N
Not-thern red oak	30.8 (0.5)	1.2 (0.07)	5.8 (0.1)	4.1 (0.2)	n/a	288
Black walnut	35.1 (0.7)	0.2 (0.01)	7.1 (0.1)	3.9 (0.2)	52.9 (0.7)	192
Eastern white pine	21.7 (0.5)	3.0 (0.15)	5.7 (0.1)	8.3 (0.1)	55.4 (0.7)	480
Norway spruce	22.3 (0.3)	9.8 (0.23)	3.6 (0.1)	4.8 (0.1)	42.8 (0.9)	400
Eastern hemlock	19.2 (0.3)	13.9 (0.26)	2.6 (0.1)	4.3 (0.2)	20.7 (0.4)	240

Stem - stem height (cm), Twig - number of primary twigs, RCD - root collar diameter (mm), FOLR - number of first-order lateral roots $\geq$ 1 mm diameter, Fioot - root length (cm)

Table 2. Seedling height (cm) at the end of five growing seasons by browsing protection method.

	Species				
Protection method	NRO[a]	WAL	WPI	NSP	HEM
Control	56.1 a[b]	32.3 a	105.4 a	80.3 ab	48.5 ab
Mesh sleeves	69.3 a	44.8 a	86.5 a	81.4 ab	63.2 b
Reemay sleeves	63.4 a	44.3 a	97.1 a	75.6 b	44.2 a
Tree shelters	132.5 b	103.3 b	134.9 b	89.4 a	63.2 b

a/ NRO - northern red oak, WAL - black walnut, WPI - eastern white pine, NSP - Norway spruce, HEM - eastern hemlock.
b/ Column values for each species followed by the same letter do not differ significantly at p $\leq$ 0.05.

[3]Use of trade names does not imply endorsement *by the Connecticut Agricultural Experiment Station.*

Table 3. Seedling height (cm) at the end of five growing seasons by initial seedling characteristics for seedlings not protected by tree shelters.

	Species				
	NRO[a]	WAL	WPI	NSP	HEM
Stem height[c]					
Short	36.1 a[b]	39.2 a	68.0 a	65.1 a	41.3 a
Average	56.6 ab	41.4 a	78.3 a	80.6 a	41.1 a
Tall	66.7 ab	44.1 a	125.8 b	82.7 a	67.2 b
Very tall	81.6 b	43.6 a	142.3 b	82.8 a	64.8 ab
Root collar diameter[d]					
Small	46.3 a	41.5 a	72.9 a	65.5 a	57.7 ab
Medium	55.3 a	43.0 a	83.1 a	69.3 a	44.9 a
Large	64.5 ab	43.1 a	1 OO.9 ab	82.4 a	52.0 ab
Very large	78.4 b	37.3 a	128.8 b	106.3 b	74.3 b
First order lateral roots					
o-2	48.6 a	45.3 a	135.0 a	66.6 a	40.2 a
3-4	71.4 ab	36.8 a	95.6 a	76.7 a	47.8 a
5-7	68.5 ab	41.1 a	87.2 a	71.8 a	60.4 ab
$\geq$8	80.7 b	45.6 a	96.7 a	103.4 b	79.0 b

a/ NRO - northern red oak, WAL - black walnut, WPI - eastern white pine, NSP - Norway spruce, HEM- eastern hemlock.
b/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.
c/ Stem height classes (short, average, tall, very tall) by species: NRO (O-19, 20-29, 30-39, and $\geq$ 40 cm), WAL (O-24, 25-34, 35-44, and $\geq$ 45 cm), WPI (O-14, 15-24, 25-34, $\geq$35), NSP (O-14, 15-24, 25-34, and $\geq$ 35 cm), HEM (O-14, 15-l 9, 20-24, and $\geq$ 25 cm).
d/ Root collar diameter classes (small, medium, large, very large) by species: NRO (O-4, 5, 6, $\geq$7), WAL (O-6, 7, 8, $\geq$9), WPI (O-4, 5, 6-7, $\geq$8), NSP (O-2, 3, 4, $\geq$5), HEM (O-l, 2, 3, $\geq$4).

Tukey's HSD test (SYSTAT 1992) was used to test differences in 5th year height among treatments and among initial seedling size classes. Pearson correlation coefficients were used to examine relationship between initial seedling characteristics and seedling height after 5 growing seasons. Five-year height was used rather than height growth because absolute height (and survival) is the ultimate criterion of success. Differences in seeding mortality rates among protection methods and initial seedling size classes were tested using procedures in Neter and others (1982). Preliminary analysis found little difference in height and mortality among tree shelter types and among sleeve types and unprotected controls. Therefore, data for the 3 tree shelter types were pooled. Data for the 2 sleeve types and unprotected controls were also pooled. Differences were considered significant at $p \leq 0.05$.

RESULTS

Heights of northern red oak, black walnut, and eastern white pine were significantly greater after 5 growing seasons when protected by tree shelters than when unprotected or protected by sleeves (Table 2). The increased height of seedlings protected by tree shelters was signiticant after 1 growing season for the hardwoods and 2 growing seasons for white pine (Ward and Stephens 1995). Unprotected black walnuts were actually shorter after 5 growing seasons than when planted. Seedlings protected by sleeves were not significantly taller than unprotected seedlings after 5 growing seasons, except for black walnut protected by mesh sleeves. Hardwoods clearly responded better to tree shelters than conifers. Trees in tree shelters were taller relative to unprotected controls: black walnut-

220% taller; northern red oak-136%; white pine, 28%; Norway spruce, 11%; and hemlock, 30%.

Initial size was important for growth and survival of seedlings not protected by a tree shelter, especially for conifers (Table 3). Initial height had the highest correlation for eastern white pine and eastem hemlock, root collar diameter for Norway spruce, and first-order lateral roots for northem red oak (Table 4). Surprisingly, there was no significant correlation between seedling height after 5 growing seasons and initial seedling characteristics for northem red oak, black walnut, and eastem hemlock protected by a tree shelter (Table 4). Initial stem height had the highest correlation with 5-yr height for eastem white pine and Norway spruce growing in tree shelters. Though not significant, larger seedlings protected by tree shelters were generally taller after 5 growing seasons than small seedlings (Table 5).

Mortality of al1 species was significantly lower when protected by tree shelters than when unprotected (Table 6). In general, mortality of seedlings in tree shelters was half that of unprotected seedlings. Neither mesh nor Reemay sleeves significantly decreased mortality rates relative to unprotected seedlings. Shorter northem red oaks had higher mortality than taller seedlings, but taller eastem white pine had higher mortality than shorter seedlings. Mortality generally decreased with increasing number of first-order lateral roots for al1 species except eastem hemlock.

DISCUSSION

Not unexpectedly, most species were significantly taller when protected by tree shelters than when protected by sleeves or unprotected (Table 2). This concurs with the earlier research which demonstrates the increased growth for hardwoods (Potter 1988; Lantagne and others 1990; Minter and others 1992; Kittredge and others 1992; Smith 1993; Lantagne 1996; Strobl and Wagner 1996; Schultz and Thompson 1996; Schuler and Miller 1996; Farley and others 1996; Clatterbuck 1996; but see Teclaw and Zasada 1996), and extends the increased height growth response to eastem white pine.

While conifers protected by tree shelters were significantly taller at the end of the 3rd growing season (Ward and Stephens 1995), the actual amount of height difference rarely exceeded one year's height growth. The increased height growth on Norway spruce and eastem hemlock protected by tree shelters was lost by the 5th growing season (Table 2). Browse damage through the 3rd year ranged from 65% for unprotected seedlings to 29% for seedlings protected by mesh sleeves (Ward and Stephens 1995). Even with the high levels of deer browse damage on these plots, tree shelters were a very expensive technique to marginally increase conifer height growth.

Earlier studies found that survival of northem red oak was increased (Smith 1993; Lantagne 1996; Farley and others 1996; Teclaw and Zasada 1996) or unchanged (Minter and others 1992; Smith 1993; Strobl and Wagner 1996; Schultz and Thompson 1996; Clatterbuck 1996) when protected by tree shelters. This study extends that observation to some conifers (Table 6). Relative to unprotected seedlings, 5 year mortality of seedlings protected by tree shelters was reduced by 28% (eastem white pine) to 72% (black walnut).

The absence of significant correlation between initial characteristics and 5th year height for hardwood seedlings protected by tree shelters was surprising (Table 4). Schultz and Thompson (1996) reported that among northem red oak and black walnut protected by tree shelters, seedlings with > 10 FOLR were slightly taller after 4 years than seedlings with < 6 FOLR, but no statistics were presented. 1 also found that among seedlings protected by tree shelters, large seedlings were slightly, but not significantly, taller than small seedlings after 5 years (Table 5). Some of the lack of difference among initial size characteristics may be attributable to grading at the nursery which discarded the lowest quality material.

Except for black walnut, initial size was more important for seedlings not protected by tree shelters and therefore subject to browse damage (Tables 3 and 4). Larger seedlings likely have more reserves than small seedlings and are better able to recover from browse damage. Absolute seedling size is probably not

Table 4. Pearson correlation coefficients of initial seedling characteristics with stem height of survivors in 1994 (5-years post-planting). Stem-stem height (cm), Twig-number of primary twigs, RCD-root collar diameter (mm), FOLR-number of first order lateral roots (>1 mm diameter), Root-root length (cm), R/S—root to shoot ratio.

Species	Stem	Twig	RCD	FOLR	Root	R/S
			Protected by tree shelters			
Northern red oak	0.206	0.106	0.193	0.086	n/a	n/a
Black walnut	-0.110	0.052	0.009	0.194	-0.085	-0.064
Eastern white pine	0.267 *b	0.164	0.176	-0.020	-0.088	0.265 *
Norway spruce	0.488 **	0.329 •	0.317 •	0.215	0.133	0.228 o
Eastern hemlock	0.142	0.124	-0.090	0.041	0.216	-0.126
			Sleeves (mesh and Reemay) and unprotected			
Northern red oak	0.265 **	0.203 o	0.268 **	0.296 **	n/a	n/a
Black walnut	0.080	0.092	0.017	-0.024	0.071	0.032
Eastern white pine	**0.543****	**0.389****	**0.351****	-0.095	-0.127	0.455 **
Norway spruce	0.148	0.305 **	0.432 •	[illegible]	0.405 **	-0.260 **
Eastern hemlock	0.510 •	0.278 o	0.280 o	0.397 **	0.200	0.273

a/ Bonferroni adjusted probabilities: (**) $p < 0.01$, (*) $p < 0.05$, (o) $p < 0.10$.

Table 5. Seedling height (cm) at the end of five growing seasons by initial seedling characteristics for seedlings protected by tree shelters. (Size classes and species abbreviation are as for Table 3).

	Species				
	NRO	WAL	WPI	NSP	HEM
Stem height					
Short	111.7 a	123.0 a	123.0 a	72.0 a	52.9 a
Average	124.3 a	101.9 a	130.3 a	83.0 a	62.0 a
Tall	142.3 a	92.9 a	166.7 b	104.5 b	72.2 a
Very tall	146.0 a	103.8 a	130.3 ab	116.5 b	66.0 a
Root collar diameter					
Small	117.5 a	95.3 a	123.5 a	82.7 a	76.5 a
Medium.	124.3 a	110.2 a	132.8 a	83.5 a	61.4 a
Large	131.9 a	107.1 a	145.6 a	90.8 a	63.4 a
Very large	148.8 a	93.4 a	148.5 a	104.4 a	61.9 a
First order lateral roots					
o-2	134.3 a	101.5 a	128.5 a	81.5 a	64.4 a
3-4	119.2 a	87.8 a	149.6 a	.83.5 a	59.6 a
5-7	132.7 a	109.9 a	132.8 a	92.0 a	65.6 a
>8	152.4 a	115.9 a	134.1 a	99.4 a	63.3 a

a/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.

as important as relative size because growth conditions vary by year and bed. The largest size class for each of the initial seedling characteristics (initial height, root collar diameter, first-order lateral roots) accounted for approximately 20% of all seedlings. One-third of seedlings were in the largest size classes for at least one initial characteristic. Grading seedlings with the criteria that at least one initial characteristic be in the upper quintile size classes would result in high proportion of culls.

None of the initial seedling characteristics was consistently accurate for estimating mortality for al1 species (Table 6). Mortality decreased with stem height for northern red oak, but actually increased with stem height for eastern white pine. Similar to studies in the Midwest (Schultz and Thompson 1996), first-order lateral roots had a significant, albeit small and inconsistent, effect on 5-year mortality for 4 of the 5 species studied (Table 4). The increased mortality of larger eastern white pine is puzzling. Pine that grow faster in the nursery may be more palatable than slower growing seedlings, and therefore are browsed more severely.

While FOLR was not as predictive of growth and mortality as found in other studies (Kormanik 1986; Thompson and Schultz 1993), this study does concur that larger seedlings have lower mortality rates and grow faster than smaller seedlings. Severe grading prior to planting, as suggested above, would decrease gross nursery production. Would a tougher grading standard be worthwhile? 1 split the northern red oak seedlings in this study not protected by tree shelters

Table 6. Seedling mortality (%) at the end of five growing seasons by browsing protection method and initial seedling characteristics. Size classes and species abbreviation are as for Table 3.

	Species				
	NRO	WAL	WPI	NSP	HEM
Protection method					
Control	25.0 a[a]	25.0 a	50.0 a	44.0 a	63.3 a
Mesh sleeves	27.8 a	14.6 ab	48.3 a	31 .0 ab	46.7 a
Reemay sleeves	22.2 a	20.8 a	50.0 a	38.0 a	48.3 a
Tree shelters	10.2b	6.9b	36.1 b	23.3 b	24.4 b
Stem height					
Shorl	29.2 a	12.9 a	37.1 b	19.2 b	29.0 a
Average	25.4 a	9.4 a	47.6 ab	32.7 ab	43.5 a
Tall	13.9 b	18.9 a	44.9 ab	36.9 a	43.3 a
Very tall	12.2 b	18.2 a	58.4 a	19.1 b	38.2 a
Root collar diameter					
Small	33.3 a	12.3 a	42.3 ab	25.5 a	65.0 a
Medium	25.9 a	17.7 a	36.3 b	37.2 a	41.4 ab
Large	13.3 b	15.4 a	49.5 a	28.1 a	37.0 b
Very large	12.4 b	6.7 a	51.2 a	28.1 a	34.5 b
First order lateral roots					
o-2	27.4 a	13.8 ab	51.2 ab	41.1 a	47.5 a
3-4	19.4 ab	15.6 ab	52.4 a	33.1 ab	37.9 a
5-7	9.0 b	22.0 a	44.9 ab	27.6 b	42.0 a
≥8	16.3 ab	3.4 b	38.0 b	23.1 b	30.4 a

a/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.

into two categories: large-those in the top 20% in at least size measure, and small-those not meeting the aforementioned criteria. If success is defined as a seedling 120 cm tall (4 ft) after five years, then 13% of large seedlings were successful compared with only 5% of small seedlings. This suggests a planter would need to plant nearly three times as small as large seedlings to reach the same stocking goals (Zaczek and others 1995).

ACKNOWLEDGMENTS

A special thanks to Division of Forestry, Connecticut Department of Environmental Protection, and the South Central Regional Water Authority who provided the land, materials, and personnel that made this research possible. This research was partly funded by McIntire-Stennis Project No. CONH-54 1.

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Nurseries and Their Role In The Effort To Maintain Biological Diversity[1]

Stewart Pequignot[2]

Abstract—Biological diversity will be an important factor that influences future management of our nation's forest resources. A critical component for managing these forests for biological diversity is the production of plant materials by public and private nurseries. There are many threats to our biological resources which may be mitigated by plant production in nurseries. Native plants can be used to replace introduced species. Plants can be used as tools to produce healthy watersheds, create fertile soils, generate breeding grounds for animals, clean air and water and help produce a stable climate. Populations of endangered and/or threatened plant species can be restored. The benefits gained by utilizing nurseries for plant production include improved and increased habitat for other species dependent on plant diversity. The cooperation of natural resource managers and partners with nurseries will lead to the maintenance and improvement of our currently diminishing biological diversity.

Nationwide controversies are ongoing over our degraded environments. Few environmental issues will affect the future management of our Nation's forest resources as much as the issue of biological diversity. Natural resource managers and ecologists have recognized the importance of adopting strategies that increase species and genetic diversity. Nurseries, public and private, can play an important role in maintaining and increasing biological diversity in our forests.

Edward 0. Wilson in his book *The Diversity of Life*, described biological diversity as ". . . the key to maintenance of the world as we know it. Life in a local site struck down by a passing storm springs back quickly; opportunistic species rush in to fill the spaces. They entrain the succession that circles back to something resembling the original state of the environment." This definition sums up the goal of natural resource managers-healthy-sustainable ecosystems.

In discussing the issue of biological diversity one can find myriad opinions on the nature and extent of the economic consequences, social implications, and potential disruption of ecological processes that result from a loss of biological diversity. In spite of this, there appears to be general agreement that quality of life issues are linked to the maintenance of biological diversity.

While it is relatively easy to define what biological diversity is (variety of life and its processes), it is harder to understand the concepts of biological diversity. Developing strategies and programs that are acceptable to all parties becomes even harder. Biological diversity issues can not be addressed without the cooperative efforts of public and private landowners and other interested publics. As natural resource managers we have the responsibility to use our understanding and appreciation of the concepts of biological diversity to influence landowners and the general public about the importance of managing land resources to ensure we maintain diverse biological resources.

The value of biological resources are not always represented in the market place, but they do have signiticant value to us as individuals and society as a whole. Wild species and their genetic variants contrib-

[1]*Pequignot, S.. 1996. Nurseries and Their Role In The Effort To Maintain Biological Diversity. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 135-137.*

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ute billions of dollars each year to agriculture, medicine, and other major industries. Plants have been used to develop cures for diseases such as Hodgkin's disease, childhood lymphocytic leukemia, and breast and ovarian cancers. The biological resources of this country and others have the potential for the development of new medicines, crops, soil restoring vegetation, petroleum substitutes and many other products that will never come to light if these plants and the ecosystems necessary for their survival are lost.

Equally valuable to society is the maintenance of essential life processes such as healthy watersheds, fertile soils, breeding grounds, clean air, clean water, and a stable climate. Conserving these processes is just as important as conserving individual species that inhabit natural ecosystems. Without species synergism ecosystems can not function effectively.

To help understand some of the factors affecting biological diversity and the role that nurseries can play it is important to understand some of the major threats to our biological resources. The following are some broad categories that affect biological resources:

- Habitat alteration and loss
- Non-sustainable harvesting
- Increasing human population
- Environmental pollution
- Climatic change
- Introduced species

Nursery programs can have a positive effect at mitigating many of the factors that are damaging our biological resources:

- Plants and/or seeds can be used for restoration and improvement of damaged or lost habitats.

- Tree improvement practices and subsequent nursery production can reduce harvest rotation time frames and create sustainable harvesting schedules.

- Plant materials can be used in riparian zones to prevent chemical runoff from reaching ground and/or surface water.

- Tree planting has been used to extract and store carbon in an effort to reduce carbon dioxide levels in the atmosphere.

- Nursery production can be shifted from a reliance on introduced species to production of native species.

States have a vital role to play in protecting habitats and wildlife. Through the development of nursery programs that address biological diversity issues and other strategies, states are establishing programs and activities for the conservation of biological diversity. There are severa1 management actions that have been and are being adopted by states to address these concerns:

- Protection of essential habitat for native species. This is one of the most cost effective strategies for protecting biological diversity. Habitat protection not only preserves specific plants but also other dependent factors (i.e., host specific pollinators) that may be limiting factors outside of their natural habitat.

- Initiation or expansion of efforts to protect species "on the brink". These actions tend to be the most expensive and can result in long-term drains on limited management resources. For many of these species survival will depend upon human intervention (i.e., collection and raising of threatened or endangered plants).

- Creation of strong incentives to protect and restore native ecosystems on private property. Conservation of biological diversity has to involve both public and private owners. Through education and landowner incentives private land management practices can be influenced. Private forest land alone or integrated with state and federal lands offers important opportunities to conserve biological diversity and still allow for the production of timber and other commodities.

- Making the public aware of the importance of biological diversity and creating opportunities for the public to be involved in the development of solutions. Environmental education curriculums are being developed or expanded to help our youth leam al1 sides of this issue. Through education of landowners and other citizens the general public can help develop viable solution for the conservation of biological diversity.

- Expanding scientific research and training focused on the challenges of conserving biological diversity. Scientific research will always be the foundation of solving biological diversity issues.

As each of these actions are considered, it is possible to see a role for nursery operations and the production of plant materials. Plant materials can play an important role in the protection of essential habitats. Nurseries can be centers for the growing and "banking"of threatened and endangered plants. The availability of low cost plant materials and other incentives can ensure landowners will set aside land for conservation purposes. Nurseries can become education centers to help inform the general public about biological diversity issues and methods. Nurseries have always played an important role within the scientific community as a location for studies or the source of plant materials for research projects. Nursery operations can be one of the cornerstones in developing an effective state program that address biological diversity concerns.

State forestry organizations have an unique role in this process. In working with landowners and other interested groups, these organizations are positioned to plan, direct, and influence activities that affect biological diversity on private and public lands. The National Association of State Foresters (NASF) has adopted a policy that encourages the maintenance of biological diversity.

State forestry organizations have supported and helped develop the State and Private Forestry Programs of the United States Forest Service. These programs assist state forestry organizations and landowners to achieve resource management goals and the conservation of biological diversity. Funds to help support nursery operations have been a historical part of these State and Private Forestry Programs.

Biological diversity issues are not just a passing fad that will soon disappear. These issues while around for a very long time are now rising to the forefront. In 199 1 the National Research Council recommended that the nation undertake a long-term program to restore 400,000 miles of rivers and 2 million acres of damaged lakes over the next two decades. In 1992 the Rio de Janeiro Earth summit resulted in many nations signing a treaty that included ecosystem restoration as a viable means to achieve biological diversity. In 1991, NASF adopted a resolution that encouraged the maintenance of biological diversity in the forest lands of the United States and agreed to maintain an active role in the support and development of national policies on this issues.

In the past severa1 years, over 70 countries have participated in a process to generate agreements that define sustainable forest management in forests of the world. Conservation of biological diversity was selected as one of the important criteria that must be monitored to achieve this goal.

The American Forest & Paper Association has adopted a Sustainable Forestry Initiative. Under this program member companies will manage with a land stewardship ethic that integrates the growing, nurturing and harvesting of trees for useful products with the conservation of soil, air and water quality, and wildlife and fish habitat.

The conservation of biological diversity will require the cooperation among professional long separated by academic and practica1 tradition. The adoption of policies that conserve biological diversity will enable future generations to continue to enjoy the many benefits our Nation's forest provide into the next century and beyond. But none of this can happen without viable nursery operations that recognize that their policies have long lasting impacts on the natural resources of our nation.

Forestry is very unique. It must plan up to a century into the future, but is bound by the conditions and decisions of up to a hundred years in the past. As forest resource managers we must continually be aware that what we do today will have lasting impacts on future generations. Nursery programs are an important factor in having a positive influence on our future forests.

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Western Forest & Conservation Nursery Association Meeting

Salem, Oregon

August 20-22, 1996

Methyl Bromide-Environmental Issues Overview and Position of the US Environmental Protection Agency[1]

Bill Thomas[2]

Abstract—Methyl bromide is used extensively on a global basis as a pesticide against nematodes, weeds, insects, fungi, bacteria, and rodents. As a soil fumigant, it is utilized in significant quantities in the production of strawberries, tomatoes, nursery crops, as well as other agriculture commodities. Grain, fresh fruit, forestry products, and other materials are fumigated with Methyl Bromide to control pest infestations during transport and storage. Structures are also treated with this chemical to control wood destroying insects and rodents. However, methyl bromide has been identified as a significant ozone depleting substance, resulting in regulatory actions being taken by the U.S. Environmental Protection Agency and by the United Nations Environment Program (Montreal Protocol). In the United States, production and importation of this material will cease in 2001. Internationally, production will be halted in 2010. It is critical to identify and implement efficacious and viable alternatives in the near-term.

Keywords: pest control, methyl bromide, fumigant, environment, ozone, policy

Methyl bromide is a broad spectrum pesticide used to control pest insects, nematodes, weeds, pathogens, and rodents. Globally, this material is used most frequently to control pests in the soil (75% of total use), but also against pests in grain and other durable commodities (13% of total), to protect fruits, vegetables and other perishable commodities against pest infestations during transport and storage (9%), and to control wood destroying insects and rodents in buildings, aircraft, ships and other structures (3%) (U.S. EPA 1995b).

In terms of world-wide sales, North America constitutes the largest market with 4 1% of the total, followed by Europe with 26%, Asia (including Israel and the Mid-East) with 23%, and lastly Africa, South America, and Australia with about 9% of the market. In North America, this pesticide is used mostly for soil fumigation (87%), but also for commodity and quarantine treatments (8%), and structural fumigation (5%) (U.S. EPA 1995b). In the U.S., most methyl bromide is used in the production of tomatoes and strawberries, but is also a common pest control tool in the nursery (USDA 1993).

The vast majority of this chemical is manufactured by three companies: two located in the U.S. state of Arkansas (Great Lakes Chemical and Ethyl/ Albemarle), and one in Israel (Dead Sea Bromine). These companies utilize naturally occurring bromide salts which are either contained in underground brine deposits (as is the case with Arkansas), or highly

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[1] Thomas, B. 1996. Methyl Bromide-Environmental Issues Overview and Position of the US Environmental Protection Agency. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursety Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 139-143.

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concentrated above ground sources like the Dead Sea. Ocean water does contain Bromine salts, but at such low concentrations that it is very energy intensive to use as a source in the manufacture of methyl bromide. Methyl bromide is often produced as a by-product of other bromide manufacturing processes.

When used as a soil fumigant, methyl bromide is injected into the soil at a depth of 12 to 24 inches before a crop is planted. This will effectively sterilize the soil, killing the vast majority of soil organisms. Immediately after the methyl bromide is injected, the soil is covered with plastic tarps, which hold the methyl bromide in the soil. The tarps are removed 24 to 72 hours later. About 50 to 90% of the methyl bromide injected in to the soil eventually enters the atmosphere (Yates et al. 1996; UNEP 1995a; Yagi et al. 1993).

When used as a commodity treatment, methyl bromide is injected into a chamber or under a tarp containing the commodities and held for severa1 hours. Commodities which use this material as part of a post-harvest pest control regime include grapes, raisins, cherries, nuts, and imported materials. Some commodities are treated multiple times during both storage and shipment. Commodities may treated with methyl bromide as part of the quarantine requirements of an importing country. About 80 to 100% of the methyl bromide used for commodity treatments eventually enters the atmosphere (UNEP 1995a).

A structural pest control treatment with methyl bromide involves the fumigation of buildings for termites, warehouses and food processing facilities for insects and rodents, aircraft for rodents, and ships (as well as other transportation vehicles) for various pests. Over 90% of the methyl bromide used in these operations eventually reaches the atmosphere (UNEP 1995a).

In addition to being a widely used pesticide, methyl bromide is an effcient ozone depleting substance (ODS) in the stratosphere. The 1994 Science Assessment of Ozone Depletion, a document prepared by nearly 300 of the world's leading atmospheric scientists, lists the ozone depletion potential (a regulatory benchmark) of methyl bromide as 0.6, and reports that "An uncertainty analysis suggests that the ozone depletion potential (ODP) is unlikely to be less than 0.3 ." The report quite clearly states that "Methyl bromide continues to be viewed as a signiticant ozone-depleting compound." Additional research is ongoing to address outstanding uncertainties and to define the precise ODP, which may turn out to be slightly higher or lower than 0.6 (WMO 1994).

Methyl bromide reaches the stratosphere through emissions from agricultura1 pesticide uses, from the burning of biomass and leaded gasoline and from the oceans. Winds and atmospheric mixing carry this pesticide to the stratosphere. Once in the stratosphere, high energy radiation from the sun release a bromide atom by breaking the bond between the bromine and the methyl group. This bromine atom is in a very reactive state, and will destroy molecular ozone (0,). The bromine atom will also react with non-reactive molecules in the stratosphere that contain chlorine, liberating the chlorine, which will then destroy additional ozone molecules. Because of this "chain-reaction", the bromine from methyl bromide is over 50 times more effective at destroying ozone than the chlorine from CFCs on a per atom basis (WMO 1994).

The destruction of stratospheric ozone molecules results in a thinning of the ozone layer. Since ozone blocks radiation that is harmful to life, the destruction of this thin layer will result in an increase of radiation reaching the surface of the earth. This ultraviolet radiation is harmful to biological organisms, including crop plants and human beings. The amount of methyl bromide produced by agricultura1 and other anthropogenic sources has considerable impact on stratospheric ozone, disrupting the natural balance of the atmosphere and increasing the amount of hazardous UV radiation that reaches the earths surface (WMO 1994).

Because science has linked methyl bromide emissions to ozone destruction, and thereby to the harmful effects of ultraviolet radiation, it is therefore necessary to control the emissions of this material. This is achieved through regulatory actions, and numerous efforts are underway to control use, emissions and production. Regulatory actions can initially be difficult and confounding for those most closely affected, but will usually lead to a better way of doing things. While the economic issues involved are complex, especially for those that use or manufacture methyl bromide, the long-term risks to human health and the environment far outweigh any short-term monetary benefit. Ozone depletion is a serious matter, with potential impact not only to human health and the environment, but to agricultural crops as well. It is ironic that some of today's farmers may be sacrificing long-term agricultural production by using a short-term economically attractive pest control method.

In the United States, the U.S. Clean Air Act Amendments of 1990 (title VI), requires that any ozone depleting substance with an ozone depletion potential of 0.2 or greater be listed as class 1 substances and be phased out within seven years. Under this authority, and with due consideration of the science, the U.S. Environmental Protection Agency (EPA) took regulatory action in 1993 to prohibit the production and importation of methyl bromide in the United States after January 1,200 1. In addition, this regulation froze U.S. production in 1994 at 1991 levels (USEPA 1993). The U.S. phaseout applies solely to production and imports and does not restrict the use of methyl bromide before or after 200 1.

Part of the U.S. regulatory effort is to insure that farmers have access to new pesticides as soon a possible. To do this, the U.S. Environmental Protection Agency Office of Pesticide Programs has set up an accelerated registration process for alternatives for methyl bromide (USEPA 1995a). This program speeds paperwork and support functions during the registration process. A task force has been set up to track alternative development, and monitor the program for problems.

On an international level, methyl bromide is regulated in a number of countries besides the United States. The Netherlands phased out the use of methyl bromide for soil fumigation in 1992 because of ground water contamination concerns. Denmark and other Nordic countries will ban agricultural use of methyl bromide in 1998, and other European countries may follow a similar schedule. The European Union and Canada will cut agricultural use by 25% in 1998. A number of other countries are now contemplating regulatory action for methyl bromide use and production.

The Montreal Protocol Treaty (signed by more than 150 countries) governs worldwide production and trade of ozone depleting substances (ODS), and is now in the process of a global ODS phase out. In 1992, the Signatories to the Montreal Protocol ("Parties") considered the science on methyl bromide, set an ozone depletion potential (ODP) of 0.7, and froze production in 1995 at 1991 levels. At the 1995 meeting ofthe Parties to the Montreal Protocol, a global methyl bromide production phaseout was agreed upon for developed countries which will require a 25% reduction in 200 1, a 50% reduction in 2005, and a complete phaseout in 20 10. Developing nations agreed to a freeze in 2002 based upon an average of the years 1995-1998 (UNEP 1995b). This agreement will be revisited in 1997. The U.S. position at these meetings was a total global phase-out by 2001.

The Montreal Protocol creates an effective, level playing field for all countries by harmonizing regulations on a global basis. However, in order to achieve global protection from increased radiation and avoid significant trade disparities, it is critical that all countries involved in the production and use of ozone depleting substances move to alternatives as quickly as possible. This is especially consequential with regard to methyl bromide.

There is no one alternative for all of the uses of methyl bromide, but there are numerous chemical and non-chemical pesticides existing today which effectively manage many of the pests for which methyl bromide is used. Viable alternative materials need not be identical to methyl bromide, but must effectively and economically manage those pests which are now being targeted by methyl bromide.

While the pests that infest nursery soil are effectively managed by methyl bromide, more species-specitic materials and methods can be used. Chemicals, such as 1,3-dichloropropene, chloropicrin, metam sodium, and dazomet can be used to achieve a similar level of pest control as methyl bromide (Carey 1994; Duncan 199 1; Noling and Becker 1994). Non-chemical pest management alternatives to methyl bromide for pest suppression include solarization, organic amendments, biological control agents, crop rotation, and other cultural practices (Chellemi et al. 1993; Gaur and Dhingra 199 1; Grossman and Liebman 1994; Kannwischer-Mitchell et al. 1994; Katan 198 1; Liebman 1994; Quarles and Grossman 1995; Rodriguez-Kabana and Jones 1987). Research on additional alternatives is underway and will likely result in a wide range of options, depending on pest control needs.

While most of the alternatives may cost more than methyl bromide in the short-term, costs will likely fall. To insure complete development of viable alternatives, however, it is critica1 that the research momentum now underway within the U.S. Department of Agriculture, academic institutions, and the private sector not be slowed by efforts designed solely to delay the methyl bromide phase out.

In conclusion, it is critica1 to acknowledge the vast amount of scientific evidence that indicates methyl bromide is a significant ozone depleting material. Because of this, use and emissions must be discontinued as soon as possible. There are number of pest and crop specific materials that are active against the pests now managed by methyl bromide. Most likely chemical alternatives will fill needs in the short-term, while eventually, non-chemical materials and methods will be the management tools of choice. It is essential to the preservation of the global ecosystem that emissions from the use of this material be halted in a rational manner.

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The Use of Chemical Fumigants and Potential Alternatives at Weyerhaeuser Mima Nursery[1]

Thomas S. Stevens[2]

Abstract — Potential loss of methyl bromide as a soil fumigant by year 2000, due to its ozone depletion potential, has resulted in extensive exploration of both chemical and non-chemical alternatives at the Weyerhaeuser Mima Nursery. Although not as effective as methyl bromide/chloropicrin (MB/CHL), both Basamid granular (Dazomet) incorporated, rolled and water sealed and chloropicrin, injected and tarped, provided control of targeted soil pathogens. However, neither fumigant controlled weeds as well as MB/CHL. Bare fallowing fields between Douglas-fir seedling crops significantly reduced soil pathogens in contrast to oat and pea green manure cover crops. *Brassica* spp., used as green manure crops, were not effective in reducing soil pathogens, as compared to bare fallow or MB/CHL fumigation treatments. In addition to MB/CHL fumigation, application of yardwaste compost and fungicides had a positive effect on Douglas-fir seedling growth. Unfortunately, seedling mortality was greater in compost amended treatments.

INTRODUCTION

The Weyerhaeuser Mima Nursery, located 12 miles southwest of Olympia, Washington produces over 20 million bare-root seedlings annually for outplanting. Two year old seedlings and numerous transplant stock types are grown in a predominately loamy sand soil type. Since the mid- 1970's, methyl bromide/chloropicrin fumigation has been utilized at the nursery to help control weeds, insects and soil-borne pathogens during the early stages of crop development. Beginning in the mid- 1980's, a series of experiments was begun, which explored chemical and non-chemical alternatives to MB/CHL.

BASAMID

In September of 1984, an experiment was installed at Mima, which tested the efficacy of Basamid, in comparison to methyl bromide/chloropicrin (MB/CHL) fumigation. The treatments tested were:

Treatment 1: Methyl bromide/chloropicrin (67/33) at 360 #/ac (1x) with tarp.

Treatment 2. Methyl bromide/chloropicrin (67/33) at 720 #/ac (2x) with tarp.

Treatment 3: Basamid 350 #/ac with no tarp.

Treatment 4: Control - no fumigation, no tarp.

[1]*Stevens, T.S. 7996. The Use of Chemical Fumigants and Potential Alternatives at Weyerhaeuser Mima Nursery. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 144-149.*

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In early May of 1985, Douglas-fir seed was sown and a 2+0 crop was grown the same across all treatments.

The methyl bromide/chloropicrin at 360 #/ac and Basamid treatments significantly increased fa11 1+0 seedling counts over the non-fumigated treatment (Table 1). Seedlings from the fumigated treatments were generally larger than control seedlings when measured in the fa11 of 1985 (Table 2). In particular, seedlings from the MB/CHL 360 #/ac treatment had significantly larger stem diameter and higher root and shoot dry weights compared to seedlings from the non-fumigated treatment (Tanaka et al. 1986).

Table 1. Effects of soil fumigants on Douglas-fir seedling emergence and 1+0 stand count. Treatments followed by the same letter are not significantly (p<0.05) different within each assessment time.

	Seedlings (#/6 sq. ft.)	
Treatment	6/85 (Emergence)	10/85 (1+0)
MBC/CHL (1 x)	187 a	177 a
MBCKHL (2x)	176 a	167 ab
Basamid	187 a	177 a
Control	168 a	158 b

Table 2. Effects of soil fumigants on Douglas-fir seedling growth assessed in October 1985. Treatments followed by the same letter are not significantly (p<0.05) different in each variable.

Treatment	Shoot wt. (mg) t	Root . (mg)	Stem ameter (mm)
MBCKHL (1x)	800 a	185 a	2.0 a
MBCKHL (2x)	595 ab	138 b	1.6 b
Basamid	496 b	134 b	1.5 b
Control	415 b	105 b	1.4 b

Seedlings were assessed for mycorrhizal infection in October 1985 and May 1986. There was no significant treatment affects at either assessment date. Essentially al1 seedlings had become mycorrhizal by May 1986 (Tanaka et al. 1986).

Al1 fumigation treatments signifícantly suppressed and preserved low levels of soilborne pathogens (*Fusarium* spp. and *Pythium* spp.) during the first growing season.

MB/CHL fumigation was slightly more effective in reducing pathogen counts compared to Basamid. Both MB/CHL treatments suppressed root infection by *Fusarium* spp., but not *Pythium* spp. (Table 3). Basamid was not as effective as MB/CHL in reducing *Fusarium* root infection (Tanaka et al. 1986).

Table 3. Effects of soil fumigants on the incidence of infections of Douglas-fir roots by species of *Pythium* and *Fusarium*. Treatments followed by the same letter are not significantly (p<0.05) different in each fungus.

	Infected Root Segments (%)	
Treatment	Pythium	Fusarium
MBC/CHL (1x)	71 a	16 b
MBCKHL (2x)	49 a	15 b
Basamid	71 a	51 ab
Control	88 a	74 a

COVER CROPS

Prior to 1990, production blocks at Mima Nursery had been used to grow a combination of 2+0 seedlings and transplants for three consecutive seasons, followed by a fallow season. During the fallow season, an oat and pea cover crop was grown and incorporated before fa11 fumigation. The role of the cover crop on soil pathogen levels and the growth of subsequent conifer seedling crops was generally unknown.

In June of 1985, a split-plot designed experiment was installed at Mima Nursery to test the effects of soil fumigation and cover crops. Oat and pea cover crop treatments were assigned to whole plots in a randomized complete block design and fumigation treatments were assigned to subplots. The cover crop treatments included: oats, peas, an oat/pea mix and bare fallow. The fumigation treatments included: tarped methyl bromide/chloropicrin (67/33) at 350 #/ac and non-fumigated. The fumigation treatment was applied in September of 1985 and Douglas-fir seed was sown in May of 1986. Seedlings were harvested in February of 1988 as a 2+0 crop (Hansen et al. 1990).

Prior to fumigation, al1 three oat and pea cover crop treatments resulted in higher soil *Fusarium* spp. and *Pythium* spp. colony counts compared to the bare fallow treatment. Fumigation significantly lowered populations of *Fusarium* and *Pythium* in al1 cover crop treatments. This trend continued across the ten soil sampling dates. Although, levels of *Fusarium* in the unfumigated bare fallow treatment were higher than those in fumigated plots, the difference was not significant. In fact, the non-fumigated bare fallow treatment continued to be comparable to the fumigated treatments at al1 but one soil sample date (Hansen et al. 1990).

Cover crop treatments did not significantly affect the number of packable 2+0 seedlings harvested. In contrast, fumigation resulted in higher amounts of live and packable seedlings at harvest. Seedlings from the non-fumigated plots were smaller and more variable in size than those from fumigated plots (Hansen et al. 1990).

BRASSICA COVER CROPS

Brassica species contain secondary metabolites, glucosinalates, which yield volatile and soluble isothiocyanates. These isothiocyanates, have similar activity to many commercial fumigants, and may suppress soil pathogens when *Brassica* cover crops are incorporated into soil (Stone and Hansen 1993).

In 1990 and 199 1, studies were installed at Mima Nursery comparing the effects of *Brassica* cover crops, bare fallow, and methyl bromide/chloropicrin (67/33) fumigation on soil populations of *Fusarium* and *Pythium* spp. and performance of subsequent Douglas-fir 2+0 crops.

Treatments in the 1990 study included: bare fallow with sawdust, *Brassica* (yellow mustard) with and without sawdust, and an oat cover crop with methyl bromide/chloropicrin (67/33) fumigation. These treatments were installed in a randomized complete block design. Propagule counts from soil samples were taken directly before, 8 weeks after fumigation, and once more immediately prior to sowing Douglas-fir seed. *Fusarium* and *Pythium* propagule counts were higher in the *Brassica* plots compared to the bare fallow and fumigated plots 8 weeks after fumigation (Table 4). Propagule counts did not significantly differ between *Brassica* plots with and without sawdust. MB/CHL fumigation signifícantly reduced soil pathogen levels. Douglas-fir seedling densities at the end of first growing season did not significantly vary among treatments. Thus, first year survival was not higher in treatments that contained the lowest *Fusarium* and *Pythium* propagule counts (Stone and Hansen 1993).

Table 4. Average numbers of *Fusarium* and *Pythium* propagules recovered from soil samples in the 1990 study.

Treatment	Pre-fum. Fusarium	Pre-fum. Pythium	Post-fum. Fusarium	Post-fum. Pythium	Pre-sow Fusarium	Pre-sow Pythium
Fallow	3534	59	1534	40	3870	180
Brassica + sawdust	2735	60	4743	1303	3174	1009
Oats + MB/CHL	4701	74	37	0	533	0
Brassica + no sawdust	5650	42	5402	1054	5736	1373

Treatments in the 1991 study included: bare fallow with and without sawdust; oats with fumigation (MB/CHL); dwarf Essex winter rape, Tilney white mustard, and brown mustard at 1 0#/ac and 20#/ac; and Gisilba white mustard at 20#/ac. The study was installed as a randomized complete block design with four blocks. Douglas-fir seed was sown in spring of 1992 for a 2+0 crop. During the first growing season, soilborne *Fusarium* population levels increased significantly in al1 *Brassica* cover crop plots. Population levels were proportional to the amount of green biomass incorporated. Soil propagule counts remained low in the fumigated and bare fallow plots throughout the first growing season. Seedling pre-emerge and post-emerge mortality was poorly correlated to soilborne *Fusarium* levels; although, the highest seedling mortality caused by *Fusarium* did occur in winter rape plots. Sawdust addition decreased seed germination and growth. Growth loss was probably related to nitrogen deficiency caused by biological tixation during sawdust decomposition.

CHLOROPICRIN

As a potential chemical alternative to methyl bromide/chloropicrin (67/33), chloropicrin (99%) was tested at Mima Nursery in 1993. Beds were fumigated on July 30th with chloropicrin at 200 #/ac and methyl bromide/chloropicrin at 350 #/ac. Both materials were covered with 1 mil high barrier film. On May 3, 1994 these beds were sown with Douglas-fu seed and a 2+0 crop was grown.

Final seedbed density was significantly greater for the methyl bromide/chloropicrin treatment than the chloropicrin treatment (Table 5). However, seedlings in the chloropicrin treatment were significantly larger in diameter and height. It may be possible that this was related to the lower seedling density of the chloropicrin treatment plots. Weed control was poorer in the chloropicrin treated plot.

In order to further test the efficacy of chloropicrin and repeat earlier work with Basamid, a chemical fumigant comparison study was installed in the fa11 of 1995. Treatments included: (1) tarped methyl bromide/chloropicrin (67/33) at 350 #/ac, (2) tarped chloropicrin at 250 #/ac, and (3) incorporated, rolled, and water sealed Basamid at 250 #/ac. In May of 1996, al1 treatments were sown with Douglas-fir seed. As of July 1996, seedling counts were not significantly different between fumigation treatments (Table 6).

FUMIGATION, COMPOST AND FUNGICIDES

Soil incorporated compost may be antagonistic towards seedling soil pathogens and result in increased crop growth. In addition, fungicides may also provide viable alternatives to chemical fumigants. Consequently, a split-split plot designed experiment was installed at Mima in 1994 to test their effectiveness in comparison to MB/CHL fumigation. One half of the study area was fumigated with 350 #/ac MB/CHL in August 1994, the other half was not fumigated. Compost (2% N) from the Purdy yardwaste facility was spread 1/2" deep and incorporated into four sub-plots in fumigated and non-fumigated beds in April 1995. Across these treatments fungicide and non-fungicide plots were superimposed. A Douglas-tir seedlot was sown on the experimental beds in May of 1995 and a 2+0 crop of seedlings was grown.

Table 5. Comparison of methyl bromide/chloropicrin and chloropicrin fumigants on Douglas-fir seedlings. Treatments followed by the same letter are not significantly ($p<0.05$) different.

Treatment	Height (cm)	Caliper (cm)	Density
MB/CHL	35.7 b	4.32 b	121.0 a
Chloropicrin	38.6 a	4.92 a	104.9 b

Table 6. Comparison of methyl bromide/chloropicrin, chloropicrin, and Basamid fumigants on Douglas-fir seedbed densities. Treatments followed by the same letter are not significantly ($p<0.05$) different.

Treatment	Density
MB/CHL	260.8 a
Chloropicrin	259.2 a
Basamid	264.0 a

In November of 1995 dramatic differences in seedling density were observed in the experimental plots (Table 7). Compost treated plots had significantly lower seedling densities (Table 8). During the summer of 1995 seedling mortality had been evident in the compost treated plots, the high nitrogen content (2%) of the compost may have led to the lower seedling densities. In a previous study at Mima, summer seedling mortality due to *Fusarium oxysporum* had been correlated to increased nitrogen fertilization (Sinclair et al. 1975). Fumigation and fungicide treatments did not significantly affect seedling density.

As of August 1996 large differences in seedling size were evident among treatments (Table 9). Fumigation, compost and fungicides al1 signiticantly increased seedling height and caliper growth (Table 10). The compost treatment could have increased seedling growth because of its nutritional properties and also the lower seedling densities in these plots. The stimulatory affect of fumigation on Douglas-fir seedling growth duplicates the results of earlier studies at Mima Nursery (Hansen et al. 1990; Tanaka et al. 1986). In the spring of 1996 upper and lower stem canker, caused by *Fusarium roseum* and *Phoma eupyrena,* was much more prevalent in plots that had not received the fungicide treatment. Since stem canker often kills only the seedling top and not the whole seedling, non-fungicide treated seedlings would be expected to be smaller in size.

SUMMARY

Due to the negative results of cover crops in the *Brassica* studies and the earlier pea/oat study, we no longer use cover crops at Mima Nursery. Fields are left bare during the fallow season and then fumigated in the fa11 with methyl bromide/chloropicrin. Chloropicrin and Basamid will continue to be tested as alternatives to methyl bromide/chloropicrin. Both of these products have the potential to reduce soil pathogens and increase growth of Douglas-fir seedlings as compared with non-treated controls. Composts may significantly increase seedling growth; however, questions remain as to their effectiveness in reducing disease and their potential negative affect on seedling density.

Table 7. Effects of fumigation, compost, and fungicides on density of Douglas-fir seedlings during their first season. Density measurements were taken during November of 1995.

Treatment	Density (seedlings/LBF)
Control	95.6
Compost	89.8
MB/CHL	93.8
Fungicides	106.4
Compost + MB/CHL	87.0
Compost + Fungicides	79.0
MB/CHL+ Fungicides	99.0
Compost + MB/CHL + Fungicides	76.2

Table 8. Analysis of variation for seedling density as affected by fumigation, compost and fungicides. Based on density measurements taken during November of 1995.

Source of Variation	F-ratio	Significance Level
Main Effects		
Compost	7.115	0.0135
MB/CHL	0.395	0.5422
Fungicides	0.057	0.8165
Interactions		
Compost x MB/CHL	0.023	0.8814
Compost x Fungicides	2.550	0.1233
MB/CHL x Fungicides	0.057	0.8165
Compost x MB/CHL x Fungicides	0.057	0.8165

Table 9. Effects of fumigation, compost, and fungicides on growth of Douglas-fir 2+0 seedlings. Size measurements were taken during August of 1996.

Treatment	Heiaht (cm)	Caliper(mm)
Control	29.8	3.38
Compost	37.3	4.00
MB/CHL	36.3	3.88
Fungicides	32.2	3.67
Compost + MB/CHL	38.8	4.10
Compost + Fungicides	42.4	4.48
MB/CHL+ Fungicides	40.7	4.57
Compost + MB/CHL + Fungicides	50.0	5.18

Table 10. Analysis of variation for seedling height and caliper as affected by fumigatíon, compost and **fungicides.** Based on size measurements taken during August of 1996.

Source of Variation	Height F-ratio	Sianificance Level	Caliper F-ratio	Sianificance Level
Main Effects				
Compost	58.124	<0.0001	18.161	0.0003
MB/CHL	38.627	<0.0001	17.204	0.0004
Fungicides	35.480	<0.0001	22.968	0.0001
Interactions				
Compost x MB/CHL	2.412	0.1335	1.349	0.2569
Compost x Fungicides	6.021	0.0218	1.199	0.2844
MB/CHL x Fungicides	4.215	0.0511	3.577	0.0707
Compost x MB/CHL x Fungicides	1.119	0.3006	0.140	0.7153

ACKNOWLEDGMENTS

The author gratefully acknowledges the work of Y. Tanaka, K.W. Russell, R.G. Linderman, P. Oster, T. Vu, E.M. Hansen, D.D. Myrold, P. Hamm, J.K. Stone, W. Littke, J. Browning and his fellow team members at Mima Nursery. The critica1 review of this paper by Y. Tanaka and T. Daniels is greatly appreciated.

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Fumigation Practices in Oregon Ornamental Plant Nurseries[1]

Richard Regan[2]

Fumigation is a pest management component of nursery crop production. The upcoming phase out of methyl bromide will impact the industry. Methyl bromide is used for field soil preparation, potting media treatment, container sanitation, and treating living plants. For the most part, alternative materials and/or practices are available to nursery managers. The following information presented in this paper was complied from informal interviews with many of the ornamental plant nurseries in western Oregon in the spring of 1996.

FIELD SOIL PREPARATION

Fumigation is not a routine practice for nursery crop production, but instead, is used for very specific purposes. Weeds and nematodes are the primary pest targets when field soil is fumigated with methyl bromide. Chloropicrin is usually combined with methyl bromide to help reduce plant pathogens such as *Phytophthora* and *Verticillium*. Soils used for the Oregon Department of Agriculture Virus Certification Program are fumigated with methyl bromide to reduce nematode populations that vector certain virus pathogens. Fumigants are also used when preparing propagation beds for seeds, cuttings, and transplants. Methyl bromide is often avoided when planting deciduous broadleaf trees, especially *Acer*, due to the poor growth thought to be associated with the loss of beneficial mycorhizzia.

There are other preplant fumigation materials used by nurseries instead of methyl bromide. For general pest management, dazomet (Basamid) and metham-sodium (Vapam) are commonly used in propagation greenhouses and field seedbeds. Nematodes and soil insect infestations are treated with 1,3-dichloropropene (Telone II). Chloropicrin is a general fumigant that also has good activity against soil pathogens. Nursery managers will also alter their pest management strategies instead of using preplant fumigation. In addition to using post-plant pesticides, crop rotation and resistant varieties can play an important role in reducing plant losses. Current research with soil solarization and biocontrol show some promise as alternative practices.

POTTING MEDIA

The potting media used for container-grown plants must be free of plant pathogens and weeds. Most potting media consists of organic matter that can support propagules of *Phytophthora, Pythium, Rhizoctonia*, and *Fusarium* and seeds or rhizomes of numerous weeds. Recycled plant material incorporated into the potting media is often contaminated and must be treated. Occasionally, plant pathogens have been discovered in peat moss, while other raw materials like Douglas-fir bark are relatively free of pests. Although few nurseries fumigate their potting media, methyl bromide is the common material selected. It is an effective treatment that is economical and easy to use.

[1]*Regan, R. 1996. Fumigation Practices in Oregon Ornamental Plant Nurseries. In: Landis, T. D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 150-l 51.*

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Two other materials, Vapam and Basamid, are also used to fumigate potting media. One specific use of Vapam, is to apply it through the mist/irrigation booms, in propagation greenhouses to fumigate the rooting media. Steam pasteurization of potting media is not as popular as it was twenty years ago. One of the contributing factors to this has been the change in heating systems. Steam boiler systems have been replaced with heated air, or circulated hot water. Composting of potting media is another alternative to fumigation but must be done correctly. Nurseries that explored this option have found that equipment costs and the space (land) needed for composting are prohibitive. One of the best practices is to only use raw materials that are free of pests and to keep the potting media clean. It should be stored on concrete under a tarp or cover.

CONTAINER SANITATION

Many types of plant containers are reused in nurseries. They range from small pots for liners to large containers for caliper size trees, and flats used for propagation. Container sanitation regarding plant pathogens has always been a concern of nurserymen and severa1 reported cases of plant disease have been related to infested containers. New containers are preferred, but are not always used due to economical or resource conservation reasons. Methyl bromide is only occasionally used to fumigate containers. Since most nurseries do not have a fumigation chamber, to use methyl bromide, containers are stacked in a pile and covered with a tarp. Worker safety issues arise because the fumigation tarp can easily be torn by the sharp edges of plastic containers.

Most of the containers that are used more than once are propagation flats and small pots for liners (less than 4 in.). These types of containers can be rinsed with high pressure water to remove most of the adhering media. At some of the nurseries, containers are stored in direct sunlight for the summer. This form of solarization appears to work quite satisfactory for most pests. For the more difficult pathogens, such as *Cylindrocladiurn*, the containers should be disinfected. Chlorine and Physan are the most popular disinfectants used by woody plant nurseries.

LIVING PLANTS

To ship certain plants into specific markets, plant fumigation with methyl bromide is required. For the most part, this is done in off-site fumigation chambers. Although there is some risk for plant damage, there are no alternatives for shipment into these markets and the loss of methyl bromide for this type of use creates concern. If changes in quarantine requirements cannot be made, nurseries would have to find new markets for their plants, or stop growing those plants.

Arbuscular Mycorrhizal Inoculation in Nursery Practice[1]

Ted St. John[2]

Abstract -The beneficial plant-fungus association known as arbuscular mycorrhiza (AM) or vesicular-arbuscular mycorrhiza (VAM) is known to improve phosphorus uptake, drought tolerance, and resistance to pathogens, among other benefits. The symbiosis is to a large extent a buffer against unfavorable soil conditions, and the benefits are generally more readily apparent in the field than in the nursety. Even so, plants intended for revegetation, habitat restoration, or forestry should be inoculated in the nursery with appropriate mycorrhizal fungi.

Fungal propagules must be placed in the root zone rather than on the surface of the medium. In the nursery inoculation is carried out by incorporating inoculum in the medium, by placing inoculum below the seedling ata transplant stage, or by dipping bare-root stock in adhesive-treated inoculum. Since the spores and other propagules of AM fungi are large and quickly settle out of suspension, it is unlikely that a successful method will be developed to apply inoculum through an irrigation system. The best procedures for each nursery will depend on properties of the inoculum, the species of plants, and site-specific factors that involve integration of the mycorrhizal program into existing nursery practices.

Fertilization in excess of the plant's current needs often reduces mycorrhizal colonization; thus fertilization procedures must almost always be modified to accommodate a mycorrhizal program. Similarly, fungicide and pesticide applications must be planned for compatibility with the symbiosis. Increasing demand for quality habitat restoration, and the mycorrhizal plants that it requires, will likely make a serious mycorrhizal program look attractive to increasing numbers of nursery managers.

INTRODUCTION

The endomycorrhizal symbiosis, also called arbuscular (AM) or vesicular-arbuscular mycorrhiza (VAM) is found in about 70% of the plant species examined to date, and is found somewhere in 80 to 90% of the world's plant families (Trappe 1987). Mycorrhiza is best known for dramatic growth responses, sometimes as much as thirty or more times the growth rate of otherwise comparable plants. These growth responses are usually related to phosphorus nutrition, and are most pronounced in soil of low fertility (Tinker 1978).

Other effects of mycorrhiza make less dramatic photographs, but may be more meaningful when nursery plants go out to a restoration or reforestation site. Other effects include drought tolerance, plant diversity, soil structure, resistance to pathogens, and ecosystem functionality.

Drought tolerance is commonly higher in mycorrhizal than non-mycorrhizal plants. Whether this is a direct effect of mycorrhizal fungi, or simply a side benefit of improved phosphorus nutrition is still in debate (Hardie 1986; Nelsen 1987).

[1]St. John, S. 1996. Arbuscular Mycorrhizal Inoculation in Nursery Practice. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursety Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 152- 158.

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Plant diversity is commonly higher after mycorrhizal inoculation (Gange et al. 1990; Fitter and Read 1994; St. John 1996). The effect is exerted mainly through improved survival of less common species (Grime et al. 1987).

The filaments of mycorrhizal fungi (the hyphae) are key players in the formation of soil structure (Bethlenfalvay and Schüepp 1994). Soil structure is a primary concern in restoration and reforestation. Some degraded forest soils are said to no longer support tree growth because they lack structure (Perry et al. 1987).

Wild plants in healthy ecosystems suffer very little from root disease, because soil pathogens are in balance with other beneficial soil organisms (St. John 1993). The mycorrhizal symbiosis is a key player in this balance, since it selectively favors beneficial soil organisms (Linderman 1994). The selective effect includes plant growth-promoting rhizobacteria (PGPR), organisms that improve plant growth by mechanisms that are still under discussion (Kloepper et al. 1991).

The beneficial effects of the mycorrhizal symbiosis are less evident in the favorable conditions of a nursery than in the harsh conditions of the final field site. Mycorrhizal inoculation is less likely to accelerate the nursery crop than it is to improve the customer's planting success.

The objective in habitat restoration is not simply to make plants grow, but to form a functional ecosystem. The characteristics of functional ecosystems include productivity, sustainability, retention of nutrients, resistance to invasive species, and biotic interactions (Ewel 1987), properties that al1 depend heavily upon mycorrhiza.

Tree of Life Nursery produces plants primarily for use in habitat restoration, where the conditions are difficult at best. The mycorrhizal program at this nursery has become a major selling point for the product and a major source of recognition for the nursery.

LACK OF NATIVE FUNGI

No one doubts the importance of mycorrhizal fungi in restoration and forestry. The only question is whether the fungi are already present on site, and will thus take care of themselves. Conditions in which native mycorrhizal fungi are typically lacking, and must be intentionally added, include land that has been graded, that is badly eroded, is overgrazed, is frequently disked, or that previously supported a nearly pure stand of strictly ectomycorrhizal trees. On graded land the top soil has been carried away, or the profile has been inverted. Eroded land usually lacks top soil and thus mycorrhizal fungi (Hall 1980; Powell 1980). Overgrazed land lacks microorganisms due to the poor condition of the vegetation (Bethlenfalvay et al. 1985). Mechanical disturbance, like disking, breaks up the mycelium in the soil and reduces its viability (McGonigle et al. 1993). Forests dominated by pines may lack propagules of endomycorrhizal fungi (Kovacic et al. 1984), as may other ectomycorrhizal forests (Gerdemann 1968).

In general, it is an advantage for the plants to already be mycorrhizal at the difticult time of transplanting. For this reason, restoration and reforestation container and bare root plants are best inoculated before outplanting.

It is of particular importance to note that mycorrhizal fungi are lacking or in low concentration in soilless nursery media (Graham and Timmer 1984) and in fumigated nursery beds (Hattingh and Gerdemann 1975). If the plants are to leave the nursery in the mycorrhizal condition, they will have to be intentionally inoculated early in production.

MYCORRHIZAL INOCULUM

The material that carries propagules of mycorrhizal fungi is called inoculum. Severa1 kinds of fungal structures can serve as propagules, and al1 are of value in mycorrhizal inoculum. Propagules include spores, mycorrhizal root fragments, and pieces of mycelium. Spores are generally considered the most resistant to adverse environmental conditions, but are slower than other propagules to colonize new roots. Mycelial fragments are usually the fastest to colonize new roots.

A significant limitation in practica1 use of mycorrhizal fungi is the size of the propagules. The spores are in the range of 1/10 millimeter in diameter, the largest of al1 fungal spores. Hyphal fragments that are large enough to constitute good inoculum may be that size or larger. A result is that they quickly settle out of suspension and do not readily pass through apertures of small diameter. Thus endomycorrhizal inoculum does not suit itself to distribution through a liquid handling system. Material applied to the surface of soil or even a very open container mix is likely to remain on the surface, and out of reach of the roots. This is in contrast to ectomycorrhizal inoculum, which works well when applied to the surface of a container mix.

In addition to fungal structures, the inoculum usually includes a carrier. The carrier may be sand, soil, peat, clay, or other solid substrate. Suspensions of fungus plus carrier in a viscous liquid, such as certain polymer formulations, work well as root dips. The polymers are likely to remain too expensive to ser-ve as carriers for direct field application.

CHOICE OF FUNGI

Trappe (1977) suggested that ectomycorrhizal fungi should be chosen for the final project site, not for convenience in the nursery. The same could be said for endomycorrhizal fungi, which vary in their responses to soil properties, especially pH. While there is no specificity between fungus and host plant, there are preferences that can be expressed in field or greenhouse experiments (Brundrett 1991; Johnson et al. 1992). That is, some fungal species work better with particular host plants.

The best way to assure a good fit between plant, soil, and fungus may be to isolate a mixture of native species from undisturbed vegetation on the same soil (Daft 1983; Perry et al. 1987). Unfortunately, native fungi are often more difficult to culture than the proven "generic" strains, and in any case require more time and expense to produce. Further, there is no assurance that the native fungi of the undisturbed soil will still be appropriate for the altered conditions after disturbance (Stahl et al. 1988).

Most often, the nursery manager must select from a very short list of commonly available commercial strains. At the very minimum, the selected fungi must be suitable for the soil pH at both the nursery and the final planting site. Two fungi now being offered in commercial preparations are Glomus intraradices and G. etunicatum. Both are strains originally tested and made available by NPI, a company no longer in the inoculum business. G. intraradices has provided good growth responses in a wide range of host plants, at soil pH from about 6 to 8.5 or higher. and G. etunicatum has been most effective in moderately acid soils.

INOCULUM PLACEMENT

A guiding principle in mycorrhizal work is that the inoculum must go into the root zone (Hayman et al. 1975; Ferguson and Menge 1986). The roots of new seedlings must be able to grow through the inoculum, unlikely if the inoculum is placed on the soil surface. The propagules of mycorrhizal fungi are large and will not readily wash into the soil, so even an open, loose container mix is difficult to penetrate.

For plants grown from seed in their final containers, the most cost-effective option may be to mix the inoculum into the container medium. This is likely to use more inoculum than might be necessary with other inoculation methods, but requires less labor. Nurseries that do not prepare their own container mixes may be able to persuade their medium suppliers to incorporate the inoculum.

Inoculation may be of greatest benefit to the plant when done at the earliest possible stage. However, germination and rooting stages can be difficult times to inoculate because the facilities commonly have low light intensity, heavy use of chemicals , and very wet medium, making mycorrhizal colonization difticult. For plants that are moved one or more times during the production cycle, the first transplant may be a more practica1 time to inoculate. Most plants at Tree of Life Nursery are inoculated by placing two ml of granular inoculum, containing well over 1 OO propagules, beneath the transplant. The cost of such inoculation is about a penny per container.

An additional possibility is a root dip. This has been used for ectomycorrhizal (ECM) species, and would be most appropriate at the end of the container phase of production. The nursery might dip bare-root plants before delivering them to the customer, or might dip container plants that were not made mycorrhizal during production. The slurry must contain ingredients that make the suspension viscous to keep the propagules from settling out rapidly, and must act as an adhesive. The root dip would also protect the root systems from desiccation.

The combined benefits of mycorrhizal inoculation may help the nursery meet environmental standards. The improved nutrient uptake of mycorrhizal plants means that nutrient solutions can be less concentrated, and that less will leach through the medium and into the ground water. Pathogen antagonists that are often associated or favored by mycorrhizal fungi may allow a reduction in other chemicals. There is a delicate balance between enough fertilizer and pesticide to maximize production, and too much for the tolerance of the beneficial organisms. The correct balance will depend on plant species and many factors that are specific to each nursery, and can only be fine-tuned by experimentation on site. The need for procedural changes is least with fumigated bare-root beds and greatest with high-tech indoor systems in small containers.

Perhaps the easiest place to begin a mycorrhizal program is in bare root beds. Fumigation has killed al1 native inoculum, and many plant species perform very poorly after fumigation. ECM fungi often disperse to the site quickly by wind-blown spores, but AM fungi may require months or years to arrive if not introduced by the nursery manager. Some growers of coast redwood, western red cedar, pacific yew,. and other endomycorrhizal species have introduced native forest soil into the fumigated beds, and have realized substantial benefits from doing so. Unfortunately, forest soil contains both desirable and undesirable organisms, and its use can be a very risky practice. Good quality commercial inoculum bypasses these risks, and can be introduced by banding or disking it into the soil. If the plants go into the bed as seedlings rather than seeds, they can be made mycorrhizal in the container or can be treated with a root dip at the time of outplanting.

A final nursery option is inoculation as the plants leave the nursery. This allows the nursery to use chemicals and methods that may prevent mycorrhizal colonization, but still make the plants mycorrhizal soon after outplanting. A root dip, as described above, is probably the most cost-effective option for this kind of application.

If the nursery has not made the plants mycorrhizal, the customer may wish to inoculate the plants at the field site. This may be done with a root dip or by dropping a pre-packaged “tea bag” of inoculum in each planting hole. Endomycorrhizal inoculum, packaged in tea bags with or without compatible fertilizer formulations, is now available.

Finally, inoculum in a solid carrier can be incorporated into the soil by broadcasting followed by disking, or by broadcasting onto freshly ripped ground, followed by dragging. A method rapidly gaining favor in habitat restoration is a specially-modified land imprinter. The imprinter places inoculum one to four inches in the soil, then shapes the soil to provide spatial heterogeneity and facilitate water infiltration. It applies seed in firm capillary contact with the soil. This single-pass operation has proven very cost effective in land restoration. The method has provided dramatic improvements in plant survival and species diversity (St. John 1996). The cost of inoculum in field application has ranged from $300 to $500 per acre.

DOSAGE

The amount of inoculum required for a particular application is an important question, because it directly influences both the cost of the operation and the chances for success. For container use, the recommended number of propagules per plant has drifted downward, from severa1 hundred a few years ago to much lower numbers now.

The recommendations come from inoculum suppliers and researchers, and the basis for each recommendation is not always clear. Obvious motivations for recommending high doses are to be sure it works and to se11 more product. This last motivation can be self-defeating, since the cost of the product becomes non-competitive at high doses. Our own recommendations are based on spatial dispersion of propagules in the medium, and on empirical tests of dosage rates. Tests are continuing, and as lower rates are tested our recommendations may go down.

It is more difficult to understand why a supplier would recommend a very low dose. One supplier with a particularly low propagule count actually recommends a container plant rate that can provides fewer propagules than the number of containers! The supplier may not realize the error, but a clear advantage of such a recommendation is that the product appears inexpensive.

VERIFICATION OF RESULTS

No mycorrhizal program can be successful without a means of verifying results, since inoculation can and will fail for numerous reasons. Low light intensity, short photoperiod, low carbon dioxide concentration, and the presence of excess ethylene are common problems in the greenhouse. Cold temperatures, excess fertility, incompatible pesticides, incompatible medium ingredients, contaminated water, and wet medium may prevent colonization either indoors or outdoors. It is critica1 that environmental conditions and procedural changes be checked at every step.

Another problem is that mycorrhizal roots look just like ordinary roots to most observers. You may be faced with competitors who will claim their product is mycorrhizal, while saving themselves the expense of a serious mycorrhizal effort. Customers are now beginning to request proof of this claim.

Setting up an in-house mycorrhizal lab requires training, microscope equipment, and the use of toxic chemicals. There is at least one commercial laboratory, in Corvallis, Oregon, that will stain and interpret roots for about $30 per sample. Your plant pathologist may be able to provide this service, or train you to do it yourself.

SUMMARY

Mycorrhiza is a normal and necessary part of plant roots if the plants are to be used in habitat restoration or forestry. Mycorrhizal plants are more independent and better prepared for existence at the restoration or reforestation site. There is now considerable demand for mycorrhizal plants in commercial projects. Most plant species used in restoration, and severa1 used in forestry, are endomycorrhizal hosts. The considerable benefits of mycorrhiza promote not only health and survival of the individual plant, but of the ecosystem as well. A functional ecosystem is not possible without mycorrhizal fungi and a range of associated beneficial organisms.

Inoculation in the nursery is entirely feasible, but may require procedural changes to accommodate the symbiosis. Media, fertilizer, chemicals, and environmental conditions may al1 have to be adjusted. Successful colonization is probably most practica1 in fumigated bare root beds, and most difficult in greenhouse crops with automated watering and fertilization.

Direct inoculation in the field is now practical, and may be the best alternative when nursery inoculation is unsuccessful or impractical. Plants may be treated at planting time with a root dip, with inoculum in the planting hole, or by incorporation of inoculum into the field soil.

By adopting a mycorrhizal program, the nurseryman may expect more efficient use of fertilizer and less need for pesticides. These will provide immediate savings in materials and better environmental compliance, which may well offset any added costs of inoculation. The procedures are demanding, however, and the program will require time to establish.

The difficulties involved in initiating a mycorrhiza, program, and the lack of evident responses in fertile nursery soils, have made it difficult to persuade nursery managers to undertake routine inoculation. It is easy to conclude that anything as invisible as mycorrhiza takes care of itself, a mistaken impression in the case of habitat restoration. Demands for success in restoration is likely to increase the pressure for mycorrhizal inoculation in the nursery.

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Microbial Mixtures for Biological Control of Fusarium Diseases of Tree Seedlings[1]

Cynthia M. Ocamb[2], Cynthia A. Buschena[3], and Joseph O'Brien[2]

Abstract-Alternatives to soil fumigation with methyl bromide are needed for controlling Fusarium diseases in tree nurseries. Studies are under way for developing microbial mixtures (bacteria & ectomycorrhizal fungi) that control Fusarium diseases of eastern white pine (Pinus *strobus* L.) seedlings. Greenhouse studies in containerized production have shown that the application of rhizosphere bacteria to conifer seed, coupled with ectomycorrhizal fungi application at sowing, can protect seedlings against Fusarium root rot. Not only do seedlings have a reduced incidence and severity of root rot, they also have greater levels of ectomycorrhizal roots. When applied to seeds for field (bareroot) production, the bacteria1 strains are associated with increased stand numbers.

INTRODUCTION

Mortality of field-grown (bareroot) *Pinus strobus* L. (eastern white pine) seedlings from Fusarium root rot (17) causes serious economic losses in the Lake States region (12,15,16). Infected seedlings suffer reduced vigor and growth, if not killed by root rot. In one survey, up to 75 % of inspected seedlings had root rot (13). Moreover, 68 % of the seedlings intended for sale from one nursery were culled due to root rot (14). In addition to causing root rot, *Fusarium* spp. are known to incite damping-off of *P. strobus* (6,7). Containerized seedlings are also susceptible to Fusarium diseases. Current control measures include soil fumigation with methyl bromide-chloropicrin (bareroot production) and biweekly applications of fungicides (containerized production), but root rot of white pine is still a serious problem in nurseries. Disease problems will undoubtedly increase when methyl bromide is no longer available for soil fumigation (19). Alternatives are needed for controlling Fusarium diseases in tree nurseries and use of biological control agents is an important method of alternative pest control.

Use of microorganisms as biological control agents has been studied with agronomic and horticultura1 plant diseases but limited information is available for diseases of conifer seedlings. Microorganisms antagonistic to *Fusarium* spp. can be applied to conifer seed. Upon successful colonization of the rhizosphere, conifer seedling roots can be protected Fusarium against root rot. Biological control microbes may also protect germinates from damping-off (1). Successful use of ectomycorrhizal fungi for suppressing pathogenic *Fusarium* spp. has been reported with *Laccaria laccata* on *Pinus banksiana* (1) and *Pseudotsuga menziesii* (18); as well as *Paxillus involutus* on *Pinus resinosa* (4,5). Abundant ectomycorrhizal root formation enables nursery managers to significantly decrease fertilization rates; generating savings above those from minimized seedling losses due to death and culling. In

[1]*Ocamb, C. M.; Buschena, C.A.; O'Brien, J. 7996. Microbial Mixtures for Biological Control of Fusarium Diseases of Tree Seedlings. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Setvice, Pacific Northwest Research Station: 159-166.*

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addition, biological control agents may preclude other soilborne pathogens from causing disease. Biological control microbes will probably benefit other Lake States conifer species, as well as conifer seedlings grown in other geographic areas. By introducing rhizosphere colonists that are beneficial to conifer seedlings and antagonistic to soilborne pathogens, growth and spread of indigenous or exotic pathogens may be minimized through protection of susceptible host tissue.

TESTING IN CONTAINERIZED PRODUCTION

Representative isolates of *F. oxysporum, F. oxysporum* var. *redolens* (W. L. Gordon), *F. proliferatum* (T. Matsushima) Nirenberg, and *F. solani* (Mart.) Sacc. were collected from necrotic *P. strobus* roots or nursery soil, purified by the single-spore method, and stored on silica gel at 5 C (20). Inoculum was increased by transferring 5-mm agar plugs from carnation leaf agar (10) cultures to sterile cornmeal-

Table 1. Bacteria used as biological control agents for suppression of Fusarium root rot in containerized or field production

Acauisition #	Identification via Fatty Acid Analvses
BCT5a	*Streptomyces violaceusniger* subsp. *violaceusniger*
BCT19b	*Streptomyces rochei* subsp. *rochei*
BCB175	*Bacillus megaterium*
BCB176	*Streptomyces lavendulae*
BC19	*Methylobacterium mesophilicum*
BC20	*Rhodococcus erythropolis/Kocuria varians/Pseudomonas diminuta*

Table 2. Treatments included in study on the microbial suppression of Fusarium root rot in containerized production

Ectomycorrhizal soil drench	Seed-application of bioloaical control bacterium
Laccaria sp.	BCT5a
Laccaria sp.	BCT19b
Laccaria sp.	BCB176
Hebeloma sp.	BCT5a
Hebeloma sp.	BCT19b
Hebeloma sp.	BCB176
Laccaria sp.	BCT5a, BCT19b, BCB176
Hebeloma sp.	BCT5a, BCT19b, BCB176
Laccaria sp.	Mycostop®
Hebeloma sp.	Mycostop®
	Mycostop®
	BCT5a
	BCT19b
	BCB176
	BCT5a, BCT19b, BCB176
Laccaria sp.	
Hebeloma sp.	
	BC20
water	

Table 3. Treatments included in study on the microbial suppression of damping-off and Fusarium root rot in field (bareroot) production in Toumey Nursery

Seeds disinfested	Ectomycorrhizal inoculation	Seed-application of bioloaical control bacteria
+		
+	*Hebeloma* sp.	
+		BCB 176
+	*Hebeloma* sp.	BCB 176
+		BCB175
+		BC19

Table 4. Treatments included in study on the microbial suppression of damping-off and Fusarium root rot in field (bareroot) production in Wilson Nursery

Seeds disinfested	Seed-application of biological control bacteria	Ectomycorrhizal inoculation
	-	*Hebeloma* sp.
-		*Laccaria* sp.
+		
+		*Hebeloma* sp.
+		*Laccaria* sp.
+	BCB 175	
+	BCB 175	*Hebeloma* sp.
+	BCB 175	*Laccaria* sp.
+	BCB 176	
+	BCB 176	*Hebeloma* sp.
+	BCB 176	*Laccaria* sp.

sand medium (97 g sand, 3 g cornmeal, 40 ml distilled water). Each pathogenic *Fusarium* isolate was added to a growing medium (Fafard #2) at a rate of 0.005 g/cc soil.

Bacteria (Table 1) were isolated from white pine rhizosphere soil (11), stored in sterile water at 24 C, and increased in oatmeal broth (2). The mycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were stored as outlined in Doudrick and Anderson (3) and grown in modified Melin-Norkrans' nutrient solution (9). White pine seeds (lot A0588-4, courtesy of G. Dinkel, USDA Forest Service) were surface-disinfested by agitation in 3 % H_2O_2 for 2 hr, rinsed four times in sterile water, wrapped in moist cheesecloth, and placed in cold storage (5 C) for eight wk. After stratification, seeds were soaked in bacteria1 cultures for 60 min then air-dried.

Pine ce11 cone-tainers (Stuewe & Sons, Corvallis, OR), 17 cm in length and 24 mm in diameter, were plugged with 5 cc of Fafard #2, then 5 cc of *Fusarium*-infested medium was added. The pine cells were filled the rest of the way with Fafard #2. Two white pine seeds were placed atop soil and 1 ml of ectomycorrhizal slurry was pipetted into the soil. Seeds were covered with 2.5 cc of Fafard #2 and perlite was spread over the top of each pine ce11 container. Treatments are listed in Table 2. Mycostop ® (8), a commercial formulation of *Streptomyces* sp., was included in this study. Mycostop ® was reapplied every 4-6 wk according to labe1 guidelines. Seedlings were grown in a greenhouse according to standard nursery practices.

Eleven months after sowing, shoot height, root volume, root rot, and percentage of root system with ectomycorrhizal roots were recorded for each seedling. Rot root ratings are based on a 1 to 5 rating system: 1 = apparently healthy, 2 = over 50 % length of one lateral root exhibiting rot, 3 = lower 1/3 of tap root is symptomatic or greater than 50 % of two or more lateral roots is necrotic, 4 = lower 2/3 of tap root is rotted (with or without lateral root injury), and 5 = upper third of tap root is rotted or entire root system is affected.

Applications of the *Hebeloma* sp. mixed with a rhizosphere-derived bacteria were associated with a significant (P=0.05) decrease in root rot severity compared to the water-disease control (Figure 1). Similarly, signilicantly greater levels of ectomycorrhizal roots were observed in these same microbial mixtures (Figure 2). In contrast, *Laccaria* sp. applications yielded fewer ectomycorrhizal roots compared to *Hebeloma* applications, though microbial mixtures that included the *Laccaria* isolate generally offered significant disease suppression relative to the water-disease control. When the rhizosphere bacteria were applied without an accompanying ectomycorrhizal fungus, the result was a significant decrease in root rot severity compared to the water-disease control. Root volume was significantly increased with mixtures of the *Hebeloma* sp. with BCT19b, BCB 176, or Mycostop ® compared to the water-disease control (Figure 3). Generally, no increase in seedling height was associated with any of the biocontrol applications (Figure 4).

FIELD TESTING (BAREROOT PRODUCTION)

Operational fields in two nurseries: Wilson State Forest Nursery, Boscobel (WSFN), Wisconsin, and J. W. Toumey Nursery (TN), Watersmeet, Michigan, were used as study sites. Fields were fumigated with dazomet at a rate of 570 kg/ha. White pine seeds of lots H-167B (courtesy of T. Marty, Wisconsin Department of Natural Resources) and A0588-4 were surface-disinfested by agitation in 3 % H_2O_2 on a orbital shaker at 120 rpm for 2 hr then rinsed four times in sterile, distilled water. Seeds of lot A0588-4 underwent stratification similar to the method described above. Prior to sowing, seeds were soaked in bacteria1 cultures for 60 min then air-dried. Seedlot H-167B was fall-sown in WSFN and A0588-4 was spring-sown in TN. Ectomycorrhizal fungi were applied by drenching slurries along side of emerging seedlings. Each field was maintained according to standard nursery practices.

Each field was blocked into four areas, across the width of the field. At TN, one of seven seed/ ectomycorrhizal treatments (Tables 1 & 3) were randomly assigned to the bed row within each block. At WSFN, one of four seed treatments (Tables 1 & 4) were randomly assigned to each row and three plots of each of the three ectomycorrhizal treatments were randomly assigned to each bed row within each block. Stand counts were made during late-summer. At TN, seed disinfestation alone or accompanied by the *Hebeloma* sp. only slightly improved stand counts whereas the presence of the biocontrol bacteria was

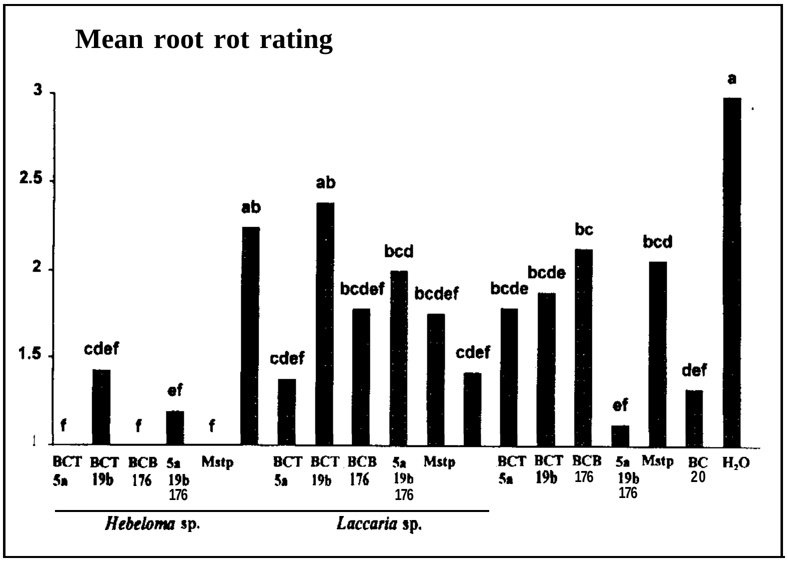

Figure 1. Mean root rot ratings of eastern white pine containerized seedlings grown in *Fusarium*-infested growing medium for II months. Seeds were coated with bacteria1 biological control agents (Table 1). Mycostop ® (Mstp) was included. Two ectomycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were drenched over white pine seeds. Sterile water (H_2O) was used as a water-disease control. Disease severity rating classes included: RR1 = apparently healthy, RR2 = over 50 % length of one lateral root exhibiting rot, and RR3 = lower 1/3 of tap root is symptomatic or greater than 50 % of two or more lateral roots is necrotic. Bars represent means based on 20 seedlings in each of two replicates (40 total). Bars labeled with the same letters are not significantly different (P=0.05) according to Tukey's W statistic.

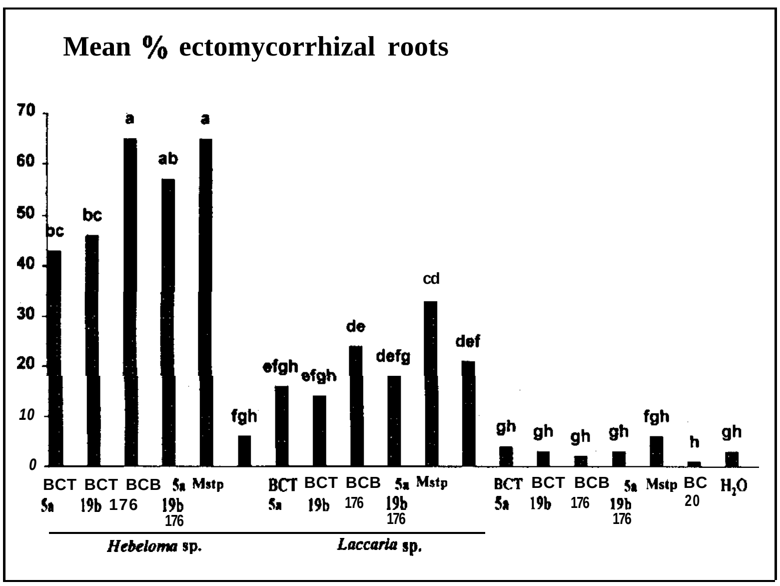

Figure 2. Mean percentage of ectomycorrhizal roots of eastern white pine containerized seedlings grown in *Fusarium*-infested growing medium for II months. Seeds were coated with bacteria1 biological control agents (Table 1). Mycostop ® (Mstp) was included. Two ectomycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were drenched over white pine seeds. Sterile water (H_2O) was used as a water-disease control. Bars represent means based on 20 seedlings in each of two replicates (40 total). Bars labeled with the same letters are not significantly different (P=0.05) according to Tukey's W statistic.

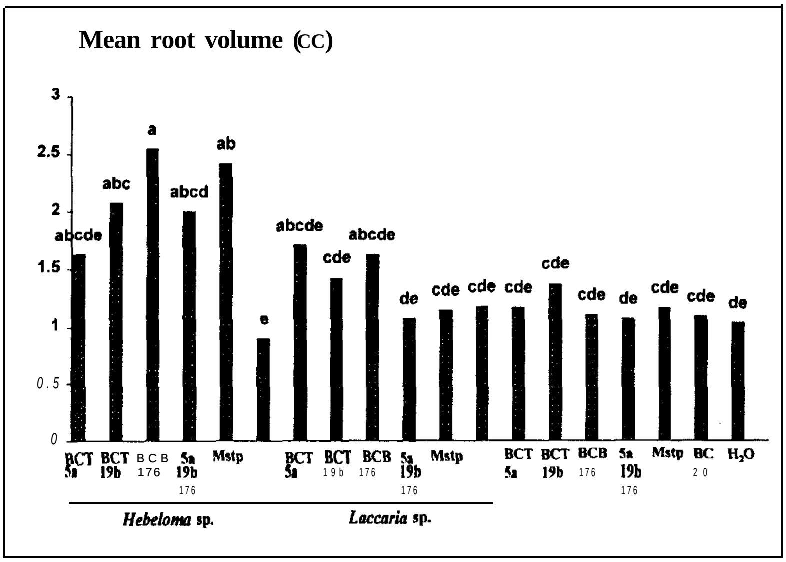

Figure 3. Mean root volume of eastern white pine containerizecl seedlings grown in *Fusarium*-infested growing meclium for ll months. Seeds were coated with bacteria1 biological control agents (Table 1). Mycostop ® (Mstp) was included. Two ectomycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were drenched over white pine seeds. Sterile water (H_2O) was used as a water-disease control. Bars represent means based on 20 seedlings in each of two replicates (40 total). Bars labeled with the same letters are not significantly different (P=0.05) according to Tukey's W statistic.

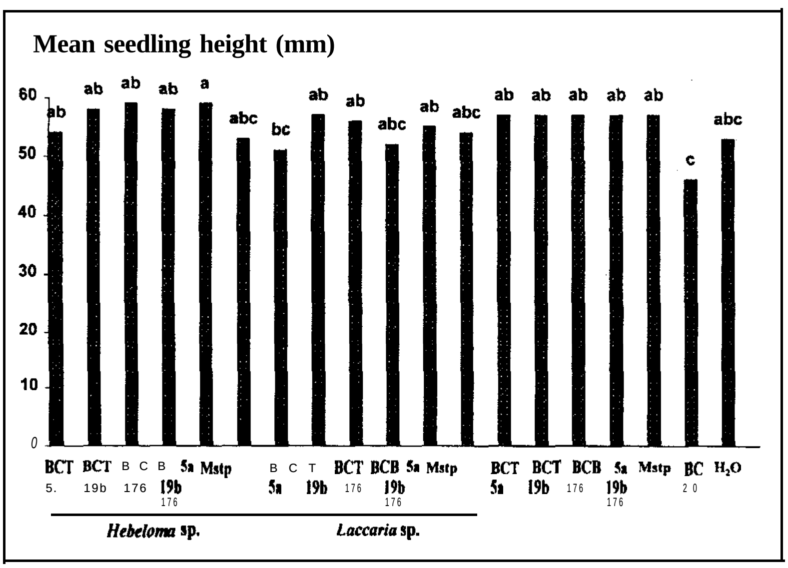

Figure 4. Mean height of eastern white pine containerized seedlings grown in *Fusarium*-infested growing medium for 11 months. Seeds were coated with bacteria1 biological control agents (Table 1). Mycostop ® (Mstp) was included. Two ectomycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were drenched over white pine seeds. Sterile water (H_2O) was used as a water-disease control. Bars represent means based on 20 seedlings in each of two replicates (40 total). Bars labeled with the same letters are not significantly different (P=0.05) according to Tukey's W statistic.

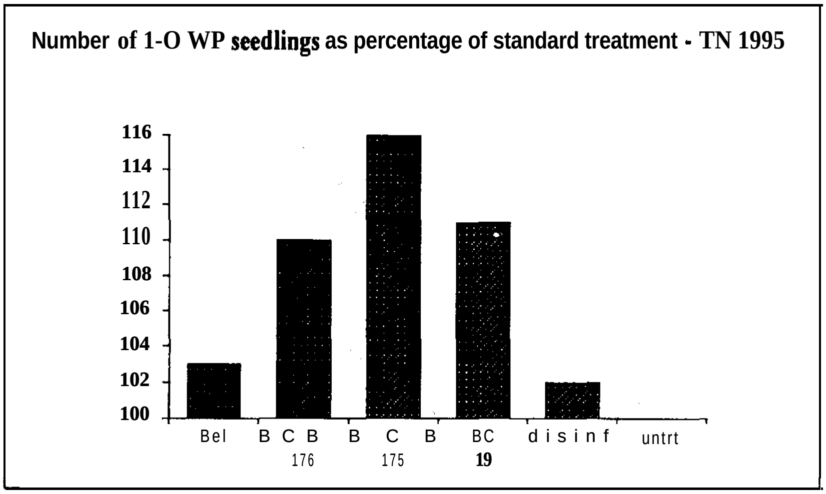

Figure 5. Mean percentage stand number improvement of 1-O eastern white pine seedlings in the field relative to stand nursery practice (untrt) in Toumey Nursery. Disinfested seeds (disinf) were coated with *Streptomyces lavendulae* (BCB176), *Bacillus* megateriom (BCB175), or *Methylobacterium mesophilicum* (BC19). The ectomycorrhizal fungus, *Hebeloma* sp. (Hel), was applied as a soil drench next to emerging seedlings. Counts are based on three plots per treatment combination.

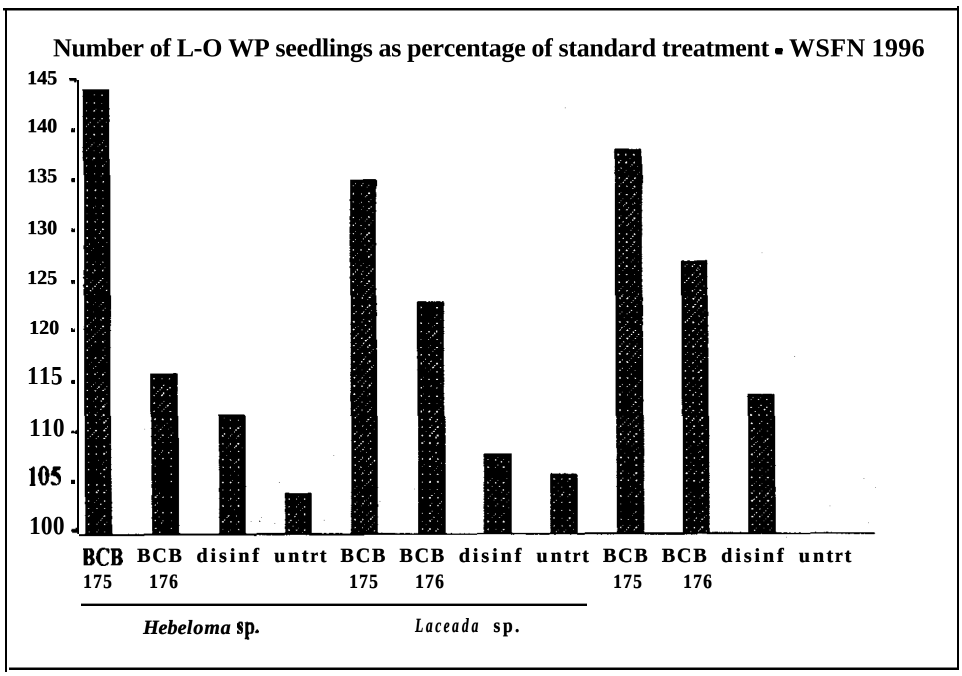

Figure 6. Mean percentage stand number improvement of 1-O eastern white pine seedlings in the field relative to stand nursery practice (untrt) in Wilson Nursery. Disinfested seeds (disinf) were coated wit h *Bacillus megaterium* (BCB175) or *Streptomyces lavendulae* (BCB176). The mycorrhizal fungi, *Hebeloma* sp. and *Laccaria* sp., were applied as a soil drench next to emerg- ing seedlings. Counts are based on nine plots per treatment combination.

associated with at least a 10 % improvement in stand relative to the untreated, nursery standard (Figure 5). In WSFN, BCB175 appeared to improve stands by 35-45 % relative to the untreated, nursery standard (Figure 6). Disinfestation of seeds alone was associated with approximately a 10 % stand improvement.

CONCLUSION

Microbial mixtures, integrated with seed disinfestation, look favorable for root rot control in containerized tree seedling production. In addition, the *Hebeloma* isolate apparently needs rhizosphere bacteria for ectomycorrhizal root formations in our study. Seed disinfestation slightly improved stand counts in the field, but application of our rhizosphere bacteria coupled with disinfestation and dazomet fumigation greatly enhanced field stand numbers. Root systems will be examined during the second growing season, and microbial efficacy for root rot control can then be determined. Current research efforts include improvement in delivery of ectomycorrhizal fungi, increased component numbers in microbial mixtures, and evaluations with *Pinus resinosa* Aiton (red pine), *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir), and *Pinuspatula* Schlechtend. & Cham. (Mexican weeping pine) seedlings.

ACKNOWLEDGMENTS

The authors wish to thank Wilson State Forest Nursery, Boscobel, Wisconsin, J. W. Toumey Nursery, Watersmeet, Michigan, and the Department of Plant Pathology of the University of Minnesota for providing assistance, equipment, and supplies. The technical assistance of J. Bitz, P. Castillo, K. Cease, A. Dejarlais, D. Gardner, L. Haugen, A. Hilmonowski, M. Jones, M. Labalan, T. Lewis, D. McDougall, S. Meyer, J. Paul, A. Reyes, and K. Weinke is gratefully acknowledged. Operating funds for a portion of this study was provided by a Technological Development grant (USDA-FS 24-42-TN-03 ll 14), Challenge Cost Share grant (USDA-FS 152 103), and USDA-FAS-RSED grant (SF08) to the first author.

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Recent Developments in Seed Technology and Obstacles to be Overcome[1]

Franklin T. Bonner[2]

Abstract — Four developments in tree seed technology are identified: (1) seed moisture in recalcitrant seeds during storage; (2) precise control of moisture during stratification; (3) spin-offs from the use of precision seeders; and (4) declining support for seed research in North America. Five obstacles to better seed utilization for nurseries are also identified as targets for improvements. They are: (1) storage of recalcitrant seeds; (2) control of moisture during stratification; (3) complex dormancy of shrubs and minor hardwoods; (4) seed cleaning and conditioning; and (5) communication. Posible solutions for these obstacles are presented.

DEVELOPMENTS

An overview of recent developments in seed technology may sound like a daunting task, but it gives me the freedom to establish my own definition of "recent" and "development". 1 would like to highlight four recent or emerging developments: (1) seed moisture in recalcitrant seeds during storage; (2) precise control of moisture during stratifícation; (3) spin-offs from the use of precision seeders; and (4) declining support for seed research in North America.

Moisture in recalcitrant seeds

Long-term storage of seeds of recalcitrant species is a difficult, if not impossible, process. A solution first proposed more than 20 years ago for southern red oaks (Bonner 1973) called for storage at maximum acorn moisture content, temperatures just above freezing, and in non-sealed containers that allowed air exchange with the surrounding atmosphere. This method doesn't help much with southern white oaks, but it does permit storage of many red oaks for 3 years with only moderate losses in viability (Bonner and Vozzo 1987). Additional tests through the years have not improved this method, but now there are new possibilities.

The new development is to reduce seed moisture content below the maximum, perhaps 5 percent. This step appears to help aeration, reduce the incidence of fungi and molds, and reduce early germination in storage. By reducing moisture content European foresters are getting 3 to 5 years of good storage of northern red oak and English oak (a white oak) acorns with only a minimum of germination in storage. In the United States, at least one southern seed dealer is also reducing moisture of his stored acorns, and others may also be doing the same. How much the moisture content should be lowered is not precisely known, but a good rule of thumb is to not have any free moisture on the pericarps of the acorns. Seed vigor, at least in oaks, may be slightly impaired, but the trade-off can be worth it. Experience with other recalcitrant seeds is lacking, so this method is suggested for oaks only at this point.

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Precise control of moisture during stratification

Seed researchers in the Pacific Northwest made the first improvements by changing our understanding of seed moisture content and its function during and after stratification (Edwards 1986). In Europe the concept was adapted to focus on precise control of seed moisture during stratification. Optimum moisture leve1 was found to vary by species (Muller 1993). European beech (*Fagus silvatica* L.) requires 30 percent, European ash (*Fraxinus excelsior* L.) 55 to 60 percent, and cherry (*Prunus avium* L.) 27 to 30 percent. New equipment has been developed to maintain control of moisture on an operational scale for nurseries. Improved oxygen supply is the supposed benefit, but this has not yet been confirmed by research. At the end of stratification, seeds can be sown, or redried to below 10 percent moisture and stored for up to 6 years (Muller 1993).

Spin-offs from precision seeding

You may be surprised to find precision seeding listed as a recent development in seed technology, but it is a significant development that has forced nursery managers (and seed dealers) to upgrade their seed lots for bareroot production. Precision seeders require clean, filled, sized, germinable seeds to make the investment in equipment worthwhile. This need has led to increased use of aspirators, gravity tables, air-screen cleaners, and the newer flat-screen cleaners. Similar problems for container operations in Sweden led to development of the Incubation-Drying-Separation (IDS) technique more than a decade ago in Sweden (Simak 1984).

Once nursery managers used these upgraded seed lots, they were convinced. Seed sizing is now being used for acorns in many places, and new hardwood sowers have been developed (usually in the nursery shops) to take advantage of these improved seed lots. With access to new brush machines that provide good control for dewinging hardwoods (Karrfalt 1992), more nursery managers are dewinging their yellow-poplar (*Liriodendron tulipifera* L.) seeds, and some are asking about dewinging ash. These changes reflect a welcome trend in seed management in nurseries; managers are no longer content to accept and plant seed lots with 30 or 40 percent empty seeds.

Declining support for seed research

When government agencies are downsized, and research budgets are cut, decisions must be made about what program stays and what goes. Some people may not like the results of these decisions, but we must recognize the reality of the situation. Tree seed research isn't faring so well in North America these days. The USDA Forest Service is closing out its tree seed research program, and the Canadian Forestry Service has made massive cuts in theirs. Most universities are not interested in applied seed technology research anymore that the nursery industry still needs; they want cutting-edge, sophisticated research programs based on gene transfer or DNA cloning.

While interest in North America is waning, interest in tree seed research is alive and well in Europe. At the Fifth International Workshop on Seeds held at the University of Reading in England in September 1995, seven papers and twice that many posters dealt with tree seeds. Some were on storage problems of recalcitrant species, but most dealt with treatments to overcome dormancy in hardwoods. Why is there so much interest in tree seeds among these university researchers, many of whom do not have forestry backgrounds? The European Economic Community (EEC) is supporting their research with grant money because Europeans are afraid their natural forest gene pools are disappearing. One British forester told me that seed dealers who have Scots pine (*Pinus sylvestris* L.) seeds from the old native stands in England can get five to six times the price of improved orchard seed. North Americans may not wish for these extremes, but we can look at this EEC research funding with a little bit of envy.

OBSTACLES

Now let's shift gears and look at what 1 consider to be five serious obstacles to better utilization of seed supplies in nurseries. They are: (1) storage of recalcitrant seeds, particularly acorns; (2) control of moisture during stratification; (3) complex dormancy of shrubs and minor hardwoods; (4) seed cleaning and conditioning; and (5) communication. Despite some improvements, storage and moisture control are also listed as obstacles.

Storage of recalcitrant seeds

With more and more planting of oaks in the South and East, storage of seeds takes on greater significance. The root of the problem, of course, is the physiology of the seeds: they simply cannot be dried, which greatly reduces the options for storage. And there is no "silver bullet" for this problem. It is extremely unlikely (but not impossible) that additional seed research will discover a way to overcome these recalcitrant characteristics; they must be accepted. Many of the best researchers in the world consider storage of recalcitrant seeds to be the most challenging problem in seed science today.

There are at least two ideas worth exploring. One is to reduce seed moisture contents below the maximum during storage, perhaps 5 percent. We need more research, however, because we do not know the applicability or the limits to this concept for individual species. The second idea is related to the first. If we decrease acorn moisture contents, we might be able to drop the storage temperature below freezing, thus slowing metabolism even further. We know that acorns can be stored successfully a couple of degrees below freezing, but results are usually no better than storage at a couple of degrees above freezing. Long-term storage trials with acorns of southern oaks at sub-freezing temperatures failed in the past (Bonner and Vozzo 1987), but survival below freezing may be a function of acorn moisture content and time of exposure. This past winter provided many examples of acorns surviving 36 to 48 hours of sub-freezing temperatures, some as low as - 10 °C while fully exposed on top of the ground. Could we possibly freeze acorns for a week or so, then move them to higher temperatures for recovery, then freeze them again? This strategy may sound like excessive handling of the seeds, but it should be investigated.

Control of moisture during stratification

While control of moisture during stratification was listed as a new development, it can also be listed as an obstacle because we have experience with only a handful of species. Both excessive and insufficient moisture during stratification can cause problems and reduce the effectiveness of treatment. Some southern and midwestern state nurseries are growing 30 to 40 different woody plants, most of which could benefit greatly from pretreatments that would provide better and more uniform emergence. Precise control of moisture during stratifícation could be the answer for some species, but someone will have to do the research. The stratification-redry results of Edwards (1986) have made the first improvements in our concept of stratification moisture. In Europe the concept was refined to allow precise control of seed moisture during stratification of European beech (Muller 1993), even to the point where new equipment has been developed on an operational scale for nurseries. Another tantalizing question is: Is this the same effect we get in seed priming? The rotating drums being used for controlled stratifícation of beech in Europe appear similar to equipment used in priming of vegetable seeds in this country. Moisture control should be an emerging research issue for al1 regions.

Complex dormancy of shrubs and minor hardwood

As public concerns for the environment grows nurseries are now called upon to grow an increasing number of species. Most of these new species, both shrubs like serviceberry and trees like arrowwood, have not been widely grown before in forest nurseries, and many of them have rather complex dormancies that confound the goal of rapid and uniform germination. Like the recalcitrant seed problem, there are no quick fixes. These dormancy mechanisms have evolved for good reasons, and there are no magic switches that turn them off. There are, however, some possible solutions. One is to look again at warm or alternating warm/cold stratification temperatures. Variations of these techniques have been used with some success for years on deeply-dormant species in northern latitudes; some examples are: plums (*Prunus* spp.) (Tylkowski 1985), hollies (*Ilex* spp.) (Bonner *Ilex*, in press), junipers (*Juniperus* spp.) (Bonner *Juniperus*, in press), and some species of dogwoods (Brinkman 1974). Tests on similar methods in our laboratory have yielded no decisive results on black cherry (*Prunus serotina* Ehrh.), eastern redcedar (*Juniperus virginiana* L.), Rocky Mountain juniper (*J. scopulorum* Sarg.) (unpublished data), and white ash (*Fraxinus americana* L.) (Bonner 1975). A more systematic approach that could more closely match the environment of a southern nursery bed might help.

There is another point to consider about these seeds. Most agricultura1 seeds must dry at maturity for al1 of the enzymes that are essential for germination and normal growth to be formed, and tree seeds such as loblolly pine and sycamore probably have similar requirements. Those species that have complex dormancies are shed from the trees in moist fruits (drupes, fruits, or fleshy cones in these cases), and they do not achieve a dry maturity on the tree as seeds in dry fruits do. Could it be that they need a warm, drying period before they are fully mature? When they are fully mature, are they as dormant as they were before? The relationship of moisture to dormancy is an area where more seed research is desperately needed.

There is another option available to nurseries for these deeply-dormant seeds: stratify a year ahead. A grower can collect in the fall, place the seeds in cold stratification, and sow in the spring 15- 18 months later. This step may sound drastic, but it could be possible with species like basswood, sassafras, haws, viburnums, or hollies. And if these drastic measures do not work, there's always vegetative propagation.

Seed cleaning and conditioning

There's not much new research in seed cleaning and conditioning. Some new equipment appears or old equipment is modified, but growers and researchers continue to use the existing methods and equipment. The condition of some hardwood seed lots that 1 have observed through the years has been appalling! A common theme has been that only a small amount of seed has been collected, and "the nurseryman doesn't want to waste any by trying to remove trash and empty seeds." Or, a grower may say "we've never grown this stuff before and don't have any idea how to clean it." Most nurseries are doing a great job these days, but we have a way to go.

Communication

No matter how hard researchers try, we don't do as good a job as we should in technology transfer. It's hard to blame the nursery managers. Who has the time to read al1 of the journals? The nursery conferences and regional training sessions that Tom Landis and Clark Lantz have arranged are really good, but they can't cover al1 everything. Another factor is that new nurserymen keep coming on the job, and few of them, if any, are getting training in seed and nursery management in forestry schools. Therefore, some training must be given repeatedly, at regular intervals, an approach that we don't always take. Maybe electronic information services are part of the answer. The revised edition of USDA's "Seeds of woody plants in the United States" will be made available on the Internet. A grower with the proper connections can go online and download individual genus chapters without buying the book! In the same way, future updates can be done genus by genus as information becomes available without having to print the whole book. Electronic information retrieval will never replace these Nursery Association meetings, but it does offer a quick, inexpensive way to get (and give) the latest results and advice. Furthermore, there would be no geographic limitations; the seed experts in Denmark would be just as close to you as those in Starkville, Macon, Corvallis, or Victoria. Just think about it; the potential is enormous!

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The Stratification-Redry Technique with Special Reference to True Fir Seeds[1]

D.G.W. Edwards[2]

Abstract-A method of more completely removing seed dormancy and obtaining very rapid and more complete germination of true fir species is reviewed. Detailed use of the method is described, emphasizing standardization and consistency. Tests on other coniferous species are described, and an explanation of how the method works is offered.

INTRODUCTION

Traditionally, seeds of true fir—*Abies* species-have been typically poor in quality, germinating erratically and unpredictably, and the bane of nursery growers. Many, if not most, of these problems were related to the phenomenon of seed dormancy, an evolutionary trait that delays germination after natural seedfall until environmental conditions are favorable for seedling growth. Also, until relatively recent times, seed producers tended to process true fir seeds for quantity, rather than for quality. This situation has now changed, especially with the better understanding of seed dormancy, and the development of a method that more completely eliminates this condition. The method is known as the "Stratification-redry technique", and the purpose of this paper is 1) to review the kind of results that can be expected from use of this method on true fir species, including results from nurseries, 2) to describe in detail how the method should be applied, followed by 3) its effects on seeds of other coniferous species, and 4) a brief discussion of how the method works.

1. RESULTS OBTAINED WITH THE STRATIFICATION/RE-DRY METHOD ON TRUE FIR SEEDS

A. The effect of re-drying with further storage/stratification

Briefly, the stratification-redry technique involves partial-redrying of seeds that have already been stratified, then continuing their stratification at a reduced moisture content. This second period of stratitication is often referred to-and will be referred to here-as "storage" for simplicity, although it actually is a continuation of stratification.

Grand fir *(Abies grandis)*

When seeds of grand fir were stratitied in a fully-imbibed state for 4 weeks at 2°C, then removed from the refrigerator and dried to three new moisture levels, and stored in the same refrigerator for a further 12 weeks (that is, their stratification was continued for another 12 weeks, but at reduced moisture contents), they germinated in the laboratory as shown in Figure 1.

[1]*Edwards, D.G. W. 1996. The Stratification-Redry Technique with Special Reference to True Fir Seeds. In: Landis, T. D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Depattment of Agriculture, Forest Service, Pacific Northwest Research Station: 172-182.*

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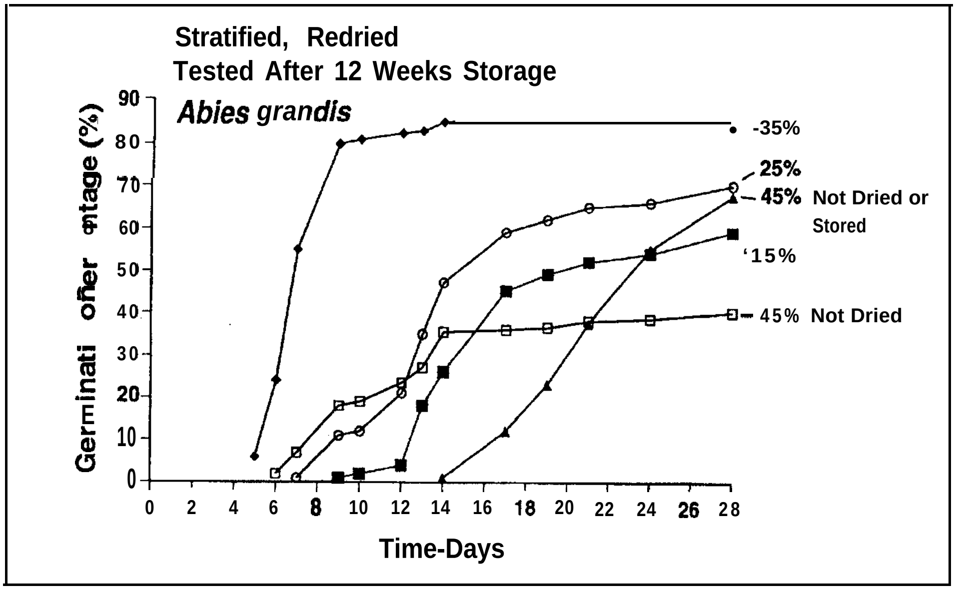

Figure 1. Cumulative germination in stratified grand fir seeds following redrying to four moisture contents and storage for 12 weeks at 2°C.

The results showed that:

a) Seeds dried to 35% moisture content

i) began germinating earlier than seeds at any of the other moisture levels,

ii) germinated most rapidly, reaching 80% less than a week later, and

iii) maximum germination, 85%, was achieved within 2 weeks. Whereas 15% of these seeds did not germinate, over 94% of al1 the seeds that did germinate after receiving this combination of treatments had done so within 9 days of being placed in the germinator.

b) Seeds dried to 25% and 15% moisture contents germinated better than seeds that were not dried at all.

c) Seeds not dried from their original 45% moisture content, but that were stored for the additional 12 weeks (i.e. stratified 16 weeks at the full moisture content) began germinating quickly, but had the lowest (40%) germination overall. This was almost entirely attributable to seed deterioration due to microbial activity during the long stratification.

d) As a control, a fifth sample of seeds that had been routinely stratified for 4 weeks with no drying or storage, that is, tested immediately (curve labeled "Not Dried Or Stored") did not begin germinating until day 14, but reached almost 68%, third best overall, by the end of the test.

All the seeds referred to in a, b, c and d were germinated simultaneously, in the same germinator; that is, stratification of the last-mentioned control sample of seeds began when the other samples had been in storage in the refrigerator (at their adjusted moisture contents) for 8 weeks.

B. The effect of re-drying without additional storage

It is important to distinguish the effect of drying from the effect of additional storage. To do this, samples of the seeds described above were tested for germination immediately after drying without any additional storage (Figure 2).

These results showed that:

a) drying the seeds to between 15% and 35% had an immediate, major impact on germination speed, but had little effect on final germination capacity.

b) dried seeds germinated 5-6% higher than routinely stratified (not dried) seeds by the mid-point of the test, although the differences in final germination capacity were not so large. Thus, drying alone greatly increased germination speed.

c) Comparing Drying Alone with Drying Plus Storage:

When the germination of seeds that had been dried, but not stored (Figure 2), was compared with the germination of seeds that had been dried and stored for an additional 12 weeks (Figure 1), the difference was mostly on germination speed, although germination capacity (completeness of germination) was increased also. While drying induced some increase in germination, a much larger increase was obtained after the dried seeds had been stored.

d. Comparing the Two Control Samples

The control seeds that were routinely stratified without drying or storing (Figure 1, "Not Dried or Stored"), and that were tested at the same time as those that had been dried and stored (also Figure 1), germinated almost the same as those routinely stratified seeds (Figure 2, "Not Dried) that were tested alongside seeds that were dried, but which were tested immediately without storage (also Figure 2). Whereas the first control seeds were tested three months later than the second, there was only a 4% difference at the mid-point of the test, and a 6% difference at the conclusion. This level of variation was well within expected experimental error, and the shape of the two germination curves were almost identical, indicating that the results were repeatable.

CONCLUSIONS

Three main conclusions were drawn from these data:

i) drying grand fir seeds to between 15% and 35% moisture content (a relatively wide window) immediately after routine stratification and before they are sown, increased germination speed.

ii) drying stratified grand fir seeds to 35% moisture content, and continuing their stratification at this moisture level in the same refrigerator for another 12 weeks, produced the earliest germinants, yielded 80% germination in 8 days, and complete germination was obtained in 14 days.

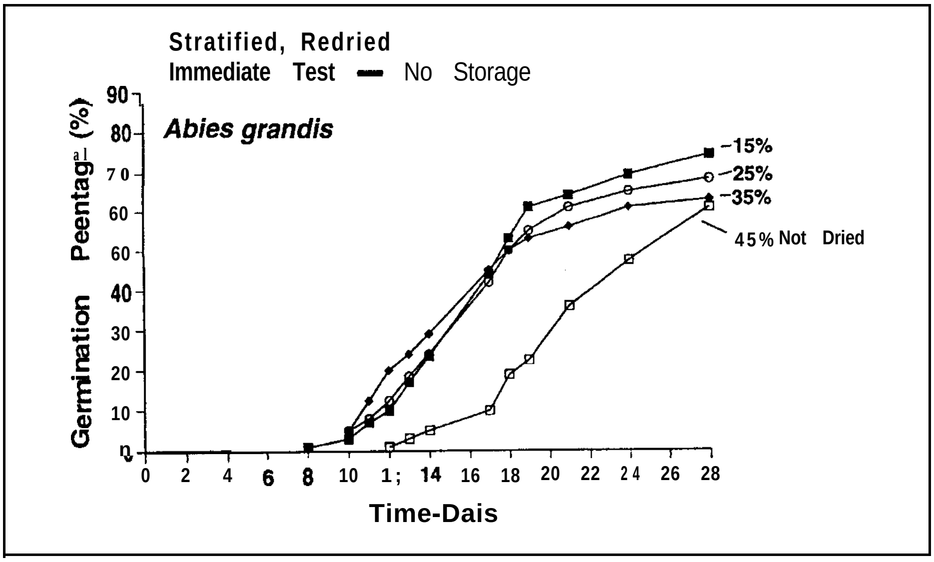

Figure 2. Cumulative germination in stratified grand fir seeds following redrying to four moisture contents-no storage, tested immediately after drying.

iii) prolonging the stratification of grand fir seeds without drying them was detrimental to their quality.

RESULTS WITH OTHER TRUE FIR SPECIES

While the tests described above were being run, other work was carried out on seeds of Pacific silver fir (also known as amabilis fir), and subalpine fir. Al1 of this research has been published (see "Suggested Reading" at the end of this paper), so only a summary is included here.

Pacific silver fir (*Abies amabilis*)

When Pacific silver fir seeds were dried to 35% moisture content and stored for 2, 4 and 12 weeks, germination speed increased to 43.7%, 50.7% and 57.3% respectively, representing increases of 6.5, 7.6 and 8.6 times respectively, over the control. For these same storage periods, germination capacity increased from 37% in routinely stratified seeds (no drying or storage) to 65.7%, 65.3% and 61.3%, respectively, representing increases of approximately 1.7 times over the control. The best overa11 germination was obtained after 3 months' storage at 35% moisture content when almost 94% of al1 the seeds that would germinate had done so within the first two weeks of the test. This demonstrated again that, even though germination capacity was increased, the effects were largely on germination speed.

Subalpine fir (*Abies lasiocarpa*)

Routinely stratified seeds (not dried or stored) germinated 10.0% after 14 days and 15.5% after 28 days. When stratified subalpine fir seeds were dried to 35% moisture content and stored for an additional 12 weeks, germination after 14 days reached 69.0%, and after 28 days reached 69.5%, that is germination was almost complete within two weeks. When seeds at 35% moisture content were stored for 6 months germination was complete at 14 days, reaching 73.5%; no more germination occurred during the second part of the test. These finding emphasized, again, that the main effect was on germination speed. Longer storage times were tested, but they did not produce further increases in germination.

RESULTS FROM OTHER TESTS INCLUDING OPERATIONALNURSERYTRIALS

To find out if drying stratified true fir seeds to 35% moisture content, and then storing them for 3 months, would consistently improve germination, the treatment combination was applied to 30 seedlots of Pacific silver (amabilis) fir. Without fail, al1 lots germinated faster and more completely than routinely stratified controls (not dried or stored). The increases in final germination ranged from 5% to 45%, and actual germination exceeded 80% in 14 lots, and was 90% or higher in 3 lots. In al1 30 lots, germination speed was consistently increased.

The method was applied to over 50 lots more of al1 three species, grand fir, subalpine fir and Pacific silver fir, as well some noble fir lots, with similar results.

When noble fir seeds from four Washington State seed zones were stratified for 4 weeks, dried to 25% and 35%, and then stored in a refrigerator for an additional 12 weeks, in the laboratory they out-germinated the non-dried controls both in terms of speed and completeness. At 35% moisture it was estimated that storage could be extended to 24 weeks after the original stratification, without affecting seed quality. This would be useful in accommodating any delay in sowing.

From nursery tests on the same seedlots, it was estimated that because of improved nursery-bed emergence, plantable seedling yields were increased by 10%- 19% over conventional stratification. Some of the lots showed premature germination in the refrigerator when they were stored for 3 months at 35%, so it was recommended that, for operational purposes, seeds should be redried to around 30% moisture content, which would reduce the tendency for pre-germination without sacrificing any of the beneficial effects on speed of germination and completeness of germination.

In another independent nursery trial on noble fir, a 30-day stratification followed by drying and another 30-day storage gave better results than stratification alone, or longer storage after drying. More than 90% of the seeds that would germinate had done so within the first 2 weeks, and final germination was doubled over the controls.

Nursery tests in British Columbia revealed that the method did not work well on seeds that had been collected early (latter part of August) in the cone-crop season. It was conjectured that these seedlots may not have been mature and, therefore, they were not as dormant. This was based on the relationship observed between seed maturation and dormancy in noble fir, specitically that dormancy increased as the seeds matured. It has long been known that mature seeds (of most tree species) usually fail to respond to stratification; in fact, stratifying immature seeds often reduces germination instead of increasing it. Also, immature seeds often decrease in viability if they are placed in dry, cold storage, and any subsequent stratification may have an adverse effect.

2. HOW TO USE THE STRATIFICATION RE-DRY METHOD

A. The Difference Between Stratification/ Re-Dry and Routine Stratification

The stratification/re-dry method differs from traditional stratification as shown diagramatically in Figure 3.

The upper part of this diagram depicts traditional stratification. In this seeds are:

a) soaked in water for 24-48 hours at room temperature, then

b) drained, and

c) chilled at 2°C for 4-8 weeks in their "fully imbibed state" seeds this means that their moisture content is around 45-55% fresh, until

d) they are sown in the nursery.

The lower part of Figure 3 shows the stratification-redry method. In this seeds are:

a) soaked for up to 48 hours at room temperature (as in the old method),

b) drained (as in the old method), then

c) chilled for 4 weeks while fully imbibed (as in the old method). After 4 weeks of chilling, the stratified seeds are removed from the refrigerator and

d) dried until their moisture content is 30-35%, then

e) returned to the refrigerator for an additional 4- 12 weeks, until f) they are sown in the nursery.

The two methods are identical through steps a), b) and c), but the newer method adds two more steps, d) and e), before the seeds are sown.

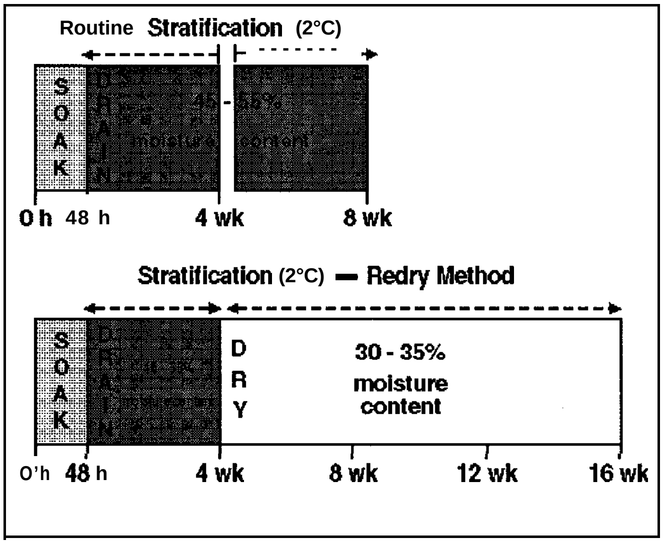

Figure 3. Schematic contrast between the traditional method of stratification (upper) and the new stratification/re-dry method (lower).

B. How the Stratification/Re-Dry Method 1s Applied

STEP 1. Soak the seeds in tap water for 48 hours. "2 days" is sufficient, but some consistency should be applied. If the seeds are put in water around mid-day, and removed first thing in the morning two days later, this will be adequate, but the operator should aim to follow the same process with each subsequent seedlot. This moisture is required to re-hydrate seed tissues that may have been dried to a moisture content of below 10% for cold-storage, and allows the biochemical changes to begin that correspond with a removal of seed dormancy. Hydrated seeds respire, even under water, so good aeration is required.

STEP 2. Remove the seeds from the soak water and drain them thoroughly, but do not permit them to dry out other than a slight surface drying, at this stage.

STEP 3a. Place the hydrated seeds into the container-plastic bag or whatever—in which they are to be chilled. Al1 containers should be large enough that a volume of air severa1 times the volume of the seeds is enclosed. Bags may be suspended in the refrigerator, and the bottoms punctured so that free water can escape. Bags are often loosely tied, or a "breather" tube is placed in the neck, so that there is a channel for air exchange, but not so much that the seeds are going to lose moisture.

Hydrated seeds respire, even at chilling temperatures, so good aeration is required:

(a) to prevent carbon dioxide build up,

(b) to ensure they are adequately supplied with oxygen, as well as

(c) to minimize heat accumulation from respiration. Some operators also lightly "massage" the bags once or twice each week to move the seeds around so that conditions within the seed mass stay as uniform as possible.

STEP 3b. Stratify the seeds. Place the seeds in a refrigerator so that they achieve and maintain a temperature of between 1 ° and 3°C. This temperature, often stated as 2°C, is critica1 as it favors the biochemical changes and morphological developments that lead to rapid and complete germination when the seeds are sown. Low temperature also reduces decay caused by microorganisms. Many manuals prescribe 5°C, but if the refrigeration unit is used for other purposes, and it is opened frequently, seed temperatures many not remain as low as 5° for the ful1 duration. It has been shown that:

a) temperatures above 5°C are far less effective for stratifying tree seeds, and

b) any less-dormant seeds in the bag are likely to chit (begin germinating) at the higher temperatures, rendering them useless for sowing.

In the wild, the seeds of some coniferous species, including the true firs, are known to germinate in melting snowbanks. Freezing and subfreezing temperatures are not effective in stratification either.

STEP 3c. Stratify the seeds for 4 weeks. This usually means 28 days, or 4 working weeks, but 30 days (1 month) can be tolerated. Longer periods simply delay the next steps, and it is these steps that bring about the improvements in germination.

STEP 4a. Dry the stratified seeds. Remove the chilled seeds from the refrigerator, and adjust their moisture content to 30-35%.

Initial water uptake is regulated only by the time of soaking, and may reach levels of between 45% and 60%, depending on the species and the seedlot, by the time the seeds are placed into the refrigerator. This moisture leve1 must now be reduced to between 30% and 35% of the fresh weight of the seeds.

The procedure for this, which is the most critica1 step in the entire process, is expressed in Table 1. Although complicated looking, it relies on the simple process of monitoring the weight of the stratified seeds as they dry out.

Table 1. Oven-Drying Procedure

1. a) Take 8-10 samples (more if there is time) of 50 seeds each.
   b) Oven dry (24 hours at 103-105°C) to constant weight.
   c) Cool in a dessicator (minimum 45 minutes to 1 hour).
   d) Weigh.

2. Calculate the average dry weight for 50 seeds.

3. a) Use the average dry weight (item 2) to calculate the new fresh weight at the specified target moisture content (M.C.%) applying the following formulae.

   b) **Formula 1:** Since $\text{M.C.\%} = \dfrac{\text{Fresh weight (FW)} - \text{Dry weight (DW)}}{\text{Fresh weight (FW)}} \times 100$

   c) **Formula 2:** Then the $\text{New FW} = \dfrac{\text{Average DW (from step 2)} \times 100}{100 - \text{the specified target M.C.\%}}$

4. a) For example, suppose original FW = 50g, and DW = 40g. The original M.C.% would be calculated as follows:

$$\text{M.C.\%} = \frac{50-40}{50} \times 100 = \frac{10}{50} \times 100 = 20 \text{ (Formula 1)}$$

   b) So the original moisture content was 20%.
   c) What must the FW be for M.C.% = 15 ?

$$\text{New FW} = \frac{40 \times 100}{100-15} = \frac{4000}{85} = 47.1 \text{ (Formula 2)}$$

   d) Thus, the new FW must be 47.1 g. That is, the sample must be dried from its original fresh weight of 50g to 47.1 g.
   e) As a check, use new FW in Formula 1 and calculate the M.C.%, thus:

$$\text{M.C.\%} = \frac{FW-DW}{FW} \times 100 = \frac{47.1 - 40}{47.1} \times 100 = \mathbf{15.07\%}$$

Thus, the actual new moisture content is 15.07%, which is close enough.

5. a) After stratification, air-dry the seeds uniformly, turning them frequently.
   b) Take five or six 50-seed samples to monitor drying. More samples would improve accuracy, but the work must be done quickly and five or six will suffice.
   c) Weigh these samples, and turn main seed mass, every 30 minutes to begin with, then more often as the target moisture content is approached.
   d) The SAME 50-seed samples must be weighed each time, so having weighed the samples once, they must be put back beside the main mass of seeds so that they are subjected to the same drying environment, and so that they can be identified for the next weighing, but they must NOT BE MIXED with the main seed mass.
   e) After each weighing, calculate the average FW for the five (or six) samples.
   f) When the average FW for the five or six samples equals the calculated new FW, stop weighing and quickly re-bag the entire seed mass, including the samples.

6. Re-bag the seeds using dry plastic bags and return to the refrigerator in which the seeds had been originally stratified (2°C).

7. Store the redried seeds in the refrigerator for the specified period, then sow.

weigh. If a dessicator is not used, the hot, dry seeds will absorb moisture from the surrounding air and the resulting "dry weight" will be incorrect.

b) Obtaining the DW expression for use in the stratification/redry method. For the stratification/redry method to work, an expression of the average dry weight (DW) of 50 seeds is needed. At least 10 samples of 50 seeds each are oven-dried as described in Table 1, to provide an expression of the average dry weight of 50 seeds. This can be done while the main seed mass is being stratified, using fresh samples drawn from the original seed container or, if the entire seedlot is to be sown, samples set aside for this purpose. When the seeds have been dried (24 hours), they must be cooled and weighed; then the weights are totaled and divided by 10 to provide an expression of the average weight of 50 seeds of that seedlot.

c) Determining moisture content (optional). If the samples are weighed before being oven dried, their average moisture content can be determined, but this is not essential to the redrying procedure. For each sample, moisture content (M.C.%), the difference between the FW and DW expressed as a percentage of the original FW, is calculated as shown in Formula 1 (Table 1). Sample moisture contents are averaged for the seedlot.

2. How to adjust the moisture content to 30-35%

When the average dry weight of 50 seeds has been obtained, the average fresh weight of 50 seeds at a moisture content of 30-35% can be calculated using Formula 2 (Table 1). In Formula 2, which is simply Formula 1 transposed, the average dry weight of 50 seeds is entered, as is the specified moisture content, 30% to 35%. Since this is a range of moisture content two calculations are required, one for the new fresh weight of 50 seeds at 30%, and a second for 35% moisture.

An example of how this works is given in items 4a-e. Samples of stratified seeds have been weighed and the average fresh weight (FW) is 50 g. After drying, the average dry weight (DW) was 40g. Using Formula 1, the moisture content was 20%. What will be the fresh weight if the moisture content is adjusted to 15%? Using Formula 2 it can be calculated that when the fresh weight of a 50-seed sample is reduced to 47. lg, the moisture content will be 15%.

As a check, (item 4e), the new fresh weight (47.1 g) is entered into Formula 1, along with the average dry weight expression (40g). This gives a moisture content of 15.07% which is well within the tolerances required by the overa11 procedure.

Thus, the redrying procedure depends on monitoring the changes in fresh weight (FW) of the stratified seeds after they have been removed from the refrigerator. Samples similar to those used to obtain the average dry weight (DW) are used to monitor the change in fresh weight (FW). No oven-drying is needed.

3. The drying operation

To dry the stratified seeds to their new moisture content, they must be spread out in a single-seed layer, preferably on an absorbent material. Newspaper works well for this, as well as making seed handling relatively easy when rebagging. Five to six samples of 50 seeds, at random spots among the spread seeds, are counted out. These samples must be clearly delineated from the seed mass, but kept within the seed mass.

The samples are repeatedly weighed until the average of their fresh weights reaches the calculated target fresh weight. <u>The same samnles of 50 seeds must be weiahed each time,</u> and they must not be mixed into the main seed mass until the drying step is complete. Provided all the seeds, the samples as well as the seed mass, have been dried uniformly, when the average fresh weight of the samples reaches the calculated fresh weight for a moisture content of 3 5%, preparations should be in hand to rebag the seeds. However, drying can be allowed to continue until the new fresh weight approaches that calculated for a moisture content of 30%. Just before the fresh weight for 30% is reached, al1 the seeds can be placed in a fresh, dry bag (or bags), and returned to the refrigerator.

Frequent stirring of the seed mass is essential to promote uniform drying; the samples will be adequately "stirred" when they are weighed. Weighings should be repeated every 30 minutes or so to begin with, then, as the target moisture content is approached, at shorter intervals. This is the main reason for using only five or six samples at this stage; the final weighings must be done quickly, more samples might take too much time, and the operator may overshoot the target moisture content.

A range of two moisture contents, corresponding with two fresh weights, is used because i) uniform drying of the main seed mass is difticult and, unless the seeds are truly spread in a single-seed layer and adequately stirred, some may not dry as well as others. Thus, ii) some seeds may still be above 35% when they are bagged, and the le.&-dormant ones may chit before they can be sown. Especially for large lots, it is recommended that the seeds should be rebagged when the moisture content of the monitor samples is lower than 35%, but above 30%. Based on experience with noble fir seeds, even at 30% the effect on germination speed and completeness will not be seriously compromised. In other words, if an error is made, it is safer to err on the side of dryness than on the side or wetness.

The time to dry the seedlot to a moisture content of 30-35% depends on how wet the seeds are to begin with, what the ambient conditions—air temperature and humidity are during drying and, to a certain extent, how frequently the seeds are stirred. A warm room can be used, especially if outside conditions are cold and moist, but the seeds should not be oven-dried. A circulating fan blowing air across the seeds greatly speeds up the drying process. Under favorable conditions, seeds will reach their new moisture leve1 within 3-4 hours.

To verify that the moisture content achieved is the correct one, at least 4 small samples (about the same size as 50 seeds, but not necessarily counted out), should be removed and quickly weighed to get fresh weights, then dried for 24 hours at 103-105°C, cooled in a dessicator, and re-weighed. The average fresh and dry weights for these samples are then used in Formula 1 to determine the real moisture content. Experimentally, it was found that the method described above gave target moisture levels within +2.5%, which is accurate enough for operational needs.

It must be emphasized that when stratified seeds are to be dried as part of the procedure described here, they are done so at ambient air temperatures, that is, at a room temperature no higher than 23-25°C, or even at externa1 air temperatures that are typically below 20°C. At no times are the seeds dried at elevated temperatures, that is, in an oven; oven-drying is used only when moisture contents are to determined. Throughout the method, moisture contents are expressed as a percentage of the fresh, or starting, weight of the sample. Fresh weight moisture content is the international protocol for expressing seed moisture contents, and it differs from the more-accepted scientific protocol of expressing moisture contents on the dry, or final, weight of the samples. Thus, if the labe1 on a 1 OO kg bag of seeds declares that the moisture content is 6.7%, the prospective buyer knows immediately that there are 6.7 kg of water in the seed mass. If the moisture content was expressed "scientifically", in this example it would be 7.2%, which is less easily calculated.

3. USE OF THE STRATIFICATION/REDRY METHOD ON SEEDS OF OTHER SPECIES

The stratification/redry method was tested in the laboratory on a small scale on seeds of five other coniferous species, western hemlock, white spruce, lodgepole pine, Douglas-fir and Sitka spruce. Al1 the seeds were routinely stratified for 4 weeks. They were then redried to four moisture levels, including no drying (the normal moisture content at the end of stratification); for western hemlock, lodgepole pine, and Sitka spruce, the new moisture levels were 25%, 20% and 15%, for Douglas-fir 35%, 25% and 15% were tested, while for white spruce 30%, 22.5% and 15% were compared.

a). Western hemlock (*Tsuga heterophylla).* Germination capacity tended to decrease in dried seeds, especially with longer storage, but no statistically significant effects were found. Germination speed was significantly reduced at 15% moisture content following 2 or more weeks of storage. Germination speed was significantly increased in seeds stored for an extra 4 weeks without any redrying, that is, a total of 8 weeks of stratification, confirming earlier research on stratifying this species.

b). Lodgepole pine (*Pinus contorta*). Germination speed was significantly increased when seeds were stored for 2 to 12 weeks without redrying (extended stratification). Fastest germination occurred in seeds stored at 25% moisture content for 12 weeks. Germination speed was significantly reduced in seeds dried to 15% moisture content and stored for 2 or 4 weeks. Germination capacity was not affected.

c). Sitka spruce (*Picea sitchensis*). Germination speed was significantly increased in seeds stored for 12 weeks either without drying (extended stratification) or after drying to 25% moisture content. Germination capacity was not affected. Germination speed tended to be reduced in seeds dried to 15% moisture content and stored, but a significant decrease occurred only after storage for 12 weeks.

d). Douglas-fir (*Pseudotsuga menziessii).* Germination capacity in a high quality seed]ot (96.5% germination after routine stratification) was unaffected by drying and storage, but redrying, even to 15%, increased germination speed. Fastest germination speed occurred in seeds stored at 35% moisture content for 3 months.

e). White spruce (*Picea glauca).* Germination capacity and germination speed decreased in seeds stored without redrying, although the effect only became statistically significant for seeds stored for 3 months. Germination speed was significantly increased in seeds redried to 30% and 22.5% moisture contents and stored for 3 months. Germination was slower in seeds stored at 15% moisture content.

These results suggest that the stratification/redry procedure may not be a panacea for al1 species, but the moisture levels tested probably were not the ideal ones for these species. However, statistically significant gains in germination speed were obtained in Douglas-fir, the two spruces and lodgepole pine. The seedlots used were already of relatively-high quality (over 80% germination capacity), so not much improvement in germination capacity could have been expected. The results showed that any leve1 of drying, even without further storage, was detrimental to western hemlock.

4. HOW DOES THE STRATIFICATION/REDRY METHOD WORK?

The increases in germination speed are brought about mainly by a synchronization of the germination of individual seeds. Less-dormant seeds that are predisposed to germinate rapidly are prevented from doing so by the moisture stress imposed at the reduced moisture content, a moisture stress that is not so great as to prevent the occurrence of the processes that accompany dormancy removal. This phenomenon is similar to the so-called "priming" and "conditioning" effects that have been reported when seeds were treated with osmotic solutions such as polyethylene glycol (PEG).

By returning the seeds to cold storage after redrying, the more dormant seeds are allowed to "catch up" in terms of dormancy removal, and at the reduced moisture content it appears that dormancy removal may be more complete. When the seeds are freed from the moisture stress by being given a free water supply in a favorable environment (when they are sown), al1 the seeds that can germinate do so synchronously. This is believed to be the reason why, for stratified grand fir seeds redried to 35% moisture content and stored for 12 weeks (Fig. 1), the germination curve was so steep during the first 10- 12 days, after which it abruptly leveled off. The seeds that did not germinate were dead.

The benefits of controlling seed moisture contents during stratification have not been confined to coniferous seeds. Research on ash (*Fraxinus*) and beech (*Fagus*) seeds has found similar responses. In France, it was shown that freshly-collected beech nuts can be stratified at 30% moisture content, then air-dried to 8% moisture and stored at below freezing temperatures for at least 3.5 years. When re-hydrated, germination in this species is complete and rapid. The initial moisture leve1 for stratification is the same moisture leve1 that works with true fir seeds. This evidence suggests that the phenomenon may be found in a wider variety of tree seeds.

Interest in the stratification/redry method has been shown in Europe, especially in Denmark where there is a large Christmas tree industry based on sowing Nordmann fir (*Abies nordmanniana*) seeds. The Forest Tree Seed Committee of the International Seed Testing Association is studying the introduction of the method into the International Rules for Testing Seeds. Thus it appears that the method is widely recognized, especially wherever true fir regeneration stock is grown.

Moisture management in forest tree seeds may not be a universal solution to complete removal of dormancy in al1 species, but it appears to have a broadly-based relevance that was largely overlooked until about 15 years ago. More research is needed to determine how other species, coniferous and broadleaved, can benefit from this approach, and to refine the techniques for full-scale, practica1 application. This will involve testing various moisture levels on numerous seedlots within al1 species of interest. The moisture content "window" that is effective for true fir seeds is quite narrow, and its achievement is based on closely following the experimental procedure that has been described. A similar approach should be taken when studying other species so that the optimum moisture content can be accurately pin-pointed.

Even though it was not found to work with true fir seeds. one approach that should be investigated is to control the amount of water that the seeds are initially allowed to absorb. Experiments on grand fir and Pacific silver fir curtailed the initial water uptake when seed moisture content had reached 35%. The seeds were then stratified for 1, 2, 3 and 4 months and then tested. Germination never reached the leve1 of routinely stratified seeds suggesting that the initial moisture content had to be above 35% for the initiation of stratification to be effective.

The reason for this is not known, but it may be connected to the pattern of moisture distribution within the seed tissues. Hydrating true fir seeds to 35% takes less time than to ful1 imbibition (45+ %) and, at the time hydration is terminated and the seeds are placed in the refrigerator, the moisture taken up is localized in the seedcoat and outer portion of the megagametophyte (endosperm). Even after soaking the seeds for 48 hours the embryo will not be fully hydrated. In the refrigerator, translocation of moisture to the embryo will proceed at a much slower pace (than at higher temperature) and it maybe that, when hydrated to 35%, there simply was insufficient moisture for the changes to occur that accompany dormancy removal. However, seeds of other coniferous species, and those of broadleaved trees, may behave differently.

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Upgrading Seeds With IDS: A Review of Successes and Failures[1]

Robert P. Karrfalt[2]

INTRODUCTION

The IDS procedure has become widely known and discussed among nursery managers. It is reported to have potential to upgrade seed lots to high quality levels. This is especially attractive to container growers who desire to single sow seeds to save seeds and labor. This paper reviews some of the literature and reports on trials made at the National Tree Seed Laboratory to help nursery managers determine if the procedure has potential to assist them in their operations.

BACKGROUND

Incubate-Dry-Separate, or IDS, is a fluid separation technique that exploits the principie that dead seeds take up and lose water faster than viable seeds do. Figure 1 is a graph adapted from Downie and Wang (1992) that shows how living and dead seeds of white spruce (*Picea glauca* [Moench] Voss) dry at differential rates. The best separations on weight and specific gravity are possible when the moisture content difference is the greatest. Both live and dead seed start at the same place and dry to the same moisture content but in between there is a point when they are very different. In this data, the maximum weight difference was observed between 5 and 20 hours. This would be the point when a weight separation could be most effected. The steps in this procedure are to imbibe or incubate the seed to ful1 imbibition, rapidly dry it and then separate it by floatation in water or other suitable fluid. The technique was developed by Simak (1984) in Sweden.

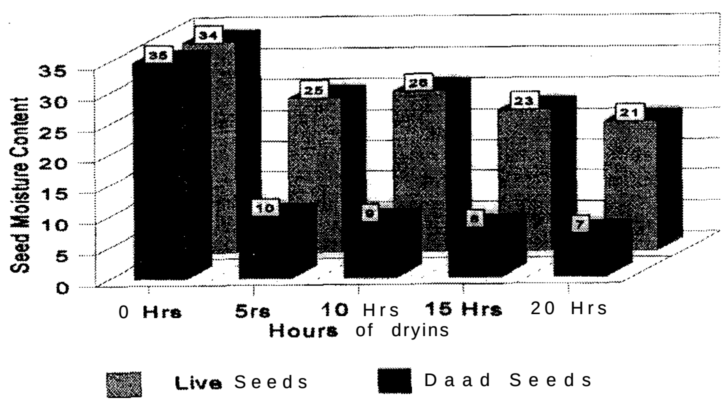

Figure 1. The moisture content of live and killed seeds dried in relative humidity of 50%.

[1]Karrfalt, R. P. 1996. Upgrading Seeds With IDS: A Review of Successes and Failures. In: Landis, T.D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 183-186.

[2]National Tree Seed Laboratory, USDA Forest Service, Dry Branch, GA; Fax: 912/751-3554.

LITERATURE REPORTS

Is a species a candidate for IDS? Will it work? The literature lists severa1 species on which the procedure has been tried. Some have been successful, others not, and still others the results are mixed. Species that have been improved include lodgepole pine (*Pinus contorta* Dougl.) (Simak 1984) (Downie and Wang 1992), Scots pine (*Pinus sylvestris* L) and Norway spruce (*Picea abies* (L) Karst.) (Bergsten 1993), jack pine (*Pinus banksiana* Lamb) (Downie and Wang 1992), *Pinus roxburghii* (Vozzo 1990) and Douglas fir (*Pseudotsuga menziessii* Mirb.) (Sweeney et al. 199 1). Attempts to improve eastern white pine (*Pinus strobus* L.) (Downie and Bergsten 1991) and western white pine (*Pinus monticola* Dougl.) (Kolotelo 1993) have not given satisfactory results. Downie and Bergsten (199 1) found white spruce to be improved by the procedure but Downie and Wang (1992) got disappointing results with this species.

IDS TRIALS AT THE NTSL

Experience with the procedure at the National Tree Seed Laboratory is mixed. A lot of Scots pine was successfully upgraded from 43% germination to 85% by removing dead filled seeds. One lot of *Acer grisium* was improved from about 40% filled seed to over 80% filled seed by removing the empties. Empties could not be removed with air separaters or the specific gravity table. This was probably due to the very thick seed coat and the light weight of the embryo. A combination that made the filled and empty seeds weigh about the same. Following an overnight water soak, the embryo became heavy enough to create a specific gravity difference with timed drying. The empty seeds could be floated off and the filled seeds sank. An attempt to remove fungus damaged seeds from slash pine (*Pinus elliottii* var. *elliottii* Engelm.) seed lots failed completely. Table 1 shows the germination of the sinking and floating fractions from 5 white spruce and 2 Sitka spruce (*Picea sitchensis* (Bong.) Carr.) seed lots. Although the germination of the sinking seeds was always higher than the floating seeds, the results were not totally satisfactory. This was because the objective was to improve the seed to the point where it could be single sown in containers, and only the one lot of Sitka spruce approached this quality. Additionally, the germination of the sinking seeds was often too high to discard. One lot of ponderosa pine (*Pinus ponderosa var scopulorum* Engelm.) with many immature seeds was separated also with mixed success. The seeds were judged to be immature by radiographs because the gametophyte tissue did not fill the seed coat. In the overnight water soak, a fraction never sank and this is was expected to be the poorest. However, the germination of this fraction was actually the very best (table 2.). The floating and the sinking seed from the completed IDS procedure germinated the same without stratification, but the sinking seed did better after stratification, 68% versus 56%. However, both germinations would not be acceptable in most nurseries for efficient seedling production. The fact that the sinking seeds did do better, however, was an indication that the stronger seeds were segregated into the sinking fraction, just not as completely as desired. An average weight of seedlings at 10 days also showed that the more vigorous seeds were found in the sinking portion of the IDS separation. The seedlings from the sinking fraction in the stratified germination test were the

Table 1. Germination after 14 day prechill of Alaskan spruce after IDS.

Species	Lot number	Floatina seed	Sinkina Seeds
White spruce	1	69	86
	2	33	89
	3	76	88
	4	58	79
	5	79	91
Sitka spruce	1	72	96
	2	34	88

Table 2. Germination of one lot of ponderosa pine after IDS.

Fraction	Unstratified	Stratified
Original lot	90	68
Floaters from overnight soak	94	89
IDS sinking seeds	80	68
IDS floating seeds	81	56

heaviest and were 12% heavier than the seedlings from the floating fraction. Compared to the seeds that never sank during the imbibition step, this most vigorous fraction had seedlings almost 17% heavier (Table 3). It should also be noted that stratification also gave heavier seedlings with al1 fractions of the seed lot. Although the stratification stressed and killed many weak seeds, those that remained were invigorated.

Table 3. Weight in grams of 1 0-day old ponderosa pine seedlings from seed treated with IDS.

Fraction	Unstratified	Stratified
Original lot	0.22	
Floaters from overnight soak	0.20	0.24
IDS sinking seeds	0.23	0.28
IDS floatina seeds	0.21	0.25

VARIATIONS ON THE TECHNIQUE

The basic criterion for a species to qualify for improvement with IDS are that the seeds need to float in the seperation fluid (usually water) when dry and sink when fully imbibed. If this condition cannot be met, then the seperation fluid needs to be modified or replaced for IDS to work with that species. For example, seeds with stoney seed coats will sink in water unless completely empty. Therefore, the separation of filled living seeds from filled dead seeds could not occurr with water. A more dense solution is needed. In the other direction a seed that is very bouyant and not able to sink in water would require using a solution that is less dense than water such as an organic solvent. Organic solvents would require quick and careful work as they can be harmful to the seed and the worker. A good example of a modified seperation fluid was reported by Vozzo (1990) where the best seperations of *Pinus* ***roxburghii*** were made with sucrose solutions of 1.04 specific gravity.

The imbibitional step has been done in different ways. Simak (1984) imbibed the seed on blotters at 15°C. Sweeney (199 1) soaked the seed in water overnight and then held it as for normal cold naked stratification at 15°C for 3 days. The trials at the NTSL al1 were done using the overnight water soak at ambient temperature or the naked stratification procedure at 3°C to imbibe the seed.

The relative humidity of the drying air is another factor that can be regulated to improve seperations. Downie and Wang (1992) used air at 50% relative humidity and got the same drying rate as with 20% relative humidity. In contrast, drying with air below 20% relative humidity can in some cases speed the drying process and accentuate the difference in the drying curves (Bergsten 1993).

The final step of separation can be done in a plain pale, in a column separator (Figure 2) or in a flume which is similar to a fractionating air aspirator (Figure 3). The pale and column separator give vertical separation while the flume gives both vertical and horizontal density gradients.

A detailed discussion of the variables in IDS separation are given by Bergsten (1993).

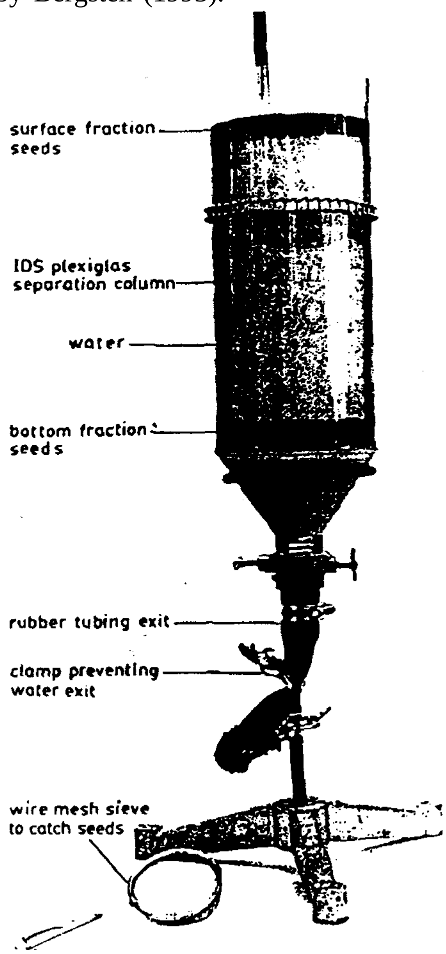

Figure 2. IDS column separator (Downie 1992).

SUMMARY

The incubation-dry-separate procedure has been used successfully to upgrade many species and is used operationally in Sweden on a large scale. It can be very technical and requires research on the specifics of the seeds to successfully use it.

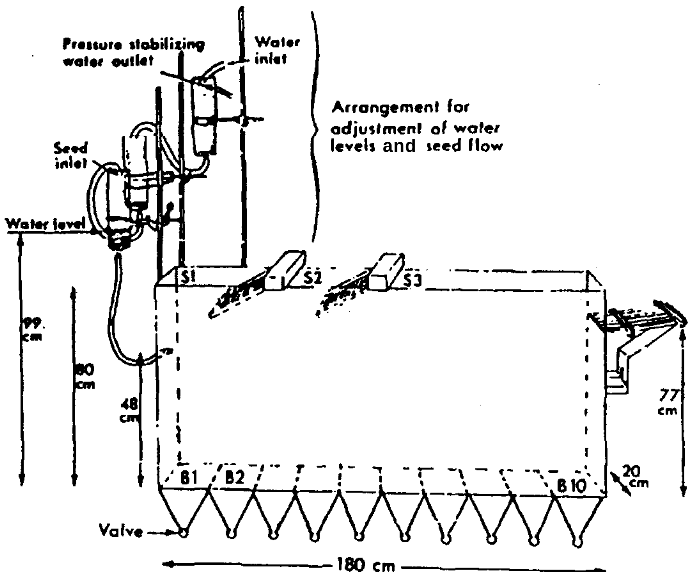

Figure 3. Sedimentation flume (Bergsten 1993).

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Seed Pathogens and Seed Treatments[1]

Will Littke[2]

INTRODUCTION

Every year, nursery growers prepare thousands of pounds of conifer seed for sowing in bare-root and container nurseries. The vigor and health of this seed is a strong determinant of the quality, uniformity and yield of the ensuing crop. To achieve the full potential from this seed and to minimize the loss from disease, growers need to be knowledgeable about seed pathogens. This is not to minimize the contribution that seed maturation leve1 and vigor play in seedling development, but rather as an insurance of quality throughout the nursery production chain.

Occasionally things can go wrong, resulting in unacceptable seedling looses from poor germination or pre-emergence or post-emergence disease. Numerous literature citations have identified seed borne fungal pathogens as the prime or contributing factor in these losses (Littke and Browning 1990). From experience, reactive response with fungicides increases production costs and often results in marginal disease control. Therefore an understanding of the origin and nature of the association of seedborne fungi with seed may be helpful in reducing losses and capturing gains in a nursery production setting.

OBJECTIVES

Today's discussion will try to capture some of our research experience on seed borne fungi. 1 would like to divide this subject into three areas:

1) Sources of seedborne inoculum

2) Pathogen detection methods

3) Seed treatments to control pathogen activity

ORIGINS OF SEEDBORNE INOCULUM:

Some 90+% of Weyerhaeuser Company seed for nursery use originates from seed orchards throughout Washington and Oregon. Littke and Browning (1990) reported that orchard seed can be associated with seed borne pathogens such as *Fusarium oxysporum* as well as other pathogens. We speculated that seed association with this pathogen, in particular, originated from aerial deposition on developing cones. From our work and the literature, we can deduce that three likely routes of subsequent seed contamination exist:

- physical transfer from exterior cone integument (bracts and scales) to seed coat surfaces during seed development, cone storage, and seed cleaning.
- cross contamination with "dirty" seedlots during cleaning, dewinging, imbibition, stratifícation, and sowing.
- contact with soil during storage or collection from squirrel caches.

This discussion will focus on the physical transfer model, since our evidence supports this as the prime

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[1]Littke, W. 1996. Seed Pathogens and Seed Treatments. In: Landis, T. D.; South, D. B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 187-191.

[2]Forest Nursery Pathologist, Weyerhaeuser Forestry Research, Centraba, WA.

origin of Fusarium in our system. Table 1 shows the seed developmental stage or processing step and our understanding of the associated disease phase. Using this model, we have attempted to understand opportunities for control of seedborne fungi through manipulation of cone processing stages. For example, in Figure 1 we examined the levels of Fusarium prior to cone opening and following extraction. Much of the Fusarium shown in Figure 1 from closed cones is thought to be a result of contamination rather than evidence for cone infection. The important fact from this data is that seed can become contaminated during seed processing.

We next experimented with ways to modify inoculum buildup during the cone storage phase. We placed one-bushel of cones in either a one- or two-bushel bag. In most cases, faster cone drying schedules reduced cone surface mold growth, which resulted in lower post-extraction Fusarium levels. Attempts to control cone mold using sterilants such as Clorox and have been tried unsuccessfully (Rediske and Shea 1965). Many opportunities remain in reducing seed contamination with fungal pathogens by changing cone and seed processing schedules. However, for the moment we will concentrate on detection and correction of seedborne "problems" where they exist.

Table 1. Physical transfer model to explain the possible associations with disease caused by seedborne fungi.

Seed Development or Process Step	Associated Disease Phase
• Deposition of airborne spores on cone flower and pollen flowers	*Contamination*
• Cone flower initiation/pollination	*Flower abortion*
• Seed development	*Seed abortion (?)*
• Mature cone at harvest (ground contact)	*Contamination*
• Mature cone in harvest bag	*Inoculum buildup*
• Ripening phase	*Seed gluing to scales*
* Cone drying and extraction	*Inoculum transfer*
• Cleaning and dewinging	*Cross-contamination*
* Freezer storage	*(too cold for activity)*
• Imbibition and stratification	*Contamination and seed-rot*
• Sowing	*Pre- and post-emergent mortality; soil inoculation*

Table 2. Methods for isolating seedborne fungi.

Method	Pathoaen Groups/ Benefits
* Broad Spectrum Agar Media (i.e. acidified PDA; 2%-malt agar; 1 %-bacto peptone; NaCl agar)	Non-specific fungal isolation
• Fusarium Agar Media (Komada's Media; Nash and Schnieders etc.)	Fusarium groups, seed rot fungi
• Blotter media (incubate seed on moist blotters with liquid base media; used with whole, crushed or frozen\thawed seed)	Various fungal pathogens
* Serological methods	ELISA for specific pathogens
* PCR technology	DNA specific probes for pathogens

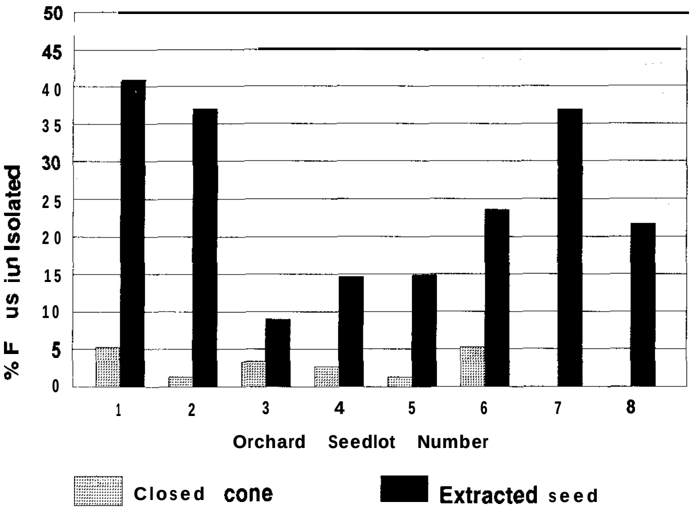


Figure 1. Levels of Fusarium prior to cone opening and after processing for Douglas-fir orchard seedlots.

PATHOGEN DETECTION METHODS

Much has been written concerning methods to detect seedborne fungi. For the purpose of this talk, 1 will restrict my comments to a broad generalization of seed assay methods. The main detection methodologies are shown in Table 2.

Seedborne fungi are routinely assayed in our research lab using the sampling protocol outlined below.

Seed Pathogen Assay Protocol:

1. Obtain 500 seed per seedlot to be tested.
2. 1 OO seed plated directly on to Komada's Fusarium media (10/petri dish)
3. 100 seed soaked in 3% hydrogen peroxide for 30-minutes, washed 3X with water and plated as in step 2.
4. Plated seed is incubated at 25C, illuminated for 7-10 days.
5. Retest seed if post-surface sterilization Fusarium level above 10%.
6. Additionally cut 1 OO seed and plate seed without seed coat.
7. Report findings to seed plant operations.

Determinations of seedborne Fusarium levels are based on the difference between recovery of the pathogen in steps 2 and 3. Typically, surface sterilization with peroxide removes greater than 90% of the surface fungi. High pathogen incidence following peroxide sterilization might be indicative of seed damage, poor handling, or other seed quality problems. However, we consider these test results along with a variety of other seed quality tests, including; purity, X-ray analysis, seed size, and standard germ tests at 20-30°C and 5- 15°C before making treatment recommendations. A common practice is to test seedlots with low germ (<90%) or with visible mold after stratification.

To date, our testing has confirmed that:

- potential seedling pathogens increase during cone storage and seed processing.
- Fusarium levels can vary by orchard source and year of collection.
- pathogenicity tests confirm some 60% of the Fusarium isolates from seed can cause disease
- some 90% of the inoculum resides outside of the seed coat, and higher interior infection levels are often indicative of seed coat damage.

Seed Treatments:

Our strategy for seed treatment consists of using various agents to remove, reduce, or block the number of pathogens below a disease threshold, while not decreasing seedlot vigor.

These treatments in order of increasing treatment efficacy are;

- soaking seed in running water baths
- using chlorine or bromine agents to sanitize seed
- surface sterilization using 3% hydrogen peroxide

Water Rinse Vs. Soak:

The rinse process involves either 24 hour soak in standing water during the imbibition phase, or to use up to 7 changes of water in a 24 hour period with air agitation to stir and mix the seed. Both methods provide the needed moisture to begin stratification. In general, rinse treatments lowered recovery of *Fusarium roseum, Cladosporium, Trichothecium,* and *Penicillium,* but not *Fusarium oxysporum.* In addition, we noticed some positive benefits from the rinse treatments in terms of better overa11 germination. A water rinse in itself does not appear to be sufficient to reduce levels of *Fusairum oxysporum.*

Seed Coat Sterilants

A 10% Chlorox seed treatment reduced pathogen levels significantly (Figure 2). Products such as Agribrom show similar efficacy to Chlorox when supplied as a 350 ppm bromine solution. Both agents effectively sanitize surface seedborne inoculum. Seed treatment with Chlorox or bromine for 1 O-30 minutes remove roughly ±50% of the surface inoculum. These treatments appear to be more effective against seed-rot fungi type of fungi (i.e. *Trichothecium, Cladosporium, Penicillium.* It must be cautioned that reduced germination vigor can occur with prolonged seed exposure to Chlorox or bromine agents.

Seed Fungicides:

A number of fungicides have been tested as seed coat treatments. The main treatment strategy has been to inactivate potential pathogens orto reduce their numbers below a disease threshold, while not decreasing seedlot vigor.

Thiram formulations for seed treatment, such as Thiram-75 WP and Scram-42S have been tested across a wide range of conifer species. Typical seed treatments rates consist of 16 oz/1 OO lb of seed, plus Dow Latex Sticker (DL-241NA). Three experimental uses of Thiram to control seedborne fungi will be briefly discussed.

Figure 3 shows the reisolation of Fusarium after treating Douglas-fir or ponderosa pine seed with sticker agent, peroxide, Thiram or Thiram+Sticker. These results clearly illustrate that Thiram is an effective fungicide against Fusarium. Similarly, Thiram, used as a seed coat treatment in non-fumigated soil can reduce post emergent mortality especially when combined with a pre-plant Subdue or post-emergent Banrot treatment. However, in Figure 4, we were able to detect some post treatment negative effects of Thiram (Arasan) on Douglas-fir seed germination performance. Germination was delayed with seed treatment, but total germination did not appear to be affected.

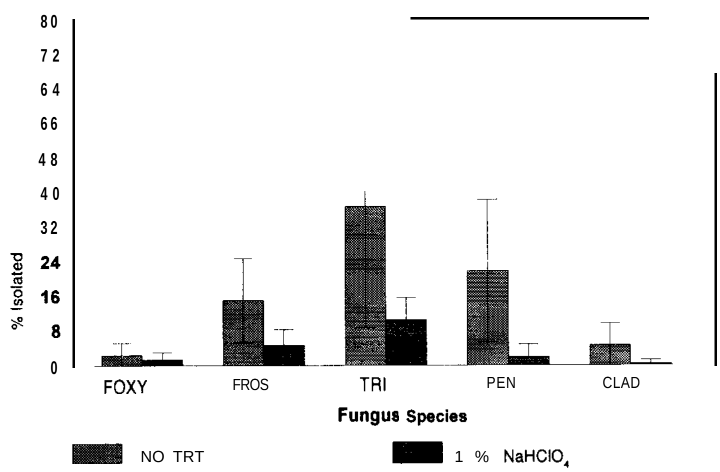


Figure 2. Reisolation of various fungi from Douglas-fir seed after 10 minutes soak in 10% Clorox solution (1% $NaHClO_4$). Variation shown as ± 1 STD. Fungus code: [FOXY-Fusarium oxysporum; FROS-Fusarium roseum complex; TRI-Trichothecium roseum; PEN-Pencillium sp.; CLAD-Cladosporium.]

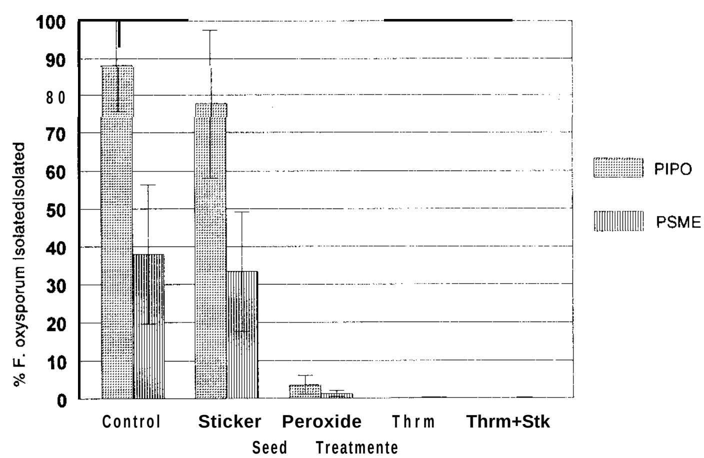
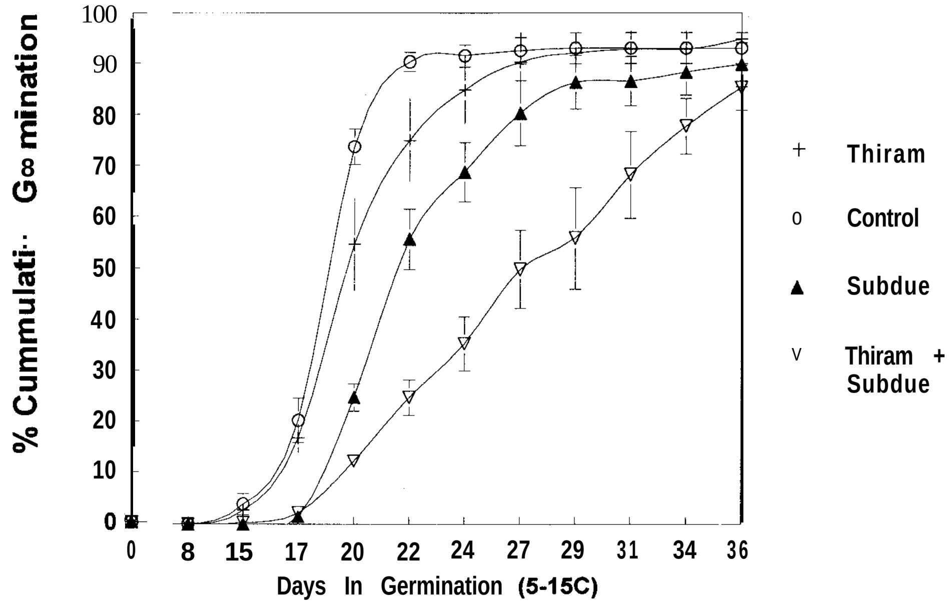


Figure 3. Reisolation of Fusarium oxysporum from ponderosa pine (PIPO) and Douglas-fir (PSME) seed after control, Sticker, 3% hydrogen peroxide for 10 minutes, Thiram or Thiram+ Sticker (label rate). Variation expressed as ± STD.

Figure 4. Germination performance of Douglas-fir with or without seed treatment with Thiram (Arasan), Control, Subdue, or combination of Thiram + Subdue. Variation shown as ± 1 STD.



CONCLUSIONS/RECOMMENDATIONS

Seed treatments to negate or control potential impact of seedborne pathogenic fungi should be viewed as an important tool in integrated nursery pest management. Some of the salient points of this discussion include:

- Seed pathogen assays play a role in the IPM strategy of a nursery, and should be used in concert with operational seed germ and vigor testing.
- Most (90%) of the seedborne inoculum resides on the seed coat surface.
- Cone fungi appear to be the most likely source of seed contamination.
- Optimization of cone handling and storage procedures to facilitate drying and sanitation can reduce post-extractive seed Fusarium levels.
- Water rinses with agitation improve aeration and improve germination, but result in minimal removal of seedborne fungi such as *Fusarium oxysporum.*
- Seed coat sterilants (hydrogen peroxide, Chlorox or bromine) reduce inoculum levels but do not prevent recontamination of seed, and can have a variable affect on germination performance.
- Fungicide seed treatments should only be considered after testing these chemical on seed for possible phytotoxicity.

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Operational Use of Vegetative Propagation in Forestry: World Overview of Cloning and Bulking[1]

Gary A. Ritchie[2]

Abstract-Rooted cuttings (stecklings) are used world-wide for cloning forest trees and for bulking scarce or valuable forest tree seed. In cloning, numerous copies are made of very few genotypes, and each genotype (clone) is tracked and managed separately. In contrast, bulking involves making relatively few copies of many genotypes of a selected family or seed lot. Management and tracking are normally at the family level. Greater genetic gains can be achieved by cloning, but extensive and lengthy testing programs are required. With bulking, genetic gains are not as high but can be captured more rapidly.

The world's oldest rooted cutting programs are the ancient cloning programs developed in China and Japan. In China, Chinese fir (*Cunninghamia lanceolata* [Lamb.] Hook.) has been clonally propagated from stump sprouts for at least 800 years. Clones are deployed in small, monoclonal blocks and clear-cut harvested. About 60 million Chinese fir cuttings were produced in 1991. In Japan, cloning with sugi *(Cryptomeria japonica* D. Don) cuttings has been carried out on a large scale for at least 500 years. These programs are highly regionalized, with the various prefectures propagating clones which are well adapted to the local climate and soils.

Hardwood cloning is accomplished primarily with eucalyptus (*Eucalyptus* sp.), poplars (*Populus* sp.) and willows (*Salix* sp.). The large eucalyptus programs began in 1953 in the Peoples' Republic of Congo, where today about 1.2 million cuttings are set annually. Soon after this (1967), the well known Aracruz program was launched in Brazil. In both of these programs, use of clones has resulted in a doubling of volume yield and dramatic improvement in wood quality. Poplar and willow cloning have been practiced throughout Europe, Mid-Asia and the near-East for centuries. Over 1,500,000 ha of these clonal plantations exist today. In the United States, interest in poplar cloning has grown appreciably during the past decade. About 20,000 to 30,000 ha of clonal poplar plantations are established here annually.

Bulking is practiced on a much smaller scale than cloning and involves primarily conifers. In Australia and New Zealand, several companies currently rely on radiata pine (*Pinus radiata* D. Don) rooted cuttings to meet their primary planting stock requirements. While methods vary across companies, most employ hedges for cutting production, followed by in-nursery rooting. Production across these programs was 3.3 million in 1992. An added benefit of rooted cuttings in these applications is that the trees derived from them tend to have higher quality stems (fewer and smaller branches and less taper) than seed-derived trees.

Several smaller spruce-based bulking programs have been developed in Europe and Scandinavia with Norway spruce (*Picea abies* L.) and in Canada with black spruce (*P. mariana* [Mill.] B.S.P.). Great Britain and Ireland have also developed programs with Sitka spruce (f? *sitchensis* [Bong.] Carr.) and, to a lesser extent, hybrid larch (*Larix* x *eurolepis* Henry). Owing to high stock costs and loss of government subsidies, some of these programs have been reduced or abandoned.

The largest bulking program in the United States is Weyerhaeuser Company's Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) program, where rooted cuttings are produced from elite control-pollinated seed. This process has achieved a bulking factor of about 21 (21 packable trees per individual seed sown). Annual production is in excess of 2 million.

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[1] *Ritchie, G.A. 1996. Operational Use of Vegetative Propagation in Forestry: World Overview of Cloning and Bulking. In: Landis, T. D.; South, D. B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 192-197.*

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BULKING AND CLONING

Nearly al1 vegetative propagation systems employed in commercial forestry, whether based on rooted cuttings, tissue culture, or somatic embryogenesis, have as their objective either to "bulk" valuable families or to "clone" valuable individuals (Ritchie 1994). So we begin here with definitions of both terms. Bulkinq involves making few copies of many individuals. This is normally done at the family leve1 and clones among these family bulks of little or no interest. Cloninq, in contrast, involves making many copies of few individuals. This is done at the genotype level, and individual genotypes (clones) are tracked through the process and into the field.

Advantages and disadvantages of bulking and cloning.

Bulking is normally conducted using genetically improved, tested families. It is assumed that the vegetative propagation process has not altered the genetic constitution of the family, therefore, the mean performance of the bulked family will equal that of the original seedling family. Further testing, then, is not needed and this material can be planted into the field immediately. This is a major advantage over cloning, because even when clones are derived from elite families, individual genotype performance cannot be predicted without field testing. In addition, during the testing period it is necessary to hold members of each clone in a juvenile condition, so that the selected clones can be easily propagated when the testing period is completed. This is often very difficult except in cases when mature trees produce juvenile tissues (discussed later). Therefore, the time between propagation and deployment can drag out for a decade or more.

In contrast, the genetic gains offered by cloning are much greater than those possible with simple bulking (Figure 1). Bulking captures the mean performance of an improved family as compared to its wild counterpart. Cloning, however, captures the gain associated with the best individual(s) in that family, which are significantly greater than the overa11 family mean.

Whether cloning or bulking is employed depends largely on the species which is being propagated. In species which produce easily retrievable juvenile tissue from mature trees, cloning is often the preferred system. Some examples are poplars, willows, eucalyptus and Chinese fir. Bulking is normally used with species in which cloning is difficult or impossible. Many commercial conifer species would fa11 into this category.

BULKING SYSTEMS

As mentioned above, bulking systems are often used to amplify scarce supplies of valuable seed. This involves both species which are difficult to propagate from seed and elite families from breeding programs.

An example of the former is a system developed for bulking Alaskan yellow cedar (*Chamaecyparis nootkatensis* [D. Don] Spach.) in British Columbia. In this system, hedges are established from seedlings which are propagated from seed collected in the wild. These hedges are maintained at a very low height by periodic shearing, which holds them in a juvenile condition. In fact, the juvenile foliage is morphologically different from mature foliage and very easy to recognize. Cuttings are set in containers and rooted under mist in greenhouses. Details of this very successful program are outlined by Russell et al (1990).

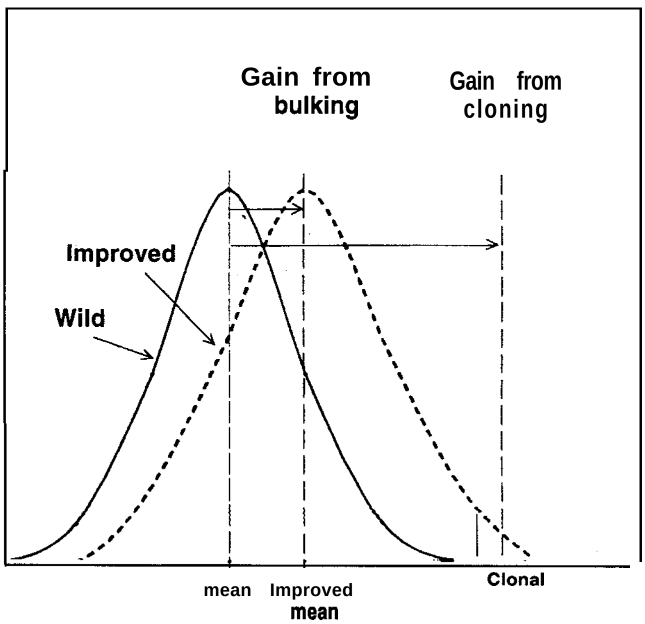

Figure 1. The genetic gains offered by cloning are much greater than those possible with simple bulking.

Most bulking programs are aimed at amplifying the most valuable orchard seed which, by definition, is always in short supply. Most current programs are used to bulk open pollinated (OP) seed because few tree improvement programs are yet producing operational quantities of controlled pollinated (CP) seed. Ultimately, bulking CP seed will probably be the highest use of this technology.

OP Sitka spruce seed is now being bulked to commercial quantities in both Great Britain and Ireland (Mason 199 1). The process used was pioneered at the British Forestry Commission's Northern Research Station in Scotland. Elite OP seed is sown into containers and grown as stock plants (cutting donors) in a greenhouse under accelerated conditions. After the second year, branches are harvested, rooted and lined out into a bareroot nursery. They are grown on for two additional years and a second crop of cuttings is removed from them. These are then rooted, grown on in the nursery and then sent to the field for planting. This program has suffered from the ebb and flow of reforestation subsidies from the British government. When subsidies are up, forest land owners can afford this high cost stock, when they are down, foresters go back to traditional lower cost seedling stock.

Severa1 bulking programs have been developed in Canada using spruces, primarily black spruce (*Picea mariana* [Mill.] B.S.P.) (e.g. Vallée 1990). Most of these are similar to the Sitka program noted above, except that plants are rooted in containers and delivered to the field as container stock rather than bareroot stock. A program in Québec employs a novel tissue culture-like rooting system coupled with container production. As in Great Britain, however, many of these programs have fallen on hard times.

The only operational conifer-based rooted cutting program in the United States is Weyerhaeuser Company's Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) program in Washington State (Ritchie 1993). This program employs first generation CP seed which is selected for good volume production and excellent stem form. Stock plants are grown under accelerated greenhouse conditions for one year. Cuttings are harvested the following winter, set in early spring, rooted, and fall transplanted into a bareroot nursery. They are grown on for an additional growing season and lifted the following winter. Currently the program is producing about 1 million rooted cuttings annually. A CP orchard is currently being established, using second generation crosses, to more fully exploit this bulking program.

Other conifer programs have been developed in Europe (Kleinschmit 1992) and Scandinavia (Lepisto 1974; Roulund 1974; Johnsen 1985; Bentzer 1993). These are based primarily on Norway spruce *(P. abies* L.) owing to its slow, erratic seed production. The European (German) program involves severa1 cycles of nursery selection, followed by cloning, hedging, and extensive field testing. A large industrial program in Sweden combines container production with high leve1 of automation (Bentzer 1993). Many of these programs are on the decline because of lack of government subsidies and the high cost of the stock.

One area where bulking programs are expanding rapidly, rather than shrinking, is Australia and New Zealand (Menzies and Klomp 1988; Duryea and Boomsma 1992). Here, rooted cuttings of radiata pine (Pinus radiata D. Don.) are currently used by many companies and governmental agencies to bulk orchard seed. In fact, in severa1 cases, the use of rooted cuttings has superseded the use of seedling-based planting stock. A particular advantage of radiata pine is that it can be readily rooted in open nursery beds rather than greenhouses. This enables the sticking, rooting, and growing-out phases of production to be accomplished in the same outdoor location in one year. This makes for a very efticient and low cost system. Another plus for vegetative propagation of radiata pine is that genetic gains in volume are attended by improvements in stem form - less taper, smaller and fewer branches on rooted cuttings. This effect is particularly marked when cuttings are taken from slightly mature (3-year-old) cutting donors. This has been reported to improve both yields and value at rotation (Spencer 1987).

CLONING SYSTEMS

It was mentioned earlier that cloning with forest trees is commercially feasible only with those species which, when mature, maintain the ability to produce juvenile tissue. This tissue almost always emerges in the form of stump sprouts. With such species it is possible to make phenotypic selections on mature trees, fell the selected trees, then propagate those individuals (clones) from the juvenile sprouts which emerge from the stumps. These can then be tested as replicated individuals. It is not surprising that most of the world's large, successful cloning programs have emerged using trees with this capability, such as eucalyptus (*Eucalyptus* sp.), poplars (*Populus* sp.) willows (*Salix* sp.)., and Chinese fir *(Czmninghamia lanceolata* [Lamb.] Hook.)

The first large eucalyptus program was initiated in the Peoples' Republic of Congo in 1953 (Leakey 1987). The success of this effort lead to the establishment of even larger programs in Brazil, which are currently the largest operational clonal forestry programs in the world, according to Zobel(1993). Cloning, coupled with selection and breeding have produced remarkable gains. Early experience at the Aracruz operation in Brazil, for example, yielded first rotation gains in yield (112%), pulpwood density (25%), percent pulp (6%) pulp content (23%) and forest productivity (135%) (Brandão 1984). Cloning has also been very useful in combating herbivores such as leaf cutting ants, which have decimated large eucalyptus stands in Brazil. Identification of ant-resistant clones has made eucalyptus forestry economical in areas where it had been previously impossible.

Poplars have been clonally propagated throughout Europe, Asia and the mid-East for centuries, with over 1,500,000 ha of plantations in existence today. The introduction of the North American *P. deltoides* [March.] during the 1700s, and its subsequent crossing with the native *P. nigra* [L.] gave rise to a stream of highly successful poplar *hybrids (P. euroamericana)* clones which revolutionized poplar forestry (Zsuffa 1985). Today in the United States severa1 industrial poplar programs have emerged in Washington and Oregon. Utilizing derivatives of fast growing hybrid clones *(P. deltoides x P. trichocarpa)* developed jointly by Washington State University and the University of Washington, these programs produce pulp in 7-8 year rotations. Owing to the short crop cycle, these plantations are considered agriculture and, hence, do not fa11 under the jurisdiction of forest practices boards.

The oldest and largest clonal forestry programs are in Asia. The sugi *(Cryptomeriajaponica* D. Don) program in Japan has been in existence for at least 500 years (Ohba 1993) while the much larger Chinese fir program has existed for perhaps one thousand years in south-eastern China (Li 1992; Li and Ritchie, in prep). This species is planted in 14 provinces in southern China and makes up about 25% of its national timber production. The sugi program has a long and successful history, with about 30 million rooted cuttings produced annually, as of 1989 (Ritchie 1991). The program is difficult to describe owing to its extreme diversity. Each prefecture in Japan has evolved, over the centuries, its own preferred techniques and clones. Many of the clones have been selected for the rooting ability as well as for their growth and yield characteristics. A detailed overview of this program is given by Ohba (1985; 1993).

Chinese fir, as mentioned earlier, has the ability to produce juvenile stump sprouts if the site is burned following harvest. These "fire sprouts" can be collected and rooted to produce clones of the adult tree. Reforestation systems have been based on this approach for at least 800 years as indicated from these evocative lines from the 12th century Chinese poet Zhu Xi..."planting cuttings of the fir along the roads; enjoying the cool air in the moonlight of the future" (Li and Ritchie, in prep.). Li (1992) estimates that more than 20 selection cycles have been carried out using this system. Each is the equivalent of a 30-year clonal test. Yields of the most productive of these clones are dramatic. For example, one plantation yielded 1,170 m^3/ha at age 39, which is about six times the yield of a wild plantation on a similar site!

The Chinese clonal forestry program carne under attack during the 1950's when Chinese agriculture carne under strong influence of the Soviet Geneticist Lysenko. He convinced the government that cloning was leading to erosion of the productive base of the forests and cloning was largely replaced with seedling plantation. Recently, the folly of this action has been recognized and an effort is underway to find, and bring back into production, many of the priceless old clones.

CLONAL DEPLOYMENT

A key challenge of clonal forestry is how to capture the impressive gains associated with cloning without risking catastrophic plantation failures owing to narrowing of the genetic base - the often cited "monoculture" problem. Historically, there have been three approaches to clonal deployment in forestry: 1) monoclonal deployment, 2) mixed clone deployment, and 3) deployment in clonal mosaics. In monoclonal deployment, a large area of land is planted into only one clone. This method clearly gives the greatest clonal gains, but also carries the'highest risk. By planting mixes of high yielding clones, high gains can be captured but with far less risk. However, when clones are planted in mixes, it is not possible to identify unique or abnormal clones within the mix, unless of course, every tree is tagged. For example, if a particular clone is maladapted so that many of its members die throughout the plantation, the maladapted clone will remain unidentified and there will be no way to remove it from the production base. Similarly, if a certain clone is particularly well adapted, its identification will also remain elusive. The third alternative, clonal mosaics, offers an attractive compromise. Here, clones are deployed in monoclonal blocks, but these are inter mixed with many other blocks containing different clones. This strategy captures the advantages of monoclonal plantations, but buffers risk by deploying many clones over small areas. In addition, the clonal boundaries may afford physical or biological barriers to destructive agents. With intelligent use of clones in forestry, it is also possible to create plantations, which carry much greater genetic diversity than natural stands. This is because artificial crosses can be made that could never occur in nature and these are then mixed in ways that nature could never accomplish.

ACKNOWLEDGEMENTS

1 wish to thank Dr. Yasuomi Tanaka, Weyerhaeuser Company, for his useful review and comments on the draft manuscript. This paper was revised from an earlier paper prepared for the symposium: Biology of Adventitious Root Formation (Ritchie 1994). Preparation of this manuscript was funded by Weyerhaeuser Company.

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Propagation of Coast Redwood (*Sequoia sempervirens*) and River Red Gum (*Eucalyptus camadulensis*) for Clonal Forestry[1]

Glenn Lehar[2]

Simpson Timber Company Tree Improvement activities have consisted of selection of individual redwood trees within the 383,000 acre ownership. Selected trees are sorted into populations of breeding zones for purposes of identification of elite genotypes.

In addition, approximately 12,000 acres of eucalyptus plantations were established in Tehama County, California for purposes of pulp fiber production.

Both Coast Redwood and River Red Gum adapt to vegetative propagation with selected individuals cloned through the tissue culture process. All selected clones are first utilized by Tree Improvement operations for establishment of breeding orchards and field performance testing. Progeny sites, clonal field trials, tests for rejuvenation and operational clonal blocks are necessary to evaluate clonal performance (Figure 1).

Once a clone has been rejuvenated to a point of successful rooting and grading percentages (along with acceptable orthotropism, storage ability, lab tissue culture process, nursery transfers and nursery survival) the clone can then be released into nursery production. Standards are established on basis of quality, quantity, efficiency of production and cost.

The laboratory micropropagation process involves the establishment of the necessary number of cultures for each production clone prior to plantlet production. Once cultures are established, lab production may begin at a rate of 300/MH. Plantlets are isolated into petri dishes and later transferred into refrigeration until approximately 250,000 shoots are available for transferring into nursery greenhouses.

Plantlets are then transferred into typical containers (styroblocks, leachtubes, etc.) and acclimatized with controlled humidity and temperature until root primordia have developed sufficiently. At this time, typical seedling growing regimes are implemented with only minor modifications until stock type criteria are fulfilled.

Annual production at the Korbel Nursery facility at this time is 300-500 thousand redwood and 500 thousand eucalyptus (5 to 10 clones each). Rotation of clones produced occurs over 2 growing seasons. Coast redwood are transferred into greenhouses from November to March and are grown until the next year (approximately 14- 12 month cycle). Eucalyptus are transferred in September to January and grown until spring (May-June), approximately 4-9 months.

Over 2.5 million clonal eucalyptus have been planted at the Tehama Fiber Farm and 600 thousand clonal redwood have been planted on Simpson's coastal properties since 199 1.

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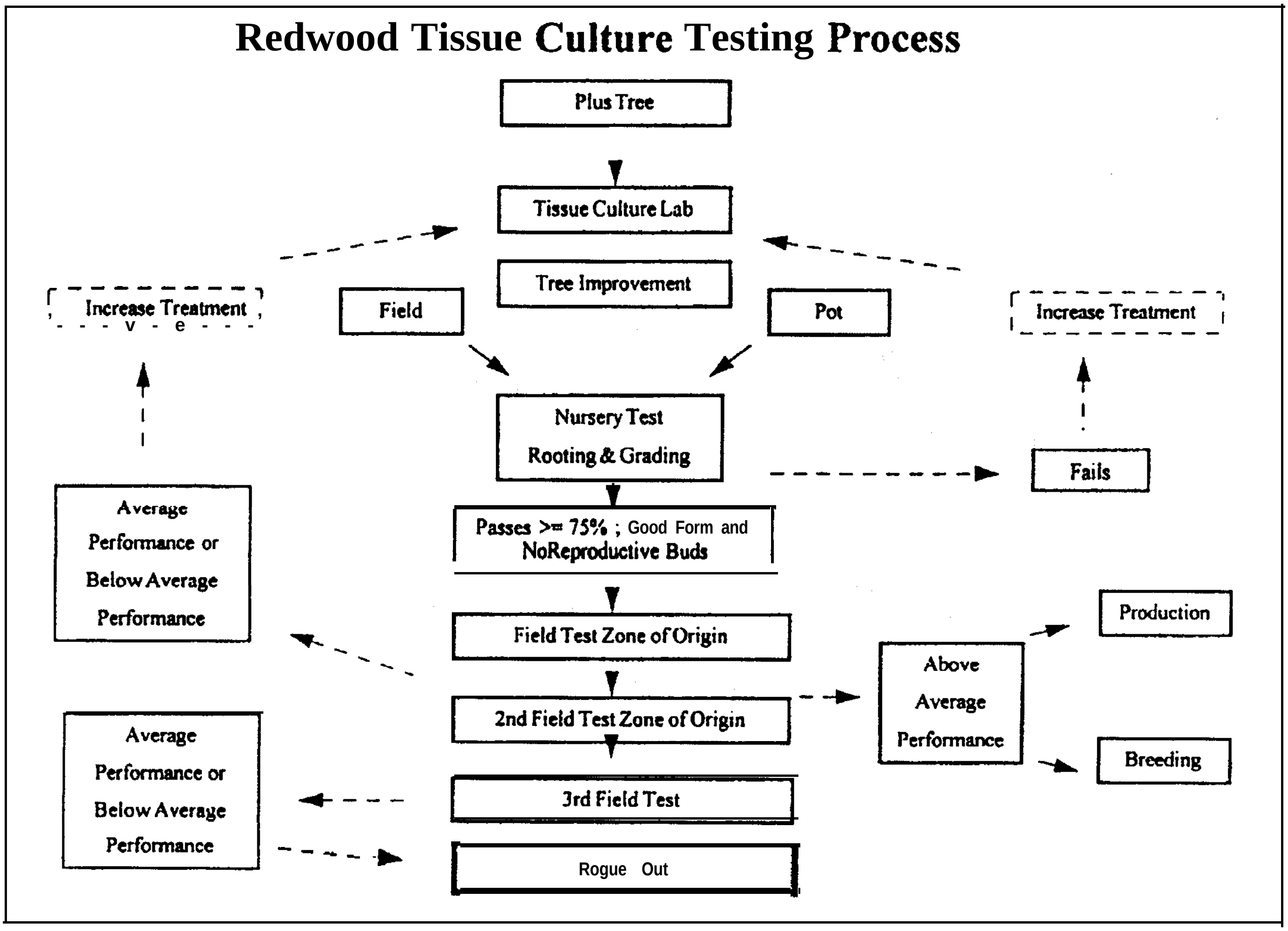
[1]*Lehar, G. 7996. Propagation of Coast Redwood (Sequoia sempervirens) and River Red Gum (Eucalyptus camadulensis) for Clonal Forestry. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 198-200.*

[2]*Simpson Timber Company, Redwood Division, Timberlands Office, PO Box 68, Korbel, CA 95550; Tel: 707/668-4400; Fax: 707/668-4402.*

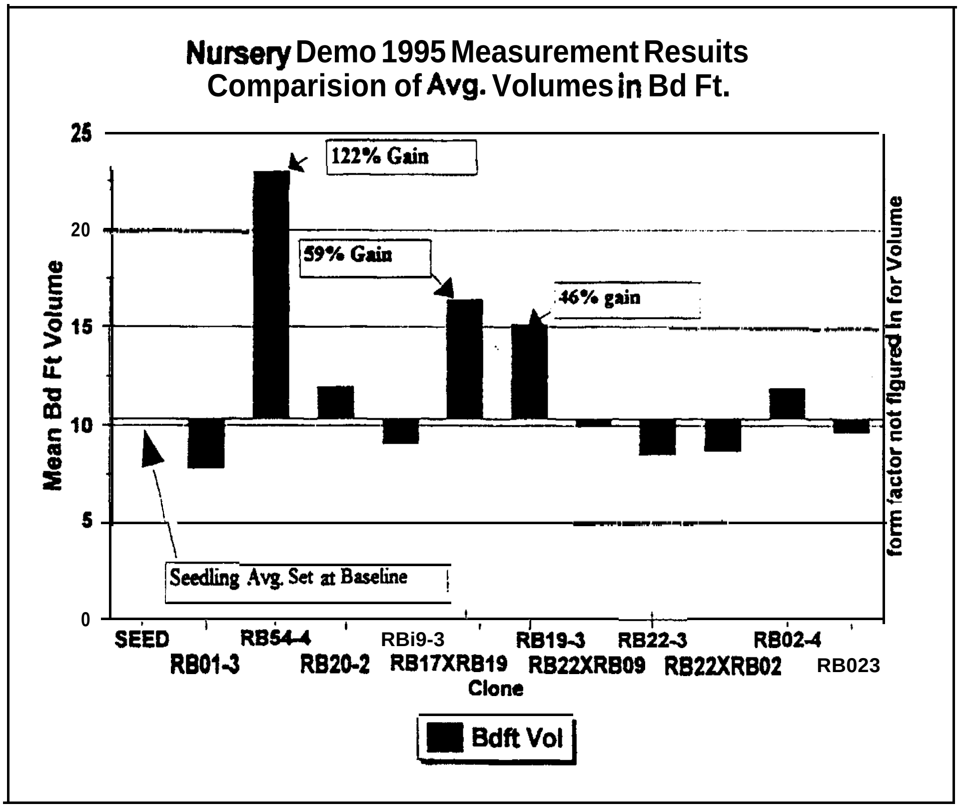
Figure 1.



Statistical evaluations are still inconclusive on any selected clones at this time. Average eucalyptus performance over seedlings have produced 20-30% greater volume per acre. Figure 2 shows the volume from several coast redwood clones (planted in 1987). Over the next few years as more data becomes available from research tests, selection of elite clones will be accomplished.

The integration of micropropagation technology into Tree Improvement programs (if reforestation species adapt to these processes) is dramatically significant in terms of time saved to produce adequate quantity of superior performance characteristics. As biotechnological advancements in tissue culturing mature, the availability and quality of clonal reforestation material will substantially increase forest productivity.

Figure 2.



Nursery Demo 1995 Measurement Resuits
Comparision of Avg. Volumes in Bd Ft.
Mean Bd Ft Volume
25
20
15
10
5
0
122% Gain
59% Gain
46% gain
Seedling Avg. Set at Baseline
form factor not figured in for Volume
SEED
RB01-3
RB54-4
RB20-2
RBi9-3
RB17XRB19
RB19-3
RB22XRB09
RB22-3
RB22XRB02
RB02-4
RB023
Clone
Bdft Vol

Somatic Embryogenesis in Interior Spruce: Successful Implementation within Forest Regeneration Programs[1]

Steven C. Grossnickle, B.C.S. Sutton, D. Cyr, S. Fan and D. Polonenko[2]

Abstract—Somatic embryogenesis is a tissue culture method that has been successfully implemented for the asexual propagation of interior spruce (*Picea* glauca (Moench) Voss x *Picea engelmannii* Parry). Essentially an unlimited number of proembryos can be developed; each proembryo is a clone of the original explant. Proembryos then proceed through more advanced stages of embtyogenesis, resulting in the formation of cotyledonary embryos, which are similar to their zygotic counterpatts. Somatic embryos are germinated in containers to produce plants which resemble young seedlings. Subsequently, they are transferred to styrofoam blocks and acclimatized to ex *vitro* conditions in the nursery.

Following acclimatization of somatic seedlings to the ex *vitro* environment of the nursery, they exhibit morphological development and physiological patterns that are comparable to normal seedlings. Comprehensive stock quality assessment prior to field planting has indicated that somatic and normal seedlings have comparable performance potential under optimal, cold and drought conditions. Somatic and normal seedlings also have comparable field petformance over two years on a reforestation site.

Initiatives are underway in the following areas to improve the somatic seedling program. First, scale-up of production capability from 250,000 to 1 ,OOO,OOO over the next three years. Second, continue to improve the quality of somatic seedlings that can be developed with new nursery cultural practices. Third, increase genetic diversity within the program to a minimum of 1000 lines (from superior seed families) for field trials that will select elite lines for deployment in reforestation programs. Fourth, develop early selection capability to identify superior families and lines.

❖**Note:** The paper accompanying this abstract will appear as a featured article in the spring edition of ***Tree Planters Notes (Volume 47, #2)*** .

'Grossnickle, S. C.; Sutton, B. C.S.; Cyr, D.; Polonenko, S. F and D. 7996. Somatic Embryogenesis in Interior Spruce: Successful Implementation within Forest Regeneration Programs. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 201.

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Customer Perspectives and Outplanting Performance[1]

S. K. "Fox" Proctor[2]

Abstract—One measurement of success in the nursery business is repeat customers. They return because the product (seedlings) has the qualities desired by the foresters. It is my perspective that this success will come from 1) seedling survival in the forest, 2) excellent seedling growth after outplanting 3) increased communications initiated from the nurserymen with regard to what's happening at the nursery and 4) increased awareness of what the foresters' situations and constraints are in the woods.

From 1979 to 1993, average first-year seedling survival has risen from 79% to 91% on Willamette Industries, Inc.'s land. Average third-year survival has remained approximately 2-5% below first year survival. Our biggest gain in the last 15 years has been in first-year survival. The trick now is to tackle that 9% that is lost to mortality in year one. My belief is that part of that 9% is nursery-related, and a portion is field related. With a handle on survival, the next item is growth in the field. In order for that tree to perform in the woods, it needs to come to the forester with all the qualities of a strong, healthy seedling.

Communication is another key to success. The forester/nurserymen link is very important and should not be overlooked. This area is constantly improving; however, there needs to be closer communication, especially when something negative happens at a nursery. It can be critical for the forester to know what has happened to his/her seedlings as soon as possible so decisions can be made.

The final ingredient of success that I will cover is awareness of what the foresters' needs are in the woods. I urge nurseryman to come to the forest to observe the environment, the constraints and the special situations in which the seedlings must grow.

With increased seedling survival and growth as well as better communication and an awareness of both the nurseryman's and the forester's constraints, success in terms of healthy forests and return customers is closer at hand

THEME

"Success" in terms of repeat customers will come from

1) increased communication initiated from the nurserymen with regard to what is happening at the nursery and

2) increased awareness of what the foresters' situations and constraints are in the woods.

INTRODUCTION

As a non-nurseryman, I feel honored to have been asked to speak to you today. 1 have been coming to these meetings since 1986 to gain a better perspective of the nursery arena in that what you do sure has everlasting effects on my world. And I keep hoping I will see more of "my kind" here, because we both have so much to glean from each other.

[1]*Proctor, S. K. 1996. Customer Perspectives and Outplanting Performance. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 202-206.*

[2]*Forester, Willamette Industries, Inc., Albany, OR.*

That will be the focus of my talk here today: gleaning from each other. 1 will address outplanting performance to some degree, however my main focus will be my perspectives concerning "Success", namely your success as nurserymen and my success as a forester as these relate to the seedlings' success at survival and growth. My belief is that al1 these "Successes" will come from:

1) an increased leve1 of communication between foresters and nurserymen and,

2) a heightened awareness of what the foresters' situations and constraints are in the woods.

1 would like to compare the nursery business to say manufacturing widgets. You can manufacture something to your heart's content. However if no one wants your product, you are not going to se11 it. 1 am not telling you anything new, am I? The key point of course is that you need to know how your product is going to be used, and then develop a product that is the most successful in that use.

So, how do you measure "Success"? 1 would say that one measurement for the nurseryman might be that you have return customers whose perspective is that you grow the best seedlings in the Northwest, which in turn, will keep you in business. How do 1, the forester, measure success with regard to seedlings? 1 measure it in terms of survival and growth. 1 would also include communication and awareness. The four points that 1 will discuss today are:

1) Seedling survival
2) Seedling growth
3) Communication
4) Awareness

SEEDLING SURVIVAL

1 reviewed Willamette Industries' tree planting survival since 1979 to focus on change in survival during the past 17 years that 1 have been intimately involved with nurseries. Field checks are taken in the spring and fa11 after planting in the first-year, and then every fa11 for three years or until trees reach a free-to-grow status.

The following information is the result from fa11 checks:

Planting years 1979-l 983 (5-year avg. & avg. all stock types)

- Average first year survival 79%
- Average third year survival 74%

Planting years 19841993 (5-year avg. & avg. all stock types)

- Average first year survival 91%
- Average third year survival 89%

What we see here is that from 1979 to 1993 seedling survival has risen from 79% to 91 % on Willamette's land. However, the ensuing mortality during the next three years has not changed considerably. In other words, if you are going to lose seedlings, the majority are going to be lost in that first critica1 year. Our biggest gain in the last 15 years has been in first-year survival. We know that on the average we have a good 89% survival after three years on al1 our stock. On most of our land, survival is actually higher. Severa1 tough units can bring that average down and 1 did not compute a weighted average for this report.

That 9 1% is a combination of your hard work and my hard work during the last 15 to 20 years. Technological and silvicultura1 advancements in both the nurseries and in the field have allowed you to produce a bigger and healthier seedling, and for me to provide that seedling the proper environment in which to grow in the forest. Gone are the days of little wimpy seedlings planted on unprepared soils, a detinite recipe for failure! And of course, a worst case scenario . . . however we have al1 seen planting sites we wished we did not have to plant (as is) and seedlings we wished we could throw away.

What about that 9% that you are sowing and growing and 1 am planting that still does not make it through year-one, let alone year 3 or SO? How much of that 9% is because of something you did or did not do in the nursery, and how much is because of something 1 did or did not do in the field, and how much of it is uncontrollable weather related versus controllable weather related? 1 am smart enough to know that 1 do NOT want to stand up here and BLAME you, the nurserymen for that field fall-down, so my answer is that we both share this responsibility equally, and in doing so, continue to search for that perfect tree!

The figures 1 have given you are fairly rough. 1 gathered input from at least seven of our tree farms that cover al1 our Oregon lands eastside and westside. What 1 was looking for was a trend, a trend that actually you all probably already know. Some years our survival is up to 99% and others it's down to 84%. As part of my functions for Willamette Industries, 1 assess the various seedling stock types that are on the market, and choose which type or types will work best for our lands. 1 am not going to give you survival data by stock type today, because 1 discovered that, quite frankly, the stock types we use al1 do very well. Survival of al1 three transplant types (2-1 's, P-l's, and 1-1 's) falls within a few percentage points of each other, and fluctuate by year.

Obviously, as well as stock type, 1 also assess the nurseries themselves to determine where we will do business. Willamette is a firm believer in spreading ourselves out. We historically have grown seedlings with at least five to seven nurseries concurrently, and usually purchase additional stock from three to seven others. While we consider ourselves loyal, we are always looking at new opportunities. Again, it would not be difficult to present seedling survival by nursery. Since percentages between nurseries are so close, and vary by year, 1 feel that kind of data is unnecessary for this discussion.

Some of you know that Willamette has a "Golden Tree Award." This award is interna1 in recognition. Each year when 1 do my fa11 nursery visits, 1 write a report to the foresters about the condition of our seedlings in each nursery. In the report 1 "give" the nursery with the best overa11 seedlings this award. The Golden Tree Award is constantly moving as each year one of you does something a little different or weather affects the outcome of stock in a particular year.

GROWTH

My first concern is that the seedlings you produce for Willamette will survive. As 1 stated earlier. this part of the equation has been almost solved. We are getting excellent survival with most stock on the majority of our planting sites.

So the next leve1 is growth. 1 am not a research scientist so 1 do not know the in's and out's of plant physiology and morphology. 1 just know what 19 years of "seat of the pants" forestry (including about 15 years of tree planting) has taught me. In order for these seedlings to really hit the ground growing, they need to come to me with a few things already in place. They need to be storing al1 kinds of nutrients and good stuff for that first year in the woods. 1 want my trees to have a really good fibrous, moppy root system with lots of fines, ideally with mycorrhizae, large caliper, preferably a minimum of 7 mm (Remember, we're talking ideally here!), average of 9 mm, ideal height of 1 8", with the range being 16 - 20", many, many large, firm buds, defined terminal with one large terminal bud, lateral branches to the ground with many long, dark green needles and a well-hardened off-seedling in order to withstand the shock of going from nursery bed to forest. Have 1 forgotten anything? Can you produce that for me? Every time? That is what 1 am really asking for!

If my trees have that going for them when they are planted, they have a much, much better chance of not only surviving, but growing like gangbusters that first critica1 year. They need each of the above qualities to do the job ahead of them. And 1 need to do my part, which involves preparing the ground, handling and storing the seedlings with care, planting the seedlings during appropriate weather conditions, vegetation and animal control, and caring for these seedlings long after they are planted. With this kind of commitment on both of our parts, we can get our forests up and running in no time.

COMMUNICATION

In order to have that kind of "Success", we also need the ingredient called "Communication". 1 went to a wedding in July of this year. It was a Catholic affair, ful1 Mass, lots of bridesmaids and groomsmen, flower girl and ring bearer, vocalist and guitarist, etc. etc. And of course, a Priest to preside over the whole affair. Now, I'm not Catholic and 1 haven't been to a traditional wedding in quite some time. So this was pretty exciting to me. Well, we did the singing part and the praying part and the vows part and then it carne time for the Priest to share with all of us some marital words of wisdom. He was amusing because he prefaced all that he said by telling us that he definitely was not an expert on marriage (we al1 laughed knowingly)! 1 would now like to paraphrase two thoughts that he shared.

He addressed the bride and groom . . ."Today, you think this is the happiest day of your lives and that there will be none happier. 1 do not want you to think in those terms. 1 want tomorrow and the next day and the day after that to be your happiest days. And then years after that, there should be again even happier days. You must learn together and grow together, each utilizing your individuality, and sharing that part of you, so you each can benefit and find even greater happiness together than you would have apart. Remember today is a very happy day but it should not be the happiest day of your life."

The second thing the Priest said was, "You come to me today as a couple so much in love, ful1 ofjoy and happiness. You are sharing this love publicly by coming before God and your guests to take each other's hands in Holy Matrimony. There will come a day when you are not happy, with yourself or with each other. It is in these times especially when you must speak openly and lovingly with each other. Just as you need each other in the good times, so too do you need each other in the not so good times. So, when you most do not want to talk to each other, TALK. And when you do not want to listen, LISTEN anyway. Take the time necessary to discuss what is going on in each of your minds and hearts. Never assume you know the other totally for we are each of us individuals. Communication is ever so important to the success of your marriage."

Well, 1 was impressed . . . and moved. And 1 believe that this Priest 1 heard on a very hot day in July had some really good words of wisdom, not only for this young couple, but for all of us as well. And not only in marriage and friendship but also in the business world.

Let's look at these two points: Happiness and Communication. Let's view them, not from the standpoint of the young couple but from the standpoint of you, the Nurseryman and me or others like me, the Forester. We have entered into a relationship by virtue that 1 am contracting with you to grow my seed into seedlings. It is a happy moment. You are pleased to have my business and 1 am looking forward to the delivery of quality seedlings. Just as the Priest warned the young couple that their wedding day should not be their happiest day, so too the beginning of our business relationship should not be our happiest moment. And just as the Priest spoke of nurturing their marriage via communication, we also need to keep our lines of communication open. 1 believe 1 have a very good rapport with the nurserymen with whom our company deals. And those of you who know me, know that 1 am open, honest and pull no punches. 1 also believe 1 am fair.

1 feel the communication 1 have had with all the nurseries which Willamette deals with has been excellent on the most part. However, there is one area that 1 feel needs improvement. This goes under the heading, "When Something Unexpected Happens." When something occurs at a nursery that may affect or has affected my seedlings, 1 want to know about it immediately, not next week, not next month. It is not just for the sake of knowing; it is because if 1 need to make choices about those seedlings, the more lead time the better. It is important to me. It is important to my foresters. And it is important to my company. Those of us who deal directly with you realize that growing trees is not like making widgets, and then there is Mother Nature to contend with, which is al1 the more reason that 1 need to be informed. Sometimes that two weeks may mean the difference between whether we can "save" the lot, or purchase some replacement. My foresters think I'm God or at least the Good Fairy when it comes to seedlings and their needs. They have absolutely no doubt that Foxie will come through with the goods. They think and feel that way because 1 have never let them down. So, the more information you can give me, favorable or unfavorable, the better 1 can do my job.

NURSERY/FIELD VISITS

Another aspect of Success comes from designing a product your customer cannot resist. In our case, this would be the perfect seedling, each and every time. Now 1 realize 1 need to leave the Land of Oz and return to the real world. However, there is always room for improvement in all that we do. In the mid 1980's 1 started seriously looking at a different Douglas-fir stock type for our company, namely 1- 1 's. At that time, our sowing was around 70% 2-1 stock. In 1988 we planted our first contract grown 1- 1 's. By 1996 our sowing consisted of 70% 1- 1 stock. One of the major reasons for this transition was because 1 made a concerted effort to visit the nurseries more often than in the past. 1 went to not only the ones we contracted with but others as well. My point here is that 1 wanted to learn as much as 1 could from you, and see what products you had that could meet my needs.

What we need now is fine tuning and tweaking the product. It is time you all got to the forest more. Observe what our special situations and constraints are. Come out to the woods in the winter when we are planting your seedlings. Look at the terrain, the soils, the brush, the weather, not to mention the fish and wildlife constraints, as well as herbicide issues. Also, look at the way we transport, handle and plant our stock. Gain further understanding about why we may be asking for a 24" 8 mm seedling or a 10" 6 mm one. There are reasons for our requests. Some of you do spend time in the woods and 1 think that is super! Do more of it, and do not wait to be called. Take the initiative and call us first; tell us you think it is important that you see what we have to deal with in the woods. This would be a wonderful opportunity for constructive discussion.

1 realize it is your responsibility to grow seed into seedlings and mine to take the seedlings to full maturity. However, the more we understand about each others' needs and constraints, the better product we will both be able to produce.

CONCLUSION

Success in this arena is measured by the ***Customer's Perspectives and the Seedlings' Outplanting Performance***. We have come a long way in the last 20 years. 1 have been around long enough to hopefully have gained some perspective and some patience. 1 remember a certain freeze that turned a whole nursery's seedlings bright red and 1 thought they were all dead. A month or so later 1 went back and they were green again. A miracle 1 thought at the time. (1 was a wet behind the ears forester.) 1 remember several years after that, another tragedy of some kind at a different nursery, and a young forester getting up in the middle of a nursery meeting and saying he would never grow seedlings at that nursery again. He obviously had lost a sizable number of seedlings and he obviously was very wet behind the ears. We have all been there and we will all be there again, unfortunately.

But the good news is this. You are really doing an outstanding job. Seedling survival in the field has improved by leaps and bounds. Seedling outplanting performance is also improving. Seedlings are just not what they were 20 years ago-they are bigger, better and have more good stuff packed into them than ever before. My perspective is that you are going to continue this upward swing. Just as my foresters' think 1 can give them everything they want, 1 think you can give me what 1 want, especially with the ever-advancing technology of today.

To help get us from here to there, we need to go that extra mile and fine tune all the good things we are doing now. That includes actively pursuing better communication in both good times and bad, and coming out to the woods and discussing the landowner's needs. Are they reasonable? Are they doable?

We, the foresters, need seedlings that will give us the survival and performance we desire. You, the nurserymen, are charged with producing those quality seedlings. 1 believe with increased communication between us, and an awareness of both the nurseryman's and the forester's constraints, and the reasons for those constraints, that this Success that 1 speak of is within our reach.

Conifer Seedling Choices in Wildfire Reforestation—Eastside Perspectives[1]

Larry S. Shaw[2]

Abstract-Wenatchee National Forest in Washington State's Cascade Mountains experiences high wildfire frequencies on its dry eastern slopes. Over 40,000 acres of these wildfires have been planted in the past 25 years. This has created a need to develop ponderosa pine and Douglas-fir planting stock that can survive the hostile environment that follows an intense wildfire on these dry slopes. Auger planting in deep trench scalps with emphasis on natural micro-sites is used to compare containerized and bareroot seedling survival, growth and site capability.

Forest Districts have spent twenty years working with Forest Service and private industry nurseries to develop seedlings with dense fiberous root systems that can survive and grow in the strong competition of native pine grass and vegetation introduced by post fire rehabilitation efforts. 2-0, l-1 bareroot, 1-O containers and plug-1 seedlings have been tried extensively. Survival and growth statistics show that even though l-l bareroot and plug-1 transplants are expensive, their high survival and growth potential make it possible to order less seedlings, use less seed, transport and plant less seedlings and replant less often. Recent improvements in containerized seedling root development are reflected by a recent outplanting of 1-O containers on over 2000 acres of dry sites. Survival of over 80% after one growing season is encouraging. Sample plots of these seedlings are being monitored to further track survival, growth and site capability. The tall, spindley growth characteristics of containerized seedlings are a potential problem in resisting being physically covered up by heavy competing grasses and wheat as they cure and are laid over by winter snow.

INTRODUCTION

Dense dry forest stands have developed along the far east slopes of Wenatchee National Forest in the Cascade Mountains in north central Washington State over the past 90 years due to man's continual fire suppression efforts. Tree numbers and fuel accumulations are no longer in tune with inherent fire disturbance regimes. In the past 26 years over 80 thousand acres of these stands have burned in wildfires (Figure 1). In the past 25 years tree planting has been done on over 40,000 acres in these burns. This has created the need to develop planting stock that can survive a hostile environment of intense radiation and sometimes desert-like conditions. Many different stock types have been used to develop reforestation programs in these areas.

THE PLANTING SITES

The sites were occupied with scattered to dense stands of ponderosa pine, Douglas-fir and grand fir. Common plant associations are mostly dry Douglas-fir —PSME/CARU and dry grand fir—ABGAR/CARU. Site productivity classes are mostly class five and some class six marginal. Slopes range from 10 to 80% and are commonly 30 to 50%. Elevations are from 1800 to 5000 feet. Precipitation ranges from 12 to 20 inches annually but comes mostly as snow. There is little prospect of summer precipitation. Soils are from shallow to rather deep and in general have fairly good water retention.

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[1]Shaw, L.S. 1996. Conifer Seedling Choices in Wildfire Reforestation-Eastside Perspectives. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 207-210.

[2]Entiat Ranger District, Wenatchee National Forest, USDA Forest Service, 2108 Entiat Way, Entiat, WA 98822; Tel: 509/784-1511.

Figure 1. Dry site planting created by 1994 Tyee Creek Fire.

Very hot and dry micro-site conditions develop after a fire due to increased radiation and blackened surfaces. Most of the forest debris is consumed by the fire. Many sites develop dense stands of native grasses (mostly pine grass) that were only a minor component in the understory before the fire (Figure 2).

Introduced grasses and wheat plus applications of fertilizer as part of emergency fire rehabilitation efforts complicate planting site evaluations.

THE PLANTING APPROACH

Plant sites where moisture competition is severe first, such as sites with heavy stands of introduced grasses or wheat and where native grasses or brush are still established.

Figure 2. Heavy grass competition.

Auger planting is done in deep trench scalps in an attempt to get seedling roots into soil that has the potential to maintain moisture through the summer and to can collect any unlikely runoff throughout the growing season. We use a 5" wide 5" deep and 12" long scalp. This scalp also provides a loose mineral soil surface that readily absorbs water. Planting contracts are written to require contractors to plant trees in the most favorable micro-sites such as north sides of stumps, snags or logs or in low spots.

PLANTING OBJECTIVES

Forest plans cal1 for developing healthy stands of low density ponderosa pine and Douglas-fir that are sustainable. Reforestation goals include having 100 to 250 surviving seedlings per acre three years after planting, keeping planting costs low, and having no replants.

THE SEEDLINGS

Since the big wildfires of 1970, we have tried planting most types of seedlings on these dry sites, starting with mostly 2-O bareroot stock from Forest Service mu-series. In the mid to late 1970's work was done with private industry to develop 1-O containers for these sites. As with the 2-0's there were problems developing good root systems. During the early 1980's, the Entiat and Chelan Districts went back to bareroot nurseries to develop a more open grown 2-O seedling. They were unsuccessful. By 1985 even though seedling survival was slightly better, Districts were still frustrated with outplanting results on these dry sites. Poor root systems were a constant problem with either bareroot or containerized stock was used. In 1985, Districts started thinking about a target seedling without cost considerations. They felt dense fibrous root systems planted deep were essential to resisting summer drought and large caliper was needed to resist intense summer radiation where the stem contacts the soil and to help the stem resist being physically bent over and covered by competing vegetation as it was laid over by winter snows. During the late 1980's and early 1990's, some Districts went back to private industry and were successful in developing containerized stock with dense fibrous root systems. In 1989, the year after the Dinkelman Ridge wildfire, another dry forest situation, the Entiat and Chelan Districts focused on further development of 1 - 1 transplants at our own nurseries. Survival rates of 85% to 95% after one year were typical and growth was good to excellent considering the dry sites and many areas where red stem ceanothus or pine grass competition was serious.

In the Spring of 1996, in an effort to get ahead of competing vegetation on our most recent fire, the 1994 Tyee Creek, the Entiat District planted over 2,200 acres on dry sites with 1-O containers grown by four private growers. Preliminary first year exams during the first week of August were promising with 75% to 85% survival. But unit survivals in mid-September had dropped to a disappointing 45% to 75%.

Comparisons:

2-O bareroot-Low initial cost but if grown at high densities, large tops with poor root systems may develop. This may result in the need to do higher density planting or culling 50-70% of the seedlings resulting in high total planting costs not to mention the wasted seed, transportation costs and potential replant costs.

Transplants-High initial cost and more handling risk but their higher survival and growth potential make it possible to order less seedlings, use less seed, transport and plant less seedlings and replant less often.

Containers-Low initial cost and less lead time, but still questions about their survivability and growth on these dry sites.

SEEDLING STORAGE

- Plan to get al1 seedlings late fa11 lifted and freezer stored.
- Plan to keep seedlings frozen and thaw just in time for planting.
- Keep all thawed seedlings at 33-34°F.
- Monitor seedling health from lift through storage.

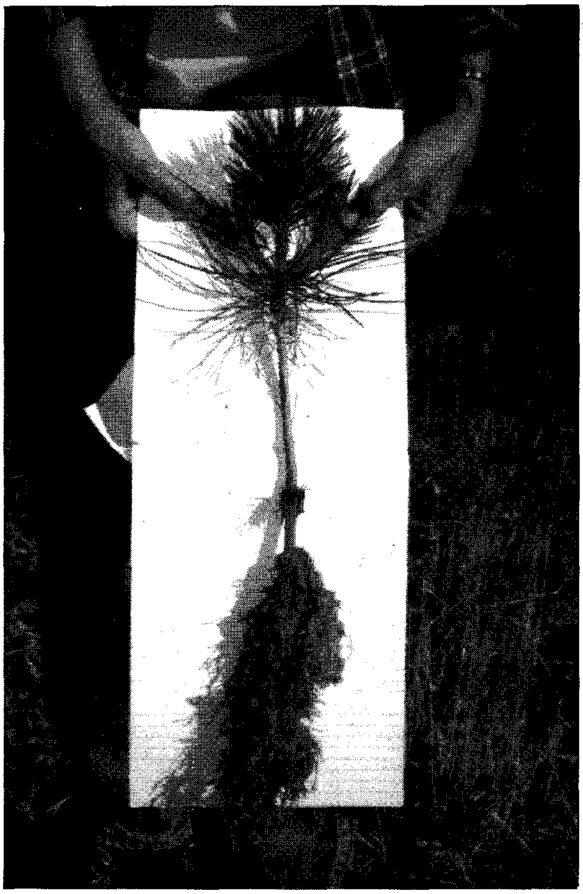

Figure 3. l-l transplant-one year after outplanting.

CONCLUSIONS

- 1-O containers-will monitor the 1996 plantations.
- 1 - 1 transplants have a good track record. They do provide the dense fiberous root systems and large caliper stems that we feel are the key to excellent survival and growth on these difficult sites (Figure 3).
- Seedling development and storage are critica1 issues in developing successful reforestation programs.
- Don't jeopardize seedling dormancy by rushing fa11 lifting for freezer storage. Very high mortality can occur in freezer storage if dormancy is not adequate.
- Plan for spring lifting and hot plant as a contingency plan if dormancy and required fa11 lifting dates conflict.

RECOMMENDATIONS TO NURSERYMEN

- Visit planting sites.
- Spend more time on telephone with clients.
- Make special invitations to clients to review seedlings.
- Learn each others language.
- Keep records of seed-lot performance.
- Re-evaluate seed/need formulas.
- Pack seedlings so there is room for them to breath. Don't fill boxes full. We had serious mold problems last spring on a containerized seedlings lot that we assume was packed before proper cooling and boxes were filled too full.
- Spend less time computer modeling and more time growing root systems.

Stock Type Trends In British Columbia: A Nursery Forester's Perspective[1]

Ev Van Eerden[2]

Abstract — The general preferences for container stock in B.C. and bareroot in PNW Washington and Oregon largely reflect differences in species, site and soil conditions, and, therefore, planting difficulty. In the two regions, the history of and the urgency for the development of biologically cost-effective container systems (as an alternative to bareroot stock production) also had a major impact on current trends and stock type uses.

INTRODUCTION

At first glance, explaining stock type trends in British Columbia and clarifying differences between B.C. and the Pacific Northwest United States would appear to be a rather easy assignment. Simply take account of the trials, developments and operational experience that led to the adoption of current stock types and, voilà, the reasons for changes and current practices will become crystal clear.

However, stock type preferences are generally not solely based on performance, but reflect consideration of many other criteria. These include logistics and costs of planting, seedling costs, the time period between ordering and delivery, delivery assurance, other operational and costs factors, and biases towards one stock type or another.

PAST EXPERIENCE

Trials, which were intended to compare the performance of bareroot and container-grown stock, frequently ignored the effects of differences in seedling physiology, dormancy, age, and size between those stock types. A recently published annotated bibliography on the "Comparative Performance of Bareroot and Container-Grown Seedlings" (Menes *et* al. 1996) leads to the same conclusion. On balance, seedling size rather than other stock type differences was probably the overriding factor that influenced stock performance, reported in the 213 references in the Menes review.

STOCK TYPES IN BRITISH COLUMBIA AND THE PACIFIC NORTHWEST UNITED STATES

The ratio of annual production of bareroot to container stock in the PNW United States, specifically Washington and Oregon, is about 150 million bareroot versus approximately 50 million container seedlings, or a ratio of about 3 : 1. Douglas-fir is the significantly dominant species in the region.

In British Columbia, on the other hand, that same ratio is about 1:22, or less than 10 million for bareroot and transplants and about 220 million for container-grown stock. Douglas-fir comprises only 7 percent of the total production. White spruce and iodgepole pine dominate at about 30 to 35 percent each, with the balance being accountable to a large number of other species.

[1] Van Eerden, E. 1996. Stock Type Trends In British Columbia: A Nursery Forester's Perspective. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 211-214.

[2] Pacific Regeneration Technologies Inc. (PRT). #4-1028 Fort Street, Victoria, B.C. CANADA V8V 3K4; Tel: 250/381-1404; Fax: 250/381-0252

The conversion from bareroot to container stock in B.C. is remarkable in that it has been so complete and has occurred so rapidly during a period of about 25 years. As a result of the almost total reliance on container stock, experienced bareroot nursery managers have become a rare breed in B.C., and *Homo sapiens* var. b.r. has been placed on the endangered species list.

THE DIVERSITY OF B.C.'S FORESTS

British Columbia has five distinct physiographic regions, comprising 14 bio-geoclimatic sub-zones, accounting for a large variety of climates and soils, and a significant number (20+) of commercial forest species.

Unlike Washington and Oregon, only a very small portion of B.C.'s seedling requirements consists of coastal Douglas-fir, which is very suited to production as bareroot stock. Perhaps, with the exception of lodgepole pine, which can be produced as bareroot in a very limited number of B.C. locations, the production of other major species, especially white and Engelmann spruce, western and mountain hemlock, *Abies spp.*, western red and yellow cedar, and western larch is more reliable and cost-effective in containers than it is as bareroot stock. Seedling survival has signiticantly improved during the last decade, as noted in Figure 1. It is noteworthy that improved plantation survival coincided with the increasing reliance on container stock. Planting productivity and costs of container stock are also more favourable relative to bareroot stock.

FOREST LAND OWNERSHIP

Most of the forest land in British Columbia, in excess of 95 percent, is in public ownership, viz. the land is owned by the Province. Consequently, much of what is done in reforestation reflects the consequences of public ownership and policies. This includes, for example, centralized seed registration and distribution, prescriptions and/or guidelines for acceptable species and stock types, and stocking densities, and free-to-grow standards. The recent introduction of the Forest Practices Code has added severa1 other regeneration performance standards, some of which are having negative impact on the forest industry and nursery sectors.

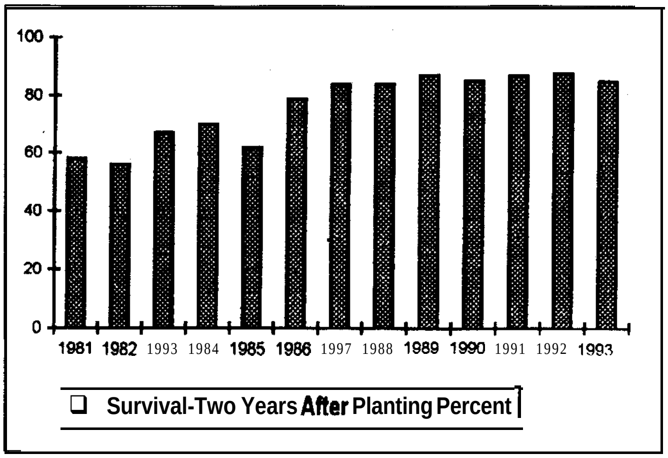

Figure 1. Survival - two years after planting percent. Ministry of Forests program only. (Source: R. Brown - Ministry of Forests).

HISTORY OF FORESTSEEDLING PRODUCTION IN BRITISH COLUMBIA

Forest nurseries in British Columbia had their origin in a small research nursery, operating in Victoria from 1927 until 1933. The first operational nursery was developed by the Provincial Government near Vancouver, B.C. in the early 1930s. A further ten forest nurseries were developed and put into operation by the Province during the next half century.

Until the early 1970s, bareroot culture was the principal method of forest seedling production. With the introduction of the "BC/CFS Styroblock System" in 1970, container-grown stock gradually and almost totally replaced bareroot stock, during the next 25 years.

Following the recommendations of a Roya1 Commission, a private sector forest nursery program was established in B.C. in 1981. In 1987, the Government of B.C. undertook privatization initiatives that would dramatically alter reforestation practices in the province. Firstly, financia1 and operational responsibility for reforestation of current logging was transferred to the forest industry in 1987. Secondly, the Government sold eight of the provincial forest nurseries in 1988. Our company, Pacific Regeneration Technologies Inc. (PRT), was incorporated by the employees for the purchase and operation of six of those nurseries.

These 1987 and 1988 Government initiatives quickly removed the constraint that had artificially held down the demand for container stock, as a result of limited ability for capital spending by Government departments. With the new policies, for lands logged after October 1, 1987, industry foresters had the freedom to work with nurseries of their choice, and, within certain guidelines, purchase the stock that they deemed appropriate to meet the Provincial standards. The B.C. forest nursery industry responded by accelerated and increased development of the required container seedling production infra-structure.

THE FOREST PRACTICES CODE

In 1994/95, the B.C. Government put into effect the Forest Practices Code, which sets out, among other things, reforestation requirements, targets, standards, and time lines. The impacts of the Code have had serious consequences for our forest industry customers in terms of costs and competitiveness. Although there was little disagreement about the need for the previously existing "free-to-grow" standards, the introduction of additional regeneration performance requirements through "adjacency" or "green-up" rules has severely restricted access to timber in adjacent cutblocks. That restriction, together with bureaucratic delays in the issuing of cutting permits, is starting to affect current seedling demand.

In terms of numbers, seedling demand has been relatively stable during the last decade (Figure 2). However, to meet the increasing performance requirements, and in an effort to ensure that they do not have to retreat areas, foresters have frequently resorted to higher planting densities and larger stock grown in larger containers. To date, therefore, the forest container nursery sector has experienced an increase in growing space requirements, as a result of the almost complete abandonment of bareroot and a continuing increase in the size of container stock.

CONTAINER SEEDLING SYSTEMS DEVELOPMENT

Development of container seedling nursery systems has followed significantly different strategies in various geographic areas. These varying approaches usually emphasized either biology, or engineering and technology, or costs, or capital intensive methods.

In B.C., it was recognized that container seedlings did not provide a "silver bullet", and that container seedling size and quality were paramount in generating satisfactory plantation performance, as they are for bareroot. This was especially true for species such as white and Engelmann spruce and western hemlock, for which field performance of bareroot plantations was frequently unsatisfactory. Consequently, in the early phases of development, heavy emphasis was placed on the biology of container seedling production.

In other Canadian jurisdictions and in Scandinavia, the primary focus was on the mass-production of relatively "small" seedlings through cropping regimes that attempted the production of more than one crop per facility per year. In Sweden, in some cases, huge capital investments have been made in the growing facilities, necessitating the production of more than one crop per year.

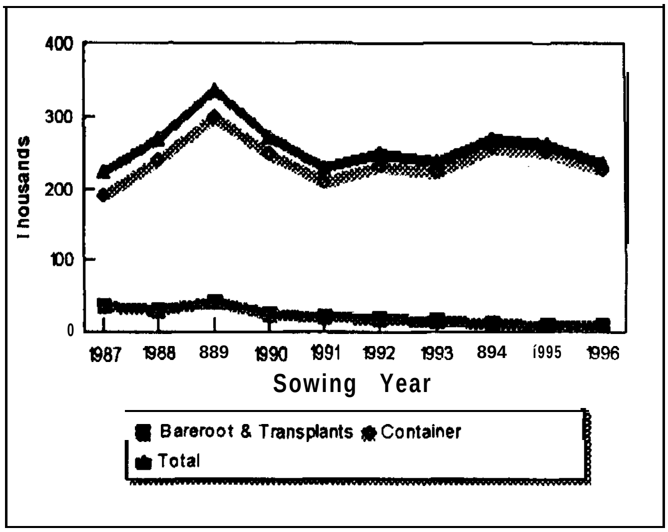

Figure 2. B.C. Seedling volume by stock type - 1987 through 1996

It is my observation that in parts of the PNW U.S. earlier (1970s, 1980s) efforts to develop container seedlings technology sometimes emphasized engineering and equipment development at the expense of the biological aspects of container seedling production. Also, the predominance of Douglas-fir and the success of bareroot planting with that species significantly reduced the urgency of developing the ful1 potential of container seedling techniques. Such an approach to container systems development was not altogether surprising, perhaps.

CONCLUSION

The very significant reliance on container-grown stock rather than on bareroot or transplant stock in B.C. reflects:

- The relatively minor role of Douglas-fir;
- The limited suitability of bareroot production to most of B.C.'s major commercial species;
- The province's difficult, mostly glacial soils;
- Superior planting productivity of container stock;
- Shorter time frames, greater flexibility, and improved delivery assurance with container stock;
- Most importantly, significantly improved field performance through the use of container stock.

In view of the impending limitations on the use of fumigants in bareroot practice, and the increasing ability to produce "larger" stock in larger containers in a cost-effective manner, it is probable that the use of container stock in the PNW U.S. will gradually increase. Ultimately, in both B.C. and the PNW, the market rather than the current availability of particular products will efficiently and effectively exercise discipline in determining stock type preferences.

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Perspectives and Outplanting Performance with Deciduous Forest Seedlings[1]

Alex Dobkowski[2]

Abstract—In 1986 Weyerhaeuser initiated a series of research studies and pilot-scale plantations to provide information pertaining to the plantation establishment of red alder (*Alnus rubra* Bong.). The establishment of operational- scale plantations began in 1990. The current target is to regenerate approximately 3,000 acres per year in western Washington to red alder. Recently, we have begun small-scale plantings to investigate the nursety culture and field performance of bigleaf maple (*Acer macrophyllum* Pursh) and Oregon ash (*Fraxinus latifolia* Benth.) seedlings.

The past ten years of experimentation and operational experience by Weyerhaeuser and others has culminated in considerable progress having been made relative to understanding the requisites for red alder plantation establishment. Proper site selection, quality seedlings, thorough weed control, and outplant timing are the keys to a successful plantation. Rapid capture of the site by the planted seedlings is critical in order to capture the early fast growth of the species. Lack of attention to any one aspect of the prescription can lead to poor plantation performance.

Poor soil drainage, frost, drought, competing vegetation, and big-game activity can provide considerable hindrance to successful plantation establishment. Through the careful evaluation of site characteristics, experienced foresters can select locations for red alder production that have a high probability of regeneration success.

It is important to plant only high quality seedlings. Bare-root seedlings, grown in open nursery beds, can provide seedlings with the attributes necessary to regenerate most sites suitable for red alder production. Nursery production can be adversely impacted by the effects of disease, unusually cool summer temperatures, and fall/winter freeze damage. Freeze damage is of particular concern because even minor top-kill can result in otherwise healthy seedlings that will develop multiple stems/poor stem quality after outplanting. Seedling performance is greatly enhanced with thorough site preparation to control weeds; herbaceous weed competition in the first-year has been shown to be very detrimental to red alder seedling performance.

The proper planting date is an important consideration. Depending upon local site conditions and expected weather trends, a planting date should be selected to balance the risks of freeze damage (planting too early) and drought stress (planting too late). Experience in western Washington places the recommended planting window between mid-March and mid-April at elevations less than 1000 feet.

These findings with red alder are expected to apply to bigleaf maple and Oregon ash as well. One difference that has already been shown is that maple and ash are more susceptible than red alder to damage from big-game browse. Maple and ash appear vulnerable to browse throughout the year. The browse can result in mortality and severely diminished vigor and growth. Browse can also predispose the seedlings to the effects of weed competition. These effects can significantly increase the amount of time necessary for the species to capture the site.

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[1]Dobkowski, A. 1996. Perspectives and Outplanting Performance with Deciduous Forest Seedlings. In: Landis, T. D.; South, D.B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 215-219.

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INTRODUCTION

Weyerhaeuser's experience with the planting of deciduous tree species has been with red alder (Alnus rubra Bong.) Red alder is one of the few quality hardwoods which can be grown to a high value commodity in a relatively short rotation (30 to 40 years). In addition to its lumber value, red alder is also a valuable pulpwood species. These facts coupled with a projected declining supply of alder and an increasing product demand gives Weyerhaeuser an optimistic view of the value of dedicating land to red alder production.

In 1986 Weyerhaeuser Company became interested in understanding the plantation culture of red alder. An operational research project was initiated to address informational needs pertaining to the following topics: planting stock production and field performance; site selection; site preparation requirements (including weed control); planting specitications (planting date, stock handling, etc.); stand culture; and managed stand growth and yield. The establishment of operational-scale plantations began in 1990. The current target is to regenerate approximately 3,000 acres per year in western Washington to red alder. Red alder will be grown to supplement the supply of naturally occurring red alder sawlogs.

The past ten years of experimentation and operational experience by Weyerhaeuser and others has culminated in considerable progress having been made relative to understanding the requisites for red alder plantation establishment. Proper site selection, quality seedlings, thorough weed control, and out plant timing are the keys to a successful plantation. Rapid capture of the site by the planted seedlings is critica1 in order to capture the early fast growth of the species. **Lack of attention to any one aspect of the prescription can lead to poor plantation performance.**

Recently, we have begun small-scale plantings to investigate the nursery culture and field performance of bigleaf maple (*Acer macrophyllum* Pursh) and Oregon ash (*Fraxinus latifolia* Benth.) seedlings. Many of the key learnings derived from research and operational experience with red alder are expected to apply to bigleaf maple and Oregon ash as well.

SITE SELECTION

Red alder will occupy sites with a range of soil and physiographic conditions. However, the risk of plantation failure can be very high on poorly drained, frost prone, or droughty sites. Through the careful evaluation of site characteristics, experienced foresters can select locations for red alder production that have a high probability of regeneration success.

Poorly drained soils have the effect of inducing seedling mortality where saturated soils persist into the growing season. It also severely restricts root growth on seedlings that survive periodic soil saturation. This can be particularly true if the periods of saturation coincide with periods of maximum root growth. The diminished root system can predispose newly planted seedlings to summer drought stress. Given the heavy herbaceous weed communities that can develop on these sites and limited site preparation options, drought stress effects can be compounded resulting in considerable seedling mortality.

Areas of severe frost hazard should not be regenerated to red alder. Sites associated with topographic features that have a high probability of cold air drainage from higher elevations in the spring and fa11 seasons should be avoided. Both late spring and early fa11 frosts can be disastrous to a first year alder plantation. On plantations located in severe frost pockets stem-kill to ground leve1 was observed on trees which were 3 to 5 feet in height. Re-sprouting from root systems may provide acceptable survival. However, the accumulation of effects from frost events can result in a stand with very poor log quality.

STOCK QUALITY

As with any reforestation program, quality planting stock is essential to red alder plantation establishment. The following seedling propagation technologies are available to produce operational quantities of planting stock:

Plug-seedlings: (green-house grown in plastic-foam blocks [82 or 13 1 cm^3] or in single plastic cells [164 cm']);

Bare-root bed-house seedlings: (seed sown in the nursery bed and grown under a transparent, tent like covering to facilitate germination and provide shading);

Bare-root open-bed seedlings: (seed sown in the nursery bed and grown without protective cover); and

Plug-transplant: (a small plug (33 cm^3) grown in the greenhouse from March until transplanted in June into a nursery bed where it remains for the rest of the growing season).

Inoculation of growing medium with *Frankia* (an actinomycete bacteria which colonizes red alder root systems and functions to fix atmospheric nitrogen) increases seedling vigor and crop yield with al1 of the above technologies.

Although these technologies differ in production cost, al1 yield seedlings of suitable quality for out-planting in one growing season. Al1 stock types have been used to successfully establish red alder plantations. The bare-root (open-bed) and plug/transplant nursery cultures produce seedlings that perform on average, across al1 site conditions, better than seedlings produced by the other technologies.

Greenhouse- and nursery-grown red alder seedlings are vulnerable to certain diseases. Considerable fall-down in crop yield has been attributed to *Septoria alnifolia* (a leaf-spot fungus that can develop stem cankers) and *Botrytis* sp. (a gray mold that results in leaf mortality and causes top-kill). An aggressive disease detection and treatment program is very necessary.

Nursery freeze damage in the late-fall/early winter and winter can also decrease nursery yields. Freeze damage is of particular concern because even minor top-kill can result in otherwise healthy seedlings that will develop multiple stems/poor stem quality after outplanting. It is essential to have the capacity to frost protect red alder nursery beds. The potential down-side of frost protection, some stem breakage and delayed leaf abscission, are minor when compared the severe effects of nursery freeze damage.

The seedling grading process needs to include an assessment of root systems, stem and root breakage, top-kill and overa11 seedling health. Seedlings with ascertainable top-damage (from freeze, disease, or mechanical damage) and damage to roots that are greater than 2 mm in diameter should be excluded from pack. Seedlings that loose apical dominance will develop multiple stems after outplanting. Given the heliotropic nature of red alder, these multiple-stems will persist at normal planting densities and cause a degrade in log quality.

Field trials have shown that seedlings with a height of 12 to 36 inches, basal caliper a minimum 0.16 inches (measure 1 inch above the root collar), and a ful1 root system will give good performance. Field performance is more a function of caliper and roots system that it is height. Forester preference is for a seedling that is 18 to 24 inches in height and greater than 0.20 to 0.25 inches in caliper. The height provides a seedling that is short enough for easy handling and tall enough to be seen by planters. Top-pruning is not a desirable method to control seedling height in nursery beds — after outplanting seedlings can develop into trees with multiple stems/poor stem quality. The larger caliper gives better resistance to the effects of sun-scald and seems to be correlated with a vigorous root system.

The selection of proper stock is dependent upon the regeneration risks associated with a particular site weighted against site preparation and stock cost. Al1 stock types are vulnerable to a degree to the effects of herbaceous weed competition. Taking into consideration stock cost and field performance, bare-root seedlings produced with open-bed nursery technology are the preferred stock type for reforesting most alder sites.

SITE PREPARATION

Red alder can be very sensitive to weed competition, particularly herbaceous weeds in the first growing season after planting. Weed competition in the extreme case can preclude seedling establishment. However, even without approaching the survival threshold, weed competition can affect growth and may retard the rate of stand development. Since there are currently few broadcast herbicides available for the release ofred alder from weed competition, the use of pre-plant herbicides to promote rapid site occupancy by the red alder crop is an important consideration.

Heavy first and second-year herbaceous weed competition has been shown to be detrimental to red alder survival and growth. On sites with the expectation of greater than 90 to 100% weed coverage, particularly with seedling over-topping, pre-plant herbicides that reduce herbaceous weed competition can be beneficial. Effective herbaceous weed control can often be the difference between plantation success and failure. Sites with an expectation of low to moderate weed competition in the first three to four years can be adequately regenerated with minimal to no site preparation. Particularly if plug/transplant stock is used. An example of low vegetation competition potential is a dense stand of western hemlock (*Tsuga heterophylla*) with little to no vegetation surviving in the understory. After harvest, the reduced weed seed bank would result in a low probability of weed re-invasion and subsequent competition

It is important to assess the risk of weed competition, then apply the appropriate leve1 of site preparation matching stock type and planting density accordingly. The current recommendation for site preparation is to: 1) limit physical site preparation (scarification and burning); 2) use site preparation herbicides in the late-Summer/early Fall to control established weeds; and 3) apply pre-plant herbicides as needed in the Spring.

PLANTING DATE

The proper planting date is an important consideration. Depending upon local site conditions and expected weather trends, a planting date should be selected to balance the risks of freeze damage (planting too early) and drought stress (planting too late).

Seedlings planted late-November through January are susceptible to winter freeze and desiccation damage. Seedlings planted in mid-February can de-harden and break bud quickly while the risk of frost is still high. Seedlings planted in May might not develop an adequate root system before the onset of summer drought. Experimentation and experience in western Washington, at elevations less than 1000 feet, places the recommended planting window between mid-March and mid-April.

CONCLUSION

Weyerhaeuser has made considerable progress relative to understanding seedling propagation and plantation establishment requirements for red alder. By applying the knowledge gained, successful plantation establishment is predictable. Much of what we have learned has been shared with other organizations; principally through participation in the Hardwood Silviculture Cooperative at Oregon State University College of Forestry. The major information gap that exists is the lack of managed stand, growth, yield, and wood quality data. Weyerhaeuser is working along with other organizations to develop the data base necessary to address those questions.

Many of the key learnings derived from research and operational experience with red alder are expected to apply to bigleaf maple and Oregon ash as well. One difference that has already been shown is that maple and ash are more susceptible than red alder to damage from big-game browse. Maple and ash appear vulnerable to browse throughout the year. The browse can result in mortality and severely diminished vigor and growth.

ACKNOWLEDGMENT

Much of the information presented in this paper is the result of work by a team of Weyerhaeuser scientists, nursery managers, and foresters. The author would like to recognize Thomas S. Stevens, Jerry Barnes, Mark E. Triebwasser, Paul Figueroa, Willis Littke, Yasu Tanaka, Heinz J. Hohendorf, and John Keatley for their contributions.

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Perspectives with Diverse Species and Restoration Projects[1]

Graig Del bol[2]

The use of native woody plants here in the West, from bigleaf maples to thimbleberries, is relatively new to a forest industry which has traditionally relied upon conifers for reforestation and revegetation projects. But within the last decade, those concerned with ecosystem management, wildlife biologists and others, have begun planting native hardwood species along streambanks, highly-erodable slopes, harsh sites and other difficult to revegetate areas. Hardwood plants also have been planted for their critica1 role in the food chain. Native plant species, therefore, have found a new place in forest practice.

About ten years ago, the Siskiyou National Forest in Southwestern Oregon was one of the first forests, to my knowledge, in the Pacific Northwest to begin experimenting with native plantings. My story begins here with wildlife biologist Kurt Ralston, then of the Illinois Valley Ranger District. He needed to shade a stream that served as a prime salmon-spawning area. Kurt thought that bigleaf maples would be an ideal solution. 1 agreed. But he couldn't just walk into a retail or wholesale nursery and find the hundreds of seedlings he needed, much less seedlings grown from seeds collected from his project site.

At the time, 1 had just started propagating ornamental plants, such as: tam juniper, pyracanthas and azalea. One fa11 day, Kurt walked into my nursery carrying a sack of bigleaf maple seeds. He asked if I'd grow them for him. 1 was absolutely flattered by the opportunity. Little did 1 know that Kurt's small, $999 order would propel me into the native plant propagation business and adventures beyond my imagination.

Luckily for me, my first native plant customer was also a smart customer. Kurt had a problem- he needed fast-growing shade on a stream. He devised a plan—plant bigleaf maples. And then he approached a grower who could provide him what he needed. Others who want to use native woody plants for their restoration projects would be wise to follow Kurt's example.

From a grower's perspective, I've learned the finer points of working with my customers to help them decide what plants they need for their project, the size of plants and proper planting time.

As growers, you need to talk directly to the person ordering the seedlings, not just administrative communicators. Typically, hardwood contract administrators are not botanists, plantsmen or qualified field personnel. Consequently, contract terms typically seem to be extracted straight out of the more familiar conifer contracts. In this new field of hardwood native plants, we at Althouse Nursery have found that contract language has to be thought through so that it recognizes that a thimbleberry is not the same critter as a Douglas fir.

I'm a plant propagator-that's what 1 like to do best. And 1 also know that a great number of you folks out there are exactly the same as me. As plant propagators, we're pretty picky about our materials - whether it be seed or cutting material.

So, as responsible nurserymen, we need to find out what our customers are trying to accomplish with their project. Revegetate a decommissioned road? Shade a stream? stabilize a slope? There are many applications.

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[1] *Delbol, G. 1996. Perspectives with Diverse Species and Restoration Projects. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursety Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 220-222.*

[2] *Althouse Nursety, 54 10 Dick George Road, Cave Junction, OR 97523; Tel/Fax: 54 1/592-2395.*

Do they want to plant the same species already in the area or do they want to introduce new species? Then, we can go about our job with an end result envisioned, rather than just trying to fill a purchase order to buy X amount of widgets.

As an example, let's say the your customer wants to decommission a forest road. He wants to plant a *Ceanothus* species, a good choice because it's a nitrogen fixer and survives in some pretty harsh conditions. He wants you to produce 1,000 seedlings for outplanting next fall.

So what's the problem? Well, it's already mid-August, and in my area of the state, the *ceanothus* seed has already ripened and shattered. So unless he already has a sack of seed in hand, he won't be getting any site specific *Ceanothus* for next fall. Therefore, timing of a project is critical.

Try to encourage your customers to, at the latest, have their species list ready for bid by March of the year that seed needs to be collected. You can plan your seed collection and commence growing the crop the following spring, with delivery by fa11 in many cases.

It's important to watch your weather pattems and know the average seed ripening dates for the various hardwood species of your area. Also, you've got to get to the seeds before the birds and mammals. Many a time I've had to kick myself, for seeing seed, driving by, then retuming just a day or two later to find that the seed was GONE.

We generally use the USDA handbook 450 to get us in the ballpark of seed ripening dates. However, your elevation and latitude will come into play. Be observant, paying attention to what's zoning on in the native plant world will be as helpful as any manual.

Here's another example of helping your customers:

We had a customer cal1 us in early May to pick up redtwig dogwood and *Ceanothus* for planting that spring. We told that customer it wasn't recommended. We went ahead with the delivery anyway. However, the timing of the project was way off base. We need to educate the customer that fa11 planting of hardwoods is recommended. The reason is because in the early fall, hardwoods still have active root growth. Provided adequate soil moisture, the seedlings will have substantial root growth before winter cold sets in. By the following spring bud push, they'll be on their way to being established. Our customers who have taken this advice have told us that their fa11 plantings were indeed successful.

OK, here's one more true-life example. Your customer has written a contract that calls for 1,000 of these, 10,000 of those and 5,000 of those. He also wants you to produce 1,000 red huckleberries from seed or cuttings with a minimum height of one foot within the one-year contract time.

Yes, you can do this with maples, alders, cascaras and maybe some oak species. But you can't do this with red huckleberry. Bottom line is, you know your species and their limitations, while your customer often doesn't. And often, you'll find that maybe the species isn't as important as the overa11 goal. So find out what the customer wants. If they want one-foot tal1 plants to produce food for birds, red huckleberry won't work. But, cascara or coffeeberry or a number of other plants will suit the purpose.

A properly written project will have help your customer more successfully accomplish his or her restoration goals.

HOW TO DETERMINE SPECIFICATIONS FOR PLANTS

Obviously, your customer now has an idea of the type of plants he wants. How about their size? This depends on a couple of things.

- **Fast growing plants,** such as alders and maples, with aggressive root systems need room to grow and will do better in larger containers. Slower growing species, red huckleberry and Pacific yew, can be grown in smaller containers.
- **Timing.** Size of the container for fast growing plants can be smaller if they'll be planted out sooner. But if outplanting is a year or more off, production is better suited to a larger container.

- **Root structure.** Species such as black oaks have such a tremendous tap root that a larger, longer container is better suited for the plant.

- **Who are the planters are going to be?** Volunteers, Boy Scouts or professionals? Volunteers need convenient containers that are easy to unplug while professions are better equipped to unplug seedlings in advance and haul to a site in a planting bag.

- **The job site, soil type aud its accessibility.** Hauling D-pots up a 40 percent grade for two miles isn't much fun.

We typically grow our seedlings in a 38-cavity blow molded poly tray. This container yields a seedling plug six inches deep, which for many applications, is a good size to work with. For example, 1 spoke with the workers who planted our *Ceanothus* on a landing site where the ground was as hard as concrete. The site was a south slope. The planters were pretty happy with the size of hole they had to dig for the *Ceanothus.* In addition, we also had low mortality with the project. If we'd grown the same plants in a larger D-pot, 1 doubt 1 would have gotten that same feedback.

Also, when considering the size of seedling, you and your customer need to remember that it's the roots, not the shoots, that are the most important consideration. Some species, such as blue elderberry, produce a substantial root mass that will fill a tube container the first year. Yet, just a short top shoot, more like a mass of leaves, will grow above. Once the root mass is planted and becomes established, buds develop and begin sending up long shoots up to six feet tal1 by the second year.

With al1 this work, you'd expect a native plant seedling to be expensive. But consider this: 1 can collect the required seed, clean it, stratify it, sow it and grow the seedlings, then deliver it to my customer at a cost of about 85 cents, for let's say an average for a one-year-old bigleaf maple. Just because this is a new field of forestry does not preclude fairness in pricing. By providing a good quality product at a fair price, the customers will return.

By working with your customer from the very beginning of a project, your customer will understand how the specifications he writes will affect the cost of his seedlings.

So to conclude, here are some Rules of Thumb that help determine native seedling costs:

- Common species with generally plentiful seed sets—maples, alders, dogwoods are less expensive to produce than species with harder-to-collect seeds, such as Western azaleas or chinquapin.

- The more specitic a collection site is defined, the more costly for a collector to find and gather adequate amounts of seed for the crop. If the customer wants you, as the seed collector or nurseryman, to hike ten miles into a site, traverse raging rivers, rappel off of steep slopes-it's going to cost them.

- Bareroot or containerized plants? Yes, many of these native species can be fieldgrown with success. We choose to grow containerized plant material because that's where our experience lies. Also, I've got lots of rocks in my ground.

  Also consider that many species with fine root systems, such as: madrone, western azalea and other ericaceous plants, aren't as successfully field grown.

- Containerized seedlings are more bulky than bareroot, but then, you don't have to refrigerate them while waiting for outplanting.

Nurseries and Reforestation in Russia[1]

John R. Scholtes[2]

Abstract—The following paper discusses the nursery portion of a Sustainable Natural Resources Management Project being carried out in the Russian Far East. It describes the project, the location, the current situation, and some of the accomplishments.

INTRODUCTION

My involvement in this project began in late May of 1995 with a telephone cal1 from Peyton (Pete) Owston of the PNW Station, Corvallis, Oregon. Pete explained that he was a Team Leader on a project and was asking about individuals who could design a greenhouse irrigation system for a greenhouse project in Russia. After discussing how "designs" for this type of equipment are usually developed, 1 told Pete 1 thought 1 could draw one out and list the needed parts. This developed into a trip to the Russian Far East. 1 was part of a group made up of Wayne Bushnell, Fire Control Specialist and Chad Converse, Nursery & Tree Improvement Specialist. Both are in State & Private Forestry, Anchorage, Alaska. Wayne was the trip leader.

THE RUSSIAN FEDERATION

The Russian Federation is a huge, very diverse country. 1 already knew that. But just how large, really didn't strike home until I began looking at maps of where 1 was going to visit.

1 have visited Alaska severa1 times and am always impressed by the distances and sizes of that great land area. Once 1 visually compared the Russian Far East to Alaska, 1 began to realize just how large Russia really is. For starters, Moscow is 7 time zones away from the place 1 was to visit! ! Compare that to Washington DC being only 3 time zones away from our west coast. The importarme of the Russian Federation to the world's environment can be expressed by the fact that it contains 20% of the world's forests and 50% of the coniferous forest lands (USAID).

Figure 1. United States vs. Russian Federation.

[1]Scholtes, J. R. 1996. Nurseries and Reforestation in Russia. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 223-227.

[2] Nursery Manager, J. Herbett Stone Nursery, Central Point, Oregon.

WHAT IS THIS PROJECT?

The U. S. Agency for International Development (USAID) is carrying out an extensive program titled *The United States Government Environmental Policy and Technology Project* (EPT). Within this project, is the Russian Far East Sustainable Natural Resources Management Program. In addition to the USAID projects, Region 10 of the U.S. Forest Service and the Pacific Northwest Research Station have a cooperative agreement with the Khabarovsk Territory of the Federal Forest Service of Russia. An implementing agreement that was established by the Forest Service in 1994 includes the following areas of emphasis:

1. Forest Fire Protection and Management
2. Forest planning and Data Management
3. Reforestation and Timber Stand Improvement
4. Administration of Forest Lands
5. Timber Harvesting and Forest Operations
6. Training of Forest Specialists
7. Environmental Education

   Forest Product Development, Utilization, and Marketing

Pete Owston the leader of the "Biology and Culture of Forest Plants" team which is working within the Reforestation and Timber Stand Improvement emphasis area.

WHAT IS THE NEED FOR SUCH A PROJECT?

Past forestry practices in the Primorski and Khabarovski Krais in the Russian Far East have led to decline of biodiversity in large areas of these Krais which are about 94% forested. Although signiticant effort has been made in terms of reforestation, the heavy selection of preferred species (primarily Kedra pine *Pinus koraiensis)* has led to an imbalance of the natural ecosystem. This imbalance is being expressed in severa1 ways. One of which is the effect upon the food chain of the Siberian tiger which is a threatened and endangered species. The tiger depends heavily upon the wild boar. The boar, in turn, depends heavily upon the large seeds of the Kedra pine. Thus interest in saving the Siberian tiger (who's population has declined to 200 or less) from complete extinction leads to the need to reintroduce Kedra pine back into its natural sites. Another major factor is wild land fire which has burned over ten percent of the Khabarovski Krai in the past ten years. Fire prevention and control is a major emphasis area in assistance programs but increased restoration activities are needed regain the biodiversity of endangered areas.

WHERE IN THE WORLD IS THIS PLACE?

The Russian Far East (RFE) is often described as the eastern most tier of **Republics, Oblasts,** and **Krai** (which are administrative units) of the Russian Federation (Figure 2). But as shown, some individuals also include a few interior subdivisions in describing the RFE.

Attention is currently centered at two nursery locations. One is the Nekrasovka site near Khabarovsk and the other is the Goorsky site near Komsomolsk-na-Amurye about 300 kilometers north of Khabarovsk. Both locations are in the Khabarovski krai, which is in the south-eastern portion of the Russian Far East.

FIRST IMPRESSIONS OF A NEWLY ARRIVING AMERICAN

Unlike the view from your airplane at an American airport, there is always an obvious presence of military security. The one or two soldiers that carne out to "guard" our plane were not particularly threatening. They were just there. At the two airports 1 visited, planes were always met by a tire truck and parked some distance away from the terminal. At Magadan, which was our first stop in the RFE, passengers were transported to the terminal via a people carrier which was somewhat like a large bus, only it was a 5th wheel trailer. There were no seats inside so passengers just grabbed a railing and held on while the truck pulled the carrier to the terminal.

The baggage carrier was also a little different. It consisted of one flatbed truck with stake racks. A11 the baggage from the flight was heaped onto the truck for the trip to the terminal. A11 of our luggage arrived in good shape but you probably wouldn't want to carry your laptop in your suitcase.

Figure 2. Russian Far East.

THE CURRENT PROGRAM

A few years ago, prior to the breakup of the Soviet Union, as many as 20,000 hectares were being planted each year (Perevertailo).

Bareroot nurseries and bedhouses have been utilized for many years. I visited a research nursery near Khabarovsk which had several bedhouses filled with nice crops of Kedra pine *(Pinus koraiensis)* and Siberian larch *(Larix siberica)* and a few minor amounts of local hardwoods. The Federal Forest Service nursery at the Nekrasovka site near Khabarovsk also had one bedhouse sown to larch. It had been sown on May 25th and the larch seedlings were growing well ranging from 4 to 8 inches high by August 1st. We where told that about seven bedhouse operations are located at ten nursery sites scattered among the 44 leshos (forest administrative units) within the Khabarovski Krai and that two to three new nurseries are being developed every five years (Chernicoff).

Bareroot seedlings are also being successfully grown and planted throughout the area but a typical production cycle takes 5-7 years. Part of the reason for the long growing period is the density of sowing. Other reasons are lack of irrigation, fertilization and other culturing methods. As we noted during a trip to the Goorsky site near Komsomolsk, some bareroot “nurseries” are little more than clearings along roads where the soil is prepared and seed is sown. Growing is left pretty much up to nature. Heavy soils, short growing seasons and of course, the harsh winters also contribute to the number of growing periods needed to produce plantable seedlings.

At the Nekrasovka site near Khabarovsk, the bareroot operation has not been as fully successful as they would like. Sergei Buten, Nursery Manager is experimenting in an attempt to overcome several problems including soil, climate and lack of labor and equipment. He is attempting sowing in single row beds more like rows for growing corn or potatoes. Seedlings were very dense within these rows. 1 dug out approximately 8 inches of seedling row and it yielded 30 seedlings. The high density was valued as a way to overcome frost heaving. To overcome the lack of irrigation equipment (they have 9 sprinklers to irrigate 1.5 hectares of 2-O seedlings and 2.4 hectares of 1-O seedlings) the recommended sowing depth is 3-4 and up to 5 cm (2 in.) for Kedra pine. The deep sowing and the lack of irrigation during the early summer dry season left seedlings emerging following the arrival of rains in late July.

Root systems of two year old seedlings 1 dug were poorly developed. They had very few secondary laterals. The root systems ranged from 5 to 15 cm in total length (approx. 2-6 inches). Interestingly, even the poorer root systems exhibited signs of excellent mycorrhizal inoculation.

In spite of these tough soil and climatic conditions, 9.2- 10.5 thousand hectares were planted with an estimated 24 million seedlings during the spring of 1995 (Chernicoff).

THE FUTURE

Through funding from USAID and training and advise from the U.S. Forest Service, American companies and other nations, the future for sustaining the natural resources and the environment within this huge land area is improving. The surface has just been scratched and much depends upon the stability of government and the economy within the Russian Far East and the Russian Federation as a whole. A target within the Khabarovski Krai is to be planting 15 thousand hectares each year with about 30 percent of the seedlings being container grown by the year 2000 (Chernicoff).

During my visit, there was a dedication ceremony for the new container nursery operation at the Nekrasovka site near Khabarovsk. Vladimir Pominov the Russian Federal Forest Service administrator of the Khabarovski Krai and Kevin Rushing of USAID provided inspiring speeches and performed a ribbon cutting ceremony. A large utility building had been constructed plus there were three greenhouse frames which were nearly identical to the ones at the research station nursery. Two of the frames had been covered with plastic sheeting. One of these was being utilized for the bedhouse of larch mentioned earlier. The other was being utilized to test containers, growing media, watering system, etc. Tests utilizing 9 different mixtures of native potting materials had been installed. As part of my mission, 1 had purchased and carried over a system of filters, a nutrient injector and an assortment of nozzles to set up the test house for irrigation and the application of fertilizer. Our group had also carried over a small supply of water soluble fertilizer which is not available in RFE.

UPDATE

This past spring (1996) Joe Myers, Nursery Manager of the U.S. Forest Service Coeur de Alene Nursery and John Bartok, Nursery Specialist and Extension Agent at the University of Connecticut made a service trip to both nursery sites mentioned above. U.S. manufactured plastic covering material and other items were pre-shipped and Joe and John packed other items with them. They redesigned and oversaw the reconstruction and covering of existing houses at both sites. In addition, they oversaw the construction of a small demonstration house built to Bartok's specifications. These redesigns and demo designs were caretüllly made to utilize locally available materials so that additional houses could be built as needed.

Pete Owston just returned (August 96) from a trip to this area and was able to revisit the project sites. He reports that some of the seedlings grown in the tests the previous summer turned out fine and were successfully over-wintered. This is great news because over-wintering was one of the larger problems to be solved. He also reports that good crops are being grown in the redesigned houses and in the demo house. In addition, John Bartok is planning to utilize his vacation time later this summer to return to RFE and oversee the construction of a ful1 sized greenhouse based upon his design of the demo house.

Pete also reports that a U.S. made container filling and sowing line has been purchased and is ready for delivery to the RFE. Seed cleaning and storage equipment is also being specified for procurement. Given the accomplishments to date, and future plans, the future of sustainable natural resource management and ecosystem restoration is looking very hopeful.

LITERATURECITED

USAID • Undated pamphlet. Russian Far East-Sustainable Natural Resources Management Project. USAID/ Environmental Policy and Technology Project.

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Forest Nursery Activities in Mexico[1]

John G. Mexal[2]

Abstract-Deforestation in Mexico has prompted efforts to increase nursery production and reforestation success. Survival of planted seedlings is often less than 50%, and less than 15% in some regions. Causes of mortality include grazing, fire, and seedling quality. Grazing and arson result in large-scale failure of plantations; whereas, seedling quality may result in only pat-tial failure. Thus, seedling quality has not received the attention of other, more visible factors. The objective of this paper is to provide an overview of nursery production practices, problems, and potential opportunities for reforestation in Mexico.

INTRODUCTION

Mexico is the eighth most populous country with nearly 90 million people. This population places enormous strain on the natural resources of a country with 40% of the land occupied by forests. Since 1980, about 1% of the forest, or 680,000 ha, is lost each year to deforestation (WRI 1996). This is a potential tragedy of enormous proportions beyond the environmental damage. Mexico has a tremendous wealth of conifer genetic resources with 80 species and subspecies of pine, including the largest seeded pine, *Pinus maximartinezii,* a pine that grows above 3,000 masl, *P. hartwegii,* and species of *Abies, Picea,* and *Cupressus* that are valuable timber species (Perry, Jr. 199 1).

Forests are managed using a selection cut method, where 10 seedlings are replanted for every m^3 removed. Usually, the same species is replanted, but there is little information regarding appropriate genotypes. If seedlings are unavailable, an alternative species may be planted which may not be adapted to the site or elevation. Furthermore, the seedling quality can vary resulting in poor survival or growth.

While forest management practices may affect long-term forest productivity, the greatest threat to the forests is the encroachment of urban centers and clearing of forestland for agriculture. As the population grows, land is cleared for the traditional 'milpa' production system, where corn, beans and melons are interplanted. Crops are grown continuously for severa1 years. The land may be abandoned for severa1 years to recover, and then cleared again and replanted. However, as the population grows, the fallow period is reduced, and consequently, yield is also reduced.

Unfortunately, Mexico has not reached the point where marginal farmland is abandoned and allowed to revert either naturally or artificially to forest. This happened in the southeast U.S. nearly 60 years ago. Land that can economically support agriculture is kept in production, while shallow, rocky, or steep soils are converted to productive forests. When this occurs, Mexico must be able to respond to the demand for reforestation. The nurseries, seed orchards, and infrastructure must be in place to ensure success.

NURSERY SYSTEMS

Mexico has over 450 nurseries producing about 500 million seedlings annually. Most (87%) of the nurseries in Mexico are state or federal government nurseries compared to just 32% for the U.S. (Figure 1). Only 13% of the Mexican nurseries are industry nurseries,

[1]*Mexal, J. 1996. Forest Nursery Activities in Mexico. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 228-232.*

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compared to 40% for the U.S. Furthermore, Mexico has no private forest nurseries, whereas 22% of the nurseries in the U.S. are owned privately.

Most of the nurseries in Mexico do not charge customers for the seedlings. Seedlings are donated to forestry operations or communities. Furthermore, some communities require tree-planting as part of the community service. Thus, no-cost (read no-value) seedlings are planted by volunteers who may have little commitment to the forestry enterprise. Thus, survival is often poor (Negreros-Castillo, unpubl., Sierra Pineda and Rodriguez, unpubl.).

While the seedlings are free to users, they are not without cost. The production costs for polybag seedlings range from $0.03 to $1 .00, with an average cost of $0.20/seedling. This compares to $0.03 for 1+0 seedlings from the southeast U.S. to $0.16 for plug +1 seedlings from the northwest U.S. The high cost is associated with the high manual labor in the Mexican nurseries. One large nursery, producing 13,000,000 seedlings/yr, had 300 permanent employees for filling bags with soil, transplanting, and weeding. Thus, this nursery produced about 40,000 seedlingsper employee. This compares to as much as 4,000,000 seedlingsper employee in U.S. nurseries.

Growing System

Typically, the nurseries of Mexico use the polybag seedling production system. There are a few small bareroot nurseries, and recently, the military has constructed fixed-geometry container nurseries. However, approximately 80% of al1 seedlings are grown in polybags. The size and drainage pattern in the polybags vary with the nursery (Figure 2). The bags range in size depending on the nursery and the reforestation problem. Diameters range from 4.5 to 12 cm, while the length of the bag ranges from 15 to 35 cm. The most common polybag has an open diameter of 5.7 cm and a length of 25 cm.

Most polybags are sealed on the bottom; although some nurseries prefer open bottomed bags. Sealed bags may have three types of drainage holes; corners removed, holes in bottom, or holes along the length of the bag (Figure 2). Some nurseries will even use a combination of removing the corners and punching holes along the length of the bag.

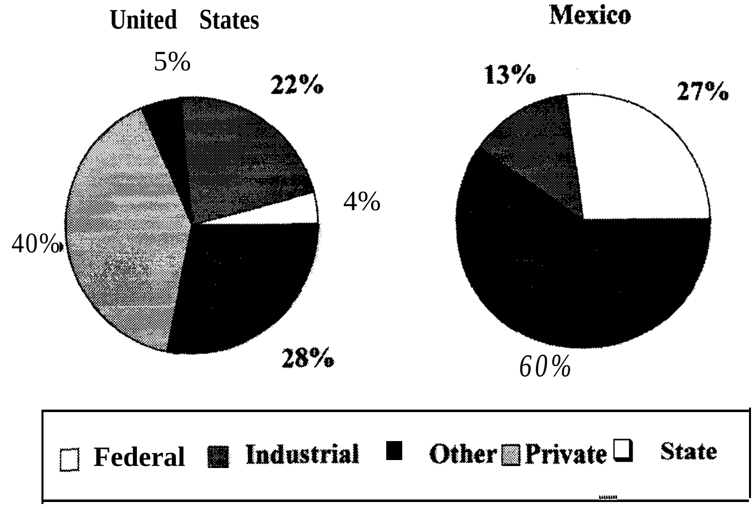

Figure 1. Comparison of nursery ownership between Mexico and the United States.

Most nurseries use forest soil as the growing medium. Occasionally, organic matter, such as bagasse or forest floor litter, or sand will be added. Nevertheless, the medium is heavy. One polybag can weigh 700 g when filled with dry soil. The medium also tends to compact and drain poorly.

Seeding

Nurseries typically do not seed directly into polybags. The poor drainage results in poor emergence and high mortality of recent germinants. In a recent trial, emergence of *Pinus pseudostrobus* in container and bareroot nurseries was over 95% with no damping off. However, emergence in the polybag system was poor and damping off high, resulting in about 3 5% survival. Thus, most nursery managers in Mexico seed in a seedbed, called an 'almacigo'. Following emergence, the seedlings will be pricked out to the nursery. Pricking out begins prior to shedding of the seedcoat when the radicle is about 2 cm long. Nursery workers prick out 1,000 seedlings/day. Thus, a nursery with a production capacity of 1 ,000,000 seedlings requires 1,000 person-days to establish the crop. The pricking out season lasts severa1 weeks, and more typically the seedling's taproot is at least 4 cm long when pricked out. Late transplanting damages and deforms the taproot which affects the long-term survival and growth of the tree. It is common to find one-third of the taproots damaged after transplanting.

Seedling Culture

Forest soil is used as the growing medium because it purportedly supplies beneficial microorganisms (i.e. mycorrhizas). However, disturbance and storage of topsoil has a deleterious effect on fungal propagules, and long-term storage (one year) can essentially eliminate the fungal population (Birch et al. 1991). Thus, the desired benefits of using forest soil may be lost before the soil is placed in the polybag. Few nurseries use alternative substrates such as sawdust, bark, scoria, or sand. The substitutes would be less expensive and result in less degradation of forest land. If forest soil is still desired, the mixture could contain 10% forest soil and 90% other materials. This would be more than adequate for mycorrhizal inoculation. However, nurseries should investigate the potential of relying in wind-blown inoculation or artificial spore inoculation. Utilizing alternative materials would preserve forest soil, and reduce the weight of the polybags.

While forest soil may provide the desired mycorrhizal inoculum, it tends to be inherently infertile. Forest soil may have as little as 50 mg N/kg soil, where the seedling may require over 100 mg N (Switzer and Nelson 1963). Thus, fertilization is as important in polybag systems as other seedling production systems. Several nurseries use formulations of slow-release fertilizers containing micronutrients and plant growth regulators (Mexal et al. 1995). These formulation are 7-8 times more expensive than the most expensive fertilizer formulation in the US. However, there is no incremental benefit from the additional micronutrients and plant growth regulators. Nursery managers would be wise to use scarce financial resources where they accrue the greatest benefit. Expensive fertilizer formulations are not economically justified.

Root Quality

Root pruning is a critical component of polybag seedling culture (Galloway and Borgo 1983; Patino Valera and Marin Chavez 1983). The taproot quickly grows to the bottom of the bag, and often escapes into the soil below the bag through a drainage hole. Generally, seedlings with roots growing outside the bag are larger because of increased nutrient and water availability. Thus, seedlings with the 'best' looking shoot morphology may have the poorest root morphology. Seedlings with R/S ratios less than 0.25 are common (Table 1). This R/S is much lower than the R/S recommended for bareroot seedlings (Mexal and South 199 1), and lower than the R/S ratio for containerized seedlings (Brissette and Barnett 1989). Low R/S ratio reduces survival potential of seedlings. In fact, nearly 50% of the mortality reported by Sierra Pineda and Rodriguez (unpubl.) might be attributable to the poor R/S of the outplanted seedlings.

Another concern with polybag seedlings is root spiraling (Josiah and Jones 1992). Seedlings with encircling lateral roots will eventually strangle and die or topple. However, spiraling roots is not a common occurrence in seedling root systems. It may occur only when seedlings are held more than one year in the same polybag. Most seedlings suffer from root deformation following pricking out or poor R/S ratio caused by the taproot escaping the bag (Figure 3).

Target Seedling Concept

The target size specifications for seedlings destined for reforestation are at least 3 mm seedling diameter, and height range of 25-30 cm. There are no specifications for root systems. However, while most nursery managers use these targets, it is often difficult to

Figure 2. Drainage patterns for different sized polybags from nurseries in Mexico.

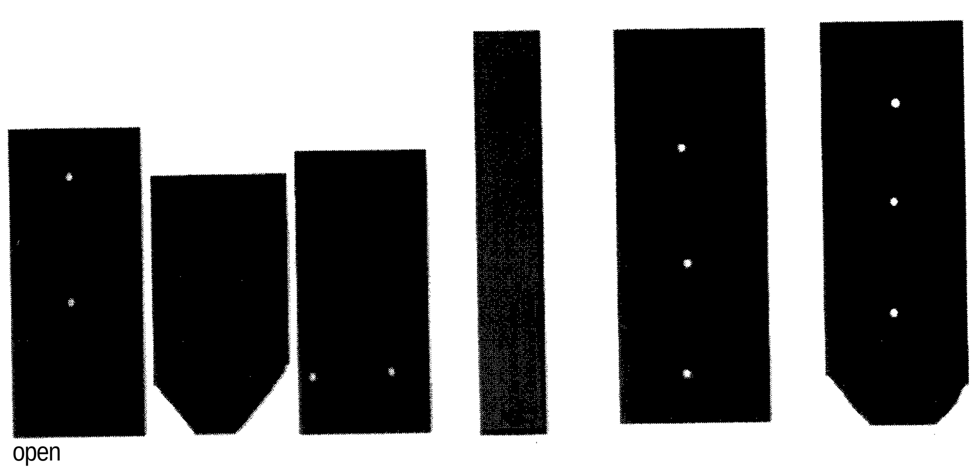

Table 1. Variation in seedling dry weight and R/S of two Mexican conifers grown at different nurseries (Cuevas Rangel and Mexal, unpublished).

Species	Nursery	Shoot D.W. (g)	Root D.W. (g)	R/S
Cupressus lindleyi	1	31.3	5.6	.18
	3	20.5	2.5	.12
	2	4.1	1.5	.36
	6	3.2	0.7	.22
Pinus pseudostrobus	3	14.4	2.6	.18
	4	10.8	5.2	.48
	5	6.3	1.9	.30
	4	3.8	1.2	.32

achieve the goal. A common problem is scheduling the seeding and transplanting early so to achieve the target size in time for outplanting. Money to hire laborers for seeding often is late, thus delaying the crop. There is little published information relating seedling size to field performance. Thus, it is difficult to convince managers of the importance of proper timing. It is not uncommon for seedlings targeted for outplanting in July to be seeded in March. These seedlings would be too small to survive the rigors of transporting and planting.

In addition to producing small seedlings, nurseries also produce seedlings too tal1 for successful outplanting. If seedling are not planted during the first rainy season, the crop may be held over for the next planting season. If not top-pruned, seedlings can achieve a height of over 1 m during the second growing season. Invariably, the root system has escaped the polybag and growing in the nursery bed below the bags. Thus, the R/S ratio is unacceptable resulting in poor survival.

Harvest and Planting

Seedlings are planted during the rainy season (June-September), while the seedlings are actively growing. Plants are removed from the nursery bed by hand, and transported in open trucks to the planting site. Seedlings are planted by members of the community as time permits. Thus, seedlings may be stored at the planting site before planting. The polybag root system tolerates short-term field storage because the forest soil has good water holding capacity. However, these root systems tend to have most of the roots on the exterior of the rootball, and the effects of handling, transport, and stockpiling may damage the roots contributing to poor survival.

Since most seedlings are planted by community members, the planting season can be long. However, survival is greatest if seedlings are planted early in the planting season (Mas Porras, 1993). Survival averaged over 80% for June plantings, while survival of August plantings was less than 60%. It is likely that growth would also be depressed with late plantings (South and Mexal 1984).

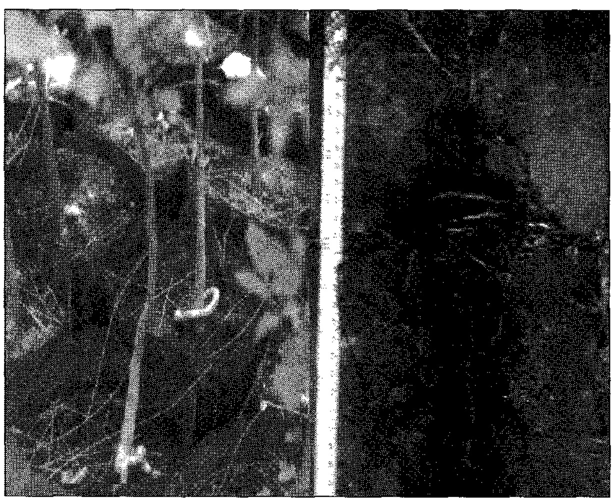

Figure 3. Examples of root spiraling caused by polybag production system. Left: Spiraling evident after transplanting from small polybag to larger bag; Right: Spiraling evident after excavation from plantation.

Once the seedlings are planted, the area planted often may be grazed. Furthermore, attempts to improve pasture by burning also may occur. About 20% of seedling mortality in central Mexico is the result of burning or grazing (Sierra Pineda and Rodriguez, unpubl.). Pasture for livestock apparently is viewed as more valuable than trees for future wood harvests.

FUTURE NEEDS

The forest lands of Mexico are diversely rich and have tremendous productive potential. However, the forests should be managed for wood products rather than cleared for agriculture or pasture. To effectively accomplish this, the nursery systems must be improved. This does not necessarily infer the nurseries must convert to conventional containerized production systems. The capital costs of conversion may be beyond the resources of some communities. Furthermore, the benefíts of converting a nursery will be lost without first an understanding of the biology of seedling growth (Mexal et al. 1994). Nursery managers need training in seed biology and seedling physiology. They need to follow their seedlings to the planting site, and excavate seedlings during the establishment year. Most importantly, they need information which will allow them to improve the quality of seedlings produced in polybag systems. Mexico needs a national nursery and reforestation center which can provide technical assistance to communities and state forestry programs. Furthermore, this center might provide consultation to communities involved in leasing lands or cutting rights to multinational corporations.

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BuRIZE™ NTC-Nursery and Turf VA Mycorrhizal Soil and Root Inoculant[1]

John Olivas[2]

BuRIZE™ NTC contains the Vesicular Arbuscular Mycorrhizal (VAM) fungi found naturally in healthy soils. VAM colonization of plant roots are key contributors to the growth of many varieties of woody shrubs, nonconiferous trees, ornamental plants, and turf. The VAM found in BuRIZE™ NTC are from Endomycorrhizae, which are able to colonize 90% of all plants. VAM fungi form a beneficial symbiotic relationship with plants, bringing in additional water and nutrient for plant growth. The plant in turn "shares" the additional photosynthate (carbohydrates and vitamins) production with the VAM fungi. Through colonization of plant root cortical cells and growth of hyphae through the roots into the surrounding soil, VAM fungi increase the surface area of the root. This expanded root surface area increases the nutrient and water uptake potential of the plant.

Many of today's high input agriculture production practices, including fumigation, steam sterilization, artificial growth media, and reduced organic matter inputs, inhibit the growth of VAM fungi. Application of BuRIZE™ NTC gives the user an added jump start on growth by allowing early recolonization by these beneficial fungi.

MIXING INSTRUCTIONS

BuRIZE™ NTC is not ready for use until BuRIZE™ NTC and BuRIZE™ Dry Concentrate are mixed together. Mixing should take place just prior to application. Combine ingredients at the concentrations specified by BuRIZE™ Dry Concentrate labe1 and shake, stir or agitate for five minutes before use. BuRIZE™ NTC is ready for use after mixing and when the liquid has turned green in color. **Do not use BuRIZE™ NTC if liquid is not green in color.**

INCOMPATIBILITIES

Always jar test newly attempted mixes. Avoid strongly acidic/basic conditions and high concentrations of free ammonia. Do not mix with liquid ammonia, sulfuric acid, urea sulfuric acid, phosphoric acid, soil fumigants, or soil fungicides. No other known incompatibilities.

DIRECTIONS FOR USE

For use as a Vesicular-Arbuscular Mycorrhizal soil and root inoculant, apply in close proximity to the seed and newly developing root system. When used in transplant operations, apply as a "root dip," "drench," or mix BuRIZE™ NTC with the transplant water/ fertilizer solution (see directions for application). As the use of BuRIZE™ NTC may affect crop nutrient response through increased root surface area, caution should be exercised when applying BuRIZE™ NTC with fertilizers to prevent "fertilizer salt" induced phytotoxicity. Where fertilizer salts are the combination of nitrogen, potassium and metal salts, do not exceed 5 lb of total salt on the seed and/or 10 lb of salt per inch away from the seed and roots. Where warranted, adjust fertilizer rates and replace with a maximum of a 1: 1 ratio of up to 15 qallons of BuRIZE™ NTC/acre/application.

[1]Olivas, J. 1996. *BuRIZE™ NTC-Nursery and Turf VA Mycorrhizal Soil and Root Inoculant. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associatíons. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 233-234.*

[2]*Bio Sci, 3574 Escalon Ave., Fresno, CA 93711; Tel: I-800-872-2461; Fax: 209/439-8639.*

GENERAL USE DIRECTIONS

Use 5- 15 gallons per acre early in the growing season, or as needed. As this product is of benefit to plant roots: **Applications of high placement accuracy will allow lower rates, while low placement accuracy will necessitate a higher rate.**

Typical product characteristics	
Statement of composition:	
Glomus intraradix	2.00 propagules/cc
Weight per gallon	8.40 lb

TURF

Apply as a broadcast application at 0.5 to 1.25 quarts per 1000 square feet in enough water to ensure movement into the root zone.

NURSERY AND ORNAMENTAL

Media inoculant-Apply 10 to 24 ounces per cubic foot of media just prior to planting. Soil drench-Apply ll .73 ml per square yard, or a 15 gallons per acre equivalent. Apply in sufficient water for coverage without excess leaching.

Transplanting-Apply as a root dip in ful1 strength solution, or dilute as a drench to the transplant site.

Cal1 1-800-BUCKMAN for more information or technical assistance concerning use rates for crops not covered in this label.

STORAGE AND HANDLING

As packaged material, shake, stir or agitate before use. Store in a cool dry place. When handled in bulk quantities, storage in a cone-bottomed tank to facilitate agitation is recommended.

When stored in a cone-bottomed tank, agitate 10 minutes prior to shipment. When stored in a flat-bottomed tank, agitate 1 hour before shipment. Avoid air blast agitation as foaming will result. If foaming does occur through normal agitation, use Harcross Chemical AF10FG defoamer. Agitation is recommended once every month. Storage for longer than 6 months is not recommended.

Follow appropriate safety procedures. In case of accidental exposure, flush with plenty of water. Product is D.O.T. nonhazardous.

Status on Commercial Development of *Burkholderia cepacia* for Biological Control of Fungal Pathogens and Growth Enhancement of Conifer Seedlings for a Global Market[1]

M. S. Reddy[2]

Abstract—Forestry is an extremely important industry in many countries. With an increasing demand for forest products, many forest companies and government organizations have turned toward more intensive management practices to increase productivity of forest lands. Seedling losses occur in conifer nurseries as well as on reforestation sites despite of the best efforts employed by nurserymen and foresters in disease control and site preparation. Fungal pathogens such as *Fusariurn, Pythium, Rhizoctonia, Cylindrocarpon, Cylindrocladiurn* and *Botrytis* are widespread causing seedling losses in nurseries. These pests are also transported to field sites where they continue to cause economic losses by killing, stunting, or deforming transplanted seedlings. One of the most acceptable and environmentally-conscious approaches to solving these problems is the use of a naturally occurring microbial inoculant. We have assessed a microbial culture collection of approximately 500 strains of diverse origin for biological control of fungal pathogens and/or plant growth promotion of various types of conifer spp. under laboratory and greenhouse conditions. Variable results were obtained for most of the strains tested, except for one isolate which is a *Burkholderia cepacia,* strain Ral-3. For further product development, a proprietary liquid formulation was developed and used in product efficacy trials as a seed or root dip treatment on several conifer species at several locations in western Canada and the Pacific Northwest, USA. Storage stability of strain Ral-3 in commercial packages was maintained, with a viable population of about log 8-9 cfu/ml for over a year when stored at 5-20°C. In most trials, strain Ral-3 showed significant suppressive effects on various soil-borne fungal pathogens. Significant growth responses including survival, root and shoot biomass, height and caliper were observed. Strain Ral-3 is compatible with many seed treatment fungicides and with other cultural practices currently used in the forestry industry. Strain Ral-3 is also an active and aggressive rhizosphere colonizer of many conifer spp., such as white spruce, Douglas-fir, jack pine, Scots pine, cedar, and western hemlock. Possible mode of action and other data related to regulatory requirements will be discussed.

INTRODUCTION

Company Background

Agrium Inc., is one of North America's largest integrated and diversified fertilizer companies. The Corporation is a major producer of nitrogen-based fertilizers and potash, and a leading marketer of the four primary nutrients vital to plant growth: nitrogen, phosphorus, potassium, and sulphur. It produces nitrogen fertilizers at four locations, two in Alberta, one in Texas and one in Nebraska; and potash at its mine and mil1 in Saskatchewan. Its net annual fertilizer production capacity is 2.9 million tons available for sale.

[1] *Reddy, M.S. 1996. Status on Commercial Development of* <u>*Burkholderia cepacia*</u> *for Biological Control of Fungal Pathogens and Growth Enhancement of Conifer Seedlings for a Global Market. In: Landis, T.D.; South, D.B., tech. coords. National* Proceedings, Forest and Conservation *Nursery* Associations. Gen. *Tech.* Rep. PNW-GTR-389. Portland, OR: U.S. Department *of Agriculture, Forest Service, Pacific Northwest Research Station: 235-244.*

[2] *Agrium Biologicals,* 402-15 Innovation *Blvd.,* Saskatoon, Saskatchewan, *CANADA, S7N 2X8; Tel: 306/975-3843;* Fax: *306/ 975-3750; Email: mreddy@innovplace.saskatoon.sk.ca.*

The company also operates a wholesale distribution, storage and marketing network in North America. At the wholesale level, the Corporation's fertilizers are purchased by a geographically-diverse group of approximately 1,500 customers in North America. Approximately one quarter of its potash production is sold offshore.

At the retail level, its subsidiaries Western Farm Services, Inc., (WFS) and Crop Production Services, Inc., (CPS) serve retail markets with a network of more than 200 outlets in the major agricultura1 areas of the western, upper midwestern and eastern United States.

Agrium Biologicals, a specialized group within the New Products R & D arm of Agrium Inc., is committed to the development and commercialization of microbial inoculants for use in agriculture and forestry as a method to increase the efficiency of fertilizer uptake and use, and to enable biological control of various crop diseases. 'This R & D unit is a natural extension to the fertilizer products and services offered by Agrium lnc., positioning the company for growth, innovation and profitability through the introduction and sale of leading edge, and environmentally responsible, new products and services.

Agrium Biologicals specializes in symbiotic, and non-symbiotic Plant Growth-Promoting Rhizobacteria (PGPR) and Biological Control Agents (BCA). Research is directed toward microbial inoculants able to directly promote plant growth and development through increased nutrient uptake, increased nutrient availability and suppression of plant pathogens.

Through the R & D efforts of the Biologicals group we have 3 successful biological products in the market. They are *Rhizobium* inoculants for legumes and are being marketed through Cargill in Canada and through WFS, CPS and Wilbur Ellis in the United States as RhizUD™ for Peas, Lentils and Beans.

Forestry

Forestry is an extremely important industry in many countries, including Canada (Reddy et *al.* 1993). With an increasing demand for forest products, foresters have turned toward more intensive management practices to increase productivity of forest lands. These methods include the breeding of forest trees with increased growth and superior wood characteristics, artificial regeneration of seedlings, control of competing vegetation, thinning stands to reduce competition between trees, fertilization to stimulate growth, and improved methods for harvesting and utilization of wood. Most of these practices are well understood and are used in modern forestry. Perhaps the most effective way of increasing productivity is the use of genetically improved material as planting stock. Unfortunately, this material is usually in short supply.

Over seven hundred million conifer seedlings are planted annually in Canada. It is imperative that seedling quality be at a high leve1 to allow for successful reforestation of harvested land. Seedling losses occur in conifer nurseries as well as on reforestation sites. Fungal pathogens inciting seed and/or root diseases in nurseries include *Fusarium, Cylindrocarpon, Cylindrocladium, Pythium, Botrytis* and *Rhizoctonia.* Diseases caused by these pathogens may be important limiting factors in production of high quality seedlings in forest and conservation nurseries. All nurseries experience some losses to damping-off and root rot diseases, despite the best efforts at control. These losses may occur in severa1 forms, the most obvious being dead and dying seedlings observed in nursery beds. The economic loss represented by this type of seedling mortality may vary with the age of the affected seedlings. Diseases may also damage seedlings, making them unsuitable for planting. Damaged seedlings are thrown away (culled) during lifting and packaging. Some diseased seedlings may escape culling or remain symptomless at the time of lifting. In these cases, pests are transported to field plantings, where they continue to cause economic losses by killing, stunting, or deforming transplanted seedlings.

Chemical pesticides were initially formulated for effectiveness on many soil-borne pathogens. This broad spectrum efficacy often resulted in destruction of both beneficial and injurious organisms (Baker and Cook 1974). However, resistance to these chemicals can develop rapidly in pathogens. In recent years, problems with pesticide resistance, toxicity to non-target organisms, and environmental contamination have greatly reduced the desirability of chemical fungicides (Campbell 1989). Recent public and government involvement in banning chemicals used in agriculture and forestry will undoubtedly make the use of chemical fungicides difficult at best. Therefore, foresters and nursery managers need to examine all alternatives for controlling fungal diseases.

Losses in forest productivity include poor seedling establishment and survival on reforestation sites due to factors other than disease. For example, root growth of transplanted seedlings is often limited, contributing to poor seedling health. Root system morphology is a major determinant of seedling success in the field. The goal of bareroot nursery managers is to produce high quality seedlings which can tolerate lifting, handling, and planting processes, and not only survive but grow competitively in the field. This goal is a challenging one to attain. No two nurseries are alike and within-nursery variation in soil and microclimate may be as great as that among nurseries. Seedling grading has been controversia1 because no scientifically based procedure has been developed for identifying which seedlings in a nursery will be the most competitive in the field. The economic impact dueto seedling losses on reforestation sites, regardless of the cause, is substantial since the approximate cost to planta single seedling is $1 .OO. In addition, it often takes more than 5 years for seedlings to reach the "free to grow" stage. A major problem associated with this in white spruce is "growth check" which refers to the lack of growth in a seedling once it is planted in a reforestation site. In conifer nurseries, losses resulting from diseases and culling can be 15-25% in some years. This represents an annual loss of up to $45 million. Moreover, at reforestation sites poor seedling survival and establishment can result in an annual loss of $290 million.

Foresters and nursery managers need to examine all alternatives for controlling fungal diseases and reducing losses. One of the most acceptable approaches to disease control is the use of naturally occurring microbial inoculants to reduce or suppress the activity of fungal pathogens (Reddy 199 1). Cook and Baker (1983) defined biological control as "the reduction or suppression of pathogen inoculum or its disease producing capacity by the action of one or more organisms, other than humans." There is a great potential to utilize beneficial microorganisms to reduce losses both in conifer nurseries and on conifer reforestation sites. The importance of microorganisms such as mycorrhizae for biocontrol of conifer seedling diseases and improving seedling growth is well established (Kropp and Langlois 1990; Harley and Smith 1983). Conifer seedling growth can also be stimulated by inoculating with strains of naturally occurring soil bacteria (Reddy *et al.* 1993; 1994; Chanway *et al.* 1991).

The rhizobacteria that exert beneficial effects on plant development are called plant growth promoting rhizobacteria (PGPR) (Kloepper and Schroth 1978). To date, most PGPR strains for which the mode of action has been investigated appear to enhance plant growth indirectly by reducing populations of deleterious microorganisms (Kloepper 1993). Direct growth promotion occurs when rhizobacteria produce metabolites *(i.e.* plant growth regulators) that directly promote plant growth without interacting with native microflora (Kloepper *et al.* 1989; 199 1; Lifshitz *et al.* 1987). Some direct acting PGPR strains can induce alterations in plant physiology and these changes may include increasing the host plant's defences to pathogen attack (Vanpeer *et al.* 199 1; Wei *et al.* 199 1). Disease reduction by PGPR may also occur as a result of competition, antagonism or parasitism. Weller and Cook (1983; 1986) showed that a *Pseudomonas* species isolated from *Fusarium* suppressive soils controlled take-all disease of wheat in greenhouse and field trials. They showed that the antagonism was due to the production of phenazine antibiotics (Brisbane *et al. 1987).* Howie and Suslow (1991) showed that a fluorescent pseudomonad produced antibiotics that suppressed P. ultimum in cotton rhizospheres, decreasing disease incidence by 70% and increasing seedling emergence by 50%. Some strains that increased yields produced siderophores that bind Fe(III), making it less available to certain members of native microflora (Kloepper *et al.* 1980). Hydrocyanic acid (HCN) is produced by many rhizobacteria and is postulated to play a role in biological control of pathogens (Schippers 1988). Biological control can also be achieved by the competition of rhizobacteria with other rhizosphere organisms for infection sites and siderophores. Pseudomonads that catabolize diverse nutrients and have fast regeneration times in the root zone are often suitable candidates for biological control by competition, especially against slower growing pathogenic bacteria (Weller 1985).

Many diverse groups of bacteria commonly inhabit nursery soil. Severa1 of these species are antagonistic toward common soil-borne pathogens (Reddy and Rahe 1989; Reddy 1991; Reddy *et al.* 1991; 1992; 1993; 1994). In our R & D program beneficial microorganisms specifically selected for forestry are being evaluated specifically for:

1. **Suppression of damping-off and root rot pathogens of conifer seedlings.**
2. **Enhancement of conifer seedling germination, growth and survival.**

Over the past severa1 years of research using many bacteria1 isolates we have successfully identified a potential bacteria1 isolate for further product development and commercialization. We are pleased to present in this paper some of the product development related experimental results.

GENERAL USE RECOMMENDATIONS OF STRAIN RALS

Agrium's microbial inoculant contains naturally occurring, nonphytotoxic, nonpathogenic soil bacteria *Burkholderia cepacia* strain Ral-3. This strain was isolated from the root nodules of a soybean plant (CV. Braxton) grown in sandy loam soil at the E. V. Smith Experimental Station research site near Shorter, Alabama, USA. To maintain purity, cultures of strain Ral-3 are stored in a Kelvinator freezer at -80 °C in tryptic soy broth amended with 20% glycerol. Ral-3 has been identified in Agrium's laboratory by determining the Analytical Profile Index (API) 20 NE, OXI/ FERM TUBE and ampicillin sensitivity. Strain Ral-3 has also been identified in two other laboratories using fatty acid analysis. Base on these tests, strain Ral-3 was identified as *Burkholderia cepacia.*

Strain Ral-3 is commercially produced under fermentation conditions and is available in a liquid formulation. The concentration of the bacterium is approximately 109 viable cells per ml. Liquid inoculant is packaged in sterile 3L plastic bags which are placed in cardboard boxes for long-term survivability and ease of shipping. The shelf-life stability of this inoculant is at least a year when stored at temperatures of 30°C (86 F) or less. Short-term exposure to 40°C or below freezing temperatures does not have any adverse effects on the shelf-Iife stability of the inoculant.

The active component is antagonistic to severa1 plant pathogenic fungi such as *Pythium, Fusariurn, Cylindrocarpon, Botrytis,* and *Rhizoctonia,* thereby aiding in suppression of infection by these damping-off and root rot pathogens. This product can be used with most other silvicultura1 practices. The types and degree of responses observed may vary depending on environmental factors and management practices. Best results are achieved if the product is used according to the instructions provided on the label.

Use Instructions

This product can be easily applied to conifer seeds and seedlings in severa1 ways.

Seed treatment

A volume of 300 ml of this product will treat 1 kg of conifer seed. Weigh the seed intended to be treated first. Place the seed in a plastic bag. Apply the product to the seed using the indicated volume and sea1 the bag. Shake the bag by hand until the surface of the seeds are evenly coated or moistened. Air dry the treated seed for 5 min. Treated seed must be planted within 5 days of inoculation. Store inoculated seed in a cool place (5 to 10 "C) away from heat and stress if not planting on the day of treatment. Planting on the day of treatment is recommended.

Fungicides

This product is compatible with Vitaflo-250, Captan, Thiram, Benlate, Baytan, Crown and Rovral. These fungicides may be applied to seed before inoculation with the product. Fungicide treated seed must be allowed to dry before treating with the product. Destroy unplanted treated seed in accordance with applicable municipal, provincial and federal statutes and guidelines.

Use a rate of 300 **ml per kg seed** for the following conifer types:

White Spruce	Jack pine
Black Spruce	Scots Pine
Engelmann Spruce	White Pine
Douglas Fir	Slash pine
Loblolly pine	Longleaf pine

Seedling treatment

Seedlings can be inoculated with the product using one of several methods.

Boom irrigation for containered seedlings

If seedlings have not been lifted from growth containers, boom irrigation/injection system is the preferred method of inoculation. Inject the product into the boom irrigation system at a ratio of 1: 1 OO (10 ml inoculant per 1000 ml water). Agitate the product continuously during injection to prevent clumping or settling of bacterial cells. Irrigate the seedlings until the plugs in the containers are completely saturated (i.e. dripping from bottom of blocks).

Portable sprayerfor containered or bareroot seedlings

If a boom irrigation/injection system is not available, the product can be applied through a portable or backpack sprayer. Triple rinse the sprayer tank with water before use. Dilute the product at a ratio of 1: 1 OO (1 ml in 100 ml of water) and fill-up the tank up to a desired volume. Spray onto seedlings until evenly irrigated 3-4 days before lifting. This method is applicable for both containered and bareroot seedlings.

Seedling dip for containered or bareroot seedlings

The product can also be applied directly to seedlings by the root dip method. Dip the bareroot seedling plugs in a suspension after diluted to 1: 10 in tap water (100 ml inoculant plus 900 ml water) and container stock in a suspension diluted to 1: 1 OO (10 ml inoculant plus 990 ml water) for a few seconds. This method is applicable either in the nursery or at the plantation site.

Timing of application

Apply the product to seedling plugs preferably l-3 days before lifting. Do not apply chemical pesticides to seedlings at the same time as the inoculant. The recommended time interval after pesticide treatment and before inoculation is 48 h. Inoculated seedlings can be lifted according normal to nursery practices. Treated seedlings can be planted or stored for winter hardiness

Product requirements for application to seedling plugs

Product uptake by the seedlings will vary depending upon seedling type (bareroot or container), container size, and moisture status of seedling plug at the time of application. For containered seedling stock use at the rate of 10- 15 L of the product diluted 1: 1 OO in water to treat approximately 100,000 seedlings. In case of bareroot seedling stock use at the rate of 10- 15 L diluted 1: 10 in water to treat approximately 100,000 seedlings.

Frequency of application

Only once at time of seeding, or only once at time of lifting or at time of planting of the seedlings.

The purpose of this report is to draw the attention of forest managers and researchers to the potential commercial value of incorporating microbials as seed or root inoculants to increase productivity in intensive forestry programs. Selection of this bacteria was based upon availability, ease of manipulation, wide geographic and host range, and demonstrated benefits to a wide variety of host trees.

Agrium Biological's team of research scientists and fermentation and formulation specialists work from a facility located in Saskatoon, Saskatchewan, Canada. Research on microbial inoculants for conifers has been ongoing for the last six years to identify microorganisms capable of improving seedling field performance and promoting seedling emergence and growth in the nursery. Research trials conducted on reforestation sites have shown that seedlings treated with our microbial inoculant survive better and have improved root and shoot growth compared to untreated seedlings. Similar trials in commercial seedling nurseries have revealed that inoculants applied as a seed treatment can promote seedling emergence and enhance shoot and root growth.

COMMERCIAL BENEFITS

The shelf-life stability of strain Ral-3 maintained an acceptable level irrespective of its storage at various temperature regimes. The strain had initial populations of log 9 to 10 cfu/ml. After 12 months of storage at 5°C, Ral-3 maintained a population of log 8 to 9 cfu/ml. The antagonistic activity of strain Ral-3 retrieved from the packages after storage at the various temperatures was tested *in vitro* using a dual plate technique against *F. solani, R. solani*, and *C. destructans*. Strain Ral-3 significantly suppressed the radial growth of the fungi tested irrespective of its storage regimes.

Enumeration of a rifampicin marked strain of Ral-3 on various conifer seeds stored at 5°C showed that its populations were maintained at about log 4-5 cfu/seed for the entire sampling period, except on black spruce (Figure 1), when tested as seed treatment at a rate of 0.3 ml per gram of seed with a cell suspension of log 9-10 cfu/ml in a commercial liquid formulation. Strain Ral-3 survived very well on white spruce seedling plugs when applied as a seedling dip at a rate of 6-8 ml/plug and stored under commercial storage conditions (2 to 3 °C) for winter hardiness before being planted on reforestation sites (Figure 2). Figures 3 and 4 illustrate the colonization potential of strain Ral-3 on growing seedling rhizospheres when introduced either as a seed or seeding treatment on various conifer species.

When applied as a seed treatment strain Ral-3 reduced disease incidence caused by *F. oxysporum* on Douglas-fir seedlings and improved healthy stand compared to the non-treated control (Figure 5). Similarly, strain Ral-3 reduced disease incidence and improved emergence of white spruce and jack pine seedlings (Figure 6). In many cases this strain also minimized symptom expression on roots infected with many fungal pathogens. As shown, (Figure 7) Ral-3 signiticantly reduced the fungal contaminants of western larch seed when cultured on filter paper.

Seedling emergence was assessed in several greenhouse nurseries for containered and bareroot seedlings. Strain Ral-3 increased the emergence in most of the cases compared to untreated control. Also the root rot symptoms, root plug quality, height and root collar diameter were evaluated at the end of the growing season. Strain Ral-3 had a significant influence on

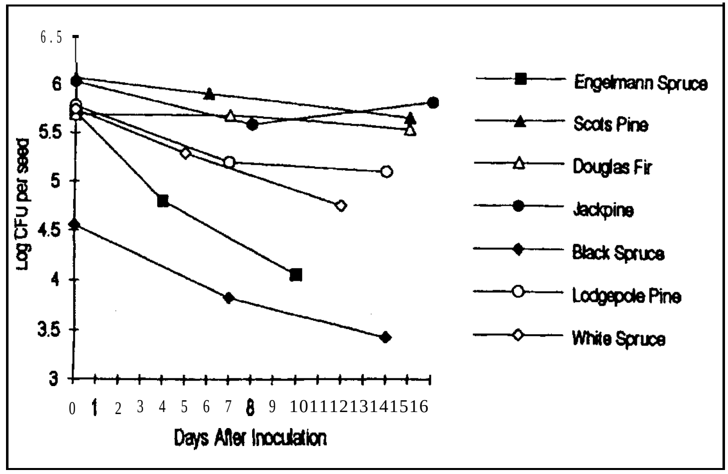

Figure 1. Shelf-life of strain Ral-3 on various conifer seeds.

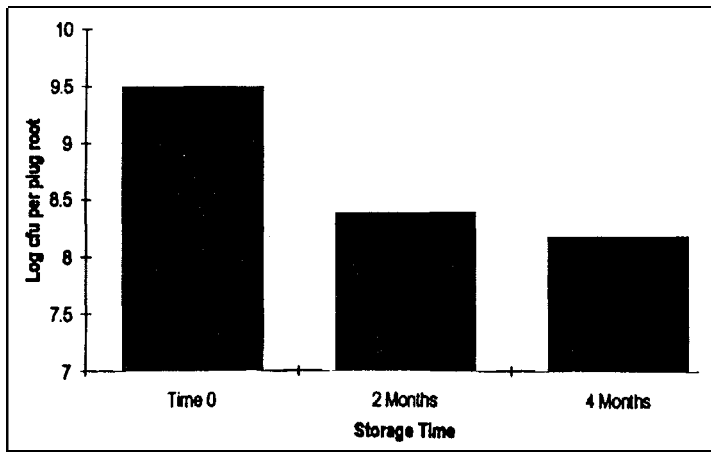

Figure 2. Shelf-life of strain Ral-3 on White Spruce seedling plugs stored under commercial conditions.

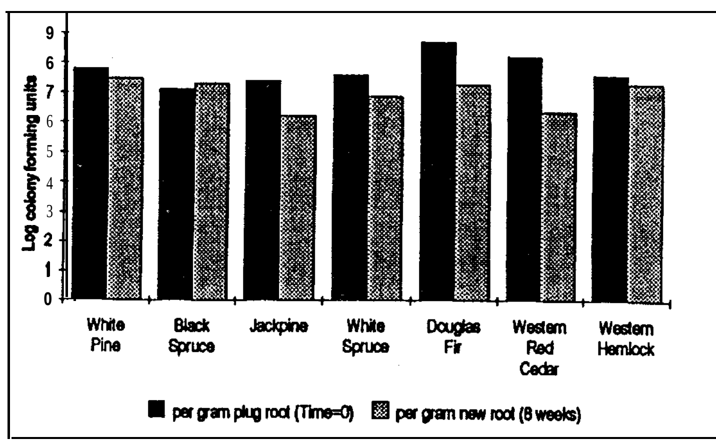

Figure 3. Colonization potential of Ral-3 on various conifer seedling rhizospheres under greenhouse conditions when applied as a seedling plug treatment.

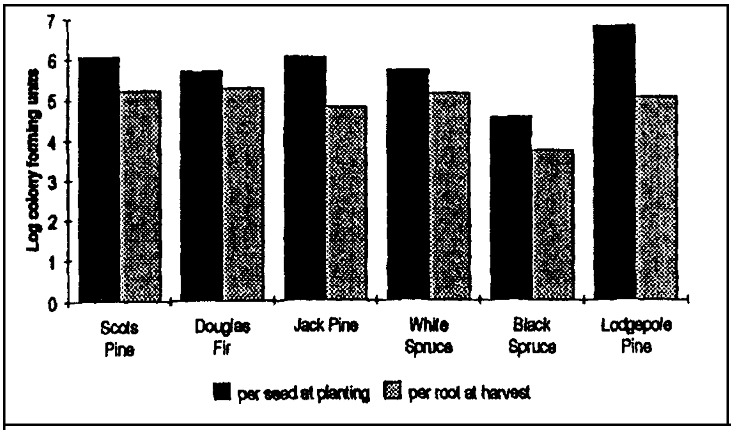

Figure 4. Colonization potential of Ral-3 on various conifer seedling rhizosheres when applied as a seed treatment.

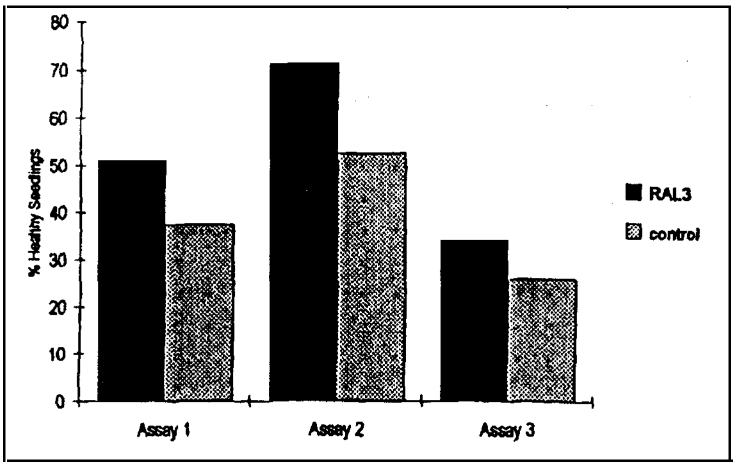

Figure 5. Healthy stand of Douglas-Fir seedlings grown in soil mix artificially infested with Fusarium oxysporum. Asterisks denote significant increases compared to control ($p \leq 0.05$).

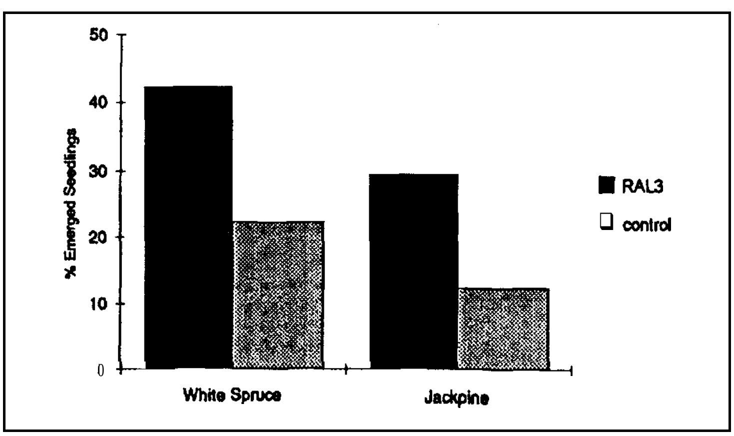

Figure 6. Influence of Ral-3 on the emergence of conifer seedlings grown in soil mix artificially infested with Fusarium oxysporum.

these parameters. These results suggests that the bacteria may be decreasing symptom expression by reducing infection or colonization of roots by pathogens.

Plant growth promotion field trials were conducted at severa1 locations across Canada and the Pacific Northwest of United States on severa1 conifer species using Ral-3 as a seedling plug treatment. Results of growth parameters measured such as root and total shoot biomass were significantly increased compared to untreated controls in most of the experiments conducted. For example, as shown in Figure 8, strain Ral-3 significantly increased survival of white spruce bareroot seedlings on a reforestation site in Saskatchewan by 19 to 23% when compared to non-treated seedlings. In addition, Ral-3 increased new shoot biomass of white spruce seedlings planted on reforestation sites (Figure 9).

Due to space constraints we are unable to discuss other product developmental activities such as scale-up of the product in commercial formulation, optimizing the delivery system either as a seed or seedling application, packaging of the product, storage conditions for the product etc.

DISCUSSION

Out of approximately 500 bacteria1 strains, Ral-3 has been selected for the ability to suppress *Fusarium, Rhizoctonia, Cylindrocarpon* and *Pythium* diseases and promote seedling growth . Inoculation of the strain onto Douglas-fir seed reduced the incidence of disease caused by these common fungal pathogens and increased the number of healthy seedlings in a commercial nursery. In tests at replant sites, root-dip inoculation with the strain increased new root dry weight, total plant biomass, and survivability of transplanted seedlings. Seedlings with more roots generally have increased incrementa1 height and diameter growth and it is these seedlings that establish most successfully after transplant.

In natural environments, growth and yield of plants depends on the quantity and balance of water, minor nutrients, air, light, and heat, but are also subject to positive and negative influences of various rhizosphere microorganisms. Both direct and indirect mechanisms

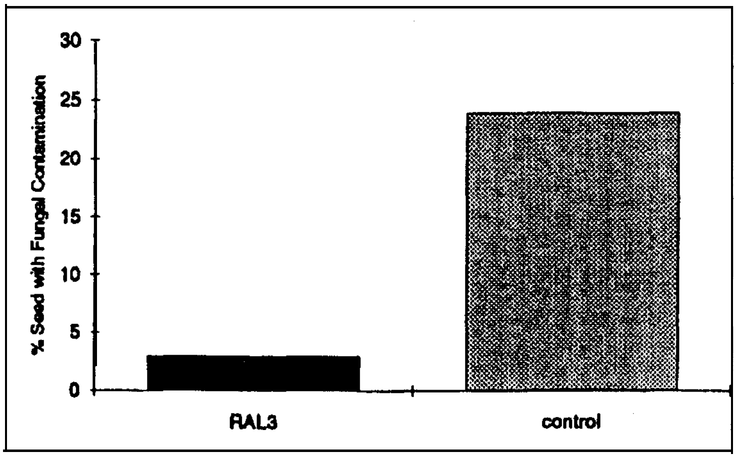

Figure 7. **Reduction** of fungal contamination **on** Western **Larch** seed. Asterisks denote significant difference **compared** to control (**p≤0.05).

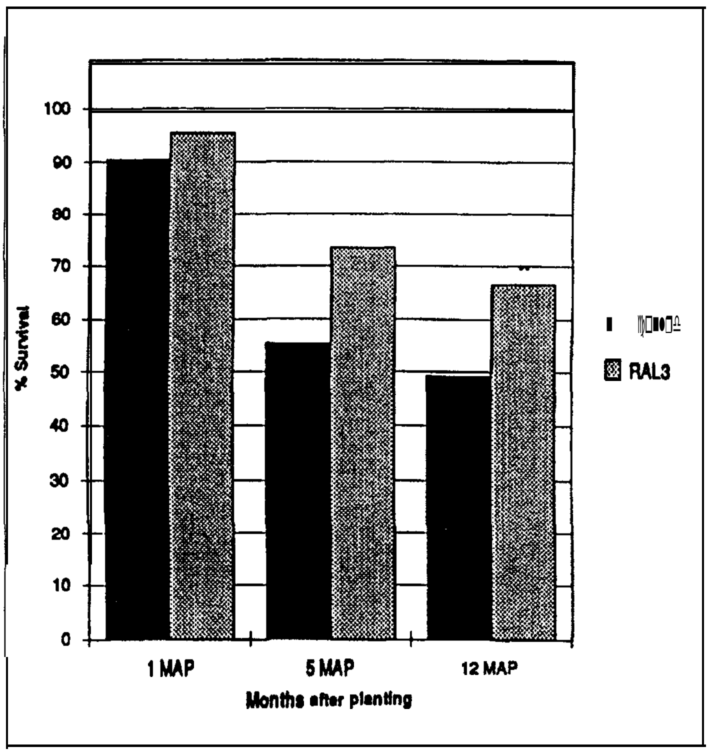

Figure 8. **Influence** of Ral-3 **on** survival of bareroot White Spruce seedlings **on** a reforestation **site.** Asterisks denote significant **increases** compared to control (*p≤0.10, **p≤0.05).

have been suggested to explain the positive influence of certain bacteria on plant growth. Hypothesized direct mechanisms are that bacteria elaborate substances that stimulate plant growth, such as nitrogen, plant growth hormones and compounds that promote the availability of phosphates in the root zone. A popular hypothesis for an indirect mechanism is that populations of various pathogenic and deleterious microorganism that affect the root system are reduced by the introduction of a beneficial organism via seed or root inoculation. Each of these hypotheses suffers from insufficient supportive data. Direct information about the activities and interactions of microorganisms in natural soil and plant root environments is technically difficult to obtain due to the complexity and variability of these environments. Regardless of the mechanisms of biological control or growth promotion, our results have implications for management within the forest industry. Seed inoculation with bacteria capable of stimulating emergence would have obvious benefits in reducing costs associated with poor seedling emergence in commercial nurseries. The inoculants may also be useful for the production of seedlings with higher root to shoot ratios. Our results are consistent with other studies that have shown new root growth to be extremely important in the establishment of outplanted conifer seedlings.

There are many opportunities for the application of microbial inoculants in forestry, but gaps remain in our knowledge of how factors such as soil type, soil moisture, soil pH, and silvicultural techniques affect interactions between microbial inoculants and plant roots. There is also a great deal to be learned about the interaction of microbial inoculants with mycorrhizae and other soil biota. As we learn more about the ecology of these microflora, we may be able to establish the critical processes and specific roles performed by different microbes in maintaining sustainable forests.

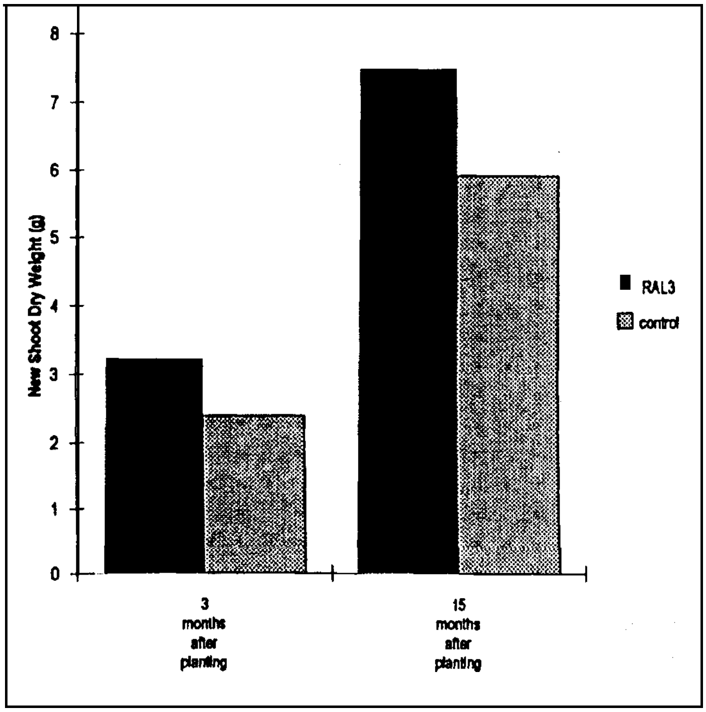

Figure 9. Influence of Ral-3 on White Spruce seedling new shoot growth on a reforestation site. Asterisks denote significant increases compared to control (p≤0.05).**

The results obtained from this and other studies demonstrate that microbial inoculants can be used operationally in container and bareroot nurseries to signifícantly improve seedling quality. Our reforestation trials have shown that survival and establishment of seedlings can be signifícantly improved through treatment with bacteria1 inoculants. The cost of inoculating seed or seedlings with these microbes represents only a minor portion of the total tree planting expense and high seedling quality is an obvious key to successful reforestation. The technology developed through this pioneering project is being expanded to other host species, forest applications and geographic locations. Our goal is to make this technology available to nursery managers, foresters, Christmas tree growers, and other land managers for use in a sustainable forest management system.

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Field Validation of Laboratory Seedling Testing Results[1]

Yasuomi Tanaka[2], Byron Carrier[3], Rod Meade[2] and Steve Duke[4]

Abstract-The Weyerhaeuser Seedling Testing System (STS) has been operational since 1985. Located in Centralia Washington, USA, the laboratory can conduct five types of tests which evaluate: (1) root growth potential (RGP), (2) seedling viability, (3) cold hardiness, (4) morphology and (5) pathogen infection level. About 500 to 800 tests are conducted annually. The seedling testing results gathered at the laboratory are compiled as base-line data for each nursery/species/stock type for interpretation of current and future test results.

Several field validation trials have been installed with Douglas-fir (*Pseudotsuga mensiezii* (Mirb.) Franco) seedlings to determine how the results of the RGP and viability tests correlate with the performance of seedlings in the field after outplanting. The results to date have shown that Douglas-fir 1+1 stock sustaining winter damage from nursery freeze showed various levels of field performance at several planting sites in the states of Oregon and Washington, USA.

Under mild weather conditions, winter-damaged seedlings, despite their reduced vigor, showed good survival. Under harsher conditions, however, performance of stock with low vigor, particularly those with Root Growth Index (RGI) less than the threshold value of 4.8 and (Growth Value) GV less than 90%, tended to perform poorly.

Under relatively mild field conditions at the Springfield and Coos Bay Regions, Oregon, USA, height growth of survived seedlings was about the same regardless of the original RGI and GV values after two growing seasons in the field.

It is recommended that Douglas-fir 1+1 stock sustaining nursery freeze damage, particularly those with RGI less than the threshold value of 4.8 and/or GV less than 90% be handled, transported and planted with utmost care to capture their maximum survival and growth potential.

[1]*Tanaka, Y.; Carrier, B; Meade, R.; Duke, S. 1996. Field Validation of Laboratory Seedling Testing Results. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 245.*

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Use of Vector Diagrams for the Interpretation of Nutrient Response in Conifer Seedlings[1]

Todd Birchler, Diane L. Haase and Robin Rose[2]

Analysis of seedling nutrient response using vector diagrams enables comparisons of nutrient concentration, nutrient content, and plant growth to be made simultaneously in an integrated graphic format (Haase and Rose 1995). Vector analysis is very useful for examining plant responses to various nursery cultural and silvicultura1 treatments, and because it is comparative, interpretations may be made independent of predetermined critica1 levels or ratios. In a nursery setting, vector analysis enables the easy detection of nutrient imbalances, nutrient interactions, and dilution effects.

To construct a vector diagram, al1 that is needed is the nutrient concentration obtained from laboratory analysis and some measure of unit dry weight of the seedling. The determination of which unit dry weight to use depends on the type of study and the objectives of the study. Commonly used units include the dry weight of a specific number of needles, whole plant dry weight, or shoot dry weight. The nutrient content is then determined by multiplying the nutrient concentration by the unit dry weight.

Absolute numbers may be used, however, relative values enable comparisons to be made between many trials and nutrient elements. To normalize the values, a reference point is determined and set to 1 OO. The other treatments are determined as percentages of the reference point. Determination of the reference point is important and influences the subsequent interpretation. Data from the control treatment is a commonly used reference point.

After normalization, relative nutrient concentration is plotted along the Y-axis and relative nutrient content along the X-axis. The resulting data point will correspond to the relative unit dry weight along the diagonal Z-axis. The vectors are then drawn from the reference point to each subsequent data point (Figure 1).

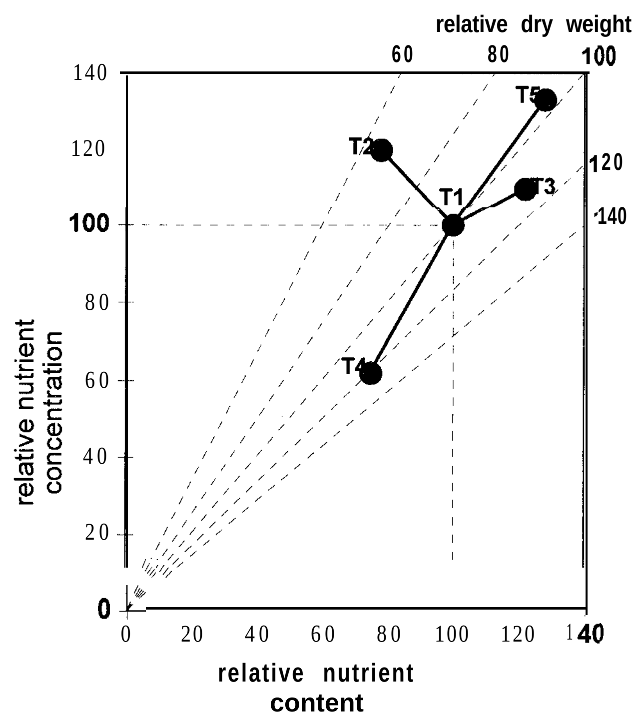

Figure 1. Example of a vector diagram showing relative responses of nutrient content, nutrient concentration, and unit dry weight for five treatments.

[1]Birchler, T.; Haase, D.L.; Rose, R. 1996. Use of Vector Diagrams for the Interpretation of Nutrient Response in Conifer Seedlings. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, forest Service, Pacific Northwest Research Station: 246-247.

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Interpretation of a vector diagram is based on the direction and magnitude of the vector. Horizontal from the reference point signify an increase or decrease in nutrient content, vertical shifts signify an increase or decrease in nutrient concentration, and shifts on either side of the diagonal Z-axis signify an increase or decrease in unit dry weight. Timmer and Stone (1978) developed interpretive guidelines for the vectors. A nutrient is considered in **sufficient** quantity when there is an increase in nutrient content and unit dry weight without a change in nutrient concentration. If there is an increase in nutrient concentration, nutrient content, and unit dry weight, the nutrient is considered **deficient**. If there is a decrease in nutrient concentration along with an increase in nutrient content and unit dry weight, **dilution** is the result. **Luxury consumption** occurs when increases in nutrient content and concentration are not accompanied by an increase in unit dry weight. Nutrients are considered to be in **excess** when there is a decline in nutrient content and unit dry weight. A decline in al1 three parameters may provide evidence of **antagonism** between nutrients.

Vector analysis is useful for illustrating seedling responses to factors such as fertilizer regimes, pH, moisture regimes, seedbed density, stocktype, and provenance. For example, Teng and Timmer (1990) used a single vector diagram to examine nutrient interactions in response to various levels of P. Timmer (1985) used vector diagrams to illustrate micronutrient deficiency and magnesium toxicity in response to lime applications. Vector diagrams were also used to illustrate carbon and nitrogen partitioning between shoots and roots of red pine seedlings grown under various fertilization and moisture regimes (Timmer and Miller 1991).

Vector analysis need not be limited to nutrients. Khan et al. (1996) used vectors to illustrate changes in shoot and root starch levels of containerized Douglas-fir seedlings in response to different soil water contents. Czapowskyj et al. (1980) showed relative differences in ash levels for both red spruce and balsam fir treated with combinations of lime, N, and P.

Vector analysis is a powerful tool for illustrating and interpreting seedling responses to various treatment or conditions. It requires one extra measurement in addition to nutrient concentration: unit dry weight. The information gained, and the ease with which the results may be interpreted, is well worth the effort.

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Manual for the Propagation of Pacific Northwest Native Plants[1]

Caryn E. Chachulski, Robin Rose and Diane L. Haase[2]

Native plants have been increasingly recognized as a crucial component of forest management. They provide many benefits to the forest ecosystem such as erosion and flood control, wildlife forage and habitat, species diversity, soil stabilization, aesthetic enhancement, riparian restoration, revegetation of road cuts, and improvement of recreational areas.

For successful native plant propagation, severa1 components must be understood. When collecting seed, the plant must be properly identified and seed harvest must occur at the appropriate time for optima1 seed vitality. The time of harvest can vary over the geographical range for a single species. Some species only produce an adequate seed crop every few years while others have prolific seed production every year. The method of seed collection can vary greatly among species based on plant form and seed size.

Unlike conifer seeds, extraction and storage of native plant seed can be a complicated task. Once collected, the variety of fruits require differing equipment and techniques for extraction. Furthermore, seed longevity varies greatly among species. Some can be stored for years while others need to be germinated immediately. The success of germination depends on each species' pre-treatment and stratification requirements to overcome physical barriers (i.e. seedcoat) or physiological barriers (i.e. dormancy)—media, moisture, temperature, scarification, chemicals, duration, light, and nutrients.

Vegetative propagation of native plants can also pose some interesting challenges. Plants can be produced by cuttings, division, layering, rhizomes, tissue culture, and grafting. Rooting cuttings is one of the most common techniques in plant propagation but must be approached on a species by species basis. Some species root more successfully using branch tips while others root well with stem, leaf, or root cuttings. In addition, many species root more readily when treated with a root growth hormone.

The proper culturing of native plants, whether propagated by seed or vegetatively and whether grown in containers or barerooted, is another essential step to ensuring a vigorous plant crop. A certain leve1 of heat and humidity is often required during germination of seed or rooting of cuttings. In addition, a careful fertilization and irrigation regime must be followed for good plant development and proper phenology.

Obviously, native plant propagation requires some experimentation and innovation. With so many species-specific propagation requirements and very little specific information available in the literature, native plant growers must refine their techniques based on trial and error and their available equipment, supplies, and facilities. Furthermore, the final product must be based on the ultimate use of the plant. For example, very large root systems may be desirable for planting in sand banks while a tal1 shoot may be needed to compete with surrounding vegetation in a riparian

[1]*Chachulski, C. E.; Rose, R.; Haase, D. L. 1996. Manual for the Propagation of Pacific Northwest Native Plants. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 248-249.*

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environment. In other cases, a small seedling may be suflicient to meet outplanting goals or more than one seedling size may be prescribed to create an instant age class. To achieve the desired plant specifications, a plant grower must allow for the necessary nursery space and growing period.

Unfortunately, there does not exist a comprehensive manual on propagation of Pacific Northwest native plants. Until recently, most articles about native species have presented findings on how to control or eradicate them. The increasing awareness of their beneficial role in promoting a healthy, stable ecosystem has necessitated a more detailed and extensive information base for their propagation. A thorough search of forestry and agricultura1 journals as well as gardening and horticultura1 handbooks does yield some useful propagation information. But such an exhaustive literature search is not practica1 or convenient for many who wish to grow native plants. Furthermore, some of the best existing information is in the minds of those who have learned through direct experience. Many of these individuals have not had the time nor funding nor inclination to publish their propagation methodology or have only published on a very limited basis (e.g. within a single National Forest).

The purpose of this three-par-t manual is to present a compilation of information from literature sources and personal contacts and make it widely available. For each species contained in the manual there is a scientific description of the plant, its habitat and geographic range, and information on how to propagate it. Volume one contains fifty species, volume two contains forty species and a glossary, and volume three will contain sixty-five species and an overview of different propagation techniques. To order a copy, please contact the Forestry Publication Office, Oregon State University, Forest Research Laboratory 227, Corvallis, OR 9733 1.

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Managing Organic Matter in Forest Nurseries[1]

Robin Rose and Diane L. Haase[2]

Organic matter has long been recognized as an essential component of a highly productive soil, yet there has been limited focus on this topic despite an exponential increase in nursery production. Recently, soil organic matter has taken on new meaning with the reduction of pesticide use, especially methyl bromide which is slated to be banned. Without the "magic bullet," methyl bromide, the role of organic matter in relation to control of pathogens, nematodes, insects, and weed seed must be better understood in order to successfully integrate it with other forest nursery cultural practices. Addition of organic material is justified when management practices are made easier or more effective, or when those benefits are reflected in better quality or quantity of production.

BENEFITS OF ORGANIC MATTER IN THE SOIL

Improved Physical Properties

Soil Structure: Tilling, seedbed preparation, lifting and other operations are easier and more effective when the soil humus leve1 is high. Organic compounds serve to bond the soil particles together resulting in crumbly, granular structure.

Bulk Density: Organic material, combined with ripping and wrenching, can mitigate compaction due to heavy nursery machinery.

Water Holding Capacity and Availability: Organic amendments, especially in coarse-textured soils, can increase the amount of water stored for plant use and thereby reduce the need for irrigation.

Erosion: Organic matter helps reduce soil erosion by increasing the moisture-holding capacity of soil, improving infiltration, permeability, and drainage and reducing soil crusting and surface runoff.

Temperature: By minimizing fluctuations in temperature in the root zone of plants, mulch protects seedlings from extremes of hot and cold and reduces frost heaving.

Aeration: Organic amendments tend to increase pore space in the soil.

IMPROVED CHEMICAL PROPERTIES

Available Nutrients: As organic material is decomposed by microbial activity, essential nutrients such as nitrogen, phosphorus, and sulfur are slowly made available to plants.

C/N Ratio: The carbon-to-nitrogen ratio is a limiting factor with organic amendments. Those with a high C/N ratio will result in a temporary immobilization of nitrogen as microbes multiply. The condition persists until nitrogen in their tissues is once again converted to inorganic states available to plants. Through this process the soil

[1]Rose, R.; Haase, D.L. 1996. Managing Organic Matter in Forest Nurseries. In: Landis, T.D.; South, D.B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 250-252.

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becomes richer in both nitrogen and humus. The C/N ratio has been linked to control of soil pathogens.

Cation Exchange Capacity: Increases in organic matter result in proportional increases in CEC thereby allowing the soil to hold necessary cations against loss by leaching while making them available to roots and microbes.

pH: A soil high in organic matter has an increased buffering capacity and will not be as susceptible to sudden changes in acidity as a soil low in organic matter. This is important when considering long-term effects of various fertilizers and pesticides.

Chelation: Organic chelation of toxic metals has been recognized.

IMPROVED BIOLOGICAL PROPERTIES

Disease and Nematode Resistance: Organic material is a critica1 energy source for soil organisms and is needed to maintain a balance between beneficial and pathogenic microorganisms. Organic amendments represent a potential way to improve fungi and bacteria populations which are antagonistic to some seedling pathogens, nematodes, and insects when used in combination with select herbicides and cultural practices as part of an integrated pest management program.

Mycorrhizae: Establishment and maintenance of populations of desirable mycorrhizal fungi is directly influenced by management of soil organic matter.

Weed Resistance: Mulch is reported to reduce hand weeding 60-90% and to stimulate growth of transplants.

Fauna: Organic matter is important for fauna1 organisms which play a key role in maintaining a stable soil environment by keeping the number of micro-organisms in check and producing good soil structure.

ORGANIC AMENDMENTS TO FOREST NURSERY SOILS

Because organic matter is continually being reduced by decomposition, weeding, cultivation, irrigation, and fertilization (which promotes microbial activity), maintenance of a suitable leve1 of organic matter requires careful monitoring and periodic application of organic materials. Organic amendments may be added to the surface as a mulch or incorporated into the soil. Mulch protects seeds or seedlings from erosion, prevents puddling and crusting of soil, and minimizes evaporation of water from surface soil. Incorporated organic materials may need additions of supplemental nitrogen.

Reduced dependency on the use of pesticides as well as fluctuation in availability and cost of organic amendments, has led to a greater need for suitable alternative products. Cooperative agreements between forest nurseries and municipalities or industries can lower composting costs and result in an environmentally beneficial soil amendment. Any material to be applied should be incorporated into the upper 25 cm of soil at least 4 months before conifer seedlings are planted. Preferably, the material should be applied before the cover crop. If analysis of the material indicates the presence of undesirable properties, a cover crop should be selected on the basis of its ability to absorb or reduce those undesirable properties. Leaching through the use of irrigation systems is also a management tool that can be used to ameliorate undesirable properties.

Straw: Fall-sown seedbeds can be protected against frost heaving by covering them with weed-free straw. Straw can also be incorporated directly into soil and will decompose readily with additions of nitrogen. However, because of its bulkiness, straw should be chopped (or mowed), disked, and tilled to alleviate desiccation of plants from air pockets in the soil

Sawdust: As a mulch, sawdust can be applied in both fresh and composted form and can prevent frost damage, control weeds, retain moisture, and improve soil structure.

Bark: Bark is preferred over sawdust or straw as a mulching material because it has a slower decomposition rate, more pleasing color and texture, is free of weed seeds, stays in place better, and reflects less heat and light from its surface to the underside of plants. Bark is useful in preventing abrupt changes in soil temperature because of its corky nature and is used effectively as a weed control. Composted bark can be used as a mulch or an amendment and can be used as a biological control for some soil-borne diseases, especially those caused by fungi.

Sludges: Because many of the organic materials available as an amendment are byproducts of an industrial process, they vary considerably in their composition. The use of paper sludge is common in nurseries as well as roadside stabilization. Studies indicate that sewage sludge can increase seedling growth and favorably modify physical properties of the soil. Fish sludge can be sprayed on the soil before planting or directly onto seedlings using a large impact sprinkler. Beneficial effects may be related more to nutrient supply than to addition of soil organic matter. Mint sludge is high in nutrients but requires adjustments in soil pH through the use of acid-forming fertilizers. If sludge is not excessively high in heavy metals, the application rate can be based on quantity needed to provide adequate nitrogen or phosphorus to plants. Immediate incorporation of sludge is advisable to minimize runoff and loss of nutrients, to reduce objectionable odors and to reduce concentrations of trace elements in the surface.

Manure: Increased yield from manure mulch has been attributed to protection from beating raindrops, greater intiltration of water, improved soil structure, and a cooling effect. However, to maximize utilization of its available nutrients, manure should be mixed into the soil. The major disadvantage of using manure is introduction of weed seeds.

Flyash: Wood ash which contains phosphate, potassium, calcium, magnesium, and various trace elements has been used for centuries as a fertilizer. Flyash from bark, however, is considered a better fertilizer because the inner bark contains more nutrients.

Peat: Because additional nitrogen is not required to decompose peat, it provides nitrogen more quickly than other materials. Peat has high water and nutrient retaining characteristics and stimulates the growth of beneficial micro-organisms.

Other: Leaves of deciduous trees, pine needles, wood chips, hop waste, cannery waste, seaweed, bracken fern, wastewater effluent and petroleum mulch are some other products which have been used as organic amendments to agricultura1 soils. Various materials differ widely as to nutrient content, percent moisture, and ease of handling

Green Manure Crops: Green manuring is used in forest nurseries in conjunction with crop rotation. Benefits attributed to green manuring include addition of nitrogen (when using legumes), addition of organic matter, increase in the conservation and availability of nutrients, improved physical condition of the soil, erosion control, and weed and disease control. Legumes should be inoculated with the appropriate strain of nitrogen-fixing bacteria when they are sown to ensure eflicient fixation. Deep-rooted legumes, such as alfalfa, sweet clover, lupines, and kudzu, can penetrate two feet or more thus improving soil physical properties. Green manure crops also shade and cool the soil. By providing a dense vegetative cover, the damage to soil aggregation produced by raindrop splash is eliminated which reduces the tendency toward crust formation.

Ideally, a green manure crop should be easily established and grow rapidly. There are a variety of legumes and nonlegumes that produce abundant growth in a short time. Choice of the crop should include consideration of the purpose for green manuring and climatic factors. Nurseries in Oregon and Washington frequently use oats, rye, Austrian peas, Sudangrass, crimson clover, and lupines.

This poster is a very brief summary of the material covered in:

Rose, R., D.L. Haase, and D. Boyer. 1995. Organic Matter Management in Forest Nurseries: Theory and Practice. Nursery Technology Cooperative, Oregon State Univ., Corvallis, OR, 65p.

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Producing Blue Oak Seedlings: Comparing Mini-Plug Transplants to Standard Bareroot and Container Stock[1]

Doug McCreary[2] and Laurie Lippitt[3]

Abstract-Blue oak *(Quercus douglasii)* is one of several species of native California oaks that is reported to be regenerating poorly in portions of the state. Although blue oak has little commercial value other than for firewood, it provides vital habitat for numerous wildlife species and is highly valued for aesthetics. In the last decade there have been efforts to develop techniques to successfully regenerate this species artificially. Procedures for growing both bareroot and container seedlings have been evaluated in research trials and both stock types have been grown and outplanted operationally. While both bareroot and container plants have petformed adequately in the field, we were interested in evaluating a relatively new stock type called a "mini-plug transplant". These are seedlings that are grown for several months in relatively small, shallow containers , and then transplanted to bareroot nursery beds in the spring. While in the containers, seedling roots grow rapidly, but due to the shallow container depth, they repeatedly air prune themselves. As a result, a highly branched root system, with numerous growing tips, develops. When these mini-plugs are transplanted to a bareroot bed, they often develop a more fibrous root system and a more favorable shoot/root ratio than conventional stock types grown for the same length of time. As such, they may be better able to survive and grow in the hot, dry summers characteristic of California's blue oak woodlands. This study was undertaken to evaluate the mini-plug approach for growing blue oak seedlings, and compare the field performance of this stock type to 1+0 container seedlings and conventional 1+0 and 2+0 bareroot nursery stock.

All seedlings for this study were grown from acorns collected at the same location. The 2+0 and 1+0 bareroot seedlings were sown in late fall, 1989 and 1990, respectively. The container and mini-plug seedlings were sown in early December, 1990. The mini-plug seedlings were grown for five months in 1.5 inch x 1.5 inch x 3 inch plant bands on raised racks with open bottoms to promote air pruning of the roots. In early May, 1991, they were transplanted into standard bareroot nursery beds, where they were grown until the following winter. All four stock types were outplanted in January, 1992. At time of planting, 20 each of the 1+0 bareroots, 2+0 bareroots and mini-plugs were randomly selected for destructive morphological assessment. Each seedling was cut at the cotyledon scar and stem height and caliper just above the cut, were recorded. The shoots and roots were then placed in separate paper bags and dried for 48 hours at 70^0 C. The shoot/root ratios were then calculated. The initial height and diameter of each field-planted seedling was also recorded. Each seedling was evaluated at the end of each subsequent growing season for survival, total height and basal diameter. This data was analyzed using analysis of variance for a split-plot, randomized block design.

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[1]*McCreary, D. and Lippitt, L. 1996. Producing Blue Oak Seedlings: Comparing Mini-Plug Transplants to Standard Bareroot and Container Stock. In: Landis, T. D.; South, D. B, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 253-254.*

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The morphological data indicated that the mini-plug transplants developed much larger and more fibrous root systems than any of the other stock types. For the first three field growing seasons, the mini-plug transplants also grew considerably larger than either the 1+0 containers or 1+0 bareroot seedling stock types. However, the average heights and calipers of mini-plug transplants and 2+0 bareroots were very similar, and there were no significant differences between these stock types for either variable during any of the four years of the study. Survival of all stock types was high, averaging over 92% for the plot as a whole at the end of four years The only significant difference in survival occurred the first year, when the 1+0 containers had significantly lower survival than the other three stock types. After the second year, only one seedling in the experiment died, indicating that once the plants survived the first two seasons, there was a high likelihood they would remain alive. During the fourth year of the study, differences among the stock types lessened. Average caliper for all four stock types was similar, although the mini-plug transplants and 2+0 bareroots remained significantly taller than the 1+0 containers or 1+0 bareroots.

This study indicates that by sowing blue oak acorns in small containers (mini-plugs), and then transplanting them to bareroot nursery beds after several months, it is possible to produce significantly larger seedlings, with larger root systems, in the same amount of time required for standard container or bareroot stock types. Mini-plug transplants also maintained their size advantage over 1+0 containers and 1+0 bareroots in the field for the first three growing seasons. By the fourth field season, however, differences among stock types diminished and there were no significant differences in survival or caliper among any of the four stock types evaluated. However, mini-plug transplants were still significantly taller, so there did appear to be some relatively long-lasting benefit from this method of production. However, if the overall trend of diminishing benefit over time continues, it appears that the initial advantage of mini-plug transplants will eventually be lost. Since they are considerably more costly to produce (at least with the current level of technology) than either standard container or bareroot seedling of the same age, mini-plug transplants do not, therefore, appear to be cost-effective for growing blue oaks at this time.

Western Forest and Conservation Nursery Association

1996 BUSINESS MEETING

The meeting was called to order by Tom Landis at 1:00 PM on Friday, August 23 at the Quality Inn Convention Center in Salem, OR. As stated in the Charter, everyone attending the meeting is considered a member of the organization and has full voting privileges.

OLD BUSINESS

1. Minutes from 1995 meeting. Tom recounted that the last business meeting was held on Thursday, August 18 at approximately 12:45 PM at the Ramada Inn Convention Center in Kearney, NE. He explained that the minutes are published on pages 137-140 in the 1995 National Proceedings: Forest and Conservation Nursery Associations - General Technical Report PNW GTR-365. The minutes were approved by a voice vote.

NEW BUSINESS

1. Standardization of seedling age codes.

Mark Triebwasser received a letter from Kintigh's Mountain Home Ranch nursery suggested that the Association take a lead in standardizing the numerical code for bareroot planting stock. In the letter, Bob Kintigh pointed out that nurseries are using different designations to refer to the same seedling stock types (*e.g.*1-1, 1+1, 1/1) which has lead to confusion. After some discussion from the floor, Tom suggested that the group consider adopting the "plus" designation which was used in the ***Forest Nursery Manual: Production of Bareroot Seedlings.*** This numbering system is both simple and logical because the accumulated sum of the years in the seedling code give the total number of years needed to produce the stock. For example, both a 2+0 seedling and a 1+ 1 transplant take 2 years to produce. This suggestion was approved by a voice vote, and so all members of the Association are encouraged to use the "plus" designation in their bareroot seedling codes.

2. Location of Future Meetings

As specified in the Charter, the WFCNA meets on even-numbered years on the West Coast and then in the Great Plains and Intermountain area on the odd-numbered years.

1997 - The meeting will be held at the Red Lion Motor Inn in Boise, ID during the week of August 17-2 1. Our host will be nursery manager Dick Thatcher and his staff USDA Forest Service, Lucky Peak Nursery. More information will be announced in the January 1997 issue of ***Forest Nursery Notes.***

1998 - Jeanine Lum of the Kamuela Tree Nursery of the Hawaii Division of Forestry and Wildlife invited the association to hold their meeting on the Big Island. Some members expressed concern over the cost of such a meeting and others were worried about whether they would be able to obtain permission to come to Hawaii. After considerable discussion, Tom suggested that we put the matter to a written vote in a few weeks to give members time to talk to their organizations. Another proposal was to hold a joint meeting with the Forest Nursery Association of British Columbia (FNABC). Ev van Eerden agreed to take our suggestion to the FNABC meeting next month and report back with their decision. This lead to a discussion on the possibility of moving the dates of the annual meeting from mid-August because of the conflict with fall transplanting. The group suggested that we poll members as to their preference between mid-July, mid-August, mid-September, or mid-October. Tom agreed to mail out a ballot that will address both the dates and location for the 1998 meeting by the first of October.

The ballots were tallied by the internationally renowned accounting firm of Barthell and Landis with the following results:

Location of Meeting:	Hawaii	**41%**
	British Columbia (Winner!)	**59%**
Date of Meeting:	Mid-July	24.9%
	Mid-August (Winner!)	28.7%
	Mid-September	20.8%
	Mid-October	25.6%

So, as you can see, the voting was close in both categories, but the 1998 WFCNA meeting will be held in British Columbia in mid-August. Because this will be a joint meeting with the FNABC, which usually meets in mid-September, the meeting date will have to deviate from the normal schedule.

1999 - The meeting will tentatively be held in Manhatten, KS where the Kansas State Forest Nursery will be our hosts.

2000 - The Association should plan a really special meeting for this millennium year, so any suggestions should be sent to Tom Landis. One proposal already has been received to have the meeting in the Corvallis, Oregon area.

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	Proceedinas
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
994	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
1 993	Aug. 2-5	St. Louis, MO	G.O. White State Nursery Licking, MO Bill Yoder	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 GTR RM-221
1991	Aug. 12-16	Park City, UT Draper, UT	Lone Peak State Nursery Glenn Beagle, John Justin		USDA-Forest Service GTR RM-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 GTR RM-184
1988	Aug. 8-l 1	Vernon, BC	BC Ministry of Forests Victoria, BC Ralph Huber	Forest Nursery Assoc. of British Columbia	USDA-Forest Service GTR RM-167

Western Forest and Conservation Nursery Association Record of Past Meetings

Year	Dates	Location	Host Nursery	Proceedings
1987	Aug. 10-14	Oklahoma City, OK	Forest Regeneration Center Washington, OK Al Myatt, Clark Fleege	USDA-Forest Service GTR RM-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 GTR RM-137
1985	Aug. 13-15	Ft. Collins, CO	Colorado State FS Nursery Marvin Strachan	USDA-Forest Service GTR RM-125
1984	Aug. 14-16	Coeur d' Alene, ID	USDA-FS Coeur d' Alene Nursery Joe Myers	USDA-Forest Service GTR INT-185
1983	Aug. 8-11	Las Vegas, NV	Tule Springs State Nursery Pat Murphy, Steve Dericco	USDA-Forest Sewice GTR INT-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 Sewice N. Forest Res. Centre Info. Rep. NOR-X-241
1980	Aug. 12-14	Boise, ID	USDA-FS, Lone Peak Nursery Dick Thatcher	USDA-Forest Sewice GTR INT-109
1979	Aug. 13-16	Aspen, CO	USDA-FS, Mt. Sopris Nursery Carbondale, CO John Scholtes	USDA Forest Sewice, S&PF Unnumbered Publication
1978	Aug. 7-11	Eureka, CA	USDA-FS, Humboldt Nursery McKinleyville, CA Don Perry	USDA-Forest Sewice, S&PF Unnumbered Publication
1977	Aug. 9-11	Manhattan, KS	Kansas State FS Nursery Bill Loucks	USDA-Forest Sewice, S&PF Unnumbered Publication
1976	Aug. 10-12	Richmond, BC	BC Ministry of Forests Surrey Nursery Bayne Vance	BC Ministry of Forests of BC
1975	Aug. 5-7	Missoula, MT	Montana State FS Nursery Willis Heron	USDA-Forest Service, S&PF Unumbered Publication

Western Forest and Conservation Nursery Association **Record** of Past Meetings

Year	Dates	Location	Host Nursery		Proceedinas
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	Coeur d' 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
1986	Aug. 30-Sept. 1	Ft. Collins, CO	Colorado State FS Nursery John Ellis		Unnumbered Publication
1965	Sept. 14-l 6	Carbondale, CO	USDA FS, Mt. Sopris Nursery Sidney H. Hanks		Unnumbered Publication
1984	Aug. 19-20	Boise, ID	USDA-FS, Lucky Peak Nursety Leroy Sprague		Unnumbered Publication
1963	Sept. 11-13	Missoula, MT	Montata State FS Nursery Don Baldwin		Unnumbered Publication
1962	Sept. 13-1.4	Monument, CO	USDA FS, Monument Nursery Ed Palpant		Unnumbered Publication
1961	Sept. 14-1 5	Halsey, NE	USDA-FS, Bessey Nursery Red Meines		Unnumbered Publication
1960	Aug. 20	Watertown, SD	Big Sioux Nursery Marvin Strachan		Unnumbered Publication

Business Meetings

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Landis, T.D. and South, D.B., tech. coords. 1997. National proceedings: Forest and Conservation Nursery Associations-1996. Gen. Tech. Rep. PNW-CTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 282 p.

This proceedings is a compilation of 51 papers that were presented at the regional meetings of the forest and conservation nursery associations in the United States in 1996. The Southern Forest Nursery Association meeting was held in Gatlinburg, TN, on June 25-27, 1996; the Northeastern Forest Nursery Association Conference was held in New England, CT, on August 19-22, 1996; and the Western Forest and Conservation Nursery Association meeting was held in Salem, OR, on August 20-22, 1996. 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.

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