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Abstract

This proceedings is a compilation of 33 papers that were presented at the regional meetings of the forest and conservation nursery associations in the United States in 2002. The joint meeting of the **Southern Forest Nursery Association and the Northeastern Forest and Conservation Nursery Association** was held at the DoubleTree Hotel and Conference Center in Gainesville, Florida on July 15 to 18. The meeting was hosted by the Florida Division of Forestry, Andrews Nursery. In addition to technical sessions, tours included Andrews Nursery and Stansel Farm & Nursery. The combined meeting of the **Western Forest and Conservation Nursery Association and the Forest Nursery Association of British Columbia** occurred August 5 to 8 at the WestCoast Hotel in Olympia, Washington. The meeting was hosted by the Washington Department of Natural Resources, Webster Forest Nursery. Morning technical sessions were followed by field trips to Webster Nursery and the Weyerhaeuser Bonsai Garden. Subject matter for both sessions included seed transfer, collection, and processing; pest problems and pesticide use; nursery culturing; transplanting; harvesting, storage, and outplanting.

Key Words

Bareroot nursery, container nursery, nursery practices, fertilization, pesticides, seeds, reforestation, restoration, plant propagation, native plants, tree physiology

Papers were edited to a uniform style; however, authors are responsible for the content and accuracy of their papers.

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NATIONAL PROCEEDINGS: FOREST AND CONSERVATION NURSERY ASSOCIATIONS—2002

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Searchable Internet Database—www.fcnet.org

Papers published in the National Proceedings are available in portable document format (PDF) on the Forest and Conservation Nursery Association Internet site: <http://www.fcnet.org>. This database can be searched by author and keyword and includes papers published in the regional nursery proceedings (Western, Intermountain, Northeastern, and Southern).

On-line Nursery Information

Visit the Reforestation, Nurseries, and Genetics Resources Internet site: <http://www.rngr.fs.fed.us>

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**SOUTHERN FOREST NURSERY ASSOCIATION AND
THE NORTHEASTERN FOREST AND CONSERVATION
NURSERY ASSOCIATION CONFERENCE**

GAINESVILLE, FL
JULY 15–18, 2002

TOP 10 STATEMENTS THAT PERSUADED YOU TO BECOME A NURSERY MANAGER

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10. Well, the winter is a little busy, but there's not much going on during the rest of the year.

9. Yes, the nursery equipment is fairly old, but it's all scheduled for replacement within the next 3 years.

8. You'll get to go to a Southern Forest Nursery Association conference and meet Bill Isaacs. I've been told he gives away cash at his display table.

7. Seedling customers? No problem there. You'll find them all very organized and understanding.

6. Paperwork?!? Heavens No! We're hiring you to grow seedlings!

5. Just plant the seeds and stand back. Mother Nature does the rest!

4. These are automatic strapping machines. They're pretty foolproof. Practically run themselves.

3. Regulations? No, not many. People don't really pay much attention to tree nurseries.

2. Women/Men dig nursery managers!!!

1. We'll discuss pay later. You know, I've always believed that the satisfaction of a job well done greatly outweighs any monetary considerations. Don't you?

FLORIDA AND FLORIDA FORESTS: A SENSE OF PLACE

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Abstract

This introduction is to give the forest nursery conference attendees a sense of place—within the state, university, school and the forests to which they relate. Florida is a large diverse state, with climates ranging from temperate to sub-tropical, reflecting diverse vegetation, including forests. The state has lost nearly half of its original forests to development, with about 15 million acres still in forests. Florida is the fourth most populous state in the US and growing at a rate of about 47 per hour, or 414,000 per year.

The University of Florida has 46,000 students, the fourth largest university in the US, and is one of 64 North American universities selected for membership in the American Association of Universities. The School of Forest Resources and Conservation is small but very productive, with its faculty attracting the second most extramural funding among 34 related units. The School began one of the first tree improvement programs to provide genetically improved seeds for high quality planting stock. Florida has been a leader in tree planting nationwide and still ranks fourth, planting about 150,000 acres annually. Notably, sustaining forest cover in Florida, the southeast, and the nation begins with the work of nursery managers like you.

Key Words

Florida climate, forestland, timber investment management companies

FLORIDA AND FLORIDA FORESTS

My task here today is not to address technical nursery topics or operational technology for running a nursery. You have many excellent presenters in an outstanding program that will ably address those topics. But first, let me acknowledge that one of my great opportunities is cooperating with your opening speaker, Earl Petersen, and the very fine Division of Forestry that he administers in Florida. I should also note that because of having our moderator, Steve Gilly, as a student in a class I once taught, I am not surprised that he put together such a fine program and that he runs one of the best nursery operations in the country.

You are in Florida at Gainesville, meeting in the University of Florida Hotel and Conference Center. You will take field trips to see North Central Florida landscape features, including a visit to the Austin Cary Memorial Forest, a property of the School of Forest Resources and Conservation. During this stay, talking and thinking about nurseries and sustaining forests, I want to make some remarks that give you a sense of place while you are here.

Florida was the 27th state, entering the union in 1845. The state tree is the sabal palm. (You will dull your chain saw on this tree. As with many tropic species, it accumulates silica, that is sand, in its matrix.) The state bird is the mockingbird (a bird you do not kill after Parker Lee's novel). The state animal is the panther (which gives us intimate awareness of T&E species). The state flower is the orange blossom (obviously designated before the infatuation with native species). The state soil is Myaka fine sand (the most wide-spread soil series in Florida and the soil most abundant for planting forest seedlings in Florida).

The area of Florida includes 35 million acres, of which 2.5 million acres of the surface are water—11,000 rivers, streams and waterways, and 7000 lakes greater than 10 acres, all bounded by 1200 miles of coastline, and twice that if tidal shoreline is measured. The highest point is 345 feet, in the panhandle in Walton County. One cannot be further than 60 miles from the coast; yet to travel from Key West to Pensacola, Florida, you would travel the

same distance as going from Pensacola to Chicago, Illinois. This distance traverses an array of climates—temperate to sub-tropical, reflecting diverse forests and habitats. Moving along this course you see pines and hardwoods typical of the Lower Coastal Plain. In the south, you encounter Gumbo-Jumbo trees, an occasional native mahogany, the abundant and invasive melaleuca, Brazilian pepper trees, and the majestic Big Cypress Swamp just before the Everglades (once called the “sea of grass”) appear. Slash and sand pine change their variety or race; slash from var. *elliottii* to *densa*, and sand pine from the Choctawhatchee to the Ocala race as you move from north to south.

When Florida was settled, about 27 million acres were forested. After clearing for agriculture, communities, and population support facilities, only about 15 million acres remain today classified as forestlands. Of these acres, 2.8 million are in public ownership, with 1.25 million in 3 national forests, and 1.55 million in other public ownerships, mostly in 30 state forests managed by your host, the Florida Division of Forestry. The remainder is in private ownership; 4.6 million acres owned by forest industry and 7.2 million owned by non-industrial private owners.

Recent trends reveal drastic changes taking place in the structure of forest ownership. Several of the forest products firms have divested themselves of land ownership or are in the process of doing so. Thus, fewer acres are in the industry-owned category. A new class of ownership has emerged that is referred to as “TIMCOs” or Timber Investment Management Companies. The large contiguous industrial tracks of several hundred thousands of acres are being sold in smaller blocks, with some being diverted to other uses. Being fragmented lessens their suitability as habitat for faunal species that have large ranges. Similarly, the lands near urban centers are being fragmented into “forest-ettes” with the average size of such ownerships now about 17 acres. Such fragmentation occurring in the urban interface is increasing the challenge to forest managers. These patterns of change reflect 2 levels of forest fragmentation. The numbers of private non-industrial owners are increasing with both those owning the larger tracks and those owning the smaller tracts.

Florida is now the fourth most populous state in the US with 16,400,000 residents, and is visited by about 60 million tourists each year. Between 1980 and 2000, the state’s population grew on average by 39

persons per hour. Last year (2001) the state grew at a rate of 47 persons per hour, which translates to 1135 per day or 414,000 per year, about twice the population of Alachua County where you are now located. At this rate, the population of Florida will reach 25 million by 2025. Depending upon the flow of abandoned agricultural land back to forests, we lose between 40 and 70 thousand acres of forests each year. Needless to say we have a lot of people watching us practice forestry in this state.

UNIVERSITY OF FLORIDA

I would be remiss if I did not tell you something about the University of Florida (UF) where you are now situated. Our Provost describes the UF as a large, major, comprehensive, research land-grant university.

Large

When the Buckner Act combined several institutions in Florida to create the Florida State College for Women in Tallahassee and the University of Florida in Gainesville in 1906, the University of Florida enrolled 102 students. In fall 2001, the enrollment was 46,000, making the University of Florida the fourth largest in the US, with students from 100 countries and all states. Ninety percent of the entering freshmen score above the national average on the SAT. These freshmen have an average GPA of 3.99 on a 4.0 scale and an average SAT of 1285. The number of merit scholars in the class ranks UF fourth among public universities. The growth plan is to reach 50,000 with the last 7000 at the graduate level.

Major

The UF is one of 64 institutions in North America selected for membership in the prestigious American Association of Universities (AAU). Membership comes by quality measures that are quantifiable, such as volume of research, numbers of PhDs, and so on.

Comprehensive

UF includes 21 colleges and schools offering over 100 academic majors. As a former president once said: “The University of Florida is exceeded by none and equaled by only two other universities in diversity of program.” This means we have all the arts and basic sciences, agriculture and engineering, and the other professional schools of medicine and law all on one campus.

Research

Last year the UF expended \$379 million on research while 10 state universities expended a total \$500 million.

Land Grant

By merging the Florida Agricultural College to form the UF in 1906, the university became a support institution for the agricultural and mechanical arts, which grew through a series of congressional acts to include the College of Agriculture, the Agricultural Experiment Station, and the Cooperative Extension Service. These give the UF a presence in every county of the State.

Athletics

I would not properly have described this place if I did not acknowledge that the UF has a very successful athletic program. Only UCLA and UF have been in the top ten among I-A institutions for 18 years based on competitive performance. In the SEC, the UF programs have been selected as “the conference best” for 10 consecutive years. The last national championship UF won was men’s golf in 2001. The ladies golf team competed for the national championship in 2002, but unfortunately lost to Stanford. One hundred thirty three athletes earned places on the all-academic team. In basketball in the last 7 years, 27 players made the all-academic team. The closest competitor SEC school had 14 and some with as few as one. Thus the UF can excel in academics and athletics.

School of Forest Resources and Conservation

The School of Forest Resources and Conservation is a unit within the Institute of Food and Agricultural Sciences that comprises the Experiment Station, Extension Service, and the College of Agricultural and Life Sciences. IFAS, as it is called, is one of the top 5 agricultural research entities associated with land grant universities. While all else is large at the UF, the School is small. We have about 150 students, about equally divided between undergraduates and graduates. The School already exceeds the graduate to undergraduate ratio that is typical of AAU universities. Our students find the job market very favorable. I tell everyone every chance I get that I have the best job in the university—a faculty of over-achievers and they like each other. One important indicator of the quality of the School’s faculty is that

among 21 academic departments and 13 research and education centers to which we relate in IFAS, our faculty ranked second in terms of the extramural funds attracted to support programs in 2001.

In our programs, we share your challenge to maintain green and growing forests. By the 1930s, the forests in this region were depleted. In 1928 the Florida Forest Service, now DOF, started providing tree seedlings to help reforest the cut over, burned down, rooted up, and over-grazed landscape. In re-greening Florida, the state became the consistent national leader in seedling production and tree planting. Even to this day, the state ranks second in nursery seedling production and fourth in replanted acres with about 150,000 acres annually. This School developed one of the first tree improvement programs to genetically improve the planting stock for re-greening Florida. This program is now in the third generation of improvement. In addition, we pioneered forest fertilization to give the re-planted acres a growth boost during stand establishment and development.

The state has been losing forest acres to other uses, but by increasing the growth rate of re-forested acres, we have been able to increase productivity of forests such that there has not been a shortfall of raw material for sustaining the \$8 billion the forest products industry provides to the Florida economy. At the same time forests provide many other goods and ecological services that citizens expect from forests.

Because of the renewable and recyclable nature of wood products, we expect demand for both wood and non-timber products to grow. With the growth in population and citizen interest in what we do, the future is for forestry to be practiced in a fish bowl. We will have to become as astute in dealing with people as with the technical problems of growing, harvesting, and using trees. No doubt we must produce more wood from fewer acres managed more intensively. Yet, we must do this with a public that has an anti-burn, no pesticide, in fact no chemicals of any kind including fertilizer being applied in forests, attitude. Today we have a growing number of citizens who see timber as a secondary objective, if an objective at all, from public forests.

For those acres where we can grow forests intensively, we look to nursery managers like you to produce genetically superior seedlings that have the health characteristics to survive and grow rapidly once out-planted. If you do this successfully, we can maintain our industries that provide economic diversity while our forests provide biological diversity to our landscapes.

The program suggests that you are properly going about your tasks and that you are prepared to lead. I wish you well in your few days here discussing the science and technology of nursery production and management, and I invite you to enjoy this place.

For more information visit the following websites:

<http://www.stateofflorida.com/index.html>

<http://www.ir.ufl.edu/facts.htm>

<http://www.sfrc.ufl.edu/>

DETERMINING SEED TRANSFER GUIDELINES FOR SOUTHERN PINES

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Abstract

The selection of an appropriate seed source is critical for successful southern pine plantations. Seed movement guidelines are described which are based on climatic similarities between the seed source origin and the planting site. Because yearly average minimum temperature is the most important climatic variable related to growth and survival, it has been used to define the rules of seed movement. This variable, which defines “plant hardiness zones”, has been used for many years by horticulturists to guide the transfer of plant materials. East-west movement to areas of similar climate is permissible, with the exception of loblolly pine.

Key Words

Pinus taeda, *Pinus palustris*, geographic variation, tree breeding

CHOOSING SEED SOURCES FOR SOUTHERN PINE PLANTATIONS

The source of seeds used to establish forest tree plantations is very important. Many years of scientific study show that the seed source can strongly affect survival and subsequent growth of southern pines. Perhaps the most important early study of pine seed sources was Philip C Wakeley’s Bogalusa, Louisiana, planting of 1927. There, loblolly pines (*Pinus taeda* L.) grown from local seeds (Livingston Parish) produced about twice the wood volume through age 22 as did trees of the same species grown from Arkansas, Georgia, and Texas seeds (fig. 1). These differences persisted through age 35 (Wakeley and Bercaw 1965). Since Wakeley’s pioneering study, a great deal has been learned about geographic variation in southern pines. The Southwide Southern Pine Seed Source Study (SSPSSS) was a cooperative effort initiated in 1951 by the Southern Forest Tree Improvement Committee. Federal, state, university, and industry foresters throughout the South worked together to discover the patterns of geographic variation in the southern pines. The results of this work are summarized in publications by Dorman (1976), Wakeley (1961), Wells (1969, 1983), Wells and Wakeley (1966), Schmidting (1995), and Schmidting and White (1990).



Figure 1. Wakeley’s 1927 Bogalusa, Louisiana, loblolly pine provenance test at age 35. The sources, from left to right, are southeast Louisiana, east Texas, central Georgia, and central Arkansas. The planting was thinned at age 35; the resulting pulpwood is shown beneath each seed source. Adapted from Wakeley and Bercaw (1965).

These studies show that most southern pine species have reacted to differences in environmental conditions by developing different traits in different places through the process of natural selection. Therefore, there are races of southern pines that grow faster in certain areas than in others. Some of these races are more resistant to disease or more tolerant of cold than other pines of the same species. The recognition of these patterns of geographic variation was the first step in the process of genetic improvement of the southern pines. All successful southern pine breeding programs first take into account geographic variation before utilizing within-population genetic variation. Important gains in growth and disease resistance can often be made simply by selecting the best seed source for a given planting location. With most species, additional gains can be obtained by using the improved stock developed by tree breeding programs.

Planting seedlings from a seed source that is poorly adapted to the site and climatic conditions can cause devastating losses. Even if the trees survive, their reduced growth will adversely affect yields throughout the timber rotation. It is better to postpone planting for a year rather than to risk the unfortunate results of planting ill-adapted seedlings.

In general, the natural distribution of the southern pines is limited to the north by low temperature, and to the west by low rainfall. Within these limits, native races have developed that are adapted to the local climate. This adaptation to local climatic variation is generally referred to as geographic variation.

Geographic variation of the major southern pine species has been well studied. Seed collected from different geographic areas vary greatly in their potential for growth and survival, depending upon where they are planted. Although a good conservative approach would be to only plant seedlings from locally obtained seed, native sources are not always the best, especially for economically important traits. For instance, it is often observed in seed source studies of forest tree species that sources from warmer climates tend to grow faster than local sources, if these sources are not moved to greatly differing climates. In loblolly pine, this is at least partly due to the warm-climate sources growing longer in the fall than the sources from colder climates (Jayawickrama and others 1998).

Climatic modeling of data from many southern pine seed source studies has shown that the most important factor influencing growth and survival within their natural ranges is average yearly

minimum temperature at the seed source (Schmidting 1997). This climatic variable has been used, not coincidentally, by horticulturists to determine plant hardiness zones (USDA 1990). These zones are used to predict the probable success of plantings of ornamentals. They are also the most important consideration in formulating the seed transfer guidelines for southern pines.

For the 3 species of southern pines that occur naturally on both sides of the Mississippi River, only in loblolly pine are there important differences between eastern and western sources. This difference between loblolly pine and other species is probably rooted in the Pleistocene geologic era. During the height of the Wisconsin Ice Age, 14,000 years before present, the South was occupied by a boreal forest. Patterns of genetic variation in allozymes indicate that longleaf pine (*Pinus palustris* Mill.) resided in 1 refugium in south Texas/north Mexico and migrated northward and eastward when the ice retreated (Schmidting and Hipkins 1998). It is probable that loblolly pine originated from 2 isolated refugia, one in southwest Texas/northeast Mexico, and one in south Florida/Caribbean (Schmidting and others 1999). The 100,000-year isolation of the 2 populations, in differing environments, resulted in the differences we see today.

There is little soil-related ecotypic differentiation in the southern pines. For instance, longleaf stands from deep sand sites do not differ in adaptive traits from nearby stands on heavier soils (Schmidting and White 1990). Similarly, "wet site" ecotypes in loblolly pine do not seem to exist, although there are individual genotypes that are well-adapted to wet sites. This is not surprising considering extensive long-distance pollen flow that has been found in studies of pollen contamination in southern pine seed orchards (Friedman and Adams 1985).

The lack of soil-related ecotypic differences in southern pines simplifies seed transfer guidelines. The guidelines are as follows (with exceptions for loblolly pine noted below):

As a general guideline, seedlings can be used from any area having a minimum temperature within 5 °F (-15 °C) of the planting site (fig. 2). Obtaining seedlings from an area with a higher minimum temperature (warmer winter) will result in an increase in growth over local sources; obtaining seedlings from an area with a lower minimum temperature will result in a decrease in growth (Schmidting 1994). Seedlings can be moved as far as 10 °F (-12 °C), but risk of cold damage increases in northward transfers, and loss of growth in

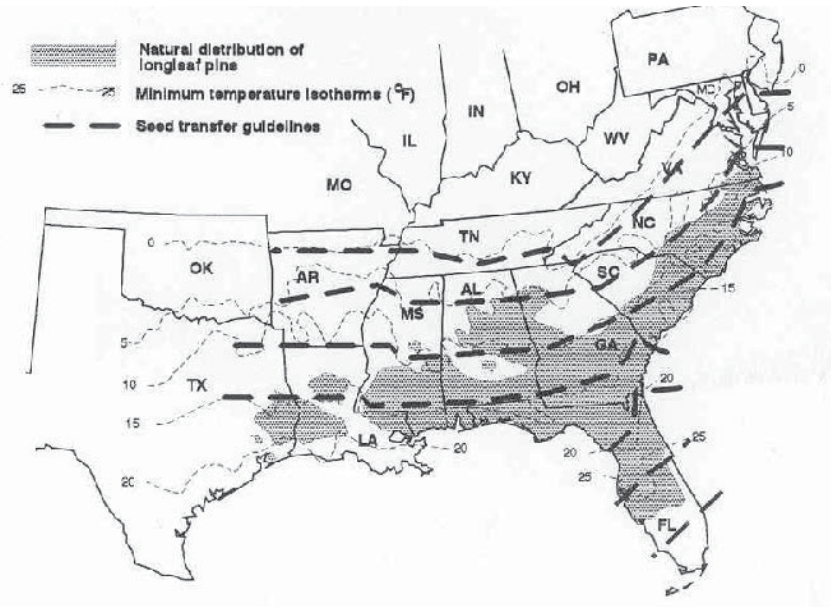


Figure 2. Map of southeastern US showing the natural distribution of longleaf pine with 5 °F (-15 °C) minimum temperature isotherms (Schmidting 2001).

southward transfers is larger. East-west transfers within the temperature guidelines are generally permissible, and in some instances may be desirable if improved stock is available.

The loblolly pine planting areas have been divided into districts because of the complex nature of geographic variation in the species (fig. 3). The eastern district is east of the Mississippi River, and the western and far-western districts are west of the

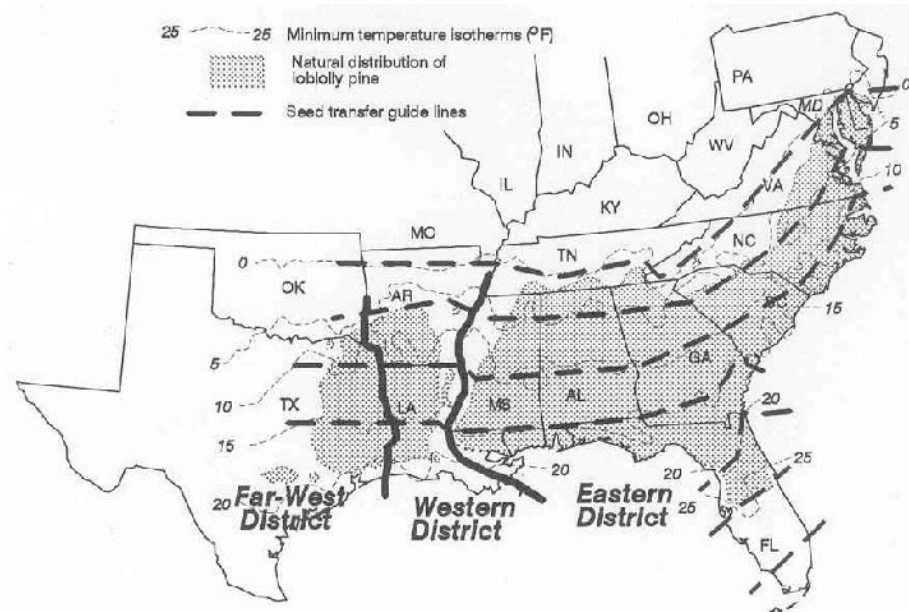


Figure 3. Map of southeastern US showing the natural distribution of loblolly pine with 5 °F (-15 °C) minimum temperature isotherms. In loblolly pine, east-west transfers should be made within districts (Schmidting 2001).

Mississippi River. The far-western district is separated from the western district somewhat arbitrarily by the Texas/Louisiana-Arkansas border. Possible losses due to drought become much more probable in the far-western district, and local seed sources are more tolerant (Long 1980).

Generally, and especially for the non-industrial small land owner or others who may not practice intensive management, it is most prudent to use seed sources from within the same district. Seed sources originating in the eastern district should not be used in the western district because of danger of losses due to drought and fusiform rust. Sources from the western districts, however, can be used in the eastern districts. Transfer in the eastern direction may be warranted for use on droughty sites or areas with high fusiform rust incidence. The western sources generally can be expected to grow slower, however. Improved seed should be used where possible. Tree improvement programs have been initiated all across the South for the major species, and have been successful in securing substantial genetic gains in growth and form. In many programs, second and third generation breeding cycles are in progress. Seed transfer guidelines for improved seed should be assumed to be the same as for unimproved seed; transfers of 5 °F (-15 °C) minimum temperature or less within districts are optimal, but transfers should not exceed 10 °F (-12 °C). In some cases, advanced generation selections may be derived from controlled crosses of superior trees from areas of different minimum temperature. The average of these 2 temperatures should be used in assessing the suitability of these sources.

More detailed guidelines can be found in "Southern Pine Seed Sources" (Schmidting 2001). It is also available on the web at:
<http://www.rngr.net/genetics/publications.html>

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THE TARGET SEEDLING CONCEPT—A TOOL FOR BETTER COMMUNICATION BETWEEN NURSERIES AND THEIR CUSTOMERS

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Abstract

The target seedling is a concept that developed out of the research on seedling quality in the 1970s and 1980s. The basic idea is that the quality of nursery stock is determined by outplanting performance (survival and growth) rather than characteristics or standards measured at the nursery. This means that there is no all-purpose seedling, but that each outplanting project will require different types of plants. The target seedling concept is collaborative because it requires information from the seedling customer. However, it is not static but must be continually updated and improved to incorporate changing nursery cultural practices as well as feedback from outplanting trials.

Key Words

Seedling quality, reforestation, restoration

INTRODUCTION

Nursery management and reforestation in North America have come a long way since the first large scale forest nurseries were established in the early 1900s. In those days, the reforestation process was very simple and linear: nurseries produced seedlings which were then shipped for outplanting. Foresters took what they got and there wasn't much choice. Tree planting was a mechanical process of getting the seedlings in the ground in the quickest and least expensive manner. Not much thought was given to seedling quality or the possibility of using different stock types.

In the last 25 years, however, more science has been infused into the process. New research into seedling physiology, and better-educated customers, have revolutionized traditional concepts of reforestation and restoration. We now understand much more about how seedlings function – both in the nursery and after outplanting. In particular, the advent of the container seedling showed the importance of nursery cultural practices and vividly demonstrated important concepts like hardiness and dormancy. Today's seedling customers are very well educated; they know what they want; and they have many choices.

My objective in this paper is to show how some basic concepts can be used to define the best nursery stock for any outplanting project—the “target seedling”.

THE TARGET SEEDLING CONCEPT

The target seedling is relatively new, but the basic idea can be traced back to the late 1970s and early 1980s when new insights into seedling physiology were radically changing nursery management. A literature search of my Forest Nursery Notes database found nothing published on target seedlings before 1990. In that year, however, the Western Forest Nursery Association conducted a symposium to discuss all aspects of the target seedling, and the resultant proceedings are still a major source of information on the subject (Rose and others 1990).

The search for the target seedling began with research into seedling quality and there have been several books published on the subject (for example, Duryea 1985).

Morphological Characteristics

The first attempts to describe an ideal seedling always start with physical characteristics. In the South, the classic research of Phil Wakeley resulted in 3 grades of nursery stock for the major southern pine species (Wakeley 1954). More recently, the “Optimum Loblolly Pine Seedling” was described by a list of morphological characteristics (fig. 1).

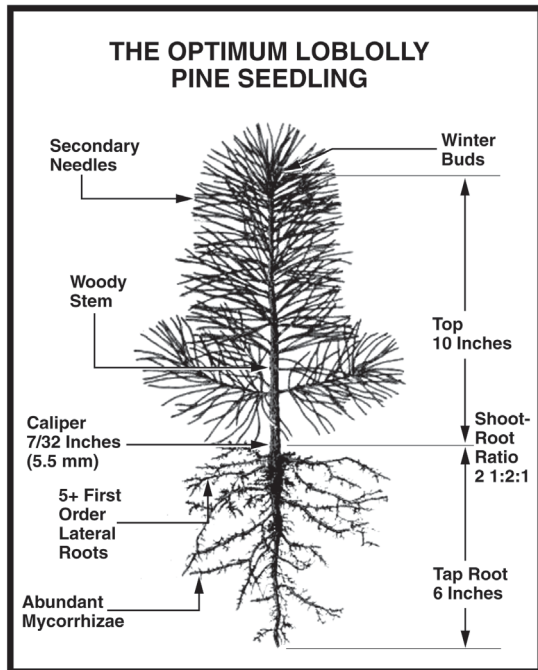


Figure 1. Although morphological characteristics can be used to grade seedlings, they do not give a full picture of the target seedling.

Physiological Characteristics

Wakeley's studies on the ideal pine seedling convinced him that there were physiological aspects of seedling quality that were just as important as morphological characteristics (Wakeley 1954). In recent years, most of the research on seedling quality has focused on physiological attributes such as dormancy and hardiness.

Outplanting Performance

Even if we can precisely describe the morphological and physiological aspects of a seedling, that does not allow prediction of outplanting performance. One of the basic tenets of the target seedling concept is that seedling quality is determined by survival and growth on the outplanting site. Seedling quality depends on the how the seedlings will be used, or "fitness for purpose" (Ritchie 1984). This means that seedling quality cannot be merely described at the nursery; it can only be proven on the outplanting site. There is no such thing as an "all-purpose" tree seedling. A nice looking seedling at the nursery will not survive and grow well on all sites. In recent years, foresters have begun to develop site prescriptions for reforestation which describe which

seedling stock types would do best on that particular site (fig. 2).

These aspects of seedling quality are important but there are other considerations when trying to define a target seedling.

DEFINING THE TARGET SEEDLING

A target seedling is a plant that has been cultured to survive and grow on a specific outplanting site, and can be defined in 6 sequential steps (fig. 3).



Figure 2. Reforestation prescriptions reflect the concept that seedling quality must be determined on the outplanting site (modified from BC Ministry of Forests 1998).

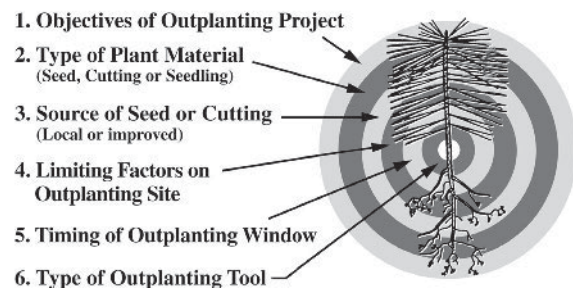


Figure 3. The 6 components of the target seedling concept.

1. Objectives of the Outplanting Project

The reason why seedlings are being planted will have a critical influence on the characteristics of the target seedling. In traditional reforestation, commercially valuable tree species that have been genetically improved for fast growth are outplanted with the ultimate objective of producing saw logs or pulp. The target seedling for a restoration project will be radically different. A watershed protection project would require riparian trees and shrubs and wetland plants that will not be harvested for any commercial product. Conservation planting projects can have still different objectives. For example, to establish windbreaks in low rainfall areas with no native trees, exotic species may be required.

Fire restoration projects will have different objectives depending on the plant community type and the ultimate use of the land. Project objectives for a burned rangeland might be to stop soil erosion, replace exotic weed species with natives, and establish browse plants for deer or elk. Target plant materials for this project might include a direct seeding of native grass and forbs, followed by an outplanting of woody shrub nursery stock. For a burned commercial forest, however, the plant materials would be native grass seed to stop erosion and then outplanting of tree seedlings to bring the land back to full productivity as soon as possible.

2. Type of Plant Materials

The term “target seedling” is limited and should be expanded to include all types of plant materials that are available from nurseries: seeds, seedlings, and rooted cuttings.

Seeds—Although direct seeding is rarely used in reforestation, seeds of native grasses, forbs, and shrubs are widely used in restoration. Federal and state nurseries have been leaders in this field. For example, the JH Stone Nursery in southern Oregon is currently producing over 30 species of native grasses and forbs. Grass seed of commercial cultivars has been used in restoration projects for decades; but it has just been in the past 10 years that reliable supplies of locally produced, source-identified seeds have been available.

Seedlings—Nurseries are currently producing a wide variety of seedling stock types. In the southern states, the 1+0 seedling is most common. But in the Pacific Northwest, nurseries grow mostly 2+0 seedlings plus 1+1 and plug+1 transplants. New stock types are continually being developed, such as the one-year

container transplant. This stock type (technically a plug+ $\frac{1}{2}$) is produced by growing a small volume container seedling early in the season and then transplanting them in the spring to a bareroot bed where they grow for the rest of the year.

Rooted Cuttings—In addition to the traditional seedling stock types, nurseries also produce plants by vegetative propagation. Some plants, notably willows and cottonwoods, are most easily propagated by rooting cuttings. Demand for willow and cottonwood species has become more common in the last decade because of an increased interest in riparian restoration. There are drawbacks to vegetative propagation, however. Sexual propagation results in a mixture of genetic characteristics so that the offspring contain both male and female plants. On the other hand, asexual propagation methods produce exact clones of the mother plant. This is of particular concern with dioecious plants, such as *Salix* and *Populus*, because all the progeny produced by vegetative propagation will have the same sex as their parent (fig. 4).

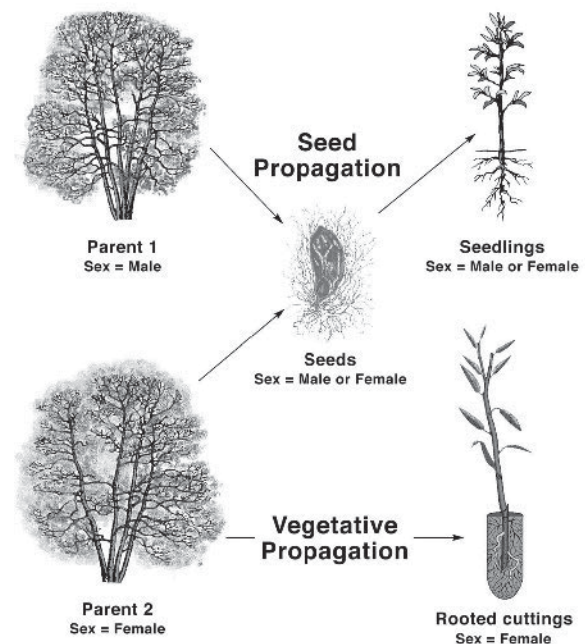


Figure 4. The target seedling concept must consider whether plants were propagated by seed or by cuttings, because the choice will affect both genetic and sexual diversity.

3. Source-identified Seeds or Cuttings

The next component in the target seedling concept is concerned with adaptation; all nursery managers and reforestation specialists are familiar with the idea of seed source. They know that plant species vary throughout their geographic range because they are adapted to local site conditions. Using a local seed source and collecting from enough individuals to maintain genetic diversity are basic tenets of restoration ecology. The same principles apply to plants that must be propagated vegetatively. Cuttings must be collected from near the outplanting site to make sure that they are properly adapted. Proper seed source can be guaranteed through the use of seed zones, and so the location and elevation of seed are always recorded and included in the seed source identification code.

4. Limiting Factors on the Outplanting Site

The fourth aspect of the target seedling concept concerns the ecological “principle of limiting factors”. The specifications of the target seedling should be developed by identifying which environmental factors will be most limiting to survival and growth on that particular site. For example, a fire restoration site in New Mexico might have shallow soils and competition for moisture and nutrients from grasses. On the Kenai peninsula in Alaska, however, cold soil temperatures are the limiting factor. Temperature measurements in the shallow rooting zone do not exceed 50 °F (10 °C) during the summer and research has shown that root growth almost stops completely below this temperature threshold (fig. 5). After the seedling customer supplies information about their particular outplanting site, the nursery manager can produce a seedling with the best chances to survive and grow.

One outplanting site condition deserves special mention: mycorrhizal fungi. Reforestation sites typically have an adequate complement of mycorrhizal fungi that quickly infect outplanted seedlings whereas many restoration sites do not. For example, severe forest fires or mining operations eliminate all soil microorganisms including mycorrhizal fungi. Therefore, seedlings destined for these sites should receive inoculation with the appropriate fungal symbiont before outplanting. The timing of the inoculation must also be considered because many mycorrhizal fungi will not survive in the high nutrient environment of the nursery.

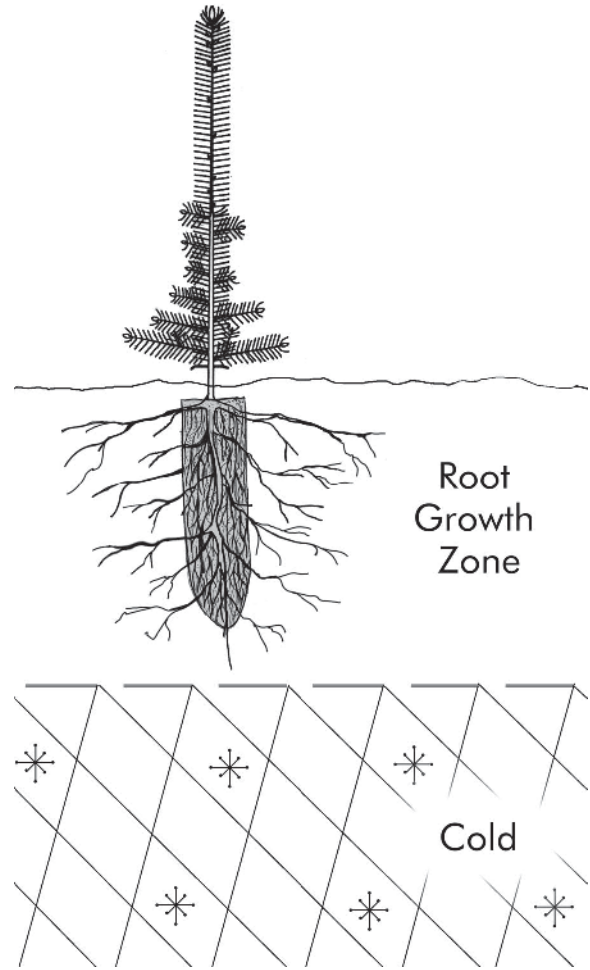


Figure 5. At high latitudes and elevations, cold soil temperatures are often more limiting than soil moisture.

5. Timing of the Outplanting Window

The timing of the outplanting project is the fifth aspect of the target seedling concept that must be considered. The outplanting window is the period of time in which environmental conditions on the outplanting site are most favorable for survival and growth. As mentioned in the previous section, soil moisture and temperature are the usual constraints. In the Pacific Northwest, seedlings are outplanted during the rains of winter or early spring but, because winters in Mexico are sunny and dry, seedling outplanting is done early in the summer rainy season. Soil temperature rather than moisture is the consideration at high elevations or latitudes. In Alaska, the outplanting window is later in the summer when soil temperatures are at their peak.

Using this information from the seedling customer, a growing schedule for the target seedling can be constructed. Starting at the date of delivery, the nursery manager plans backwards to determine how much time will be required to produce a seedling with the target specifications.

6. Type of Outplanting Tool

The last aspect of the target seedling concept is how the seedlings are going to be outplanted. There is an ideal planting tool for each outplanting site. All too often, foresters or other seedling customers will develop a preference for a particular implement because it has worked well in the past. However, no one tool will work under all site conditions. Special planting hoes called hoedads are popular in the steep terrain of the Pacific Northwest, but shovels or planting bars are traditionally used in Mexico. The level terrain in the Southern Coastal Plain or on the Kenai peninsula in Alaska allows machine planting. Nursery managers must know the planting tools in advance so that they can grow target seedlings with the appropriate root length and volume.

IMPROVING THE TARGET SEEDLING

The target seedling is not a static concept but must be continually updated and improved. At the start of the project, the forester and the nursery manager must agree on certain seedling specifications. This prototype target seedling must be verified by outplanting trials in which survival and growth are monitored for up to 5 years (fig. 6). The first few months are critical, because seedlings that die immediately after outplanting indicate a problem with stock quality. Plants that survive initially but gradually lose vigor indicate poor planting or drought conditions. Therefore, plots must be monitored during and at the end of the first year for initial survival. Subsequent checks after 3 or 5 years will give a good indication of seedling growth potential. This performance information is then used to give valuable feedback to the nursery manager who can fine tune the target seedling specifications for the next crop (fig. 6).

SUMMARY

The target seedling concept emphasizes that seedling quality cannot be defined in the nursery but instead must be proven on the outplanting site. Successful reforestation and restoration projects require good communications between the seedling user and the nursery manager. Instead of the traditional linear

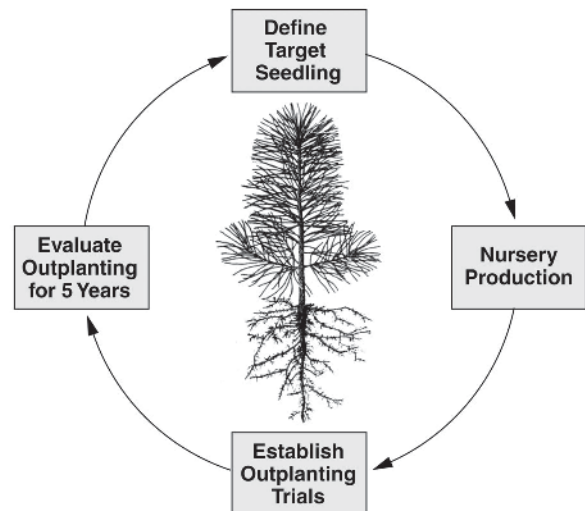


Figure 6. The target seedling must be continually updated with information from outplanting trials.

process which begins in the nursery, the target seedling concept is viewed as a circular feedback system where information from the outplanting site is used to define and refine the best type of seedling.

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MORPHOLOGICAL DIFFERENCES OF THE ROOT SYSTEM OF BAREROOT AND CONTAINER LONGLEAF PINE AFTER OUTPLANTING

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Abstract

For container longleaf pine (*Pinus palustris*), this study seeks to confirm the presence or absence of a true taproot or sinker root (from laterals), and to record differences in sinker root length and diameter. Bareroot and container longleaf seedlings were dug up on a dry site and a wet site. The trees were 4 and 6 years old respectively. Measurements of sinker root length, diameter at groundline, diameter 8 inches (20 cm) below groundline, diameter 16 inches (41 cm) below groundline, and number of first order lateral roots were taken. The deepest sinker root was measured whether it was a true taproot or a lateral that developed to replace the primary taproot. On the dry site, no significant differences in sinker root (or taproot) length, diameter at groundline, diameter at 8 inches below groundline, and diameter at 16 inches below groundline were found. On the wet site, no significant difference in sinker root length, groundline diameter, or diameter at 16 inches was recorded, but container seedlings were significantly smaller in diameter at 8 inches. Multiple sinker roots were observed on the both sites, but appeared more common on the wet site. Root origin, as the true taproot or a primary lateral expressing dominance, could not be positively identified. Sinker roots were significantly longer on dry sites with less variance, while sinker root length on the wet site was variable and limited by a high water table and soil hard pan. No correlation between root size and tree height was indicated. In all cases a single or multiple sinker root was present.

Key Words

Root conformation, outplanting survival

INTRODUCTION

Container longleaf pine seedlings typically have a shorter, smaller diameter taproot than bareroot longleaf seedlings. This is due to the container size used to grow longleaf seedlings (6 inch³ [98 cm³] volume is common) that restricts root growth. The taproot of a container longleaf seedling air prunes as it grows out the drain hole of the container cell. It has been suggested that a taproot of a container seedling does not develop after outplanting and that the absence of a taproot necessary to anchor the tree makes them susceptible to windthrow. Our objective was to measure the number and size of taproots and sinker roots of longleaf pine grown as bareroot or container seedlings.

METHODS

The study was located in Bladen Lakes State Forest on 2 sites planted with both container and bareroot longleaf seedlings in 1994 and 1996. One site was a wet sandy soil with the high water table about 4 feet (1.2 m) below the surface. The other was a dry deep sand. The trees were destructively sampled by digging them out of the ground using a backhoe. A trench was dug about 1 foot (0.3 m) away from the stem to a depth of 6 feet (1.8 m) and the soil was carefully removed from around the sinker root. Tree height, sinker root length, stem diameter at groundline, sinker root diameter at 8 inches (20 cm) below groundline, sinker root diameter at 16 inches (41 cm) below groundline, and the number of primary laterals in the upper portion of the root were measured.

Tree height and sinker root length were measured to the nearest inch using a tape measure. Root diameter was measured to the nearest 0.01 inch (0.25 mm) using digital calipers. The deepest and most prominent sinker root was selected for measurement when multiple sinker roots were found. The sinker roots on the dry site grew deeper than the capabilities of the backhoe, so the diameter at the end of the sinker root, where it broke, was taken. Photos were taken of all the trees measured. Duncan's Multiple Range Test was used to determine statistical significance of recorded measurements.

RESULTS

Dry Site

Sinker root length was not significantly different between the container and bareroot trees on the dry site (table 1). Sinker root length could not be measured beyond 6 feet due to the limited capability of the backhoe; therefore true length was not determined. At a depth of 5 to 6 feet, the sinker root diameters measured between 0.11 and 0.25 inch (2.79 and 6.35 mm) and roots continued downward to an undetermined depth. Sinker root length was essentially the same for bareroot and container seedlings on this site. Sinker roots were more obvious and better defined on the dry site and had fewer multiple sinker roots. It should be noted that in all the trees extracted, at least one sinker root was present.

No statistical difference in sinker root diameter or taper was measured on the dry site. Average sinker root diameter at 8 inches was 0.89 inch (22.6 mm) for the container and 0.69 inch (17.5 mm) for the bareroot. At 16 inches, average sinker root diameter was 0.51 inch (13.0 mm) for the container and 0.48

inch (12.2 mm) for the bareroot (tables 2 and 3). Sinker root diameter for container trees was larger on the dry site, while on the wet site the sinker root diameter of the bareroot seedlings was larger.

Wet Site

Sinker root length between the bareroot and container trees was not significantly different on the wet site. The bareroot trees had a higher average length than the container trees (29.4 inches [74.7 cm] compared to 25.2 inches [64.0 cm]), but because of the wide range of values in the sample, the difference was not statistically significant (table 1). A hard pan located about 20 inches (51 cm) and a high water table near 4 feet influenced sinker root development for both treatments. Damage to the root from planting, as well stem damage, was also observed and likely contributed to both length and diameter differences. Pigtail and ball ends were observed on both bareroot and container seedlings. Sinker roots were less obvious or well defined on the wet site, particularly for the container trees. Multiple sinker roots were observed more often on the container trees than the bareroot trees suggesting that in the absence of a true sinker root, one or more laterals express dominance to replace the damaged sinker root.

On the wet site, the sinker root diameter differed between the bareroot and container trees. Generally the bareroot roots were larger with a more carrot-like form and taper. The container trees, while having no difference in groundline diameter, tapered quickly. This was evidenced by the significantly smaller diameter at 8 inches below groundline: 0.62 inch (15.8 mm) compared to 0.86 inch (21.8 mm) (table 2). The diameter at 16 inches below groundline, although not statistically significant, was smaller for the container trees: 0.29 inch (7.4 mm) compared to 0.39 inch (9.9 mm) (tables 2 and 3).

Table 1. Root measurement summary (inches) for a dry and wet site in eastern North Carolina.

	Length	Taproot		Number of laterals	
		Ground line	Diameter		
			8"	16"	
DRY					
Container	54a	1.7a	0.9a	0.5a	10a
Bareroot	59a	1.6a	0.7a	0.5a	10a
WET					
Container	25a	1.9a	0.6a	0.3a	10a
Bareroot	29a	1.9a	0.9b	0.4a	10a

Sites analyzed separately.

Table 2. Root measurement data for container longleaf seedlings (inches) for a dry and wet site in eastern North Carolina.

	Height (inches)	Sinker root (inches)	Taproot Diameter			Number of laterals
			Ground line	8"	16"	
DRY	6	56	1.3	0.58	0.47	9
	16	56	1.5	0.79	0.45	12
	15	52	1.0	0.53	0.30	12
	80	56	2.6	1.10	0.61	9
	66	50	2.4	1.60	0.74	13
	70	20	1.6	0.92	0.30	16
	50	66	2.1	1.30	0.91	9
	42	58	1.9	0.81	0.48	9
	45	64	1.4	0.68	0.49	4
	14	62	1.2	0.55	0.37	9
Ave	40	54	1.7	0.90	0.50	10
WET	46	26	1.81	0.68	0.20	11
	37	23	1.87	0.42	0.35	6
	64	25	1.87	0.61	0.31	12
	68	29	2.12	0.64	0.40	9
	41	18	1.82	0.14	0.05	9
	53	31	1.95	0.86	0.50	16
	57	33	1.67	0.60	0.25	10
	26	11	1.70	0.18	—	6
	30	18	2.00	0.67	0.09	9
	59	22	1.50	0.67	0.12	6
	58	40	2.14	0.56	0.26	18
	49	21	2.15	0.66	0.20	6
	31	11	1.50	0.15	—	13
	45	19	1.77	0.49	0.13	8
	48	31	2.09	0.96	0.30	13
	34	42	1.77	0.82	0.38	12
	78	28	2.54	1.49	0.80	7
Ave	48	25	1.90	0.60	0.30	10

Table 3. Root measurement data for bare-root longleaf seedlings (inches) for a dry and wet site in eastern North Carolina.

	Height (inches)	Sinker root (inches)	Taproot Diameter			Number of laterals	
			Ground line	8"	16"		
DRY	28	69	1.9	0.63	0.48	9	
	66	68	1.9	0.92	0.77	17	
	38	56	1.5	0.68	0.40	10	
	46	64	1.9	0.94	0.51	16	
	24	59	1.7	0.72	0.53	6	
	26	60	1.7	0.70	0.57	5	
	14	50	1.3	0.59	0.37	8	
	40	60	1.5	0.58	0.41	10	
	23	52	1.4	0.59	0.42	10	
	17	55	1.3	0.59	0.34	10	
	Ave	32	59	1.6	0.70	0.50	10
	WET	109	19	2.15	0.44	0.14	12
106		23	2.33	1.32	0.61	11	
69		17	1.79	1.04	0.34	10	
48		32	1.85	1.20	0.74	11	
65		32	1.90	1.29	0.54	8	
35		14	1.63	0.24	—	14	
58		51	1.81	0.13	0.47	9	
65		25	1.52	0.65	0.22	9	
57		24	1.89	1.33	0.35	12	
47		27	1.77	0.47	0.14	9	
100		29	2.40	1.56	0.69	10	
28		32	1.58	0.61	0.34	8	
55		18	2.18	1.26	0.63	12	
84		48	2.33	0.88	0.22	12	
59		38	1.90	0.65	0.22	11	
84		58	1.84	0.80	0.19	8	
40		13	1.62	0.73	—	7	
Ave	48	29	1.90	0.90	0.40	10	

Laterals

The average number of primary laterals was the same for both container and bareroot trees on both sites. It appeared that lateral roots of container seedlings on wet sites were concentrated in the top 6 inches (15 cm) of the root system, while the lateral roots of bareroot seedlings were better distributed along the top 10 to 12 inches (30 cm). Twisting of the laterals was observed on both the container and bareroot seedlings, which was likely a result of planting technique used. This damage may have effected sinker root development in some instances.

CONCLUSIONS

The study results do not support the hypothesis that lack of a sinker root or differences in sinker root development makes container longleaf seedlings more susceptible to windthrow. A sinker root was present on all trees sampled. On both sites, no significant difference in sinker root length was recorded. Many of the most notable differences in

sinker root length could be attributed to planting damage or environmental hindrances within the soil, such as a frag-pan or high water table. The smaller average sinker root diameter for container trees on wet sites may be due to multiple sinker roots observed or that the high quality site provided more nutrients and water, and therefore an extensive root system was not needed. Perhaps several small sinker roots serve the same function as one larger sinker root. We could not determine if the true sinker root developed on the container seedlings, but the presence of multiple sinker roots indicate that laterals do develop to replace the primary taproot to anchor and supply resources to the newly planted seedling.

Based on this study, it seems the risk of windthrow in longleaf pine is just as likely for trees from bareroot seedlings as for those from container seedlings. Longleaf is susceptible to windthrow at an early age. The site characteristics, the type of storm, storm intensity, and storm frequency factor into the susceptibility.

NUTSEDGE (CYPERUS SPP.) ERADIATION: IMPOSSIBLE DREAM?

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Abstract

The elimination of methyl bromide use will affect a broad range of crops, from vegetables to cut flowers to pine seedlings. In many plant production scenarios, once methyl bromide applications have ceased, nutsedges have become significant problems due to their tolerance of many herbicides and their prolific production of energy-rich tubers. Instead of independently researching nutsedge management in each of these diverse crops, sharing knowledge concerning nutsedge biology, ecology and management may allow us to efficiently find viable solutions to this problem. This paper is a brief review of some of the knowledge of purple and yellow nutsedge biology, ecology, and management in agronomic and vegetable crops.

Key Words

Cyperus rotundus, *Cyperus esculentus*, noxious weeds

NUTSEDGE IMPORTANCE AND DISTRIBUTION

The Cyperaceae or Sedge family consists of 17 different genera in the Southeast US (Radford and others 1968). While several of these genera are weedy (examples: *Kyllinga* spp. and *Carex* spp.), those commonly described as most troublesome across a broad range of crops are found in the genus *Cyperus*. There are 45 *Cyperus* spp. found in the southeastern US, of which 29 are perennial. Two of these perennial species, purple nutsedge (*Cyperus rotundus* L.) and yellow nutsedge (*Cyperus esculentus* L.), can be separated from the rest due to their economic impact on agriculture.

Nutsedges were food crops before they were considered weeds. Purple nutsedge tubers have been identified as a staple of the diet of Egyptians in the late Paleolithic era (circa 1600 BC) (Negbi 1992). Recipes for ground-up yellow nutsedge tubers mixed with honey have been discovered in Egyptian tombs dating from the 15th century BC (Negbi 1992). The first reference to purple nutsedge as a weed occurred in the first century AD (Negbi 1992). Nutsedges have since become important weeds throughout the world. Based on the worldwide distribution (considered weeds in at least 92 countries) and importance in many diverse crops (infesting at least 52 different crops), purple nutsedge was ranked as the world's worst weed, while yellow nutsedge was listed among the top 15 worst weeds (Holm and others 1978). A

survey completed by county extension agents in Georgia ranked the nutsedges among the top 5 most troublesome weeds in corn, cotton, peanut, and soybean, and the most troublesome weeds of tobacco and vegetables (Webster and MacDonald 2001).

The 2 nutsedge species have different distributions in the US. Yellow nutsedge is found throughout the continental US, while purple nutsedge is primarily restricted to the coastal states of the southern US and along the Pacific coast in California and Oregon. Researchers determined that 95% of yellow nutsedge tubers survived 36 °F (2 °C) for 12 weeks when buried in the soil to a depth of 4 inches (10 cm); however less than 10% of purple nutsedge tubers survived this treatment (Stoller 1973). The general conclusion is that purple nutsedge will typically thrive only in areas where the soil freezes infrequently.

HOW TO DISTINGUISH THE NUTSEDGE SPECIES

Both nutsedges have triangular stems (easily felt if you roll the stems between your finger and thumb), distinguishing them from grasses that have flat or round stems. Purple and yellow nutsedge can be difficult to separate; however there are distinguishing characteristics for each. Purple nutsedge tubers are cylindrical, with a brownish-black coat, susceptible to desiccation, and have a pungent taste. Yellow nutsedge tubers are also cylindrical. However, they

are a yellow-beige color, can be dried to a wrinkly consistency with minimal affect on viability, and have a pleasant nutty taste. In fact, chufa is a subspecies of yellow nutsedge that is grown as a crop for wild turkey and swine feed. Purple nutsedge tubers form chains, capable of expanding beyond the shadow of the mother plant. In contrast, yellow nutsedge tubers will be relatively close to the mother plant, as all rhizomes that end in a tuber will be attached to the mother plant.

The tips of the leaf blades are important for distinguishing between species. Yellow nutsedge often has long blades with a gradually tapering leaf tip. Yellow nutsedge leaves also tend to be “pinched”, forming folded boat-shaped blades near the tips. In contrast, purple nutsedge often has a shorter leaf blade that always comes to an abrupt tip that remains flat near the tip of the blade. Yellow nutsedge plants tend have a lighter yellowish-green color, while purple nutsedge plants are often darker green in color. Soil fertility, however, will often influence this and should not be used a definitive identification tool. Inflorescence color is a good means of easily distinguishing these species. Purple nutsedge has a reddish-purple inflorescence, while yellow nutsedge has a yellow inflorescence.

WHY ARE NUTSEDGES SUCH PERSISTENT WEEDS?

Purple and yellow nutsedge are perennial weeds that are prolific producers of tubers. Studies have demonstrated that purple nutsedge will produce seed, but viability of the seed is very low. As a result, there is minimal genetic variation in purple nutsedge populations (Okoli and others 1997). In contrast, yellow nutsedge has greater genetic variation and higher seed production (17% of flowers produced seed) (Thullen and Keeley 1979; Okoli and others 1997). Yellow nutsedge seeds were viable two weeks after full bloom and had a high rate of germination (78%) (Lapham and Drennan 1990). However, under agronomic conditions, less than 1% of the germinated seeds survived and became a mature plant. Yellow nutsedge seeds are important in dispersing this species into new areas; once established in a field, yellow nutsedge predominantly relies on vegetative reproduction to sustain itself.

Tubers of purple nutsedge have been estimated to have a half-life of 16 months and a predicted longevity of 42 months (Neeser and others 1997). This is not long when compared to other weed species, which have survived in the soil profile under

natural conditions for greater than 70 years (Regnier 1995). While tubers may not be as long-lived as seeds, tubers possess large carbohydrate reserves, which allow for rapid emergence and growth, an advantage over seeded crops.

Purple nutsedge tuber production begins approximately 6 to 8 weeks after foliar emergence, corresponding to flower initiation (Hauser 1962). Roots and tubers have more biomass than aboveground foliage by 6 weeks after foliar emergence and tuber chains are initiated a month later (Hauser 1962). When purple nutsedge was planted at 43,560 tubers/acre (107,340 tubers/ha), after 1 season of growth there were 3,090,000 shoots/acre (7,635,400 plants/ha) and 4,442,000 tubers/acre (10,980,000 tubers/ha) (Hauser 1962). A single yellow nutsedge plant growing without competition in a bareground area produced 700 tubers after 6 months of growth (Webster unpublished data). It is critical to remember that nutsedge populations can increase rapidly when fields are not managed between crops.

Yellow nutsedge appears to be more tolerant to shading than purple nutsedge, but neither thrives under low light conditions. Yellow nutsedge biomasses were not different when grown in either full sunlight or 30% shade, while purple nutsedge biomass was reduced linearly as light levels decreased (Jordanmolero and Stoller 1978). Supporting this finding is the lower light compensation point (amount of light needed for photosynthesis to equal respiration) for yellow nutsedge than for purple nutsedge (Santos and others 1997).

EXPANSION OF NUTSEDGE PATCHES

Once nutsedge plants become established in the field, little is known about how fast nutsedge patches expand. A single tuber of each nutsedge was established and allowed to grow and expand in a non-competitive environment. After 3 months of growth, the number of shoots was similar for both yellow nutsedge (22 shoots) and purple nutsedge (29 shoots) (Webster unpublished data). However, the average number of purple nutsedge shoots (323 shoots/patch) after 6 months of growth more than doubled the number of yellow nutsedge shoots (136 shoots/patch). There were not only striking differences in shoot population among the nutsedge species, but the sizes of nutsedge patches were also different. Yellow nutsedge growth formed compact, densely populated patches. In one particular patch after 6 months of growth, a single tuber expanded to form a patch with an area of 1.9 ft² (0.18 m²) (Webster unpublished data). At the center

of this patch, the density was 650 shoots/ft² (7000 shoots/m²). [However there were only 177 shoots over the 0.6 ft² (0.18 m²) area, for an average patch density of 91 shoots/ft² (980 shoots/m²)]. In contrast, purple nutsedge tubers formed a much larger patch that was sparsely populated (relative to yellow nutsedge). After 6 months of growth, the purple nutsedge patch expanded to an area of 84 ft² (7.85 m²), over 43-fold larger than the yellow nutsedge patch. In this particular purple nutsedge patch, there were 518 shoots in the patch, with the maximum density of 26 shoots/ft² (280 shoots/m²), with the average patch density of 6 shoots/ft² (66 shoots/m²). The primary conclusion that can be drawn from this preliminary data is that purple nutsedge populations are capable of distributing themselves throughout the environment, while it appears that yellow nutsedge tubers require human action to distribute them throughout the environment. This supports the conclusions of Schippers and others (1993) that farming operations are the main causes of yellow nutsedge dispersal in the field.

How Do I Get Rid of My Nutsedges?

The majority of purple nutsedge tubers are relatively shallow; 45% of the tubers are within the top 1.5 inches (4 cm) of the soil profile and 95% are found within the top 4.7 inches (12 cm) of the soil profile (Siriwardana and Nishimoto 1987). With relatively shallow distribution in the soil, frequent tillage was the primary means of controlling nutsedges prior to the development of herbicides. Tillage every 3 weeks over a 2-year period eradicated purple nutsedge from fields on more than 10 different soil types (Smith 1942; Smith and Mayton 1938). While frequent tillage over time can be effective in controlling tuber populations, it is possible that infrequent tillage may serve to fragment tuber chains, releasing apical dominance and possibly increasing nutsedge populations.

Successful nutsedge management requires the integration of knowledge of the biology and ecology of these species with management strategies (which include herbicides and cultural crop production practices). One of the keys to managing nutsedge species is to target postemergence herbicide applications to coincide with the maximum number of emerged nutsedge shoots. Emergence of nutsedge shoots is largely dependent upon soil temperature. While moisture extremes will affect emergence, due to the large carbohydrate reserves in the tuber, soil temperature will largely be the driving force behind emergence. We followed nutsedge emergence

throughout the growing season and found a relation between temperature and nutsedge emergence. Using a base temperature of 41 °F (5 °C), the accumulated number of growing degree days that corresponded with 80% emergence of yellow nutsedge was 782 growing degree-days (GDD), which occurred on 6 May 1999 and 30 April 2000 (Webster unpublished data). Purple nutsedge required more growing degree-days, 1264 GDD, to achieve 80% emergence, corresponding to 1 June 1999 and 21 May 2000. These dates were 3 to 4 weeks later in the growing season than yellow nutsedge (Webster unpublished data). Why is this important? Several herbicides require foliar contact (for example, glyphosate and paraquat) or have better activity against nutsedge when applied to the foliage (for example, halosulfuron). Proper timing of postemergence applications will improve the efficiency of these applications.

The following section contains estimated purple and yellow nutsedge control levels for several compounds. These estimates are based on research in agronomic (in other words, corn, cotton, and peanut) or vegetable crops (in other words, cucurbits, eggplant, and tomato) and are collective ratings from several research and extension weed scientists with the University of Georgia and USDA-ARS in Tifton, Georgia (table 1). While weed control effectiveness may be similar in pine seedling nurseries (depending upon herbicide rate, time of herbicide application, and desired length of control), crop tolerance has not been evaluated for pine seedlings. In many of these crops, a competitive crop canopy is established within the first several weeks in the season, which may improve overall control. Also, discussion of these products does not imply that these herbicides are registered for use outside of agronomic and vegetable crop situations. Please refer to the herbicide label before making any herbicide application.

There are 3 types of herbicides that are used to manage nutsedge populations. The first type of herbicide is applied to the soil prior to nutsedge emergence, called preemergence (PRE) herbicides. The most common examples of these types of herbicides are metolachlor (trade name: Dual[®]) and fomesafen (trade name: Reflex[®]). Yellow nutsedge control (55% to 85%) is more effective than purple nutsedge control (< 35%) with these compounds. While anecdotal evidence suggests fomesafen has PRE activity on yellow nutsedge, control of this species is not listed on the registration. Fomesafen has a 24C registration in Mississippi for use in pine seedling nurseries.

Table 1. Estimates of yellow and purple nutsedge control with herbicides commonly used in agronomic and vegetable crops. The tolerance of pine seedlings has not been tested.

Herbicide activity	Herbicide	Rate Kg ai/ha	Percent control	
			Yellow nutsedge	Purple nutsedge
Soil activity only	Metolachlor PRE ^a	1.40	55 to 85	< 20
	Fomesafen PRE ^b	0.56	85	< 35
	Fomesafen POST	0.42	50 to 60	?
Foliar activity only	Bentazon POST ^c	1.12	75	< 20
	Glyphosate POST ^d	2.24	55	70
	MSMA POST ^e	1.12	45	30
	MSMA POST	2.24	90	65
Soil and Foliar Activity	Imazapic POST ^f	0.07	90	95
	Imazethapyr POST ^g	0.07	60	70
	Halosulfuron ^h	0.07	85 to 95	85 to 95
	Trifloxysulfuron ⁱ	N/A	75 to 95	?

^a Trade name: Dual[®] Magnum (7.62 lbs ai/gal of product); 1.3 pt product/ac.

^b Trade name: Reflex[®] (2 lbs ai/gal of product); 2 pt product/ac. There is a 24C label for application of Fomesafen PRE in pine seedling nurseries in Mississippi. This label does not exist in any other state.

^c Trade name: Basagran[®] (4 lbs ai/gal of product); 2 pt product/ac.

^d Trade name: Roundup[™] and many generics; rate of product depends upon formulation.

^e Trade name: Various generics; rate of product depends upon formulation.

^f Trade name: Cadre[®] (0.70 lbs ai/1.0 lb of product); 1.44 oz product/ac.

^g Trade name: Pursuit[®] (0.70 lbs ai/1.0 lb of product); 1.44 oz product/ac.

^h Trade name: Sandea[™] and Permit[®] (0.75 lbs ai/1.0 lb of product); 1.3 oz product/ac.

ⁱ Trade name: Evoke, CGA-362622; experimental, not yet registered.

The second class of herbicides is applied following nutsedge emergence (commonly referred to as postemergence or POST treatments) and these rely on foliar contact because they do not possess any soil activity. The most common examples of these herbicides include bentazon (trade name: Basagran[®]), glyphosate (trade name: Roundup[™] and similar generic brands), MSMA, and paraquat. Differential effectiveness for these herbicides between the nutsedge species has been noted. Yellow nutsedge is more susceptible to MSMA (90% control) than is purple nutsedge (65% control). Bentazon is more effective on yellow nutsedge (75% control), while purple nutsedge control is poor (less than 20% control). There appears to be a similar efficacy among the nutsedge species for paraquat (50% control), while glyphosate has better activity on purple nutsedge (70%) than on yellow nutsedge (55%). Glyphosate will translocate through the plant within 3 days and subsequently kill the foliage and the tuber directly attached to the foliage (Rao and Reddy 1999). The key to controlling or suppressing nutsedge growth with these compounds is ensuring the herbicide contacts the nutsedge foliage, which can be predicted using growing degree-days.

The final class of herbicides used to manage nutsedges has both soil activity and foliar activity. These herbicides include some of the more recently registered compounds, including halosulfuron, imazapic, and imazethapyr (Richburg and others

1993, 1994; Vencill and others 1995; Molin and others 1999). Imazethapyr and imazapic tend to have greater activity against purple nutsedge (70% and 95%, respectively) than yellow nutsedge (60% and 90%, respectively), while halosulfuron is equally effective (85% to 95% control) against both nutsedge species. Vencill and others (1995) determined that 53 g ai/ha (1 oz of product/ac) of halosulfuron reduced purple and yellow nutsedge regrowth at least 96% when applied to the foliage, the soil, or both the foliage and the soil. The number of purple nutsedge tubers was reduced 50% after consecutive years of halosulfuron applied at 72 g/ha (1.3 oz of product/ac) (Webster and Coble 1997).

The effectiveness of several of these herbicides, including glyphosate and halosulfuron, in controlling nutsedges is largely dependent upon the growing conditions. Conditions favoring nutsedge growth (in other words, warm temperatures, adequate moisture and fertility) will tend to improve nutsedge efficacy of these herbicides. Dry conditions will often reduce the effectiveness of these herbicides (including metolachlor).

Nutsedge control is a multi-season effort. Herbicides will often be the basis of nutsedge management programs. While control of foliage is important, successful long-term control will require management options that reduce or eliminate tuber production and viability.

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STUNTING OF SOUTHERN PINE SEEDLINGS BY A NEEDLE NEMATODE (LONGIDORUS SP.)

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Cram M.M., Fraedrich S.W., Fields J. 2003. Stunting of southern pine seedlings by a needle nematode (*Longidorus* sp.). In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. *National Proceedings: Forest and Conservation Nursery Associations—2002*. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 26–30. Available at: <http://www.fcnanet.org/proceedings/2002/cram.pdf>

Abstract

An undescribed needle nematode (*Longidorus* sp.) was consistently associated with stunted loblolly pine seedlings at the Flint River Nursery in south Georgia. Seedlings in affected areas had root systems that were greatly reduced in size, and lacked lateral and fine roots. In a growth chamber experiment, the needle nematode significantly reduced the size of loblolly pine root systems in containers initially infested with 100 and 200 nematodes. Populations of the needle nematode increased in all containers during the course of the experiment.

Slash and longleaf pines have also been found to be hosts for the needle nematode. Cover crops typically used at the nursery, including sorghum, wheat and rye, were not found to be hosts. Yellow nutsedge was also not a host.

A survey conducted in pine seed orchards that border the nursery indicated that 37% of the soil samples were positive for the needle nematode. The nematode was not found in redcedar windrows, an oak seed orchard, and pine stands adjacent to the nursery.

Key Words

Pinus taeda, *Pinus elliotii*, *Pinus palustris*, fumigation, seedling stunting

INTRODUCTION

Areas of stunted pine seedlings have been periodically observed by personnel at the Flint River Nursery (Byromville, Georgia) for over a decade. In 1996 and 1997, we examined stunted loblolly seedlings in block I of field 7S, but the cause of the damage could not be determined. Blocks I and II were being used to test rotating pine with white oak crops (table 1). In 1998, blocks II and III were fumigated and sown with slash pine. According to nursery records, block I was too wet in 1998 to fumigate and was taken out of production. In 1999, stunting recurred in block II and was also found in block III. Seedlings were evaluated for pathogenic fungi and soil samples were forwarded to a nematode testing laboratory for evaluation. In spite of these efforts, the cause of the stunting remained undiagnosed. In the spring of 2000, blocks I-III were

fumigated with MC33 (methyl bromide 33%/chloropicrin 67%) and sown with loblolly pine in 2000 and 2001. Stunting was not observed in blocks I-III in 2000, but in 2001 stunting reappeared in all 3 blocks, with most of the damage in Block II.

A fumigation study was established in 1998 in blocks IV and V of field 7S (Cram and others 2002), which were adjacent to the areas affected by stunting. In the third year of the study (2000), patches of stunted loblolly pine seedlings appeared in nonfumigated plots. The damaged seedlings had poorly developed root systems that lacked lateral and feeder roots (fig. 1). In August 2000, soil samples were forwarded to a nematode laboratory where low levels of lesion (*Pratylenchus* sp.) and ring (*Criconemella* sp.) nematodes were found in both damaged and undamaged areas. Laboratory evaluations of roots for fungal pathogens were also inconclusive. However, during our examination of unwashed roots under the

Table 1. Field history of fumigation and crop rotations of pine, hardwoods, and cover crops for blocks I-V in field 7S of Flint River Nursery, Byromville, Georgia.

Date	Block 1	Block 2	Block 3	Block 4	Block 5
1989	MC33 ^a	MC33	MC33	MC33	MC33
1990	Lob ^b	Lob	Lob	Lob	Lob
1991	Lob	Lob	Slash	Slash	Slash
1992	Lob	Lob	Slash	BasamidSlash	MC33Slash
1993	Oak Lob	Lob	Slash	Slash	Slash
1994	Oak	Oak	Dogwood Sweetgum	Slash	Slash
1995	Oak	Oak	Dogwood Sweetgum	Virginia	Virginia Sand
1996	Lob Oak	Oak	Lespedeza	Lespedeza	Wheat
1997	Lob	Lob	Sorghum	Sorghum	Sorghum
1998	Fallow	MC33Slash	MC33Slash	Fumigation studyLob	Fumigation studyLob
1999	Fallow	Lob	Lob	Lob	Lob
2000	MC33Lob	MC33Lob	MC33Lob	Lob	Lob
2001	Lob	Lob	Lob	Lob	Lob

^aMethyl bromide 67% / chloropicrin 33%.

^bLob=loblolly pine.

dissecting microscope, we routinely observed a needle nematode (*Longidorus* sp.) associated with the stunted seedlings. This nematode had not been reported by the nematode testing laboratory. Samples of the needle nematode were sent to the USDA, ARS, Nematology Laboratory in Beltsville, Maryland, for identification and were determined to be an undescribed species (Handoo 2000). The nematode is large (7 to 8 mm long) and requires extraction techniques specific for large nematodes (Flegg 1967; Shurtleff and Averre 2000). This paper summarizes findings of our field and growth chamber studies to determine the cause of the seedling stunting, and to identify other possible hosts of the needle nematode.

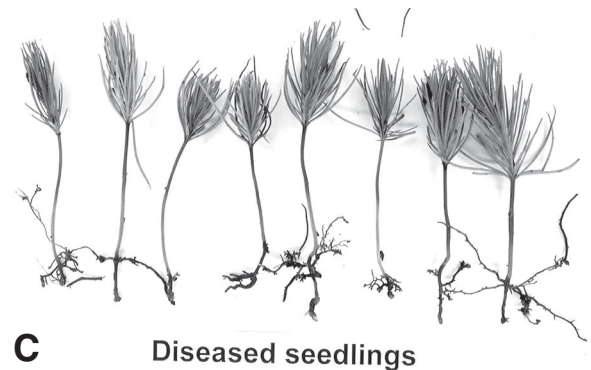


Figure 1. Patches of stunted loblolly pine seedlings at Flint River Nursery A. Root systems of healthy B, and diseased C, 10-week old seedlings.

METHODS

Identifying the Causal Agent

Field Survey—Patches of stunted seedlings in the fumigation study ranged from 10 to 29.5 ft (3 to 9 m) long and were one seedbed wide. Soil and seedlings were sampled from 4 patches of stunted seedlings in August through October of 2000 (Fraedrich and Cram 2002). Samples were taken in August from the center of the patches, the margins, and 5 to 10 ft (1.5 and 3 m) from the margins. In October, samples were removed from the margins of the patches and 5 ft (1.5 m) from the margins. Nematodes were extracted using a modified Flegg (1967) technique with 90 μm aperture sieves (Fraedrich and Cram 2002).

Growth Chamber Study—The effect of the needle nematode on loblolly pine seedlings was tested by infesting microwaved field soil from Flint River Nursery with 0, 50, 100, and 200 nematodes, and planting 5 germinating loblolly pine seeds per container (Fraedrich and Cram 2002). There were 4 replications for each treatment. Seedlings were removed after 22 weeks and dry weights of the roots and shoots were measured. Population densities of needle nematodes in containers were also determined using the modified Flegg technique (Fraedrich and Cram 2002). Relationships between root dry weight, and initial and final needle nematode populations were determined by regression analysis (Draper and Smith 1981).

Host Range and Survey for the Needle Nematode

Host Range Studies—Initial host range tests were conducted on pine species normally grown at the nursery (Fraedrich and others 2002). The effect of the needle nematode on slash, longleaf and loblolly pine was evaluated by infesting microwaved nursery soil with 0 and 200 nematodes, and planting 5 germinated seedlings in each container. There were 4 replications for each pine species and treatment. Seedlings were removed after 26 weeks, and seedling root and shoot dry weights were measured. The population of needle nematodes was determined for each container.

A second study was conducted to evaluate the host suitability of wheat, rye, sorghum, and yellow nutsedge to the needle nematode. Loblolly pine and a fallow treatment were included for comparison. Containers of microwaved nursery soil were infested

with 100 needle nematodes and planted with 5 germinating seeds or tubers (nutsedge) of each species. There were 4 replications for each treatment. Soil was removed from containers, and the needle nematodes were extracted and counted after 12 weeks.

Area Survey—Soils from various locations in and around the nursery were evaluated for needle nematodes in October 2001 and January 2002. Composite soil samples consisting of 8 to 10 cores at a 6 inch (15.2 cm) depth were taken along transects in 3 redcedar windrows, an oak seed orchard, and pine stands on lands adjacent to the nursery. Sixteen composite soil samples were also obtained from loblolly and slash pine seed orchards that border the nursery.

RESULTS

Identifying the Causal Agent

Field Survey—Population densities of needle nematodes were greater in soil samples from the root zone of seedlings at the centers and margins of patches with stunted seedlings than in areas with healthy seedlings at distances of 1.5 and 3.0 m from the margins of patches. In August, 26.6 needle nematodes per 0.8 oz (25 g) soil were obtained from the center of patches, 13.1 at the margins, and 0.5 and 0.2 nematodes at 5 to 10 ft (1.5 and 3 m) from the margins, respectively. In October, evaluations of soil samples from the root zone of seedlings found an average of 25.8 needle nematodes per 0.8 oz of soil from the margins of patches, and 1.5 nematodes/0.8 oz soil at locations 5 ft outside the margin. Nematode extractions from bulk soil samples resulted in an average of 17.5 needle nematodes/6 in³ (100 cc) in the margins of patches and 2.5 needle nematodes/6 in³ at 5 ft from the margins. Seedling damage occurred in approximately 4% of the nonfumigated area within the fumigation study in 2000.

Growth Chamber Study—Loblolly pine seedlings in containers with 100 and 200 needle nematodes had damaged root systems similar to stunted seedlings in the field. Roots of affected seedlings lacked lateral and feeder roots. Root dry weight of seedlings decreased with respect to both the initial needle nematode dose (fig. 2A), and the final population per container (fig. 2B). The shoot dry weight of seedlings was not affected by initial or final populations of needle nematodes in containers.

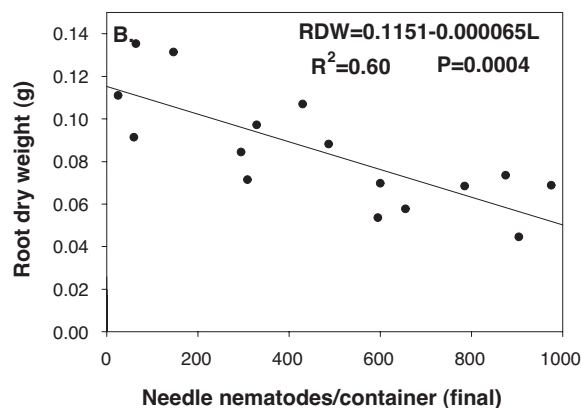
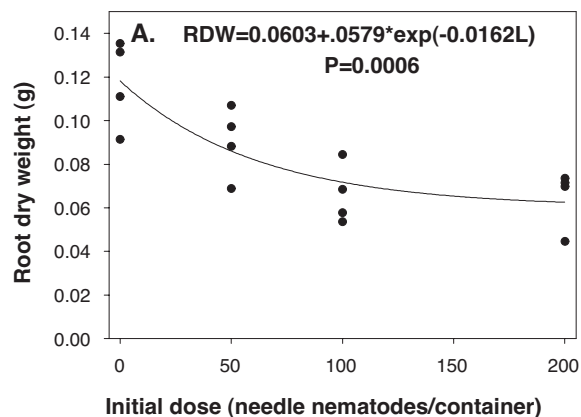


Figure 2. Relationships between the initial dose of needle nematodes (L) and root dry weight (RDW) of loblolly pine seedlings A, and final population of needle nematodes per container and root dry weight B. Data was collected 22 weeks after infestation. Each data point represents the mean root dry weight of 5 seedlings per container.

Host Range and Survey for the Needle Nematode

Host Range Studies—Population densities of the needle nematode increased on slash, loblolly and longleaf pine roots, and reduced the root dry weights of slash and loblolly but not longleaf pine (table 2). The needle nematode population densities decreased substantially in containers with wheat, rye, sorghum, and yellow nutsedge, as well as the fallow containers (table 3).

Area Survey—Surveys conducted in and around the nursery failed to recover the nematode in windrows composed of redcedar, an oak seed orchard, or in pine stands on lands adjacent to the nursery. However, the needle nematode was found in 37% of

Table 2. Final needle (*Longidorus*) nematode population densities and root dry weights of southern pine species 26 weeks after infestation.

Pine species	Initial needle nematode	Final needle nematode	Root dry weight
	--- Number/container ---		g
Loblolly pine	200	1257	0.159*
	0	0	0.295
Slash pine	200	1683	0.334*
	0	0	0.556
Longleaf pine	200	820	0.681
	0	3	0.825

* Means within species are significantly different ($P \leq 0.05$) according to t-test.

the soil samples from the loblolly and slash pine seed orchards that border the nursery.

DISCUSSION

Needle nematodes have been found in soils where southern pines are grown (Hopper 1958; Ruehle and Sasser 1962); however, there has been no report of these nematodes damaging loblolly pine or any other southern pine. The results of our survey indicate that the needle nematodes found were associated with the stunting of loblolly pine seedlings at Flint River Nursery. The ability of this needle nematode to feed and reproduce on roots of pine was confirmed in growth chamber studies. The nematode can also stunt the root systems of loblolly and slash pines. In growth chamber experiments, the lack of a difference in shoot height is most likely due to the lack of stress from high summer temperatures that would occur under field conditions. Possible interactions of the

Table 3. Final needle (*Longidorus*) nematode population densities in containers with cover crops, yellow nutsedge, and loblolly pine 12 weeks after infestation with 100 needle nematodes.

Species*	Initial needle nematode	Final needle nematode
	----- Number/container -----	
Loblolly pine	100	1089
Sorghum	100	7
Wheat	100	3
Rye	100	1
Nutsedge (yellow)	100	3
Fallow	100	6

*Sorghum – *Sorghum bicolor*; Rye – *Secale cereale*;
Wheat – *Triticum aestivum*; Loblolly pine – *Pinus taeda*;
Yellow nutsedge – *Cyperus esculentus*.

needle nematode with other biotic and abiotic factors require additional study.

We suspect that the needle nematode was spread to our fumigation study in blocks IV and V by equipment during field preparations for fumigation of field 7S in 1998. The nematode populations appeared to have built up in blocks I and II that had been continually cropped with loblolly pine or white oak from 1990 to 1997 without fumigation. When fumigation was applied to affected blocks in 1998 and again in 2000, the stunting consistently reappeared within these fumigated areas during the second year of pine production. In 2001, soil samples from damaged areas of blocks II and III were processed with the modified Flegg technique (Fraedrich and Cram 2002), and the needle nematode was found consistently associated with stunted seedlings. Species of needle nematodes can occur at soil depths as great as 36 inches (91 cm) and in some soils routinely occur at depths of 24 to 36 inches (61 to 91 cm) (Shurtleff and Averre 2000). The fact that this undescribed needle nematode was able to cause stunting of pine seedlings in the second year following fumigation suggests that this species occurs at depths below the fumigation zone. This factor would make it difficult to manage this nematode with the conventional fumigation routinely used at most nurseries.

Loblolly, slash, and longleaf pines are hosts for the species of needle nematode found at the Flint River Nursery. The host range test indicates that the sorghum, wheat and rye evaluated are not suitable hosts, and therefore, can be used as cover crops in areas affected by this needle nematode. The use of these cover crops, or leaving the fields fallow, would be an important component of an integrated pest management program to manage this nematode. Additional studies are being conducted on the host range of the needle nematode, and survival of the nematode over time without a host.

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HARDENING FERTILIZATION AND NUTRIENT LOADING OF CONIFER SEEDLINGS

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Abstract

Continuing to fertilize bareroot and container seedlings during the hardening process (from cessation of height growth until lifting) can improve seedling viability. The process of fertilizing during hardening has many names, but in the last decade a new term, nutrient loading, has come into use. The process of nutrient loading seedlings leads to luxury consumption indicated by foliar nitrogen (N) concentrations > 2.5%. Increasing foliar nutrient concentrations during hardening can result in increased cold hardiness, seedlings with thicker stems, heavier root systems, better root-to-shoot ratios, higher foliar N concentrations and contents, and the potential for better survival and growth on the outplanting site.

Key Words:

Loblolly pine, *Pinus taeda*, slash pine, *Pinus elliottii*, longleaf pine, *Pinus palustris*, irrigation, crop scheduling, bareroot, container seedlings, water management, hardening

INTRODUCTION

Nursery managers are most concerned with levels of nitrogen (N) in seedlings because this nutrient fuels seedling growth rate. Traditionally, in bareroot and container nurseries a standard operating procedure is to reduce N applications once target height is achieved (Tinus and McDonald 1979; Duryea 1984; Landis and others 1989). The idea behind this is that seedlings need to be hardened for outplanting, and cessation of shoot growth is necessary for the hardening process to begin. However, reducing N applications while the seedling is still growing results in a “dilution” of N within the plant—the N *concentration* will decline because the N *content* is spread throughout more tissue (see sidebar).

Seedling N content is usually expressed as a weight, often in milligrams—it is the physical amount of N within the seedling. The N concentration, however, is N content divided by biomass and expressed as a percentage. Both N content and concentration can be determined for particular seedling parts such as needles, buds, stems, or combined together as shoots or roots or even whole seedlings. For nursery stock, foliar N concentration is the most commonly used value.

Realizing that seedling nutrient reserves are important for survival and growth after outplanting, nursery managers can begin to increase seedling nutrient concentrations prior to harvesting. The rationale is that these nutrients can be translocated during the establishment phase until seedling root systems can again provide the necessary nutrient uptake. Such fertilization applications have often been referred to as late-season, post budset, late summer, early fall, or fall fertilization. In the past decade, a new term has come into use: nutrient loading.

Nutrient loading is the practice of applying large doses of fertilizers to seedlings in order to allow luxury consumption of those nutrients (fig. 1). Luxury consumption is, simply, an increase in nutrient concentration above what the seedling can use for growth under optimum conditions. In conifer seedlings, foliar N concentration ranges from about 0.8% to 3.5%, with the optimum range considered to be from 1.5% to 2.5% (Landis and others 1989). Therefore, using my definition, foliar N concentrations > 2.5% are the result of nutrient loading and indicate luxury consumption. Although nutrient loading is usually done just prior to harvesting, Dr VR Timmer advocates using this technique throughout the growing season (see

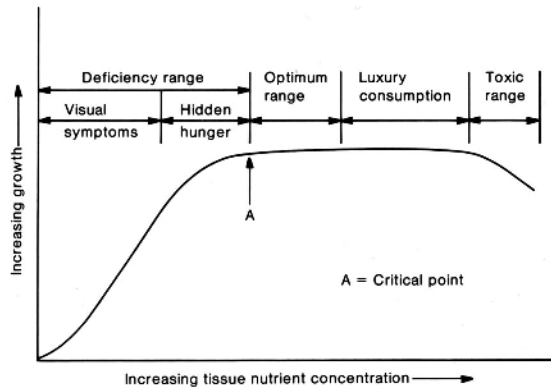


Figure 1. Growth increases with increasing nutrient levels up to a critical point (A), after which, increasing nutrient levels do not result in more growth, but lead to luxury consumption. Nutrient loading is a new term for luxury consumption. Source: Landis and others (1989).

Timmer and Aidelbaum 1996). His trials have been mainly done with Canadian conifer seedlings with determinant growth patterns (Timmer and Munson 1991; Miller and Timmer 1994).

Because of Dr Timmer’s prolific publishing on nutrient loading, this phrase is being more commonly used in bareroot and container nurseries. My objective for the remainder of this paper is to review a little of what we know about the interactions of seedling growth, cold hardiness development, and hardening and nutrient loading fertilization of conifers in general, and southern pines in particular.

NITROGEN AND CONIFER SEEDLING COLD HARDINESS

One justification for reducing N late in the growing season is to stimulate cold hardiness development. Unfortunately, reducing N too much may actually suppress development of cold hardiness (fig. 2). Timmis (1974) found that Douglas-fir (*Pseudotsuga menziesii*) seedlings with low N concentration (0.8%) had a LT₅₀ (the temperature at which 50% of the population died) of 9 °F (-13 °C) but those with a higher concentration (1.6%) were much more cold hardy (-22 °F [-30 °C]). Similarly, red spruce (*Picea rubens*) with 2.3% foliar N concentration were as cold hardy as those with only 0.6% N (Klein and others 1989) and in a study with many types of plants, Pellet and others (1981) found that plants with luxury amounts of N hardened as well as those with optimum N and better than those with N deficiency.

Well-fertilized Scots pine (*Pinus sylvestris*) suffered less frost damage than nutrient-deficient seedlings (Rikala and Repo 1997), and Norway spruce (*Picea abies*) seedlings showed similar frost damage despite a range of foliar N concentrations between 2.2% and 3.3% (Floistad 2002). Sugar metabolism, and therefore presumably other seedling physiological processes, were not affected by late season N applications to loblolly pine (*Pinus taeda*) in Georgia (Sung and others 1997). Hansen (1992) found that prolonged fertilization of Japanese larch (*Larix leptolepis*) did not translate into low cold hardiness development. Coastal Douglas-fir seedlings, given an additional 285 lb N/ac (320 kg N/ha) over a 10-week period from mid-September to early November, had the same cold hardiness as nonfertilized seedlings (Birchler and others 2001).

It is important to realize that these fertilization practices were not designed to “push” seedlings to continue height growth late into the season, but rather to maintain or enhance foliar N concentrations. Naturally, we are all aware that conifer seedlings with active height growth are very susceptible to frost injury. Therefore, the difficulty in nutrient loading is balancing N inputs while avoiding bud break or shoot extension.

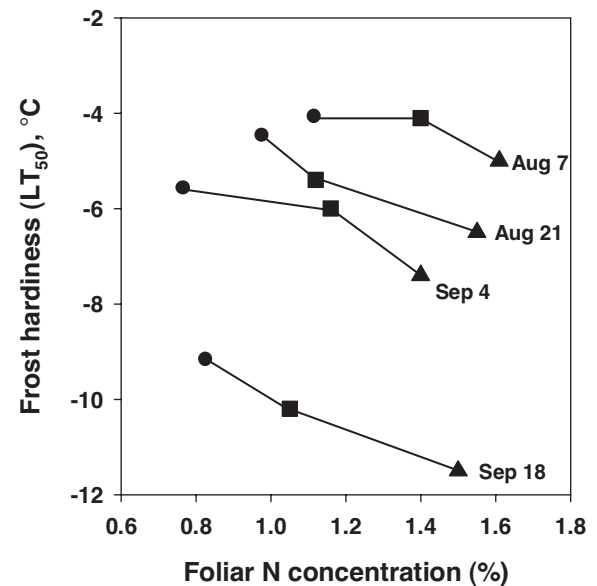


Figure 2. At each sampling date, seedlings receiving the highest rate of fertilizer (triangles) had the highest foliar N concentration and were more cold hardy than seedlings receiving the least amount of fertilizer (circles). Source: Rikala and Repo (1997).

DOES NUTRIENT LOADING APPLY TO SOUTHERN PINES?

In reading through the following studies on fall fertilization of southern pine species, note that none of them truly addresses foliar concentrations > 2.5% N. In other words, no nutrient loading occurred. Despite this lack of nutrient loading, benefits to fertilizing in fall were still realized.

Bareroot Slash Pine

Slash pine (*Pinus elliottii*) seedlings grown in Florida with 2 applications of 150 lb/ac (168 kg/ha) ammonium nitrate (51 lb N/ac [57 kg N/ha]) and receiving an additional 150 lb/ac ammonium nitrate in late August were taller and had larger root collar diameter (RCD), root dry weight, and foliar N concentration at lifting in January than seedlings that did not receive supplemental fertilization (Duryea 1990). Seedlings fertilized much later in the season (early November) with 75 lb/ac (84 kg/ha) ammonium nitrate had similar morphology but foliar N concentration and content were higher. After the first year in the field, August-fertilized seedlings were taller than the controls, but this characteristic failed to persist after 3 growing seasons (Duryea 1990).

Subsequently in Florida, Irwin and others (1998) grew seedlings in beds incorporated with 300 lb/ac 10N:10P₂O₅:10K₂O (30 lb N/ac [34 kg N/ha]) and later topdressed with 5 ammonium sulfate applications at various rates during the growing season (mid June to mid August; 143 lb N/ha [160 kg N/ha] total applied). Seedlings were fertilized 1 or 3 times between mid November and mid December with 51 lb N/ac (57 kg N/ha) ammonium nitrate. A month later (mid January) seedlings were lifted. The 1 to 3 additional fertilizations had no effect on RCD, height, bud length, dry weight, root:shoot, premature bud break, days to budbreak, or the number of lateral roots. Foliar N concentration was higher, however, in all fertilizer treatments and N content was higher in the roots, stems, and needles of seedlings given 3 late season fertilizer applications (fig. 3). Foliar N concentration ranged from 1.8% in the 3X fertilizer treatment to 1.4% in the 1X treatment and 1.1% in the control. Not only are none of these treatments nutrient loading, the 1X fertilization and the control are below optimum levels. Seedlings with the higher N concentrations, however, had higher survival, more height growth, and thicker stems after the first field season than control seedlings.

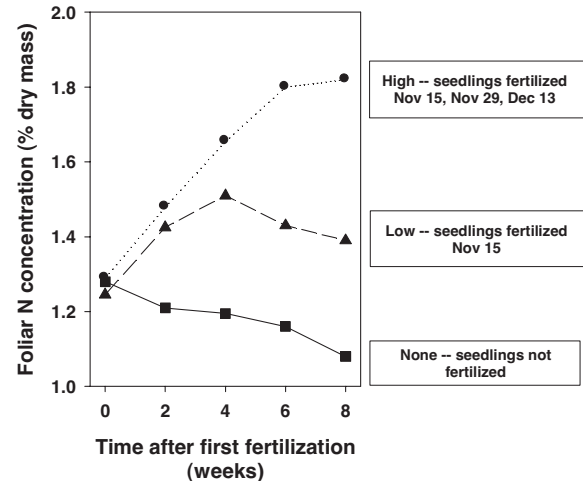


Figure 3. Slash pine seedlings without fertilization (None) continued to grow, but nitrogen (N) content remained the same resulting in the dilution of foliar N from 1.3% to 1.1% over a 2-month interval. Although seedlings in the Low treatment showed an initial increase in foliar N concentration after being fertilized, after 1 month seedling growth again outpaced N uptake and dilution occurred, with concentration dropping from 1.6% to 1.4%. None of these seedlings were nutrient-loaded. Source: Irwin and others (1998).

Bareroot Longleaf Pine

During spring and early summer, longleaf pine (*Pinus palustris*) seedlings were given small periodic applications of ammonium nitrate totaling about 100 lb N/ac (112 kg N/ha). In late October, seedlings were fertilized once with a variety of fertilizers, but always with 150 lb N/ac (168 kg N/ha). Fertilized seedlings had 20% more dry weight with roots and buds accounting for three-fourths of that increase. RCD was 11% greater and subsequently root:shoot was increased. Foliar N content averaged 60% more than nonfertilized controls. The average foliar N concentration of fertilized seedlings was 1.4% versus 1.1% in the control. Again, neither of these treatments were nutrient loading and both resulted in less than optimal foliar N concentration. The result, however, was a trend toward fall fertilization decreasing the time the seedlings spent in the grass stage and better survival after 8 years in the field (Hinesley and Maki 1980).

Bareroot Loblolly Pine

One study with loblolly looked at the effects of foliar N concentration on subsequent seedling performance in the field (Larsen and others 1988). Data from 20

nurseries indicated the average foliar N concentration was only 1.7%, a value at the low end of the optimum range (1.7% to 2.3%) suggested by Fowells and Krauss (1959). This low average value was unfortunate because Larsen and others (1988) found that foliar N content was positively correlated with initial and subsequent field growth, and in fact, was the only variable after 3 years in the field that was significantly correlated with both diameter and volume growth—seedlings with higher N content performed better than those with low content. A modest application of 41 lb N/ac (46 kg N/ha) in mid September in a southern Georgia nursery raised foliar N concentration from 1.2% to 1.6% (Sung and others 1997). The fertilized crop had fewer culls and more first-order lateral roots, thicker stems, and higher dry weights of roots and shoots. Further, fertilization had no effect on sugar metabolism or the pattern of dry matter allocation. Recently, South and Donald (2002) report that applications of N and phosphorus one month before lifting increased foliar N concentrations up from 2.0% to 2.4% which translated into taller seedlings, higher volume production, and better survival 5 years after outplanting. Again, none of these studies involved nutrient-loaded seedlings but show that fall fertilization can increase seedling viability.

Container Seedlings

Although the container industry is relatively young in the South and mostly restricted to longleaf pine

(although interest is mounting in growing loblolly and slash in containers too), it is important to recognize that fertilization during hardening can greatly improve seedling viability.

For container nursery managers, more methods are available for applying nutrients: conventional, foliar, and steady-state. Conventional fertilization, applying soluble fertilizers through the irrigation system, is the most straight-forward way of applying nutrients. In Scots pine, late-season fertilization increased RCD and resulted in more cold-hardiness development (Rikala and Repo 1997).

In addition, foliar fertilizers, specially formulated for application onto needles at high rates, can be used to quickly recharge nutrient-depleted seedlings or to add high doses of nutrients for luxury consumption. An advantage of foliar fertilization is that nutrients can be applied to the crop without adding water to the medium, allowing the grower to keep seedling growth under control through water management while still adding nutrients directly to the crop. This has been demonstrated in a crop of ponderosa pine (*Pinus ponderosa*), where Montville and others (1996) used foliar fertilizer during the bud initiation phase to concurrently cease height growth, grow buds, and avoid foliar N concentration dilution—the benefit was a 45% increase in RCD (fig. 4).

The theory of steady-state nutrition is that during production, seedling foliar N concentration is maintained at the same level. Much of the literature on this deals with red pine (*Pinus resinosa*), black

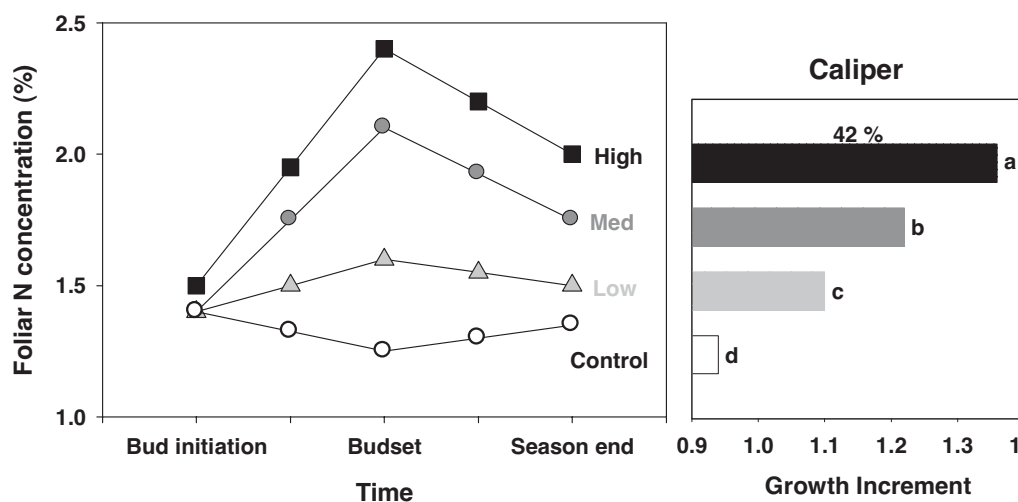


Figure 4. At bud initiation, seedlings received 3 rates of foliar fertilizer with a nonfertilized control. Note the dilution of N in the control seedlings during the bud initiation treatment. Avoiding N dilution increased RCD (caliper) growth—higher rates of fertilizer resulted in higher RCD increments (cm) compared to the control. Source: Montville and others (1996).

spruce (*Picea mariana*), and white spruce (*Picea glauca*) in Canada. The benefits of maintaining optimum or luxury foliar N concentrations (3.0%+), particularly late in the growing season, include increased root:shoot, N accumulation in roots, and height and biomass growth on the outplanting site (Timmer and Miller 1991; Timmer and others 1991; Miller and Timmer 1994; Malik and Timmer 1995; McAlister and Timmer 1998).

CAUTION—ANIMAL DAMAGE

Animal damage is a problem on many plantations—the literature is full of “animals ate our seedlings” stories. Further, plenty of anecdotal information exists from plantations that animals prefer “normal” nursery seedlings over naturals, presumably because of their higher nutritional value. Unfortunately, I could not find any published information on the correlation between foliar N concentration and herbivory in seedlings. In young plantations, however, fertilization resulted in increased animal damage (Sullivan and Sullivan 1982) and in a plantation where fertilization raised foliar N concentrations 20%, damage increased 6X (Gessel and Orians 1967). I think we should be concerned about nutrient loading because it may exacerbate this problem on some sites.

SUMMARY AND RECOMMENDATIONS

The only way to know seedling nutrient concentrations is to measure them—sending in a few foliar samples during the hardening process will enable you to know if your crop has optimum nutrition. As seen from the above discussion, seedling viability can be enhanced by maintaining optimum nutrient concentrations during the hardening process. For southern pines, that probably does not involve true nutrient loading, but adherence to a hardening fertilization program that keeps foliar N concentrations in the optimum zone (1.5% to 2.5%) and regulates height growth through water management. At these optimum nutrient levels, growers may expect normal development of cold hardiness; improved RCD, bud size, and root biomass (and therefore improved root-to-shoot ratio); and enhanced survival and growth after outplanting.

It is important to remember that each nursery has its own idiosyncrasies, and fertilizer regimes develop in response to many variables, including species, seed sources, irrigation system, water quality, nursery elevation and subsequent microclimate, annual days of sunshine, age of greenhouse roofs and subsequent

light quality, feedback from customers, anticipated conditions on the planting site, and the experience and philosophy of the nursery manager. Elucidating “the” fertilizer regime that will work universally well in all nurseries is impossible (Dumroese and Wenny 1987). With that in mind, however, I hope you are encouraged to reexamine the use of hardening fertilization toward the goal of improving seedling viability.

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INCORPORATING CONTROLLED-RELEASE FERTILIZER TECHNOLOGY INTO OUTPLANTING

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Abstract

The application of controlled-release fertilizers (CRF) at the time of planting offers a means to improve the establishment of forest tree seedlings. As compared to conventional fertilizers, the gradual pattern of nutrient release from CRF may better coincide with plant needs, minimize leaching, and improve fertilizer use efficiency. Many different CRF types are available and products differ in both the technology by which nutrients are contained and the environmental stimulus for nutrient release. Coated CRF use a polymer or sulfur coating to encapsulate water-soluble nutrients; coating thickness and media temperature primarily control the rate of nutrient release. Uncoated nitrogen reaction products are relatively insoluble in water and nutrient release is generally controlled by water availability and/or microbial decomposition. Results from field trials in the Pacific Northwest (USA) indicate that attaining a positive response at outplanting with polymer-coated CRF is largely dependent on soil moisture availability. Continued release of fertilizer nutrients under hot and dry conditions may cause root damage and increase seedling susceptibility to drought. In the southeastern US, rainfall during summer may reduce the potential for this problem. On drought-prone sites, however, a conservative polymer-coated CRF application rate or the use of CRF with moisture-dependent forms of nutrient release is recommended.

Key Words

Nutrient leaching, fertilizer efficiency, plantations, forest regeneration, *Pseudotsuga menziesii*, *Pinus ponderosa*

INTRODUCTION

Controlled-release fertilizers (CRF) have traditionally been used in the horticultural industry to improve nutrition of nursery-grown plants. These fertilizers offer a potential means to improve forest regeneration efforts substantially, and interest in their application for plantation forestry has increased in recent years (Haase and Rose 1997). With a single application, CRF can supply seedlings with enhanced nutrition for as long as 2 years, providing a consistent and sustained flow of nutrients that may better coincide with plant development (Donald 1991) as compared to conventional forms of fertilizer with immediately-available forms of nutrient release. The gradual release of CRF may act to minimize nutrient

leaching, reduce plant damage, and improve overall fertilizer use efficiency.

Many different types of CRF are currently marketed for use with forest tree seedlings. Controlled-release fertilizers primarily vary in terms of their nutrient formulations, estimated product longevities, and mechanisms of nutrient release. The ultimate goal of CRF manufacturers has been to develop a product that delivers nutrients at a rate matching plant demand, thus improving crop yield and minimizing the loss of nutrients due to leaching (Hauck 1985; Goertz 1993). To date, the use of CRF in field plantings has been primarily experimental. Attaining a positive seedling growth response from CRF following application at planting appears to depend on a complex interaction of factors including plant

material, CRF type and application rate, soil characteristics, environmental growing conditions, and so on. Both positive and negative responses can be found in the literature.

The purpose of this paper is to: 1) provide an overview of CRF technology; 2) outline some products currently available on the market; 3) present an overview of recent research conducted by the Nursery Technology Cooperative at Oregon State University with CRF; and 4) briefly discuss possible implications of CRF to reforestation programs in the southern region.

OVERVIEW OF CRF TECHNOLOGY

Controlled-release fertilizers differ from conventional forms of fertilizer (for example, urea and water-soluble products) in that the majority of nutrients are not available immediately following

application but released slowly over time. The vast array of different CRF types makes selecting a product for a specific planting application difficult. The purpose of this section is to provide a brief technical overview of some common forms of CRF that may be applicable to field plantings. Two primary distinctions between individual CRF products are the technology associated with encapsulating or binding fertilizer nutrients and the environmental mechanism by which these nutrients are released into the soil solution (table 1).

Coated Materials

Coated CRF products currently represent the most widely expanding form of CRF technology due to the flexibility in patterns of nutrient release and the capacity to release nutrients other than nitrogen (Goertz 1993). Coated CRF products usually involve

Table 1. Abbreviated list of different types of controlled-release fertilizers, mechanisms of nutrient release, and product examples.

Category	Mechanism of Nutrient Release	Examples of Products
Coated Materials		
Sulfur-Coated	Cracks and imperfections in sulfur coating allow water vapor transfer through coating to reach soluble urea, osmotic pressure builds to further disrupt coating and urea released. Disruption of coating accelerated at high temperatures and in drier soils. Quality and quantity of sulfur coating determines release rate.	Lesco [®]
Polymer-Coated Polymeric-resin	Water vapor transfer through tiny pores in coating creates internal osmotic pressure that acts to distend semi-permeable and flexible membrane, which enlarges pores and allows dissolution of solution. Higher temperatures cause membrane to swell more rapidly. Thickness of coating determines nutrient release.	Osmocote [®] Sierra [®] High N [®]
Polyurethane	Unique method of coating known as “reactive layer coating” produces very thin membrane coating. Nutrient release occurs by osmotic diffusion through coating. Coating tends to resist swelling characterized by polymeric-resin products and may result in somewhat less temperature-dependent release.	Polyon [®]
Thermoplastic resin	Coating highly impermeable to water and coating thickness nearly the same for all products. Nutrient release controlled by added level of ethylene-vinyl acetate and surfactants which modify permeability characteristics. Results in a slightly less temperature-dependent release.	Nutricote [®] (polyolefin)
Uncoated Materials		
Ureaform	Product composed of methylene urea polymers. Broken down by soil microbes (primarily) and hydrolysis. Release rate extended by increasing polymer chain length. Environmental factors affecting microbial activity (soil temperature, moisture, pH, aeration, etc.) influence rate of release.	Nitroform [®]
IBDU	Product of urea and isobutylidene diurea. Nitrogen released through hydrolysis (accelerated at low pH and high temperatures). Rate of release primarily affected by particle size and amount of water available.	Woodace [®]

the encapsulation of soluble fertilizer nutrients within a water-insoluble coating, creating a 2 to 3 mm granule commonly referred to as a “prill”. The variability and unevenness of an individual prill makes attaining a complete and uniform coating difficult. This often results in areas of uneven coverage that detract from the ability to accurately meter nutrient release. Many different types of coatings have been used experimentally and it is likely that the “ideal” material has yet to be discovered. Some materials release nutrients too rapidly while others never effectively release nutrients. Two common CRF coatings used commercially are sulfur and polymer.

Sulfur coated—Sulfur was one of the first materials used as a coating for CRF due to its low cost and value as a secondary nutrient (Goertz 1993). Sulfur-coated urea (SCU) is often marketed for use in the turf grass industry. Following the coating of urea particles with sulfur, a wax sealant may be used to close sulfur pores. Nutrients are released from SCU by water penetration through micropores or inconsistencies in the sulfur coating. Urea inside the prill dissolves and is rapidly released into the soil solution. The release rate of SCU is controlled by modifying the quality and thickness of the sulfur coating. Environmental conditions, such as high temperatures and exposure to relatively dry soils, act to further degrade the coating and accelerate nutrient release (Allen 1984). A disadvantage to SCU is the potential for urea to be released at a rapid initial rate and then quickly taper off, which may contribute to plant damage and reduce fertilizer efficiency. An advantage is the lower cost. Lesco[®] is an example of a SCU on the market.

Polymer coated—Polymer-coated CRF are considered the most technically-advanced form of CRF due to the considerable ability to control product longevity and subsequent efficiency of nutrient delivery. In most horticultural systems, polymer-coated CRF have replaced SCU because they provide a more gradual and consistent pattern of nutrient release (Goertz 1993). Nutrient release of most polymer-coated CRF is determined by the diffusion of water through the semi-permeable membrane (Goertz 1993). This process is accelerated at progressively higher soil temperatures, with soil water content providing little influence on release (Kochba and others 1990). Thus, manufacturers of polymer-coated CRF generally provide estimates for 90%+ nutrient release based on an average media temperature (typically 70 °F [21 °C]). The general term polymer refers to a compound of high molecular weight derived from many smaller molecules of low

molecular weight. Thus, many specific coating materials fit into the general class of “polymer-coated CRF”. These may include polymeric resin, polyurethane, and thermoplastic resins.

Polymeric resin—Polymeric resin-coated CRF are primarily produced by Scotts Company and include market brands such as Osmocote[®] and Sierra[®]. The resin coating is applied in several layers and nutrient release is controlled by regulating the thickness of the coating. Product longevities range from 3 to 16 months. Water vapor transfer through microscopic pores in the coating reaches the soluble fertilizer and creates an internal osmotic pressure that acts to expand the flexible coating. This causes the pores to enlarge and nutrients are then released into the soil solution (Hauck 1985). High soil temperatures accelerate expansion of the coating and subsequently increase the rate of nutrient release. Depending on coating thickness and media temperature, polymeric resin-coated CRF may produce an excessive initial flush of nutrients. Osmocote[®] has been shown to release nitrogen at a more rapid initial rate than comparable polymer-coated CRF (Huett and Gogel 2000).

Polyurethane—An example of a polyurethane-coated CRF is Polyon[®] (Pursell Industries Inc), which uses a coating technology known as reactive layer coating (RLC) to polymerize 2 reactive monomers, forming a very thin membrane coating (Goertz 1993). Nutrients are released by osmotic diffusion and release is controlled by adjusting the thickness of the coating. The RLC technology results in a coating material that is more resistant to swelling than polymeric-resin CRF and the original coating thickness tends to be maintained. Although temperature is still the primary environmental factor governing release, this technology results in a less temperature-dependent release than polymeric-resin coated fertilizers, which may promote a more gradual pattern of nutrient release.

Thermoplastic resin—Thermoplastic resins, such as polyolefins, poly (vinylidene chloride), and copolymers are also used as coating materials within the polymer-coated CRF grouping. An example is Nutricote[®]. Because these coatings are highly impermeable to water, nutrient release is controlled by added release agents, such as ethylene-vinyl acetate and surfactants, which act to modify permeability characteristics (Goertz 1993). Similar to other polymer-coated fertilizers, nutrients are released by diffusion through the coating. However, the added level of release agents determines the rate of nutrient diffusion rather than coating thickness.

High soil temperatures accelerate nutrient release, though the coating technology is designed to minimize this effect in order to provide a gradual and consistent pattern of release.

Uncoated Organic Materials

Several different nitrogen reaction products are produced for use as CRF. These involve reacting low-cost urea with one of several aldehydes to form a compound that is sparingly soluble in water (Hauck 1985). These compounds then slowly release nitrogen into the soil solution by chemical and/or biological activity. A disadvantage as compared to polymer-coated fertilizers is that independently, these products release only nitrogen, and supplemental products may be needed to provide additional macro- and micronutrients. A potential advantage is that nutrient release is controlled by factors other than soil temperature; soil moisture being the most notable. Two common examples of uncoated organic CRF are urea-formaldehyde (ureaform) and isobutylidene diurea (IBDU).

Ureaform—Ureaform is a form of slow-release nitrogen technology dating back to the 1950s and is the product of the reaction of urea and formaldehyde in the presence of a catalyst. An example is Nitroform[®], produced by Nu-Gro Technologies, Inc. The urea-formaldehyde reaction produces methylene urea polymers of varying molecular weights and chain lengths (Goertz 1993). The chain length is the technological mechanism by which nutrient release is controlled; a longer chain length is less water soluble and requires more time to break down. Microbial decomposition is the primary mechanism by which ureaform is converted to plant available forms of nitrogen in the soil. Thus, the numerous environmental conditions that regulate microbial activity (for example, soil moisture, temperature, pH, aeration, and so on) also control the rate of nutrient release.

IBDU—Another nitrogen reaction product is IBDU, which is the condensation product of urea and isobutyraldehyde. Commercially, Woodace[®] uses IBDU as a nitrogen source. This compound is relatively insoluble (< 0.1%) in water and a commercial product may contain roughly 31% nitrogen (Hauck 1985). As compared to ureaform, water is the primary mechanism for nutrient release as nitrogen from IBDU becomes available to plants strictly through hydrolysis. In the presence of water, the compound hydrolyzes to urea and isobutyraldehyde and this process is accelerated at

low pH and high temperatures (Goertz 1993). Smaller particles tend to hydrolyze faster.

CURRENT TRENDS IN FOREST REGENERATION CRF RESEARCH

Recent interest in the potential for CRF to improve the establishment of outplanted seedlings has stimulated research in this area. The Nursery Technology Cooperative (NTC) in the Department of Forest Science at Oregon State University has been actively conducting CRF outplanting research in recent years. The purpose of this section is to present a brief overview of some recent findings from these studies.

There are 2 primary methods for incorporating CRF into outplanting. The first method is to apply CRF to seedlings at the time of planting. Researchers have advocated applying CRF to the bottom of the planting hole in field plantings to facilitate efficient nutrient uptake (Carlson 1981; Carlson and Preisig 1981; Gleason and others 1990). This placement positions the fertilizer in close proximity to the root zone where nutrients can be rapidly extracted (fig. 1). Other CRF placement options include dibbling to the side of the root system, placing directly on the roots within the planting hole, and broadcast application at the base of the seedling. The ideal placement of CRF at outplanting is still a matter of debate.

A second and relatively new approach involves incorporating CRF directly into the growing media of containerized seedlings (fig. 2). The CRF is uniformly mixed at a specific rate into soil media



Figure 1. Application of controlled-release fertilizer at outplanting. Fertilizer is typically measured by volume and then applied to the bottom of the planting hole prior to seedling planting.

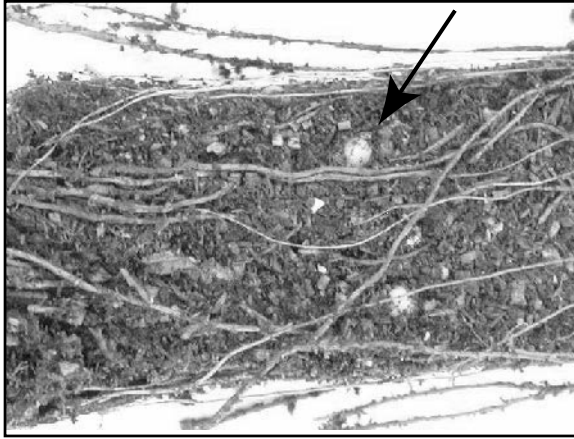


Figure 2. Controlled-release fertilizer incorporated into the media of a containerized seedling. Fertilizer is uniformly mixed into media prior to application to containers.

prior to seed germination and seedling roots grow into the CRF media while in the greenhouse. When using CRF with a relatively long product life (for example, 12 to 14 months), seedlings should experience 2 growing seasons of added nutrition. Roots begin to extract CRF nutrients in the greenhouse and these nutrients may continue to release following transplant to the field.

The majority of NTC research thus far has involved polymer-coated CRF. Results have been somewhat variable and, observationally, results seem to differ based on soil moisture availability. Perhaps the most striking positive results thus far were observed on a site near Toledo, Oregon (Nursery Technology Cooperative 2001). This site is located adjacent to the Oregon coast and receives over 120 inches (305 cm) of rainfall per year. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings were grown in containers with treatments consisting of various CRF products mixed into the growing media. Fertilized seedlings had up to double the height growth of unfertilized control seedlings during the first year following planting and continued to have significantly greater growth than controls during the second and third growing seasons. One CRF treatment resulted in more than double the mean stem volume of controls after three growing seasons.

Results on drier sites have been less positive. On a site at the Warm Springs Indian Reservation in central Oregon, a negative influence of fertilization with CRF applied to the planting hole was observed.

Survival of fertilized Douglas-fir and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings was reduced compared to unfertilized controls and no differences in growth were apparent after 2 seasons (Nursery Technology Cooperative 2000). An additional field study was designed to investigate the effects of various methods of CRF placement (that is, bottom of planting hole, dibble, on roots, and broadcast) on Douglas-fir establishment on a drought-prone site in the Oregon Coast Range. Results suggested that performance decreased with increasing proximity of CRF to seedling roots, particularly at higher CRF rates (Alzugaray 2002).

Speculation that the use of polymer-coated CRF on drier sites may negatively affect root growth and make seedlings more susceptible to drought stress stimulated several experiments designed to investigate the influence of CRF on root architectural development (Jacobs 2001). In a controlled study, CRF was applied as a single layer beneath the root system of transplanted Douglas-fir seedlings. At progressively higher CRF rates, root penetration below the soil layer was severely restricted; this was attributed to detrimental changes in soil osmotic potential following CRF nutrient release. A subsequent study on a drought-prone site in the Oregon Coast Range found that at a relatively high rate (2.1 oz [60 g]) of CRF applied to the planting hole, fertilized seedlings became significantly more drought stressed than controls during the first summer following planting. Fertilized seedlings also had very poor root growth. Analysis of fertilizer nutrient release over time (based on changes in dry weight) indicated that nutrients continued to release when soils dried during summer and plants entered dormancy. This resulted in changes in rhizosphere osmotic potential that, along with poor root growth, were attributed to the drought stress incurred.

Several lessons have been learned thus far from research with CRF at outplanting. Polymer-coated CRF work very well in a nursery environment due to the ability to control water availability. In the field, polymer-coated fertilizers continue to release nutrients as soils dry. On drier sites in the Pacific Northwest, this may present a problem during the summer dry season because water to leach excess nutrients from the root zone is unavailable.

Detrimental changes in rhizosphere osmotic potential may be intensified at progressively higher CRF rates. It is possible that products with moisture-dependent nutrient release characteristics (for example, ureaform and IBDU) will minimize the potential for damage, and research into this area is currently being conducted by the NTC.

IMPLICATIONS FOR THE SOUTHERN REGION

Literature reviews on the use of CRF at outplanting in the southern region produced few examples from which to draw inference. Based on results from recent NTC studies, it is clearly important to match the level of field fertilization with polymer-coated CRF to the anticipated degree of moisture stress on the site. Compared to many sites in the Pacific Northwest, a distinct advantage in the southern region is the occurrence of precipitation during summer. This may act to periodically leach excess fertilizer salts from the root zone, minimizing potential for root damage and susceptibility to drought stress. However, high soil temperatures in the southern region may result in rapid CRF nutrient release during dry periods.

It is best to err on the side of conservative polymer-coated CRF application rates, particularly on drought-prone sites. Continued evolution of polymer-coated CRF technology to produce a nutrient release mechanism that is less dependent on soil temperature may improve seedling response to fertilization on moisture-limited sites. Consideration should also be given to applying fertilizer 1 to 2 years following planting when seedling root systems have established. The use of uncoated organic CRF with mechanisms of nutrient release that are largely dependent on moisture availability may be a better source of CRF on dry sites. On sites where drought is extreme, however, it may be necessary to avoid field fertilization entirely.

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NURSERY ACCREDITATION

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Abstract

The need for accrediting forest and conservation nurseries is stated. An example of accreditation is given from the case of accrediting the USDA Forest Service National Tree Seed Laboratory. The elements necessary to bring about nursery accreditation are outlined and suggested alternatives are given to bring the process into reality.

Key Words

Nursery standards, quality assurance, seed movement

INTRODUCTION

Successful conservation and forest regeneration has always required using reproductive materials that met appropriate genetic, morphological and physiological quality standards. Both survival and growth of planted trees and shrubs diminish in direct proportion to decreases in seedling quality. Sometimes these standards were formalized, as in state seed certification standards. These standards specified how seed source or level of genetic improvement would be certified. The state certification standards have been little used. Instead, producers and users have set stock specifications informally. This informal process uses the best judgment of growers based on observation or the recommendations of an expert. There have often been differences of opinion on seedling cultural practices, seed transfer guidelines, or seedling morphological standards. How big a seedling, what kind of root system, top pruned/not top pruned, good to plant in this area/not good for this area are some of the many differences that have been debated. As long as the number of producers was relatively small and stable, workable if not optimal consensus usually was achieved.

Cost share programs, increased interest in timber as an investment, and the expanded general interest in regenerating wild plant communities have resulted in an increase in demand for seeds and seedlings. For example, numerous longleaf container seedling growers, hardwood nurseries, and seed collectors have entered the market place. Some new entities

have done great work, while others without experience, colleagues, or formal standards to guide their work or protect the public have created havoc. Skilled nursery managers have been forced to drop a product line because they were being undersold with poor quality stock. The end result is that reforestation failures are occurring and will continue to occur. There are reports of new seed collectors who offer certain sources of seed for sale when none of the experienced and established collectors are able to find the same sources. One can only conclude that, at best, there are some uneducated persons at work in the field and quite possibly some others who are looking for quick and easy profit. A system of nursery and seed plant accreditation or certification is needed to at least set minimum quality standards for reproductive materials. Without standards for nursery stock and nursery management, the general public will have a frustrating experience or become critical of forestry practices. Accrediting nurseries and seed plants can serve as a great way to educate the public, landowners, and new vendors. It will also allow forest managers to take the moral high ground when harvest and reforestation activities are criticized. They will be able to prove that they have used quality reproductive materials produced by scientifically sound and widely accepted practices. Another way to say it is that US forest and conservation nurseries need a universally recognized quality assurance system. An additional introduction to the rationale for nursery accreditation can be found in Karrfalt (2000).

DISCUSSION

Quality Assurance Terms

Accreditation, certification, registration, and licensing are various terms that are used by various authorities to indicate a specified level of skill, knowledge, ability or quality. For this discussion, the term accreditation is chosen. What term is ultimately used to recognize nurseries will have to be determined by the parties involved in the process.

An Accreditation Example

Accreditation means that the authority has been granted to an entity to conduct a certain activity or produce a certain product. The International Seed Testing Association (ISTA) has given the National Tree Seed Laboratory (NTSL) the authority to issue International Seed Analysis Certificates and International Seed Lot Certificates. The NTSL is, therefore, an accredited ISTA laboratory. What this means and the process of becoming accredited are described here to illustrate accreditation.

The accreditation process began by preparing a quality assurance manual. The very first part of the manual contained a statement of commitment to perform seed tests with the highest quality possible. Secondly, all standard operating procedures were described in complete detail. This included how tests were prepared; how all equipment was maintained; how persons were trained; what standard did each employee or piece of equipment have to meet; how each employee's work and piece of equipment was validated against this standard; what occurred when work or test conditions did not meet standards; and finally what records were kept to document these activities. More simply put, it was a matter of stating what was to be done and how it was to be done, doing what was said, and preparing documents to prove that what was to be done was done.

Preparing the standard operating procedures was the easy part, as this had existed in some form for many years. Setting standards for work and equipment was fairly easy. This was outlined well in testing rules and standard laboratory procedures. The documentation part tended to be more challenging. The detailed documentation required to pass a quality assurance audit was a new experience and rather dull at first. Once the benefits of documenting were grasped, the whole process seemed more worthwhile. The documentation was proof to anyone who wanted to know that we had done everything possible to control error and produce seed test data of the highest

quality. This was a point of considerable pride and accomplishment for the laboratory. An additional benefit was that we had proof for ourselves that the operation was moving along correctly. We had given ourselves the assurance that we were doing the best we could in our support role to make the nurseries and seed plants successful at their work.

Verifying temperature records on the germination rooms is a specific example of a control process adopted at the NTSL in the process of accreditation. From the beginning of the laboratory, temperature recorders were attached to all germination rooms. Most nurseries have such recorders on seed and seedling storage units. What had never been done formally was check to determine, on a daily basis, if the recorder was giving the correct temperature. Now, each day, the recorder is compared to a mercury bulb thermometer and the inspector records the temperature on a control chart. Any differences between the two thermometers are to be immediately investigated to determine which device was correct. Any necessary repairs or adjustments are then made. Once a year the check thermometer is compared to a NIST thermometer at the lab, and every three years the NIST thermometer is sent for verification of its accuracy. (NIST stands for National Institute of Standards and Testing.) This level of precision is needed at the NTSL because temperature cannot vary more than ± 36 °F (2 °C) before test results are affected adversely. By following this procedure, we know we have the best temperature control that is possible to provide accurate and repeatable germination tests.

It would be most unlikely that a nursery would need a NIST thermometer; but how certain are nursery managers of the temperatures in their seedling coolers? Strong verification of seedling storage temperatures at the nursery might be very comforting and useful when trying to determine the cause for poor quality seedlings arriving at a planting site. Temperature uniformity within coolers is also very important in maintaining quality. Often temperatures can vary and need to be balanced within the cooler. Accreditation would simply require that steps be taken to ensure the coolers are doing the job they are intended to do, something any nursery manager would want to know.

The next steps in accrediting the NTSL were review steps. The quality assurance (QA) manual was sent to ISTA headquarters where it was reviewed for completeness and correctness. Next came the onsite audit conducted by two auditors selected by the ISTA. One auditor was a process auditor who looked at how we executed the QA manual. The other

auditor was a technical auditor who focused on the application of the ISTA rules and the scientific measurements made. Following the audit, some improvements were made according to the findings of the auditors. Then, upon the auditors' recommendation, the ISTA granted accreditation to the NTSL to continue issuing ISTA certificates. Subsequent audits will occur every three years to maintain the accreditation.

Information on the accreditation process conducted by the ISTA and the Association of Official Seed Certifying Agencies can be obtained at their websites (AOSCA 2000; ISTA 2000). These are examples that show the process in a seed and agricultural context. A nice general introduction to accreditation with the International Organization for Standardization (ISO) can be found in Katner (1994). ISO initials can be easily found in our modern world on many trucks, signs, products, and literature, indicating the associated company has ISO accreditation credentials.

Building a System to Accreditate Nurseries

The parts to a system to accredit nurseries would be the same as for the NTSL. While ISTA has existed for decades and is an established authority in seed testing, there is no counterpart for the nurseries. Therefore, the first step in building a system would be to establish an accrediting authority. State Crop improvement authorities might serve in this capacity. They are familiar with accreditation of seed producers and the accreditation process. Most have some genetic certification standards for seeds of trees, shrubs and other wild plants. Some even have standards to genetically certify seedlings. Properly documenting seed source and interpreting this for the customer remains a major issue. This is especially true in years of seed shortage and with newer nurseries. Crop improvement associations are also recognized by their respective state governments as being the sole authority within their state for the certification of all seeds. They also have a national organization (the Association of Official Seed Certifying Agencies) that works to make standards uniform across the nation and internationally. Past experiences have been, however, that crop improvement authorities are often weak in the technical aspects of forestry. Another drawback of crop improvement associations might be that they operate only within one or a few states. Regional, if not national, systems of nursery accreditation are needed. The regional nursery associations might cooperate with the crop improvement associations

and be the source of technical expertise for drafting standards and performing audits. Alternatively, the nursery associations could take on the full role of accreditation, or be the parent to yet another accrediting body. Such a role would be a major evolutionary step for the associations in providing leadership in forest regeneration. The critical factor in establishing an accrediting body is that it has legitimacy and technical stature great enough to accomplish the task and be accepted by a strong majority of the players in reforestation. Leadership by the associations or from among the members of the associations would be imperative as they already represent a broad spectrum of private, state and federal entities. Government and non-government agencies outside the current scope of nursery associations probably should also be engaged in the discussion. The USDA NRCS, Arbor Day Foundation, American Forests, and the forest certification bodies will have or should have interest in accreditation of nurseries as all would be concerned with quality nursery stock for reforestation. Including them in the effort might lead to a broader base for support of accreditation.

Once a recognized accreditation body is established, its first job would be to draft accreditation standards. For seed testing, the official rules for testing seeds served as the technical basis for accreditation. No similar unified body of technical information on what constitutes high quality nursery management exists. The breadth and technical specificity of the standards for nurseries could be difficult. Some factors for nurseries would be easier than others. Topics such as pesticide use and handling are already covered in detail in federal and state laws and would probably not be difficult to include, or even could be excluded because they are adequately handled elsewhere. Other factors such as stock type, genetic identity preservation, movement of seed sources, and qualifications for nursery personnel might be more difficult to formulate into an accreditation standard. Various options to follow might have to be included on more controversial topics with guidance to the consumer on what the options mean. The key principle is that accreditation of a nursery must mean to the buyer and user of reproductive materials that the materials purchased and the information given are adequate for successful regeneration that benefits the environment for the long term.

The final aspect of the accreditation process is that it must not be burdensome—financially or administratively. A good system will have costs, but there must be good return on the time and money

invested. This should be an attainable goal welcomed by managers. For example, most managers benefit from having all procedures written down, especially when they are new on the job. Accreditation would help communicate to workers and successors how to run the nursery most efficiently and successfully. A good accreditation standard would outline many procedures in a general way so that the manager need only adapt the standard to fit the particular circumstances of the individual nursery.

Affordability is necessary in order to include as many nurseries as possible so that an industry wide standard can be achieved. Simplicity and affordability will help assure the system is useful to producers and consumers alike. As new initiatives occur or situations evolve and change, the process must also be responsive to new requirements.

Accreditation schemes are everywhere a part of modern life. Forest nurseries need to begin the process of accrediting their work immediately to meet current challenges and ensure forests for the future. The regional nursery associations are the logical organizations to begin the process.

SUMMARY

Recent concerns over inappropriate seed movement and the marketing of low-grade seedling types have

prompted calls for the establishment of genetic and morphology standards for forest and conservation seedlings produced in the United States. Accrediting nurseries would be one way to set a standard for the production of quality reproductive materials for reforestation, educate new practitioners to reforestation and nursery work, and educate and assist the general public to buy only materials that will give good results. The steps toward this end include establishing an accreditation authority, developing accreditation standards and protocols, and conducting the necessary audits to accredit nurseries. Accreditation needs to become a reality in the very near future. The regional nursery associations are the logical organizations to begin the process.

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NURSERY PROJECTS AT THE MISSOULA TECHNOLOGY AND DEVELOPMENT CENTER

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Abstract

The USDA Forest Service Missoula Technology and Development Center provides technical expertise, new equipment prototypes, and technology transfer services to Federal, State, and cooperator forest tree seedling nursery managers. Some recently completed or current projects at MTDC involve: a seedling temperature monitor, a shielded herbicide sprayer, hardwood cuttings preparation equipment, equipment to replace the copper coating on used styroblocks, equipment to sterilize styroblocks, an improved bench root pruner, a nursery soil sterilizer, study of animal damage to seedlings and repellents to prevent damage, snow-making equipment to protect overwintering seedlings, and a whitebark pine seed scarifier to improve germination.

Key Words

Seedling temperature, Roundup, herbicide, soil pathogens, nursery equipment, whitebark pine, sterilizing equipment

INTRODUCTION

The Missoula Technology and Development Center (MTDC) is one of two technology and development centers that serve the USDA Forest Service by helping to solve problems identified by field employees. For over 50 years, MTDC has been evaluating existing technology and equipment, developing equipment prototypes, and conducting technology transfer through its reports, web sites, and videos.

The main focus of the nurseries program is to develop new equipment or technology to improve nursery operations and processes. The program is sponsored and funded by the Forest and Rangeland Staff group at the Washington Office, and by the State and Private Forestry, Reforestation, Nurseries, and Genetic Resources group.

Projects originate from ideas or concepts from field personnel. A national steering committee reviews the project proposals that typically come from employees at the Forest Service Federal nurseries, and from State and Private cooperators. The steering committee selects the highest priority projects for MTDC to work on.

Projects typically last from 2 to 3 years depending on the complexity of the project. Equipment-based

projects are field tested and fabrication drawings are made so the equipment can be duplicated by other nurseries. Results are usually formally documented and available from MTDC.

A complete listing of nursery projects completed over the years is available electronically to Forest Service and BLM employees at MTDC's intranet site, <http://fsweb.mtdc.wo.fs.fed.us/programs/ref>. The list is also included in the printed report, *Reforestation & Nurseries*, (0224-2805-MTDC), available on request by calling 406.329.3978.

This presentation will describe current nursery projects at MTDC that may be of interest to you.

SEEDLING TEMPERATURE MONITOR

The objective of this project was to measure and record tree seedling storage and transportation temperatures to determine if and when the seedlings were exposed to harmful conditions. MTDC engineers found a commercially available product, the Thermochron *iButton*, manufactured by Dallas Semiconductor Corp., that met this need.

The Thermochron *iButton* (fig. 1) is a small device about the size of 2 stacked dimes. It records time and



Figure 1. The ThermoChron iButton, the size of 2 stacked dimes, measures time and temperatures of seedling bundles while they in storage or being transported.

temperature. It can be programmed to log at specific time intervals, for example 5 minutes or 1 hour, and to record the temperature at the end of that time period. The information is downloadable to a computer using a special adapter and cable, and the data can be easily graphed with time on the X-axis and temperature on the Y-axis. This display readily shows whether the seedlings were subjected to extreme temperatures and, if so, when.

The ThermoChron iButton has an internal battery that does not need recharging, and can last for up to 10 years or 1 million temperature measurements. The device is inexpensive, about \$10 per button. A starter kit that includes an iButton, computer cable, and adapter costs about \$25.

For more information, view the iButton web site at <http://www.ibutton.com>, or request a copy of *Monitoring the Temperature of Tree Seedlings with the ThermoChron iButton Data Logger* (0024-2311-MTDC). Andy Trent is the project leader.

SHIELDED HERBICIDE SPRAYER

One of the challenges in hardwood nursery beds is killing the weeds that grow between the crop rows. Chemicals such as Roundup kill the weeds, but also kill the seedlings if the spray is misdirected. Several nurseries have made their own shielded sprayers to prevent herbicides from being applied to the hardwood seedlings. MTDC was asked to review this existing equipment, select the best features, and incorporate those features into a new prototype model.

Project leader Keith Windell worked with machinery developed by several Southern nurseries. He developed a prototype spraying system, had it fabricated, and field tested it in May 2002.

The MTDC prototype sprayer is mounted on a three-point hitch (fig. 2). It is a fully contained system with up to nine nozzles. The shields are adjustable, and the sprayer can be steered for perfect alignment as it is pulled down the rows. The spray pump is run off the tractor's power take off and is calibrated before spraying.

Field testing was done at the Virginia Department of Forestry's New Kent and Augusta nurseries. Two

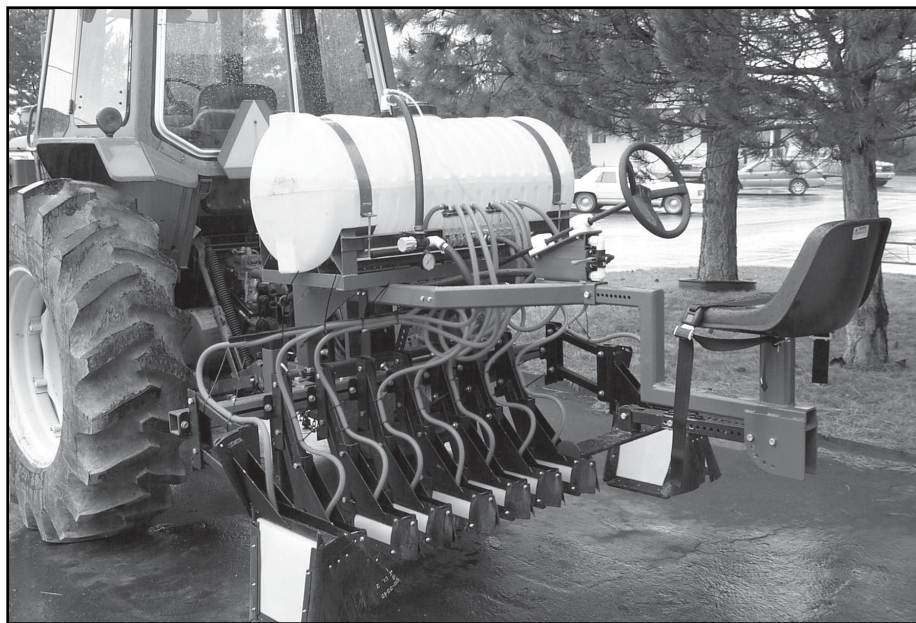


Figure 2. This new shielded herbicide sprayer applies Roundup between rows of hardwood seedling crops in nurseries.

deficiencies became evident. Steering was awkward because the steering wheel, support, and gear box blocked the view of the shields and the crop rows. This made it hard to see where to steer. The second problem was that, in soft soils, the shields tended to dig rather than float on the surface as intended. MTDC will make some modifications to the sprayer unit and retest it in 2003.

HARDWOOD CUTTINGS PREPARATION EQUIPMENT

Several years ago MTDC developed a machine to plant hardwood cuttings into nursery beds. The new project is to develop equipment to prepare the cuttings before planting. The current practice at many nurseries is to cut long whips from stumps, then use table saws to cut the whips into 6- to 8-inch (15- to 20-cm) cuttings. This work is time consuming and raises safety concerns because of the close proximity of the operator's hands to the saw.

Project leader Gary Kees has completed a prototype saw that should make the job of preparing the cuttings easier and safer. The electric miter saw has a brake that stops the blade once the cut is made and a foot-operated clamp that holds a bundle of whips as they are cut. The saw will be tested at the Bessey Nursery in Halsey, Nebraska, early in 2003.

COPPER TREATMENT FOR STYROFOAM BLOCKS

Copper-coated styroblocks are becoming the containers of choice for some nurseries as the benefits of these blocks become better understood. These benefits include ease of seedling extraction, reduced root spiraling, improved seedling development, and longer usable container life.

Copper-coated styroblocks can be purchased from styroblock manufacturers, but the coating wears off after about two growing cycles. MTDC was asked to look at methods and equipment to recoat the blocks with the copper treatment, assuming it is feasible to do so. Project leader Wes Throop is just beginning the project.

STYROFOAM BLOCK STERILIZER

MTDC is looking at methods and equipment to sterilize styroblocks before filling them with media and sowing seeds. Certain pathogens like *Pythium* and *Fusarium* remain in the residual soil and in some roots that may remain after the seedlings have been extracted.

Many nurseries dip their used blocks into vats of hot water (160 °F to 180 °F [71 °C to 82 °C]) and hold them there for at least 2 minutes. This method works, but is very slow and labor intensive. A typical nursery can dip only about 25 to 30 blocks at a time, but must sterilize thousands of blocks each year.

MTDC has been looking at alternative methods of sterilization. We first looked at infrared heat, but we could not provide enough heat to the inner cavities without melting the tops of the blocks.

Next, we looked at using microwave or radio frequency waves, using a large radio frequency oven made for drying. MTDC tested several styroblocks at various exposure durations and found that the oven was effective at reducing pathogen levels to acceptable levels, but the equipment costs were excessive.

We are now evaluating whether using dry heat, like that in a sauna, will effectively sterilize the blocks. The concept is that a large room could be constructed where pallet loads of blocks could be treated at one time. The blocks could be left in the oven for a specific period of time, perhaps 1 or 2 hours, and then removed. Preliminary testing indicates that the styroblocks must be wetted or sprayed down before heating. Further work is planned within the next year. Andy Trent is the project leader.

ROOT PRUNER

In Western nurseries, roots are pruned before seedlings are stored. Pruning is typically done with a blade mounted like a large paper cutter. This method is slow, repetitive, and subjects workers to the risk of finger lacerations.

MTDC has developed a new root pruning system that incorporates a commercially available rotary cutting head (fig. 3) to prune the roots. The device uses large

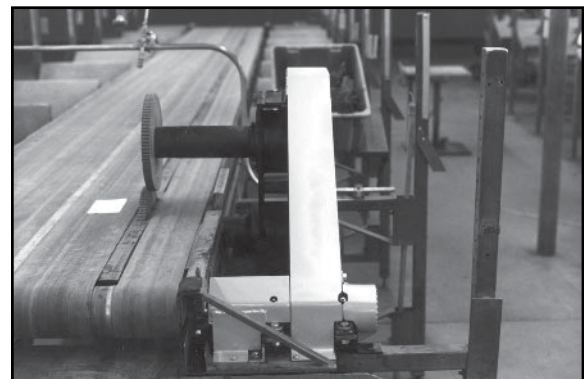


Figure 3. This root pruner cutting head trims roots to length in the packing operation better than the paper-cutter type of equipment currently being used.

12-inch (30.5 cm) counter rotating gears that are mounted flush with the sorting table to draw in and shear the roots. It stays sharp for a long time, and the gears can be reground and remounted when necessary. The cutting head has been tested and proven to effectively prune roots without ripping the roots, jamming, or bogging down.

Initial testing was done at the J Herbert Stone and Coeur d'Alene nurseries. Although the system cut the roots very well, overall production was slowed down because of the additional time it took for workers to align the seedlings on the conveyer. MTDC is working with the nurseries to use the pruner as a stand-alone unit at the end of the sorting table. This will allow the workers to concentrate on sorting without having to align the seedlings for pruning. Wes Throop is project leader.

NURSERY SOIL STERILIZATION

Methyl bromide has been the preferred method at most nurseries for fumigating soil to combat soil pathogens. However, methyl bromide has been found to be environmentally harmful and its use will be banned or severely curtailed. MTDC was asked to look at alternatives to chemical fumigation for tree seedling nurseries.

Looking at an older technology still used in Europe, MTDC built a prototype steam treatment machine for treating nursery beds. If soil is heated to at least 160 °F (71 °C) for 20 minutes, tree seedling pathogens are killed, while desirable microorganisms survive. MTDC's steamer featured a 1-million BTU (293 kw) boiler that has been outfitted to inject steam into the soil at about 8 inches (20 cm) deep (fig. 4). Field



Figure 4. MTDC developed this prototype machine to inject steam into nursery beds, sterilizing the soil as an alternative to using pesticides. It proved to be too slow for production use.

testing of the steamer concluded that it effectively controlled the pathogens, but the prototype machine was too slow for field production use. Test results are documented in *Nursery Soil Steam Fumigation* (9724-2833-MTDC), available from MTDC.

As another alternative, we are evaluating infrared heat for sterilizing the soil. In theory, infrared or radiant burners should be much more efficient in heating the soil than steam. The idea is to lift soil from the soil bed onto a conveyor belt where infrared burners mounted 12 inches (30.5 cm) above the conveyor will heat the soil. Project leader Andy Trent is conducting preliminary tests to determine if this concept warrants full field testing.

ANIMAL DAMAGE/REPELLENTS

MTDC has an ongoing cooperative agreement with Dr Dale Nolte, USDA Animal and Plant Health Inspection Service (APHIS), that offers technology transfer of important animal pest control research. Together, MTDC and APHIS have been: 1) testing commercial repellents and barriers on animals confined in pens. *Comparison of Commercial Deer Repellents* (0124-2331-MTDC) documents the results; 2) developing equipment and conducting studies to reduce pocket gopher populations in reforested areas; 3) developing a comprehensive manual on animal damage management practices that will be published in 2003; and 4) providing information to national forests on bear foraging behavior and management practices.

MAKING SNOW TO PROTECT OVERWINTERING SEEDLINGS

Artificially made snow can help protect nursery seedlings from extremely cold temperatures in northern climates when there is little natural snowfall. MTDC was asked to develop a snow-making machine that is portable, needs little maintenance, and is inexpensive.

Itasca Greenhouses in Cohasset, Minnesota, reported using a commercial snow maker called the Back Yard Blizzard to make snow for seedling protection. It is a small unit costing around US\$ 2000 that works well but does not provide enough coverage for the needs of most nurseries.

As an alternative, MTDC developed a prototype snow gun that provides four times as much snow as the Back Yard Blizzard. All parts of the prototype snow maker are commercially available and cost a total of about US\$ 300. They are simple to assemble and operate. Project leader Andy Trent plans to test

this prototype in the winter of 2002-2003 with Itasca Greenhouses. This machine does require an industrial air compressor, but these compressors are readily available at rental stores.

WHITEBARK PINE SEED SCARIFIER

Whitebark pine is being planted for restoration projects because its seeds are an important food source for grizzly bears. Scarifying the seed coat increases germination dramatically at the nursery, from about 1% to 2% natural germination, to more than 60% germination if there is a 1-mm cut in the seed coat. Currently, each seed is being cut manually with an Exacto knife, a tedious process that presents its own set of safety concerns.

MTDC has developed an instrument that may replace the Exacto knife operation. The instrument uses a rotary-head cutting tool to make a 1-mm cut through the seedcoat (fig. 5). Laser sensors adjust the cutting tool for the size of the seed. Germination tests using seeds cut by the tool were conducted at the Coeur d'Alene Nursery during the spring of 2002. Andy Trent is project leader.



Figure 5. Several whitebark pine seeds that were cut using the whitebark pine seed scarifier.

CONTACTS FOR MORE INFORMATION

Many nursery drawings done by MTDC are available electronically at the Reforestation, Nursery, and Genetic Resources web site:

<http://www.rngr.fs.fed.us>

Most drawings and reports done by MTDC are available to Forest Service and BLM employees at the FSWeb intranet site:

<http://fsweb.mtdc.wo.fs.fed.us>

Paper copies of MTDC's reports and drawings are available from:

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PRODUCING HIGH-QUALITY SLASH PINE SEEDS

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Barnett J., Varela S. 2003. Producing high-quality slash pine seeds. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 52–56. Available at: <http://www.fcnanet.org/proceedings/2002/barnett.pdf>

Abstract

Slash pine is a desirable species. It serves many purposes and is well adapted to poorly drained flatwoods and seasonally flooded areas along the lower Coastal Plain of the Southeastern US. The use of high-quality seeds has been shown to produce uniform seedlings for outplanting, which is key to silvicultural success along the Coastal Plain and elsewhere. We present information for nursery managers who collect, process, and treat slash pine seeds.

Key Words

Pinus elliottii, *P. taeda*, *P. palustris*, *P. echinata*, seed storage, seed processing, stratification, seed pathogens

INTRODUCTION

Slash pine (*Pinus elliottii* Engelm. var. *elliottii*) is an excellent timber tree and one of the premier pine species in the Southern US. Many prefer the species because of its fast growth and excellent utility for fiber, lumber, poles, and gum naval stores. The habitat and preferred sites within its natural range include poorly drained flatwoods and stream edges, as well as seasonally flooded areas such as bays and swamps.

The ease and success of planting slash pine has resulted in a significant increase in its range. Extensive planting and natural regeneration of open agricultural and forest land led to a sharp rise in acreage of slash pine between 1952 and 1970 (Sheffield and others 1983). Although its range now includes coastal areas from South Carolina to eastern Texas, almost 80% of slash pine ecosystem acreage occurs in Florida and Georgia (Barnett and Sheffield 2003).

Nursery practices for slash pine are similar to those for loblolly pine (*P. taeda* L.), and relatively little seed and seedling research has focused on the species. There are, however, some distinct differences between slash pine cone and seed maturation and performance and that of the other southern pines. The purpose of this paper is to review important aspects of producing high-quality slash pine seeds.

COLLECTING AND PROCESSING CONES AND SEEDS

Cone and Seed Maturity

Date of collection and length of cone storage significantly influence yields and germination of slash pine seed. As indicated in table 1, the number of recovered seeds per cone generally increases with later collection dates (McLemore 1975; Barnett 1976a). Yields from each collection increase with length of cone storage. One week of storage was unsatisfactory for all dates of collection; 3 weeks increased yields, but 5 weeks proved best. Even cones with a specific gravity of 0.86 yielded only half as much seed after 3 weeks as they did after 5. Storage for 5 weeks also increased germination in most cases. Seeds in cones that are immature continue to ripen and improve in quality with cone storage, and seed viability in mature cones also continues to improve with cone storage (table 1). In this respect, slash seeds respond differently than those of longleaf (*P. palustris* Mill.) and loblolly pine. Studies indicate that loblolly seeds mature before the cones; as soon as the cones open the seeds are mature (will germinate at the maximum level) (McLemore 1975; Barnett 1976a). However, longleaf pine seed quality normally does not continue to

increase during cone storage (table 1). In fact, it typically decreases in storage. So, longleaf cone collection should be delayed until the cones are fully mature.

Cone Storage

Although cone storage is important in maximizing seed recovery, there are no sound recommendations for conditions under which cones should be stored. Typically cones are stored in 1-bushel (35 l) burlap bags, 20-bushel (105 l) wooden crates, or large plastic-mesh bags and either in open or covered conditions. Early studies have indicated no significant differences between burlap bag or crate storage if the cones are handled properly (Barnett 1979a; Bonner 1987). There seems to be benefit in holding loblolly pine cones in the open, where cyclic wetting and drying improves seed extraction (Bonner 1987). Providing cyclic wetting to eastern white pine (*P. strobus* L.) cones during storage, however, reduced germination (Barnett 1988). Storing both slash and longleaf pine cones in the open under rainy, high-humidity conditions causes mold development, which potentially reduces germination of these more sensitive seeds both initially and during seed storage. Seeds from slash pine cones sampled from the center

of crates held in the open germinated markedly less than those from the outer portions of the crate (Barnett 1979a). Tests with shortleaf pine (*P. echinata* Mill.) indicate that, although seeds from cones in open storage germinated better initially, they deteriorated significantly during 1 year of storage (Barnett 1979a). It is thought that the open cone storage provided a stratification effect that hastened initial germination, but lowered seed quality. This effect probably occurs in other species as well as slash pine.

Seed Processing

Seeds are normally extracted from pine cones in forced-draft kilns where temperatures are maintained between 95 °F and 105 °F (35 °C and 40.5 °C). After extraction from the cones, they must be dewinged, cleaned, and dried. The wings of slash pine and the other southern pines (except longleaf) are completely removed by brushing and tumbling in mechanical dewingers. The dewinging process is hastened and improved by moistening dry seeds, but excess moisture should be removed before storage. Dewinging that is done in a manner that does not damage the seed coats has no effect on seed storability (Belcher and King 1968; Barnett 1969).

Table 1. Seed yields and germination of three southern pines affected by date of collection and length of cone storage (from McLemore 1975).

Date of collection	Specific gravity	Seed yields per cone when stored for:			Germination when stored for:			
		1 week	3 weeks	5 weeks	1 week	3 weeks	5 weeks	
		----- No. -----			----- % -----			
Slash								
Aug	19	0.95	0	8	58	37	52	68
	26	.95	0	41	63	76	46	63
Sep	3	.91	22	37	89	38	38	70
	9	.86	26	40	75	69	46	90
	16	.77	27	75	82	49	63	98
Loblolly								
Sep	9	.98	0	27	25	96	98	100
	17	.92	11	26	38	92	98	95
	23	.90	19	31	20	97	98	98
	30	.85	21	37	32	100	99	99
Oct	7	.77	41	34	54	98	99	99
Longleaf								
Sep	9	.99	0	38	46	83	58	31
	17	.95	0	10	61	76	59	48
	23	.93	3	30	50	80	60	49
	30	.92	2	70	72	84	70	72
Oct	7	.88	4	40	72	86	85	83
	14	.83	52	77	77	87	92	90

SEED TREATING AND STORING

Storing Seeds

Careful control of seed moisture content and storage temperature is essential to maintain viability, and the recommendations are to dry below 10% moisture and store at temperatures below freezing (Barnett and McLemore 1970). Slash pine seeds maintained 66% viability when stored for 50 years at temperatures just above freezing and moisture content of 9% (Barnett and Vozzo 1985). Donald and Jacobs (1990) have shown that lower storage temperatures are better. Under their storage temperatures of 36 °F and 4 °F (2 °C and -15.5 °C), slash pine seeds germinated at 77% and 92%, respectively, after 25 years.

Seed-coat Pathogens

Southern pine seed coats are host to significant populations of pathogenic fungi (Pawuk 1978; Barnett and Pesacreta 1993). Treating with sterilants, such as hydrogen peroxide (Barnett 1976b), or

applying fungicidal drenches improves germination of less-vigorous seeds (Barnett and Pesacreta 1993). Pathogens carried on the seed coats also provide a source of infestations that can result in early seedling mortality. Studies show that removing fungal contamination from the seed coats will markedly improve seed germination and seedling establishment in the nursery (Barnett and others 1999).

Tests also indicate that there are important differences among pine species on the degree of seed-coat contamination. Slash pine seeds have high levels of *Penicillium* fungi on their coats, with low levels of *Fusarium*, a primary pathogen on pine seeds (table 2). Longleaf seeds carry the greatest load of fungi, with much greater amounts of *Fusarium* (table 3). By contrast, loblolly seeds have a lower level of contamination (table 4). Contamination among species is related to the different levels of seed-coat density. Loblolly has a very hard coat and longleaf a softer, fibrous one, with slash coats being intermediate in hardness.

Table 2. Levels of seed coat contamination and germination of slash pine seeds following treatment with fungicides¹.

Seed coat treatment	Fungus infestation			Germination
	<i>Penicillium</i>	<i>Collototrichum</i>	<i>Fusarium</i>	
	----- % -----			
Untreated control	100	2	4	33
Thiram TM 42S with Colorant	0	0	0	67
Thiram TM 42S, ABG-3035, Colorant	0	0	0	39
Thiram TM 42S, Vitavax [®] PC	0	0	0	58
Thiram TM 42S, ABG-3035, Vitavax [®] PC	0	0	0	54
Vitavax [®] PC	0	0	0	46

¹ Testing was conducted at Gustafson's Research and Development Center. Two replications of 50 seeds each were used for all treatment evaluations.

Table 3. Levels of seed coat contamination and germination of longleaf pine seeds following treatment with fungicides¹.

Seed coat treatment	Fungus infestation				Germination
	<i>Penicillium</i>	<i>Collototrichum</i>	<i>Fusarium</i>	<i>Rhizopus</i>	
	----- % -----				
Untreated control	58	2	32	10	33
Thiram TM 42S with Colorant	2	0	12	0	67
Thiram TM 42S, ABG-3035, Colorant	4	0	10	0	39
Thiram TM 42S, Vitavax [®] PC	0	0	2	0	58
Thiram TM 42S, ABG-3035, Vitavax [®] PC	0	0	8	0	54
Vitavax [®] PC	0	0	16	0	46

¹ Testing was conducted at Gustafson's Research and Development Center. Two replications of 50 seeds each were used for all treatment evaluations.

Table 4. Levels of seed coat contamination and germination of loblolly pine seeds following treatment with fungicides¹.

Seed coat treatment	Fungus infestation		Germination
	<i>Penicillium</i>	<i>Aspergillus</i>	
	----- % -----		
Untreated control	70	6	20
Thiram™ 42S with Colorant	0	0	42
Thiram™ 42S, ABG-3035, Colorant	0	0	39
Thiram™ 42S, Vitavax® PC	0	0	32
Thiram™ 42S, ABG-3035, Vitavax® PC	0	0	34
Vitavax® PC	0	0	33

¹ Testing was conducted at Gustafson’s Research and Development Center. Two replications of 50 seeds each were used for all treatment evaluations.

Because Thiram™ 42-S is a labeled seed treatment, tests were installed to evaluate it, and two other fungicides (ABG-3035 and Vitavax® PC) in combination, for effectiveness in reducing seed-coat contamination. Gustafson’s Research and Development Center treated the seeds and conducted both pathological and germination evaluations. Germination of seed samples from the same treatments was tested at the Pineville Seed Testing facility. Results from the 2 facilities were similar, so only the Gustafson’s results are shown in tables 2 through 4.

All treatments eliminated fungi from slash and loblolly pine seeds that had low levels of microorganisms on the coats (tables 2 to 4). However, germination was improved in both species with all fungicidal applications. For these species, the Thiram™ 42-S treatment singly was as good or better than any combination of treatments. Longleaf pine seeds had much higher levels of infestation and the treatments reduced, but did not eliminate, seedborne fungi. In the case of longleaf, the combination of Thiram™ 42-S and Vitavax® PC was the most effective. Thiram™ 42-S alone resulted in greatly improved germination—an increase of from 53% for the control to 72% for the treatment.

These results suggest that the Thiram™ 42-S seed treatment significantly reduces seed-coat contamination, and the process improves germination of low-quality seed lots.

Prechilling Needs

Generally, slash pine seeds require little prechilling or stratification to overcome dormancy. If

germination conditions in the nursery are near 75 °F (24 °C), most lots will germinate well without prechilling. However, if nursery seedbed temperatures are below 65 °F (18 °C), a short period of prechilling will improve seed germination and early establishment (Barnett 1979b).

SEED SOWING AND PERFORMANCE

The presence of fungi on the seed coat may reduce germination and seed establishment under normal conditions in container nurseries. Covering of germinating seed may contribute to additional mortality. When the container medium is kept continuously moist and the seeds are covered, germination can be adversely affected due to damping off as the infested seeds germinate (table 5). These results reaffirm the benefit of reducing seedborne pathogens. If the surface of the container medium dries between watering, seed covering speeds and enhances germination.

Table 5. Effects of seed covering on slash pine seed germination (from Barnett 1978).

Watering method	Depth of cover (inches)	Total Germination	Proportion at 15 days
		----- % -----	
Mist	0	96	95
	0.25	69	72
	0.50	26	38
Hand	0	60	0
	0.25	80	58
	0.50	67	46

CONCLUSIONS

Slash pine seeds are more sensitive to injury during collection, processing, storage, and treatment than loblolly pine seeds. To obtain seedling uniformity in the nursery, particular attention should be paid to cone maturity and storage, presence of seed-coat pathogens, and application of treatments that may enhance performance.

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**WESTERN FOREST AND CONSERVATION NURSERY
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FOREST NURSERIES IN FINLAND

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Poteri M. 2003. Forest nurseries in Finland. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. *National Proceedings: Forest and Conservation Nursery Associations—2002*. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. *Proceedings RMRS-P-28*: 59–63. Available at: <http://www.fcnet.org/proceedings/2002/poteri.pdf>.

Abstract

In Finland, forest tree seedling production has shifted between 144 to 207 million seedlings during the last decade. Currently 7 enterprises own 24 nurseries which produce about 85% to 90% of the total number of seedlings. The main tree species in Finland are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and European silver birch (*Betula pendula*). About 90% of the seedlings are grown in containers. Hard plastic containers like Plantek® (Lannen) and Blockplanta® (BCC) have nowadays almost replaced the former widely used Ecopot® (Lannen). Container Scots pine and silver birch seedlings are usually 1 year old and spruce seedlings 1 and 2 years old when shipped. During winter, seedlings are stored either in the nurseries outdoors under natural or artificially made snowcover, or seedlings are packed into plastic-laminated cardboard boxes and placed in freezer storage. A minority of the seedling production is bareroot, and that is mainly Norway spruce. It is likely that seedling production will become more centralized, meaning that the amount of seedlings produced per nursery will increase while the number of nurseries will decrease. Other new challenges to seedling production are the extension of the outplanting season to cover the whole growing season from May to September, and the development of seedling types suitable for increasing machine planting.

Key Words

Silvicultural operations, seedling culture, forest regeneration, seed orchard

Abbreviations: FFCS = The Finnish Forest Certification Scheme, EMAS = The EU Eco-Management and Audit Scheme, ISO = International Organisation for Standardization

INTRODUCTION

Forestry and the forest industry in Finland have important roles in the national economy, as the products of forest industry constitute almost one third of the total exports of goods. To date, 90% of roundwood consumed in the forest industry has come from domestic resources, although roundwood import has slightly increased during the last decade.

Forest land area in Finland is about 49 million acres (20 million hectares). Peculiar to Finnish forest ownership is a high proportion of private forest owners. At this moment, 62% of forest land area is owned by private families, with the state controlling 25%, and forest industries owning 9%. The mean forest area owned by private (families) is about 62 acres (25 hectares), and there are some 400,000 private forest owners. It is clear that all logging and silvicultural operations are challenged by these relatively scattered forest areas and many associates.

Cutting and forest regeneration methods follow national standards and regulations that are roughly the same between different forest owners. To regularly evaluate the state of the forest managements, different quality and environmental certification systems are nowadays applied among the various groups (EMAS and ISO for forest industry and state owned forests, and FFCS for private forests).

Although Finland is located between 60° and 70° latitudes, the climate is mild (fig. 1). The reason for this is the Gulf stream that carries heat from the Indian Ocean to the North Atlantic Sea, and has an effect on the climate in the whole of North Europe and Scandinavia.

The duration of the growing season in south Finland is about 180 days, but only 120 days in the north; the annual temperature sums of degree days are about 1350 and 750, respectively. The annual precipitation is 16-28 inches (400 to 700 mm) and snow cover occurs



Figure 1. Finland is located in the northeastern corner of Europe between 60° and 70° latitudes.

in the whole country; even the southern and western coasts have snow for some weeks every year.

Finland belongs to the Eurasian boreal forest zone where forests are dominated by conifers. The tree species having silvicultural importance are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and, of the broad-leaf trees, European silver birch (*Betula pendula*). Other less cultivated species are larch (*Larix sibirica*), aspen (*Populus tremula*), hybrid aspen (*Populus tremula* x *P. tremuloides*), black spruce (*Picea mariana*), alder (*Alnus glutinosa*) and downy birch (*B. pubescens*).

The regeneration methods have shifted during the past decades. Natural regeneration has replaced artificial regeneration, especially planting. At this moment, however, almost 50% of the regenerated forest area is planted. During the last 10 years, the annual planting area, including private, forest industry, and state owned forests, has shifted between 193000 to 252000 acres (78,000 to 102,000 hectares). Depending on the regeneration site and tree species, 650 to 800 seedlings are planted per acre (1600 to 2000 seedlings per hectare).

In 2001, the forest tree seedling production was 154 million seedlings and, in addition, some 10 million seedlings were imported from Sweden. Seedling

Proportions of produced seedlings in Finland in 1966 - 2001

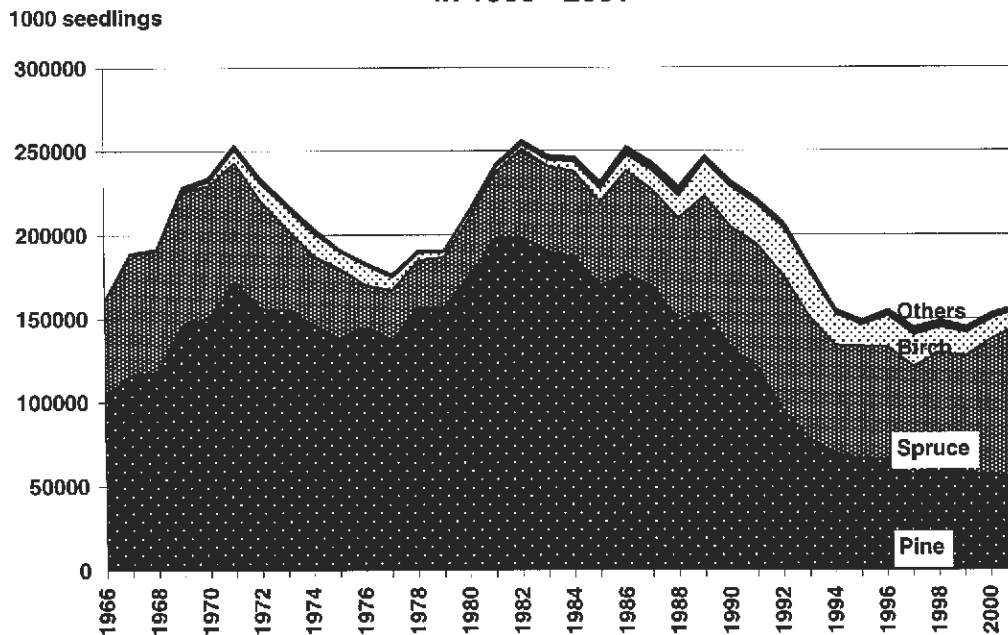


Figure 2. Forest tree seedling production in Finland from 1966 to 2001 (Ministry of Agriculture and Forestry).

production has decreased from its peaks, which were in the end of 1960s and in the 1980s when the annual production was 250 million seedlings. The main reason for the decrease is that natural regeneration has replaced the planting of pine (fig. 2).

NURSERIES OWNED BY ENTERPRISES

Until the beginning of 1990, most forest nurseries belonged to state owned provincial forest organisations. A privatisation of forest nurseries occurred and, as a consequence, the number of nurseries decreased. At this moment, there are 7 nursery companies who own a total of 24 nurseries. The seedling production of these enterprises covers about 85% to 90% of the total number of seedlings delivered for planting. The remaining 10% of the total planting stock is grown in small, family-owned nurseries, comprising a total of around 60 to 70 nurseries. The average amount of seedlings produced/nursery is between 5 to 10 million, but some of the biggest nurseries produce 15 to 20 million seedlings (fig. 3).

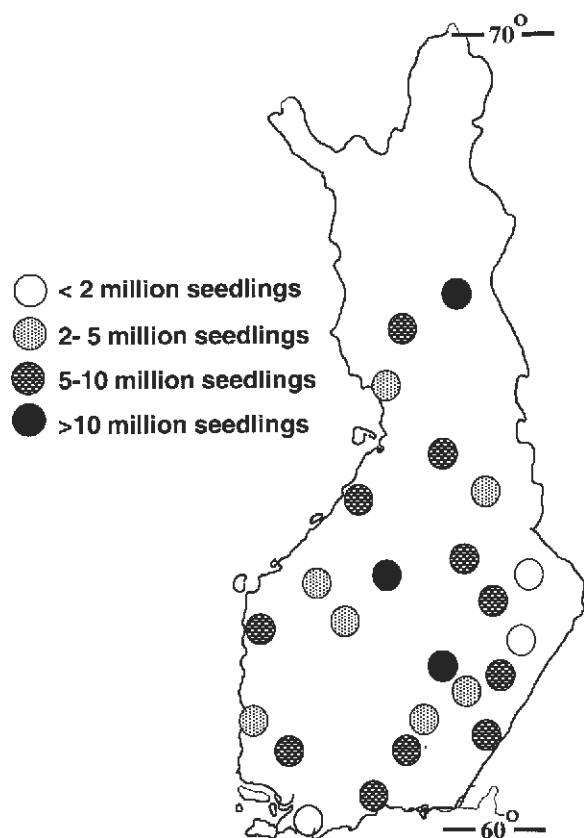


Figure 3. Map of Finnish enterprise owned nurseries and their annual seedling production.

When extensive seedling production for forest regeneration started in the beginning of the 1960s, the main product was bareroot pine. Many of the forest nurseries were established on forest land, and only a minor part was located on former agricultural farm land. Most of the nurseries are still “in the forest”.

The change from bareroot to container production has been very fast. Nowadays, about 90% of the seedlings are produced in containers (fig. 4). Bareroot production is mainly spruce, which is grown for 2 years in nursery beds or for one year in containers and transplanted. Bareroot spruce seedlings are grown especially for areas with rich vegetation cover and are usually 4 years old when shipped.

HARD PLASTIC CONTAINERS

The most common container type at this moment is a hard plastic container like Plantek® (Lannen) and Blockplanta® (BCC). To some extent, Ecopot® (Lannen) containers are still in use, where seedlings are separated by paper strips which are removed before lifting. Other less used systems are Jiffy® and a Finnish Vapo-plug system.

As a growth substrate, sphagnum peat is used. Normally no additional compounds like sawdust, vermiculite, or perlite are used. Commercial peat is adjusted to fit suitable pH and nutrient content for forest tree seedlings. Finland has rich peat resources, so national peat manufacturers can supply custom mixtures and tailor-made products.

Over 60% of nursery seeds come from seed orchards (fig. 5). North Finland has a lack of seed orchards; therefore seed collecting from known stands or

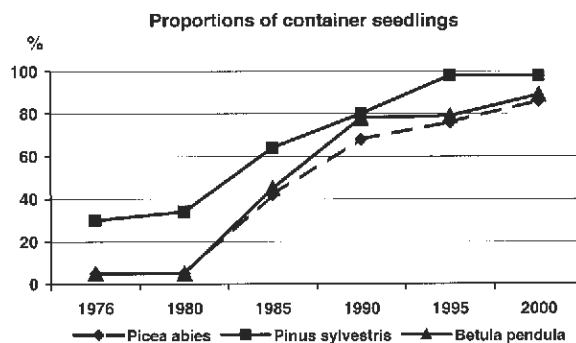


Figure 4. Proportion of container seedlings of the planting stock in Finland from 1976 to 2000 (Ministry of Agriculture and Forestry).

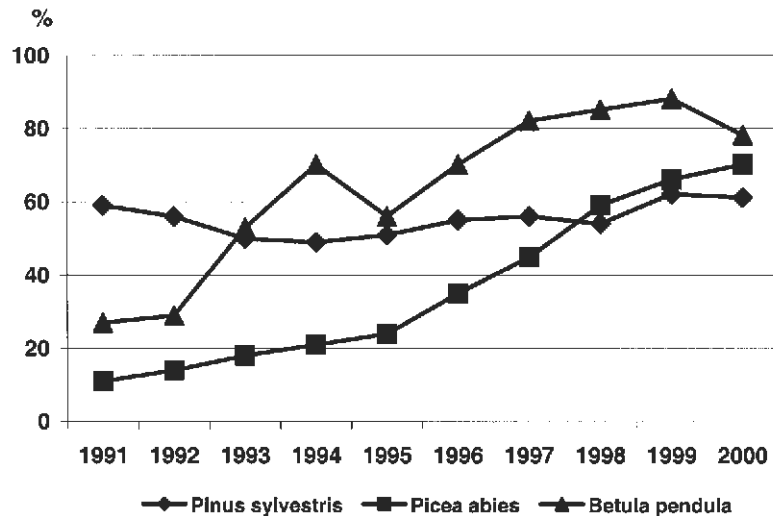


Figure 5. Use of seed orchard seeds in Finnish nurseries from 1991 to 2000 (Ministry of Agriculture and Forestry).

regions is more common there. Nursery sowing lines (machines Lannen[®] and BCC[®]) use mainly double or single seed sowings. After sowing, containers are covered with sand or vermiculite.

Seeded containers are placed on metal frames or pallets which are transported with jack lifts to plastic houses. In the greenhouses (and outdoor growing areas as well) pallets are raised some 8 to 10 inches (20 to 25 cm) from ground level to improve root pruning and air ventilation.

GROWING PROCEDURES

Early sowings start in March to April and usually heating is needed at that time. Also, additional light is used to prevent bud formation in the most early sowings. Seedlings are grown in plastic greenhouses from 6 weeks to 5 months, depending on the species and seedling type. Bigger nurseries commonly grow 2 crops in a greenhouse. The latest sowing times (usually spruce) are in the beginning of July.

In container production, irrigation is done with moving booms both in the greenhouse and in the outdoor growing areas. Sprinklers are used in bareroot production. Most fertilizers are applied with irrigation water.

In growing pine, fungicide sprayings against Scleroderris canker and snow molds are needed, especially in the northern part of the country. Grey mold can be a problem in storage and usually has to be controlled by sprayings. Insecticides are used

mainly against aphids. To protect the planted seedlings against *Hylobius* weevil attack at the planting site, container conifer seedlings are sprayed in the nursery before packing or shipping.

Herbicides are used in bareroot production to treat the field area before transplanting. Selective products are used in the transplant beds usually after the seedling growth has stopped. To control liverworts in containers, it is possible to use quinoclammin (product Mogeton[®] WG).

For winter, seedlings are stored either in freezer storage or left outdoors. Pallets or large container frames which will remain outdoors under natural or artificially made snowcover are set on the ground in fall to prevent frost injury to roots. After winter storage, either outdoors under the snowcover or in freezer storage, many nurseries do routine root growth potential (RGP) tests to check the condition of the root system before shipping.

Short-day treatments are used to control the growth of seedlings and to harden them. One-year-old spruce seedlings are the main species requiring black-out. The treatments are used to especially protect fall planted spruce seedlings from the damages caused by night frosts. Nurseries can also gain more time for packing in the fall if the work can be started earlier with hardened, short-day treated seedlings.

Container spruce seedlings are 1 to 2 years old when shipped; pine and birch seedlings are usually 1 year old. Plastic laminated paperboard boxes are used to

store and ship seedlings. Normally, seedlings are not graded individually at packing; but the evaluation of seedling stock is based on the lot samples taken before hand and checked for their size and quality requirements.

For contracts, seedling lot specifications are set by the producer and customer. The key role of national authorities in size specifications of seedling stock has ended, although the annual evaluations of seedling stock are still performed regularly by authorities. In Finland, the national seedling requirements are in accordance with the directive of forest reproductive material described by the Council of European Union.

FUTURE TRENDS

It is obvious that the centralisation trend will continue, that is, more seedlings are produced per nursery. It also seems that the proportion of container seedlings will remain or even increase further.

The role of terminal freezer storage will become more essential in the shipping of seedlings from

nurseries to planting areas. It is likely that more seedlings will be packed and transported into terminals in fall. In spring, the seedlings are delivered from freezer storage to local planting areas.

The extension of the planting season to cover the entire growing season from May to September/October will demand more hot-lifted seedlings during June to August. The wider planting window is connected to the increased interest on machine planting (Bräcke[®], EcoPlanter[®]). Although there are many issues to be solved before machine planting can become routine, the lack of labour for manual planting is one force driving current regeneration research. New research topics include finding more optimal site preparation methods, and developing container seedlings more suitable for machine planting.

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ENVIRONMENTAL IMPACTS OF NURSERIES

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Abstract

Forest seedling production could be seen from at least 2 environmental standpoints: nurseries as possible point sources of harmful chemicals, and as part of the artificial regeneration process in life cycle analyses of wood products. If nurseries are looked upon as point sources of agricultural pollution, then the harmful substances of importance to human health and the environment are nitrogen and phosphorus compounds, as well as pesticides and their metabolites. The handling of bio-wastes could indirectly influence the pollution potential of nurseries. For example, effective waste management and good nursery hygiene could decrease the risk of diseases and the need for chemical control.

Evaluation of production systems and methods could help nurseries to develop growing practices that decrease the nutrient and pesticide load on the environment. Many factors must be considered when nutrient and pesticide losses from a container tree seedling nursery are estimated. For example, it is important to identify the sources of nutrient and pesticide load so that the control measurements are concentrated correctly. Fertigation of nutrients into aisles and other empty spaces around container blocks could cause higher nutrient load than the leaching of nutrients from containers into the ground. Water management is an important means of controlling contamination of the environment. Practices that increase the efficiency of irrigation and efficiency of nutrient use by seedlings obviously decrease the environmental impact.

Key Words

Fertilizer, groundwater, eutrophication, fertilizer efficiency, container nursery, leachate, Scots pine, *Pinus silvestris*, Norway spruce, *Picea abies*, silver birch *Betula pendula*

INTRODUCTION

Ground water pollution and eutrophication of surface waters due to agricultural practices have been reported worldwide. Still, the risk posed by production of forest tree seedlings, although widespread, is poorly known. Although the total use of fertilizers and pesticides in forest nursery production is small compared to that in agriculture and horticulture, there can be at least local risks, since some nurseries are situated on areas near lakes and rivers and/or where ground water reservoirs are found.

Use of chemical fertilizers has increased the amount of nitrogen (N) and phosphorus (P) transferred from agricultural fields to surface and ground waters (Tiessen 1996; Vitousek and others 1997). Excess P, in particular, and N in the surface water has accelerated the eutrophication of these waters. Small shallow lakes, typical in Finnish agricultural regions, are most sensitive to eutrophication (Kauppi and others 1993). In the European Union (EU), NO₃ levels

greater than 50 mg/l (= NO₃-N 11.3 mg/l) in drinking water are considered unsafe for humans (European Community 1998). In the US, the NO₃-N limit is 10 mg/l (USEPA 2001). High nitrate concentrations in drinking water could affect, in particular, the health of infants.

Pesticides are a heterogeneous group of chemicals, and their risks to human health and environment vary greatly. According to Gallivan and others (2001), the health and environmental risk is a function of the toxicity of the pesticide and the level of exposure. Risk characterization defines the likelihood that humans or wildlife will be exposed to hazardous concentrations. For example, in the EU, the guideline limit for an individual pesticide in drinking water is 0.1 µg/l. The total limit for all pesticides is 0.5 µg/l (European Community 1998).

Not only in Finland, but also in Norway, Sweden, and Canada, the change from bareroot production to container seedling production has probably influenced

the risk of environmental contamination by forest nurseries. The production of bareroot seedlings is similar to agricultural production, and knowledge about the impact of agricultural operations can be used in evaluation of bareroot production. Production of container seedlings, on the other hand, is more like horticultural production.

Information about the impacts of forest nurseries is needed for the environmental management work of nurseries and for life-cycle analyses of wood products (fig. 1). This article is a short summary of studies carried out in the Finnish Forest Research Institute, Suonenjoki Research Station and nursery during the years 1995 to 1998. The main aims of these studies were to survey the environmental impact of forest seedling production by surveying the use of fertilizers and pesticides in Finnish forest nurseries and assessing how much is leached into the ground in production of container seedlings.

MATERIALS AND METHODS

Questionnaire-based Survey

Information about the actual systems and practices used by Finnish forest nurseries to grow seedlings and data on the use of fertilizers and pesticides were gathered in 1996 in a large questionnaire-based survey. The first part dealt with the number of

seedlings grown and the areas, equipment, and growing methods (Juntunen and Rikala 2001). In the second part of the questionnaire, more detailed questions were asked about cultivation practices and the schedule of the largest container seedling lots, for example sowing dates, period in the greenhouse, and dates of fertigation and fertilizer doses (Juntunen and Rikala 2001). For pesticides, such information as application dates, trademarks of the pesticides used and the doses used per hectare was collected (Juntunen 2001). In the third part of the questionnaire, the nurseries gave information about disease and insect problems in their nursery during the 1996 growing season (Juntunen 2000).

Leaching Studies

The leaching of N and P and 4 pesticides from peat growing medium in containers was monitored in commercial forest seedling production at Suonenjoki nursery in 1995 to 1998. The water percolated from container medium was collected with the same system in all experiments from May to October/ November. Sloped polystyrene plates (16 x 16 inch or 16 x 24 inch [40 x 40 cm or 40 x 60 cm]) equipped with a hole and a sampling vessel were placed under container trays (fig. 2). The trays were placed systematically among the commercial production stock. The volume, electrical conductivity (EC), and pH of leachates were measured daily (excluding

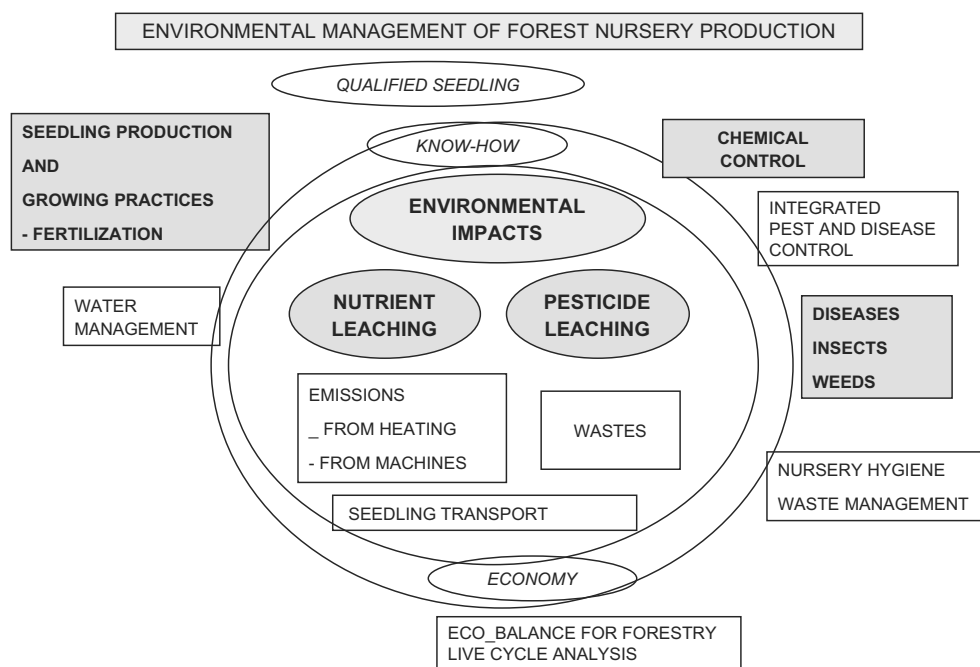


Figure 1. Environmental impact of forest tree nurseries and some influencing factors.



Figure 2. Leachate collector with plate and vessel. One-year old Norway spruce seedlings in Plantek 81F container tray. (Photographed by Pekka Voipio)

Saturday and Sunday) in 1995, and weekly in other years. The samples were stored frozen for 4 to 6 months until analyzed for nutrients or pesticides.

Soil water was collected using tension lysimeters (P80 ceramic cups). The lysimeters were installed at a depth of 1.6 ft (0.5 m) beneath 2 greenhouses in 1996 and 1997. The birch greenhouse included 16 lysimeters collecting water from 3 different points and the pine greenhouse another 16 lysimeters collecting water from 4 different points.

In the first study, the leaching of N and P from peat medium in containers into the ground and the nutrient uptake of seedlings were investigated in commercial production of Scots pine (*Pinus silvestris* L.), Norway spruce (*Picea abies* Karst.) and silver birch (*Betula pendula* Roth) (Juntunen and others 2003a).

In the second study, N and P leaching and uptake by container silver birch seedlings were measured when 2 different types of slow-release fertilizers were used in the commercial growing of seedlings (Juntunen and others 2003b). The source of N in the fertilizer “Vital Nursery” (“Taimiston Kestolannos” Kemira Corp., Finland) was methylene urea. Part of the P, K, and Mg was also in slow-release form; the source of these forms was apatite for P and biotite for K and Mg. The other fertilizer used in this study was Nutricote® T70 (Nichimen Corp, Japan). The N and

PO₄-P concentrations in soil water beneath the container area were also measured.

In the third study, possible leaching of pesticides, propiconazole (Tilt 250 EC®) and chlorothalonil (Bravo 500®), from peat growing medium into the ground was determined during commercial production of container Scots pine seedlings (Juntunen and Kitunen 2003). The concentrations of chlorothalonil in soil water beneath the container areas were also measured.

In the fourth study, the leaching of pesticides, triadimefon (Bayleton 25®) and (alpha-)cypermethrin (Ripcord® and Fastac®), was studied in container birch production, and only a part of this data has been published (Juntunen 2002).

RESULTS AND DISCUSSION

Use of Fertilizers and Pesticides

Per each shipped bareroot seedling, nurseries used about 8X more N, 5X more P and 4X more pesticides than used for each shipped container seedling. Most container seedlings were delivered for planting as 1-year-old seedlings, when most of the bareroot seedlings were 4-year-old seedlings. In Sweden, nurseries have applied even more nutrients to bareroot seedlings than in Finland (Nyström and others 2001).

The survey nurseries used 385,800 lb (175,000 kg) of fertilizer in 1996. More than half of that amount was used to grow 15 million shipped bareroot seedlings and the rest to grow 100 million shipped container seedlings. About half of the total amount of pesticides, 1460 lb (662 kg) ai, was used in bareroot production and the other half in container production. In Sweden, the southern nurseries produced more bareroot seedlings and used more pesticides compared to the northern nurseries, which mainly produced 1-year-old container seedlings (Hannerz and Nyström 2002).

During the last 20 years, the annual use of fertilizers in Finnish forest nurseries has decreased from about 1,763,700 to 441,000 lb (800,000 to 200,000 kg ai, and the use of pesticides from about 39,000 to 2200 lb (18,000 to 1,000 kg) ai. The main reason for the decrease has been the increased proportion of container production. In conclusion, an average Finnish nursery used much smaller amounts of nutrients and pesticides to grow the same number of seedlings at the beginning of the 2000s than at the beginning of the 1980s.

Great Variation among Nurseries in Use of Nutrients and Pesticides in Container Production

The amounts of N and P applied in fertigation varied greatly between nurseries (fig. 3). The nursery with the greatest use of fertilizers applied about 6X more N and P than the nursery with the smallest use of fertilizers. Often there were 1 or 2 nurseries that differed from most of the nurseries. Depending of tree species, the nurseries applied, on an annual average, 143 to 205 lb N/ac (160 to 230 kg N/ha) and 62 to 89 lb P/ac (70 to 100 kg P/ha), when the amount of nutrients applied in premixed fertilizer were included. Tree species had little influence on the mean amounts of nutrients premixed and fertigated per unit area. Because of the different growing densities, the mean amounts of N applied per seedling grown in a container were 145, 46, and 36 mg for 1-year-old birch, spruce and pine, respectively.

The Finnish survey nurseries used 7.5 lb (3.4 kg) ai pesticides per million shipped container seedlings and (32.4 lb (14.7 kg) ai per million shipped bareroot seedlings. The variation in pesticide use between individual nurseries was great. The Swedish studies have given the same result (Hannerz and Nyström 2002). The mean amounts of pesticide use were greatest for pine seedlings (8.5 lb/ac [9.5 kg/ha]) and smallest for spruce seedlings (0.8 lb/ac [0.9 kg/ha]). The largest number of products was used in growing

Scots pine seedlings. The number of pesticide applications was greatest, and the chemical control season was longest for growing pine. Scots pine, in particular, has many nursery diseases (Lilja 1986; Lilja and others 1997; Juntunen 2000).

The reasons for differences in fertilization and in chemical control cannot be analyzed in a survey study. The published data, however, give individual nurseries the possibility to compare their practices and the amounts of chemical applied with the amounts used in other nurseries and could thus provide the impetus for evaluation and development of growing practices.

Percolation of Water from Container Trays

In the Finnish system of container seedling production, the outdoor time was critical for amounts of leachate. Depending on tree species, a total of 1 to 7 inches (25 to 175 mm) water, that is 11% to 31% of the applied water (irrigation + precipitation), percolated from the trays. During the greenhouse period, percolation was < 10%. In the autumn, however, 50% to 70% of rainwater leached through the trays. During the greenhouse period, the water content of peat medium could be maintained inside the optimum level; but in August and later in autumn, when evapotranspiration decreased, the water content of peat medium increased permanently to high levels (fig. 4).

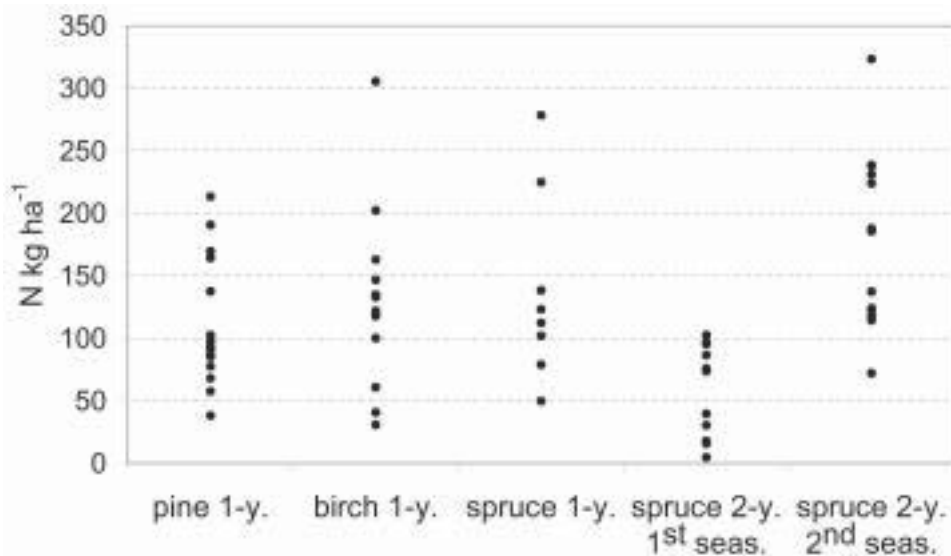


Figure 3. Amounts of nitrogen applied by nurseries to container seedlings in fertigation. Each dot represents one nursery.

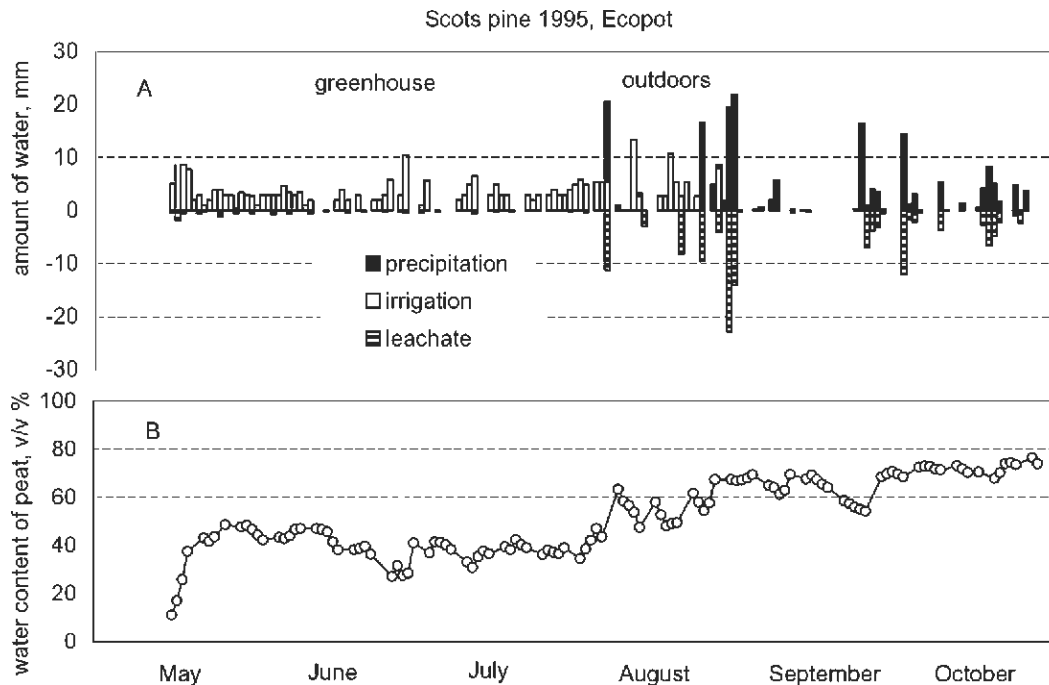


Figure 4. A) Amounts of water applied (irrigation + precipitation) and the amounts of leachate (mm) produced daily (excluding Saturday and Sunday) in production of container Scots pine seedlings in 1995; B) Water content of peat medium as a proportion of the peat volume in container trays.

The irrigation (fertigation) method used in Finnish forest nurseries was based originally on the studies of Puustjärvi (1977) and is discussed by Heiskanen (1993) and confirmed by Heiskanen (1995). According to their conclusions, the water availability and aeration are optimum for the growth of tree seedlings when the water content of the light *Sphagnum* peat medium in containers is at the level of 40% to 50% of the peat medium volume. Lamhamedi and others (2001) have also concluded that a water volume of 30% to 45% of peat-vermiculite (3:1 v:v) substrate volume in large containers (21 in³ [350 cm³]) is optimum for the growth of white spruce seedlings.

In Dumroese and others (1995), the amounts of discharged water were as large as 450 to 800 mm. The different irrigation (fertigation) methods could explain this difference. Dumroese and others (1995) irrigated according to recommendation of Landis and others (1989): "The key consideration in applying liquid fertilizers is to apply enough solution each time to completely saturate the growing medium profile and flush out excess fertilizer salts." The greater the leachate fraction is, the greater is the risk of nutrient contamination of the environment (McAvoy and others 1992).

Water management is an important means of controlling contamination of the environment, because water carries both nutrients and pesticides (Landis and others 1991). Water management includes 2 aspects: the reduction of the amounts of water discharged in seedling production, and the management of waste water.

Leaching of Nutrients

The annual leaching of N in the production of container forest tree seedlings (fig. 5) was not much greater than the mean losses of N, about 16 to 18 lb/ac (18 to 20 kg/ha), from Finnish agricultural fields (Rekolainen and others 1993). The P leached in substantially greater amounts (10 to 50 lb/ac [11 to 56 kg/ha]) than what had been measured from agricultural fields, which was 0.85 to 1.5 lb/ac (0.95 to 1.7 kg/ha) (Rekolainen and others 1997). Although the results for amounts of N and P leached are only from one nursery, it was fairly representative of most forest nurseries in Finland.

The premixing of fertilizer into the peat growing medium can increase the leaching risk of nutrients. When the nutrient content of peat is large at the beginning of seedling growth, the irrigation can

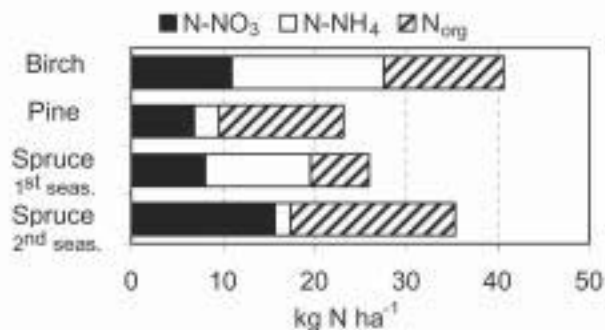


Figure 5. Leached amounts of $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$ and organic N by tree species in 1995.

cause nutrient leakage. In leaching studies, N in particular leached from birch containers in late May and early June, although about half of the N premixed into the peat was in slow-release form as methylene urea. On the basis of the leaching study, the use of slow-release fertilizers instead of fertilization used in Finnish nurseries does not necessarily diminish the leaching of N from containers into the ground in birch production.

About 50% to 90% of the N leached from conifer trays during July and August (during the fertigation period). The number of fertigations, 3 to 8 sessions during the growing season, was very low. The few fertigations must have caused high peaks in the nutrient content of the peat medium. When the nutrient content of peat is large, irrigation water and rain could leach nutrients. In 1995, for example, a heavy rainfall (0.4 inch [10 mm]) that occurred soon after 1 fertigation leached about one-third of the total N leached from the pine and second-season spruce container trays during the whole collection period.

The N leached in nitrate, ammonium, and organic N form from peat growing medium (fig. 5). The N forms, ammonium, urea, and methylene urea, premixed into the peat and applied with fertigations may explain the amounts of $\text{NH}_4\text{-N}$ in the leachates. Ammonium and organic N compounds can also increase the risk of groundwater contamination, since they can later be transformed to nitrate in the soil (Addiscott and others 1991; Colangelo and Brand 2001). Apparently $\text{NO}_3\text{-N}$ analyses are not enough; when the risk of contamination is evaluated, total N analyses are also needed.

Nutrient Load

In the production of container seedlings, the total nutrient load consists of the amounts of nutrients

leached from containers into the ground and fertigated directly into the ground alongside and between the seedling containers. Depending on the containers and their layout within the nursery, the amounts of nutrients leached may be smaller than the amounts of nutrients fertigated directly onto the ground.

In Finnish pine and spruce production, the container trays usually cover the whole production area; that is, the fertigation falls outside containers only around the blocks of container trays. In a greenhouse (164 ft x 36 ft = ~5900 ft² [50 m x 11 m = 550 m²]) the irrigation could overlap the area covered by container trays from 1.6 to 5 ft (0.5 to 1.5 m) (the middle aisle and sides), which means that from 10% to 20% of the nutrients are applied outside the seedlings. Based on the results from pine production in 1995, it could be estimated that fertigation outside seedlings and leaching were of the same magnitude (9 and 10 lb N/ac [17 and 18 kg N/ha], respectively).

In birch production, the situation is different because most nurseries placed the birch container trays about 8 inches (20 cm) from each other before fertigations started. Due to tray separation, the container trays covered only about half of the total irrigation area; that is, about half of the irrigation (fertigation) water fell outside the containers. Based on the leaching study in 1995, the load caused by fertigations was much greater, 78.5 lb N/ac (88 kg N/ha), than that caused by the amounts of N leached, 18 lb N/ac (20 kg N/ha).

When slow-release fertilizers were premixed to peat growing medium, no fertigations were given in birch production; that is, no nutrients were applied outside the container trays. The amounts of N that leached from container trays caused the total load.

Soil Water Beneath Pine and Birch Container Areas

The different lay-out of pine and birch containers in greenhouses, after birch containers were placed 8 inches (20 cm) apart at the end of June, influenced the leaching of water and nutrients in the soil beneath the containers.

In pine production, the small amounts of leachate, and complete container tray cover, caused a small hydrological load. From May to July, these leachates were less than 0.4 inch (10 mm) per month, and from August to October, less than 4 inches (100 mm) per month. In these conditions, the downstream flow of water beneath containers was small, which was noted in the amounts of water collected by lysimeters. In

1997, the lysimeters took up water poorly (only 6 cups total). In 1998, some water samples were collected when the soil above the lysimeters was watered twice artificially.

Beneath the birch container area, the situation was different. Separation of the containers increased the hydrological load. For example, in July the applied amount of water on the ground without container cover was 12 inches (300 mm), while the leached amount was only 2 inches (50 mm). The increased N load and irrigation volume increased both the water volumes collected by ceramic cups and the N concentration in soil water (fig. 6). The soil water contained nitrate and organic N compounds, but little ammonium ($\text{NH}_4\text{-N} < 1 \text{ mg/l}$). The concentrations of $\text{PO}_4\text{-P}$ were also less than 1 mg/l in all soil water samples.

Efficiency of Nutrient Use by Container Seedlings

The N and P content of seedlings varied from 15% to 63% of the applied N and from 5% to 33% of the applied P. The efficiency of N use by birch seedlings (63%) was slightly better than that of pine seedlings (42% to 52%). When spruce seedlings were grown for 2 years in the nursery, the efficiency of N use by first season seedlings (15%) was much lower than that of second-season seedlings (42%). Results for Swedish nurseries are similar (Hannerz and Rosenberg 2001).

The efficiency of N use by birch seedlings fertilized with slow-release fertilizer was lower (29% to 45%) than that of seedlings fertilized partly with liquid fertilizer (66% to 81%). One disadvantage of slow-release fertilizers is that the amounts of fertilizer applied have to be large enough to guarantee the desired growth of birch seedlings in Finnish growing conditions. However, the differences between fertilization systems were no longer so clear when the amounts of N fertigated outside the seedlings were included in the efficiency calculations. The efficiency of N use of fertigated seedlings dropped to 50% (1998) and to 60% (1997).

When efficiency is examined from the seedling standpoint, we measure how effectively a seedling has used nutrients applied to it. On the other hand, when we look upon efficiency from the production standpoint, we calculate how effectively the shipped crop has used applied nutrients. We have to take into consideration, for example, the amounts of nutrients applied outside the seedlings. Obviously the number of shipped seedlings is smaller than the number of

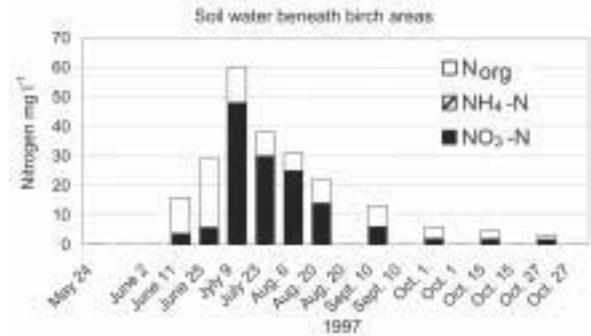


Figure 6. Total nitrogen concentration in soil waters beneath birch areas in 1997.

seedlings grown, which also influences the use of resources.

Determination of seedling nutrient content could be one means to develop fertilizer efficiency. However, with nutrient content of seedlings or the crop, only the potential risk of nutrient leaching can be estimated. On the basis of leaching studies, only a part of the amount of N and P, which the seedlings did not take up from applied N and P, leached from container medium.

Pesticides in Leachates and Soil Water

The seedling canopy and peat medium adsorbed pesticides effectively. During the growing period, less than 4% of the applied chlorothalonil, triadimefon, cypermethrin, and alpha-cypermethrin leached from the container trays. Propiconazole was an exception; almost 30% of applied amounts leached from Plantek containers in 1997.

The different water solubility of propiconazole and chlorothalonil, 100 and 0.9 mg/l (Tomlin 1997), respectively, could be a reason for the differences in amounts leached. Bruhn and Fry (1982) have shown that rainfall removed chlorothalonil from leaves of potatoes; the sooner after application the rainfall occurred, the greater was the removal. Because of the higher water solubility of propiconazole, removal of propiconazole from needles could have been even greater than that of chlorothalonil.

When pesticides passed through the seedling canopy and peat medium, the concentrations of pesticide were thoroughly diluted. The concentrations in application solutions were from 300 to 2500 mg/l, but the mean weekly concentrations in leachates were usually less than 100 µg/l. The fluctuation was

typical for the concentrations; concentrations were usually highest after application and decreased before a new application. Repeated applications did not increase pesticide concentrations in the leachates. During 1997 to 1998, chlorothalonil was analyzed from 18 soil water samples. The chlorothalonil concentration of 4 samples exceeded the limit of detection, 0.1 µg/l in 1998. The highest measured value was 2.4 µg/l.

In addition to processes on needles and shoots, the processes in peat medium are obvious causes of the small amounts of pesticides leached. Because triadimenol, the degradation product of triadimefon, was the only degradation product measured, it is impossible to know whether the reason for the small amount of leaching was adsorption of pesticides to peat and/or pesticide degradation to their metabolites.

SUMMARY

Regardless of the small production area used for producing container tree seedlings compared to the area used for agriculture, forest nurseries may also be a risk for contamination of ground water, especially if the area used for seedling production is located on a ground water reservoir. In addition, 2 aspects connected with production of tree seedlings in containers may increase the risk: the same type of production continuing at the same place for years and most of the annual nutrient leaching occurring during 1 or 2 months. If a nursery locates near surface water bodies, P and pesticides toxic to aquatic animals in runoff water could also be a risk.

It is important to determine the amount of nutrients that fall outside seedlings during fertigations of container seedlings. If the fertigation area without seedlings is large compared to the area covered by seedling containers, it is important to try to minimize this area. Some solutions could be the use of mobile boom sprayers instead of sprinklers, and improving the lay-out of irrigation systems and/or container trays.

The use of slow-release fertilizer could be one solution. However, this option includes uncertainties. Obviously, to get the desired growth of seedlings, large amounts of fertilizers have to be used in Finnish growing conditions. The risk for leaching of nutrients is high at the beginning of the growing period when the nutrient content of the growing medium is high and the uptake by seedlings is low. Indeed, the slow-release fertilizers include a large group of products with different properties, which means that the results concerning a product might not be valid for other products.

The seedling canopy and the peat medium in containers effectively adsorbed the pesticides studied when seedlings were grown in containers. The container type and the active ingredient, however, influenced the amounts of active ingredient leached through containers. More studies with different pesticides used on different seedlings and growing media are needed before it will be possible to say with certainty that the container production of forest seedlings has decreased the contamination risk of environment caused by pesticides.

In Finland, about half of the herbicides were used in areas without seedlings. Weed control in all adjacent areas is important because they serve as a source of weeds both in outdoor areas and in containers (Juntunen 2000). However, outdoor areas and edges are places where the risk of herbicide leaching may be high, possibly due to the low organic matter content of the soil. Although the nurseries already use textiles to cover the empty spaces between containers, solutions other than chemical control for preventing the growth of weeds on sites without seedlings would be most welcome.

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ASSIMILATION LIGHTING FOR GREENHOUSES

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Key Words

Photosynthesis, light sources, measuring light, photoperiodism, lighting system selection

Visible light provides the source of energy for plant growth. Considerable intensity and duration are needed to get good plant growth. That is why plants grow better during the summer when the light is stronger and the days, longer.

Visible light is a composite of wavelengths from violet to red (380 to 780 nanometers [nm]). Light with wavelengths below 400 nm is called ultraviolet and can be harmful to plants in large quantities. Far-red light (700 to 750 nm) in combination with red light controls germination and, in combination with blue light, keeps plants from becoming too short or tall.

Sunlight is adequate for plant growth in most sections of the US for most of the year. In late fall, winter and early spring, short days and cloudy weather may limit the amount of light available. A rule of thumb states, “1% reduction in light results in 1% reduction in growth.” Structural design, glazing materials, orientation of the greenhouse and other factors have a significant influence.

Supplemental lighting is used to:

1. Maintain optimum growth and get uniform crops (photosynthesis).
2. Regulate germination, rooting growth, stem elongation and flowering (photomorphogenesis).
3. Vary the day length to keep tree seedlings from going dormant (photoperiodism).

PHOTOSYNTHESIS

With light as the energy source, carbon dioxide, and water are combined to give carbohydrates and oxygen. The carbohydrates are then translocated to various parts of the plant and transformed into other compounds for growth or maintenance.

Most plants can only utilize a limited amount of light called the saturation level. For example, the saturation levels for various species are: white oak – 1400 foot-candles (fc); northern red oak – 3300 fc; Douglas-fir – 3000 fc; Sitka spruce – 3000 fc; western hemlock – 3000 fc; loblolly pine – 9300 fc; and ponderosa pine – 11,100 fc. To get this level to the lower parts of the plant or for seedlings that are spaced closely together, levels 2X to 3X more may be needed.

LIGHT SOURCES

While almost any light source can be used for photosynthesis, some are much more efficient. Knowledge of the light source’s construction, efficiency, and electrical characteristics is useful in making the best choice for plant lighting.

Incandescent

The standard incandescent bulb is used mainly for daylength control. Its short life and low light output per watt of electricity input have limited its use. Efficiency: 10 to 20 lumens/watt.

Fluorescent

These bulbs are commonly used in growth rooms where more uniform lighting is needed. Lamp life is about 12,000 hours. For most horticultural applications, cool white or warm white bulbs will give good growth. With special design, banks of lights can provide up to 2000 fc. Efficiency: 30 to 75 lumens/watt.

High-intensity Discharge (HID)

This is the standard bulb for photosynthetic lighting in greenhouses today. Lamps contain a mixture of

gases and metals enclosed within a glass tube. As electricity passes between the electrodes at the ends of the tube, the gas/metal mixture heats up and emits light. Bulbs are available from 75 to 1000 watts. Lamp life is 24,000 hours. Efficiency: 80 to 120 lumens/watt.

HID lamps can be either high pressure sodium (yellow light) or metal halide (white light). Sometimes a combination of both types of bulbs is installed to give a more uniform spectrum.

Reflectors are used to direct the light toward the plants. When selecting a reflector, look for uniform distribution of the light at plant level and highly polished surfaces that keep dirt accumulation to a minimum and diffuse the light. Contact the manufacturer to get a computer analysis of the best height, spacing, and location for fixtures. This usually results in more fixtures being required at the edges of the growing area than in the middle.

MEASURING LIGHT

Light can be measured in photometric or quantum units. Photometric units (foot-candles) have been the standard for many years and most printed recommendations use these units. Measurement is made with a low-cost foot-candle meter similar to a light meter on a camera. Typical greenhouse supplemental lighting levels for tree seedlings might be in the 600 to 900 fc range. Germination/growth room levels may be in the 1000 to 2000 fc range.

Quantum units [(micromoles of photons/m² · s)] more accurately represent what the plant sees. Most current research is being reported in these units. Photosynthetically active radiation (PAR) is a measure of quantum units in the 400 to 700 nm range utilized by plants. A PAR meter is used. The above typical greenhouse readings in fc would convert to 79 to 118 μmol/(m² · s) if high-pressure sodium bulbs are used. Other types of bulbs have different conversion factors.

Light measurement can be made as an instantaneous reading or can be integrated and accumulated over a day. Instantaneous readings are good to establish the level at which supplemental lighting can provide, and its uniformity. But it is the total light integral, the sum of the sunlight plus the artificial light that the plants receive, that is important. On a cloudy day, more supplemental light is needed than on a sunny day to provide the plant requirements. The total light integral is made by placing a PAR sensor at the top of the plant canopy and connecting it to a computer that does the integration. The computer software

makes the decision on when to turn on the supplemental lights. It may also include evaluating the cost of electricity at different times of the day.

SUPPLEMENTAL LIGHTING SYSTEM SELECTION

Several factors should be considered before purchasing supplemental lighting equipment.

Light intensity. Determine what level of supplemental light is needed on the darkest day to make up the total light integral the plants need. Don't install more than is needed.

Distribution. Select and locate fixtures so that they create the least amount of shadow. Location under trusses or retracted curtains reduces the amount of shading.

Uniformity. Check light intensity uniformity once lamps are installed.

Cost of operation. Supplemental lighting should not be operated more than is needed. Utilize off-peak electricity rates and long term purchase power agreements where available.

Maintenance. Develop a lamp replacement schedule and reflector cleaning program.

PHOTOPERIODISM

Photoperiodism is the response of plants to the day-night cycle. It can affect flowering, tuber and bulb formation, the shape of newly forming leaves, red pigmentation in bracts of plants, and dormancy in tree seedlings. Photoperiod can be extended by providing continuous light, either after sunset or before sunrise, or by interrupting the dark period with intermittent lighting. Light intensity needed varies with species from about 5 to 30 fc. The light source should have some red spectrum in it.

With intermittent lighting, the duration of the light during the dark period must also be controlled. A dark period no longer than 30 minutes and a light period of 1 to 2 minutes works well on most plants.

Intermittent lighting can be provided with incandescent bulbs connected to a power line stretched over the growing area. Reflectors will distribute the light over the bench. A new light source, Beamflicker, (Hydrofarm Inc, Petaluma, California) utilizing a 400 or 600 watt sodium vapor bulb with an oscillating reflector has been developed and is being tested. One 400 watt fixture will provide a minimum 10 fc to a 30 x 100 foot greenhouse. This unit is much less expensive to install and operate than incandescent bulbs.

COPPER-COATED CONTAINERS AND THEIR IMPACT ON THE ENVIRONMENT

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Abstract

The following statements and information address public concerns about copper in the environment. They are based on many years of research on the use of copper in agriculture and aquatic weed management and its impact on the environment.

Key Words

Spin-Out[®], fixed copper, elemental copper, copper toxicity

WHAT IS COPPER?

Copper (Cu) is a pliable, malleable metal having a bright reddish metallic luster. It is an excellent conductor of electricity and heat. Copper occurs naturally in a wide range of mineral deposits and is present in many forms in our daily lives. Copper is an essential micronutrient required for growth in both plants and animals. In humans, it helps in the production of blood hemoglobin. Unlike copper, heavy metals like lead, cadmium, arsenic, and mercury are not involved in biological systems and can be very toxic to plants and animals.

COPPER IN OUR LIVES...

Copper is present in many forms in our everyday lives including money in our pocket, kitchen cookware, water pipes, jewelry, electrical wiring, decorative arts, and construction materials. What separates these things from what is used in agriculture to control plant disease, aquatic weeds, root development, wood preservatives, and antifouling marine paints is the form of copper and its biological activity. Copper fungicides and paints only contain a small portion of biologically active copper and the remainder is referred to as “fixed copper”. The “fixed copper” particles provide a reservoir of copper ions for residual disease and pest control. The first copper fungicide was Bordeaux mixture, developed in France in the 1880s to control grape diseases.

COPPER IS ELEMENTAL

Copper is an element and does not break down. When elemental copper is present in the environment it is not biologically active. The only form that is active is ionic Cu^{+2} . Copper in the ionic form quickly complexes with organic matter in the soil and container substrates, rendering it biologically inactive. Fixed copper salts used for root control, like copper hydroxide, release active copper ions over a long period of time. These are quickly made biologically inactive upon contact with soil or container substrates.

COPPER IS TOXIC TO PLANTS

Copper can be toxic to roots when readily available for uptake. The mode of action for copper treated containers is the controlled-release of copper ions along the container-substrate interface, where Cu ions inhibit root elongation at the root tip. The root inhibition is localized to the root tip, and very little to no excess copper is translocated to other plant parts. Copper treated pots do not affect rhizomes; the effect is very specific to root tips.

COPPER LEACHES

Statements like “Huge quantities of copper leach from treated containers into surrounding soil...” are not true. This is definitely not true for Spin Out[®]-coated plastic pots and has not been shown to be an issue for pots and trays made using other technologies or coated with other forms of copper.

Copper hydroxide in the Spin Out® coating is encapsulated in a latex matrix and is very resistant to leaching and dislodging by rain and irrigation.

COPPER IN THE SOIL

Copper is present in most soils at levels less than 100 ppm. However, this is total copper. Biologically active copper is in the ppb range at pH 7. For all this copper to be available, the soil pH would need to be below 3.0, which does not favor plant growth. In the pH range of 5.5 to 8.0, 99.99% of the total copper is not available to plants for uptake by the roots. Nurseries concerned about runoff, such as those that grow forest seedlings in treated containers, can prevent any potential movement of copper from the production area by applying agricultural lime to the soil under benches. Raising the soil pH to 6.5 to 7.0 will tie up any soluble copper. This is a common practice where copper fungicides are routinely used on perennial crops, like citrus, grapes, and walnuts. Very high levels of copper (>450 lb/ac [>500 kg/hectare]) can be tolerated by most plants as long as soils are not in the acid range. Soils with high cation exchange capacity are able to bind much more copper than sandy soils with a low CEC.

COPPER CAN RESTRICT GROWTH

Yes, excess available copper can restrict plant growth. However, the copper used to control root growth is limited to the container-substrate interface. Copper ions do not leach throughout the soil media. Free copper ions are either absorbed by root tips or bound by the media. Research has shown that elevated copper levels are confined to the root tip and are not translocated to stems, leaves, and fruit of most species. Residue studies on fruit crops have also shown no change in copper between plants grown in copper-coated and nontreated pots. Certain plant species have been identified as able to absorb and accumulate excess copper. However, these are an exception.

COPPER CAN HAMPER NUTRIENT UPTAKE

Excess copper can result in a condition known as copper-induced iron chlorosis. This is caused by the competition of iron and copper, which are both absorbed as divalent ions. When using copper coated pots, this condition is most common where there is a high ratio of container surface area to substrate volume, such as containers used to grow forestry seedlings, bedding plants, or plugs. The condition is rare with the use of pretreated containers because the

coating has been formulated to minimize this effect. If the condition occurs, it can easily be corrected with an application of a chelated iron fertilizer. Nutrient uptake for some species is related to mycorrhizal colonization of the roots. Copper treated pots do not kill mycorrhizal fungi (fig. 1). Three published studies show enhancement of mycorrhizal colonization of seedlings grown in treated pots due to an increase in the number of fine roots. Studies also show that *Trichoderma*, used to reduce root diseases, is not adversely affected by copper-treated pots.

COPPER STUNTS SOME SPECIES

Of the numerous university and grower trials, there are only a few cases where copper treated pots have caused any significant reduction in plant growth. In general, growers that have used copper treated pots are very satisfied with the performance. Not all plant species react the same to treated pots, which is why extensive research has been conducted in the last 12 years. Even species showing a slight reduction in growth may benefit from an improved root to shoot ratio when transplanted. Applying the copper coating at the correct rate is important to avoid excess root control and nutrient imbalance. Plants can become stunted if left in containers too long before transplanting. Unfavorable results published in the 1970s were most likely due to mixing copper salts in house paint. Today, pots are treated with products specifically formulated and EPA registered for root control.

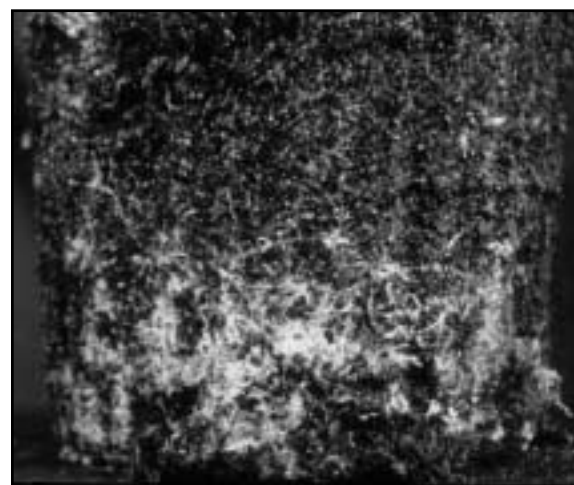


Figure 1. Mycorrhizal growth on oak roots in a copper-treated container.

COPPER COATING WORKS PRIMARILY WITH FIBROUS ROOT SYSTEMS

The benefits of root branching have been demonstrated on numerous tap-rooted species like oaks, bald cypress, and ash. Air root pruning has been practiced on many of these species when grown in containers. However, copper coated containers are equally effective when used in conjunction with timely transplanting. On many species of trees and shrubs, the benefits of using copper coated pots are numerous, including improved root structure, improved utilization of soil media and fertilizer, much easier removal from the pot at transplanting, significantly more root tips for regeneration and a reduction in shock and disease due to mechanical root pruning of root bound trees and shrubs. However, it is important not to substitute the use of treated containers for timely transplanting into larger containers or the field.

The use of copper-coated pots has evolved from hand painting a few pots or trays with copper salts mixed in house paint to pots pretreated with formulated coatings at uniform rates using precision spray equipment to provide better root systems. Years of research in the US, Canada, Europe, Asia, and Australia have demonstrated the benefits on plants grown in treated containers. All this research has demonstrated the benefits to growers and the benign environmental effects to government regulators. There are many ways to improve root growth of container-grown plants and no one way is the magic bullet. Using proven methods of root modification should be encouraged so nursery growers will provide a better product to the professional landscapers, arborists, foresters, and the gardening public.

COPPER HYDROXIDE ECOLOGICAL INFORMATION

Ecotoxicity

Bluegill fish: LC₅₀ 180,000 ppb

Fathead minnow: LC₅₀ 23 ppb

Rainbow trout: LC₅₀ 23 ppb

Bobwhite quail: Acute oral LD₅₀ >340 mg/kg

Bobwhite quail: 8 day dietary LD₅₀ >10,000 mg/kg

Mallard duck: 8 day dietary LD₅₀ >10,000 mg/kg

Honeybee: Non-toxic

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PHYTOTOXICITY WITH METAM SODIUM

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Abstract

At Lawyer Nursery in Olympia, Washington, we fall-fumigated fallow nursery ground with Vapam® and Telone™ II and Vapam® and Telone™ C-17 from 1998 through 2001. This fumigation provided excellent results when hardwood and conifer seedlings were sown into the treated areas the following spring. Seedling crops were larger and suffered less mortality than crops sown into unfumigated ground. The fall 2001 fumigation, however, resulted in significant damage to established *Pinus* crops growing adjacent to and up to 400 feet (120 m) from the fumigation area as a result of MITC escaping from the soil into the atmosphere.

Key Words

Bareroot nursery, alternatives to methyl bromide

INTRODUCTION

Lawyer Nursery Inc, of Plains, Montana, established itself on the West Coast in 1988 when the company purchased a 120-acre nursery site in Olympia, Washington. This property was developed as a forest nursery in 1970 and operated by an industrial forest seedling producer until 1985. In 1991, the company purchased an additional 55 acres (22 hectares) adjacent to the nursery. Lawyer Nursery currently produces an annual crop of 7 to 8 million bareroot seedlings and transplants on the 175-acre (70-hectare) nursery site. Lawyer Nursery in Olympia grows approximately 300 species of seed propagated woody trees and shrubs for a number of markets, including ornamentals, conservation, forestry, Christmas trees, commercial orchards, and so on.

This discussion will document soil fumigation experience at Lawyer Nursery in Olympia and evaluate the effectiveness and phytotoxicity of the chemical fumigant Vapam® HL.

DISCUSSION

When I came to the nursery in 1989, my recent nursery background was in forestry seedling and Christmas tree production. At that time, periodic soil fumigation with methyl bromide/chloropicrin (MBC) was a standard practice in the industry. I utilized this technology in the fall of 1991 through 1993. We achieved typical results with the MBC fumigation in

terms of reduced seedbed mortality and excellent weed control, but we struggled with stunted 1+0 conifers, which we attributed to mycorrhizal starvation. In 1994, we sowed a fumigated field with several species of *Acer*. The subsequent poor growth was so dramatic that we discontinued the use of MBC for soil fumigation. This response of *Acer*, thought to be associated with the loss of beneficial mycorrhizae, was reported by Regan in 1996. Many hardwood trees, including *Acer*, associate themselves with endomycorrhizal fungi, which have spores that are only soil borne. This means that re-inoculation can be a slow process if fumigation damages endomycorrhizal fungi (Davey 1994). For the next several years, we utilized crop rotation and post plant fungicide applications to control soilborne pathogens in our seedbeds. We considered soil pathogens to be a much less formidable obstacle to seedling production than the lack of beneficial mycorrhizal fungi.

Interest in alternative chemical fumigants to MBC was studied as early as 1986 (McElroy 1986) because of the relatively high application cost of MBC, the fear of regulatory intervention, and the acute toxicity of MBC. Two chemicals, metam sodium (Soil Prep, Vapam®, Metam™, Nemasoll) and dazomet (Basamid®) were evaluated in 1985 (Campbell and Kelpas 1986) and were found to perform as well as MBC in terms of seedling survival and growth. When MBC was listed as a potential ozone depleter in November of 1992 and assigned a phase-out

schedule by the EPA, more studies on alternative fumigation chemicals were undertaken in the South (Carey 1994).

In 1998, Lawyer Nursery participated in a small soil fumigation trial comparing Vapam[®], Vapam[®] and Telone[™] II, Telone[™] C-17, and Telone[™] C-35. Telone[™] C-17 is a combination of Telone[™] (1-3-dichloropropene) and 17% chloropicrin and Telone[™] C-35 is a combination of Telone[™] and 35% chloropicrin (Dow AgroSciences 1999). This 4-acre trial was done in the fall of the year and the following spring the area was sown with several species of deciduous and conifer crops. The performance of crops sown into fumigated ground in 1999 was quite dramatic in terms of increased seedling size and reduced seedbed mortality in the Vapam[®]/Telone[™] II plot compared to the non-fumigated control. Seedling performance in the Telone[™] C-17 and Telone[™] C-35 plots was better than the unfumigated control, but not as good as the Vapam[®] plot. It was my feeling that Vapam[®] reduced soil pathogens without eliminating beneficial mycorrhizal fungi. Based on results of this trial, we hired a contractor to treat 13 acres (5.3 hectares) with Vapam[®]/Telone[™] II in 1999. The rates were 30 gal/ac (272 l/ha) for Vapam[®] and 24 gal/ac (224 l/ha) for Telone[™] II.

We spring sowed both deciduous and conifer crops into the fall 1999 fumigated soil and the results were again very promising. Seedlings in the fumigated soil sized up better and we noticed less seedbed mortality in fumigated areas compared with seedling crops in non-fumigated areas. In fall 2000, we increased the Vapam[®] rate to 60 gal/ac (560 l/ha) in an effort to improve weed control. We fumigated 18 acres (7.3 hectares) that year with Vapam[®] and Telone[™]; the Telone[™] rate remained at 24 gal/ac (224 l/ha). The

performance of seedlings planted into fields fumigated in fall 2000 was again very dramatic. We continued to see good size and reduced seedbed mortality.

Weed control, however, was erratic. In some fumigated areas, the population of weed seeds was significantly reduced while in others we did not see any significant reduction in the number of weeds. In 2001, we decided to use the combination of Vapam[®] at 60 gal/ac (560 l/ha) and Telone[™] C-17 at 23 gal/ac (215 l/ha) instead of Telone[™] II. We fumigated 28 acres (11.3 hectares) in the fall of 2001. Seedbeds in the fumigated areas continued to show the same results we had seen the previous 2 growing seasons in fumigated soil.

In 2002, we sampled soil in deciduous 1+0 seedbeds 10 months after fumigation to see if a soil pathogen assay would confirm what we saw when we visually compared crops in fumigated soil with similar crops sown in non-fumigated soil. These results are summarized in table 1 and they confirm that Vapam[®] is effective at reducing the levels of *Pithium* and *Fusarium*. It is my feeling that Vapam[®] reduces pathogen levels without severely impacting mycorrhizal fungi levels and this is what made this material so appealing to Lawyer Nursery. I do not have data other than crop performance to support this hypothesis.

Weed control with Vapam[®] continued to be erratic; in some areas the chemical had reasonable efficacy on weed seeds while in others we saw little, if any, affect on weed control.

Vapam[®] HL, or metam sodium (4.26 lb ai/gal [0.5 kg ai/l]) is a dithiocarbamate aqueous sodium salt. The Stauffer Chemical Company first patented Vapam[®] in 1956 (Herbicide Handbook 2002). Fumigation of soil with metam sodium was discovered in 1950 and

Table 1. Soil pathogen levels detected 10 months after soil fumigation.

	<i>Phytophthora</i>	<i>Pythium</i>	<i>Fusarium</i>
	----- propagules per gram of soil -----		
Fumigated soil <i>Acer rubrum</i> 1+0	0	80 (vl)	880 (h)
Non-fumigated soil <i>Acer circinatum</i> 1+0	0	410 (h)	2000 (vh)

(vl) = very low numbers of propagules of the pathogen isolated per gram of soil sample
(h) = high numbers of propagules isolated
(vh) = very high numbers of propagules isolated

Soil fumigation, 9-27-01, Vapam[®]/ Telone[™] C17
Pathogen assay, 7-27-02, Ribeiro Plant Lab, Inc
Soil samples were taken from 1+0 seedbeds.

it was reported as early as 1962 as a soil fumigant in a forest nursery (Hodges 1962). Metam sodium is considered to be a methylisothiocyanate (MITC) generator because it is quickly broken down in moist soil to MITC. MITC is toxic to nematodes, fungi, bacteria, and insects in the soil (Herbicide Handbook 2002). This chemical gained some notoriety outside of the nursery industry in July of 1991 when a train derailment in northern California resulted in the spill of approximately 13,000 gallons of Vapam[®] into the upper Sacramento River. This spill killed virtually all of the aquatic life in 40 miles of river; from the site of the spill to where the river empties into the Shasta Reservoir (Fechner-Levy 1991).

No phytotoxicity to crops as a result of Vapam[®] fumigation was noted at Lawyer Nursery in 1998 or 1999. In spring 2000, a strawberry grower in Olympia treated a portion of his farm that is adjacent to the nursery with Vapam[®]. The rotovate and roll application is a standard procedure for this grower and several days after the application I noticed some needle burn on approximately 100 *Pinus monticola* 2+1 transplants. This was in early spring prior to bud break and the cause of the needle necrosis was not readily apparent to me. This bed of transplants ran perpendicular to the neighbor's fumigation path and the end of the bed was within 50 feet (15 m) of the Vapam[®] application. A significant number of trees at this end of the bed were affected and the concentration of affected crop declined in the bed as the distance from the fumigation increased. We sent samples of these affected trees to WSU Puyallup and they noted no pathogens or insects that could be attributed to causing the needle necrosis, so we concluded that *P. monticola* had some degree of sensitivity to Vapam[®]. The percentage of the crop affected was insignificant and the trees broke bud and looked fine later in the growing season, so we did not give the matter much additional thought.

In fall 2000, I discussed the *Pinus* phytotoxicity incident of the previous spring with the fumigation contractor and, because the areas that had been designated for fumigation were not near *Pinus* crops, we proceeded as we had the previous year. The application method utilized by the contractor was to inject a portion of the Vapam[®] at a depth of 6 to 9 inches (15 to 23 cm) and spray a portion of the Vapam[®] on the soil surface. Just behind the surface nozzles was a cultipacker which pushed a berm of soil over the treated surface soil, thus rolling the Vapam[®] under the soil surface and sealing the surface with the cultipacker. The label suggests that light watering or a tarp after rolling helps prevent gas escape (AMVAC

1997). The Telone[™] C-17 was injected at a greater depth with a separate tractor. We did not see any phytotoxicity in the nursery in 2000 following the Vapam[®] fumigation.

In fall 2001, we did have some *P. monticola* transplants growing in close proximity to the areas we had designated for fumigation. We discussed this with the fumigation contractor and the decision was made to inject all of the Vapam[®] at depths of 3 and 9 inches (8 and 23 cm). Again, a cultipacker behind the application shanks sealed the soil.

The 2001 fumigation was done on 26, 27, and 29 September. I was away from the nursery during the week following the fumigation application and when I returned to the nursery, I was advised by staff that a number of conifer crops adjacent to the fumigated areas were showing signs of distress. When I inspected the crops on 8 October 2001, I discovered that a significant number of *Pinus* and some *Picea* crops were exhibiting signs of Vapam[®] injury. These symptoms are discolored needles that appear "bleached out". In some trees, only a portion of the needles showed this affect, and in others, every needle on the tree was affected. In all, 13 species of *Pinus* and 6 species of *Picea* were affected. In some crops, only sporadic individual trees were affected and in other crops, as many as 90% of the population was affected. Of the damaged *Pinus* crops, 6 of 13 affected species suffered damage to over 40% of the population. The damage to *Picea* crops exceeded 4% in only 1 of the 6 species that were affected. Most of the damaged trees were within 50 feet (15 m) of the fumigated areas, but one crop of *Pinus banksiana*, which sustained considerable damage, was over 400 feet (120 m) from the source of the chemical.



Figure 1. 2+2 *Pinus strobus* transplant stock (center) shows bleached out needles following fumigation of fallow field (right) with Vapam[®].

It appeared that the MITC emerged from the soil and was held close to the soil surface either by an inversion or a very still air event. This type of condition is not uncommon during late September and early October in Olympia, as the days are generally warm with cool, calm nights. The unaffected portions of crops that suffered heavy damages were in areas such as the ends of beds, which were slightly elevated from the rest of the crop.

The Washington State Department of Agriculture investigated the incident to determine if the application was within the guidelines of the product label. The Department speculated that, "Some escape of fumigant is almost unpreventable unless the soil is tarped immediately after the application." The investigator also stated in the report, "I believe in this particular case, the applicator could have followed all the label directions and still caused the damage" (WSDA 2001). The Department concluded that the application was in compliance with the Vapam® label.

Similar damage to *Pinus* crops as a result of metam sodium or dazomet have been reported previously on at least 4 occasions. In fall 1988, *Pinus monticola* seedlings were damaged at the J Herbert Stone Nursery in Central Point, Oregon, as a result of fumigation with dazomet (Basamid®) (Scholtes 1989). Dazomet is also considered a MITC generator, as the immediate breakdown product of dazomet is also methylisothiocyanate (Landis and Campbell 1989). In this case, an untarped application of dazomet coupled with an inversion layer caused damage to non-target crop (*Pinus monticola*) seedlings. Unfortunately I did not read the published report of this incident until after the 2001 fumigation at Lawyer Nursery. More recently, in November 1999, an International Paper Nursery in Texas lost 20 million seedlings after fumigation with a mixture of Sectagon® (metam sodium) and chloropicrin (Peoples 2001). A similar, but less severe incident in terms of numbers of damaged seedlings occurred at the Mississippi State Nursery in fall 1999. Another crop injury incident involving metam sodium damage to *Pinus* seedlings occurred at the Arkansas State Nursery about 10 years ago (Carey 2002).

CONCLUSION

The reported incidents of phytotoxicity to crop seedlings as a result of metam sodium or dazomet fumigation would indicate that certain conifer trees, particularly those of the genus *Pinus*, are very sensitive to MITC exposure. Based on our experience, *Pinus* foliage is significantly more sensitive to MITC

than any of the other 300 species of woody trees that we grow. Of the more than 78,000 trees that were damaged at Lawyer Nursery, over 95% were pines. Had I researched Vapam® prior to using this chemical in the nursery as thoroughly as I did to prepare this paper, I would probably have still used the material and been able to do so without damaging non-target crops.

I think it is safe to speculate that while not all nursery managers read the entire nursery meeting proceedings every year, they do read the product labels for pesticides they use. It is my feeling that the pesticide label is the most efficient place to publicize known risks to crops that may result from the application of a particular pesticide. Certainly there are risks of crop injury associated with many pesticides used by nursery growers. In the case of Vapam®, there are a number of precautions that could be taken to minimize or eliminate the risk of crop injury. These would include not using the chemical within 400 feet (120 m) of *Pinus* seedlings, and sealing the chemical in the soil more effectively with irrigation water or a tarp. It is my feeling that Vapam® offers nursery growers an additional tool to reduce the impact of soil borne pathogens on bareroot nursery crops. If known risk associated with use of this product, such as the documented sensitivity of *Pinus* seedlings, was identified on the product label, the effectiveness of this tool in the nursery would be much improved.

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ECOPHYSIOLOGICAL RESPONSE OF DOUGLAS-FIR SEEDLINGS TO POLYMER-COATED FERTILIZERS

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Abstract

Application of polymer-coated controlled-release fertilizers (CRF) during outplanting has resulted in variable growth responses in the Pacific Northwest (PNW). Results have been linked to several factors, including soil moisture availability. Multiple experiments were designed to examine the influence of CRF on Douglas-fir seedling root architectural development and establishment. Placement of CRF as a uniform layer beneath transplanted seedlings restricted root penetration at progressively higher CRF rates and this was attributed to damaging rhizosphere osmotic concentrations. Dry summers on many sites in the PNW may compound this effect because moisture to leach excess fertilizer salts from the root zone is absent. Application of 2.1 oz (60 g) CRF to the planting hole on a droughty site in the Oregon Coast Range impaired seedling root development and increased plant moisture stress. For all treatments, new root growth was positively correlated with xylem water potential, emphasizing the need for vigorous root growth during establishment. Drought stress may limit photosynthetic capacity and force seedlings to expend stored carbohydrates, which may impair whole-plant growth. On drought-prone sites in the PNW, negative fertilizer responses may be avoided with conservative polymer-coated CRF application rates, utilizing CRF with moisture-dependent nutrient release characteristics, or avoiding field fertilization entirely.

Key Words

Nutrient leaching, fertilizer efficiency, plantations, forest regeneration, *Pseudotsuga menziesii*, electrical conductivity

INTRODUCTION

Field foresters in the Pacific Northwest (PNW) are no longer concerned with simply getting good survival following planting. The ability of newly-planted seedlings to rapidly establish within a new environment and grow vigorously during the first several years is of principle concern. Recently, there has been a great deal of interest in using controlled-release fertilizers (CRF) in both the nursery and field to enhance reforestation productivity (Haase and Rose 1997). Both positive and negative results associated with using CRF at outplanting can be identified in the literature. Attaining a positive seedling growth response with CRF appears to depend on a complex interaction of factors, including the technology associated with controlling nutrient

release, plant material (that is, species, stocktype, age, and so on), and planting environment. These fertilizers offer a means to improve reforestation success dramatically; but an inadequate understanding of the proper use of this technology may result in plantation failures.

This paper provides a synthesis of some relevant findings associated with recent research conducted by the Nursery Technology Cooperative (NTC) at Oregon State University with CRF and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings. These results were presented in greater detail in Jacobs (2001). The objectives of this paper are to: 1) provide a brief overview of the technology associated with nutrient release in polymer-coated CRF; 2) discuss the influence of polymer-coated

CRF on Douglas-fir seedling root development; 3) explain the importance of soil electrical conductivity to root growth; 4) describe how changes in root growth associated with CRF may affect field performance; and 5) provide implications for reforestation programs in the PNW.

POLYMER-COATED CRF TECHNOLOGY

There are many different types of CRF on the market today. These fertilizers are generally distinguished from fertilizers with immediately-available forms of nutrients (for example, Peters[®] water soluble or urea) and from each other by their mode of nutrient release. Whereas immediately-available fertilizers release nearly all nutrients soon after application, nutrients from CRF are released slowly over a time period of up to 24 months following application. A primary advantage is that with a single application, seedlings may receive enhanced nutrient levels for up to 2 growing seasons. The slow-release nature of CRF better coincides with plant needs, reduces the potential for plant damage, and minimizes nutrient leaching as compared to conventional fertilizers (Hauck 1985; Donald 1991).

Polymer-coated CRF represent the culmination of many years of research in CRF technology and are considered the “state of the art” CRF for horticultural plant production. Product examples include Osmocote[®] (OM Scotts Co), Nutricote[®] (Chisso-Asahi Fertilizer Co), and Polyon[®] (Pursell Industries Inc). To manufacture this product, a water-insoluble polymer material (several different polymer types may be used) is applied as a coating to a water-soluble fertilizer nutrient core, creating a small, granular piece of material commonly referred to as a “prill”.

Nutrient release from polymer-coated CRF occurs first by the diffusion of water through the semi-permeable membrane (Goertz 1993). Water then condenses within the soluble fertilizer core and creates an internal osmotic pressure gradient that forces nutrients out into the soil solution. This process is accelerated with increasing media temperature. Beyond a certain range, soil water content has little influence on nutrient release (Kochba and others 1990). Manufacturers of CRF provide an estimated time for 95%+ nutrient release based on a standardized media temperature (typically 70 °F [21 °C]). Manufacturers vary time periods for nutrient release from CRF by altering the polymer coating thickness or coating composition. Time periods for nutrient release of CRF may range from 3 to 16 months, depending on product.

A series of research trials established during the 1950s illustrated the potential for improving Douglas-fir seedling plantation establishment using urea-formaldehyde (Austin and Strand 1960), at that time a new CRF technology. Since then, the majority of studies investigating the application of CRF to reforestation have utilized polymer-coated CRF. Results from many applied studies have been variable and Brockley (1988) suggested that future research should attempt to better understand the physiological mechanisms by which fertilizer applications affect the growth of planting stock.

INFLUENCE OF CRF ON ROOT ARCHITECTURAL DEVELOPMENT

In an effort to understand how locally-applied CRF may affect early root proliferation of Douglas-fir seedlings, a controlled greenhouse experiment was established. Three-month-old Douglas-fir seedlings grown in 2.4 in³ (39 cm³) containers were transplanted into 135 in³ (2200 cm³) pots. Prior to transplant, Osmocote Plus[®] 15-9-12 (5 to 6 month release) CRF was applied at 1 of 4 fertilizer rates (0, 0.3, 0.6, and 0.9 oz [0, 8, 16, and 24 g]) as a single uniform layer beneath the transplanted root system (fig. 1).

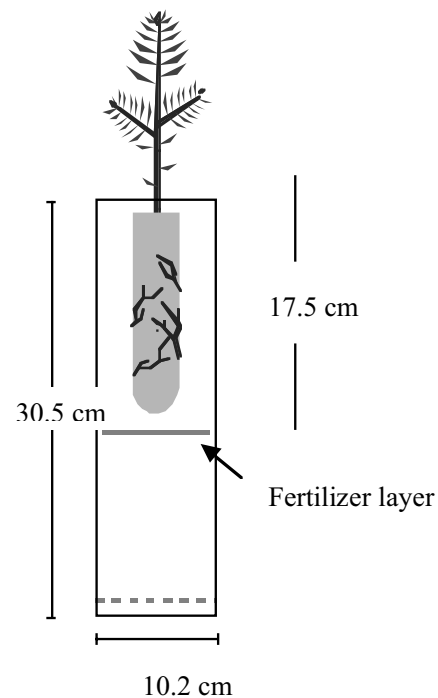


Figure 1. Placement of CRF treatments within pots as a single, uniform layer beneath the transplanted root system.

Seedlings were grown in a controlled environment greenhouse and well-watered throughout the duration of the experiment. Six months following transplant, seedlings were lifted from pots to examine root architectural development in relation to the localized positioning of the CRF layer. Root penetration into the soil zones beneath the CRF layer was severely restricted at the highest CRF rates (fig. 2). Overall mean seedling shoot and root production were greatest in the 0.3 oz (8 g) CRF treatment, but significantly less in the highest (0.9 oz [24 g]) CRF treatment. The negative influence on root penetration at the highest CRF rates and the corresponding reduction in whole-plant growth were attributed to detrimental changes in soil electrical conductivity (EC) associated with an excessive release of nutrients from the CRF.

SOIL ELECTRICAL CONDUCTIVITY

An important concept when applying fertilizers in any plant propagation operation is the resulting influence on soil EC. As fertilizer nutrients are released from CRF, the total salt level within the soil solution increases. Electrical conductivity provides a

measure of the total salt level of a solution and therefore gives an indication of the quantity of fertilizer salts dissolved in the solution (Landis and others 1989). Conifer seedlings range from sensitive to moderately sensitive to high salt concentrations (Tinus and McDonald 1979). High salt concentrations resulting from the release of excessive fertilizer salts into the soil solution may act to kill root apical meristems due to the buildup of toxic ion concentrations and detrimental changes in osmotic potential (Drew 1975).

Considering the importance of EC levels in plant propagation, surprisingly little research has been reported concerning ideal EC ranges to promote growth of forest tree seedlings. Phillion and Bunting (1983) recommended EC ranges between 1200 and 2500 $\mu\text{S}/\text{cm}$ for seedlings of spruce (*Picea*) species. Timmer and Parton (1982) recommended similar EC ranges for black spruce (*Picea pungens* Engelm.) seedlings. They illustrated that as EC levels increased to roughly 1800 $\mu\text{S}/\text{cm}$, seedling growth increased. Beyond this range, however, growth gradually decreased until reaching mortality at EC levels above approximately 4000 $\mu\text{S}/\text{cm}$.

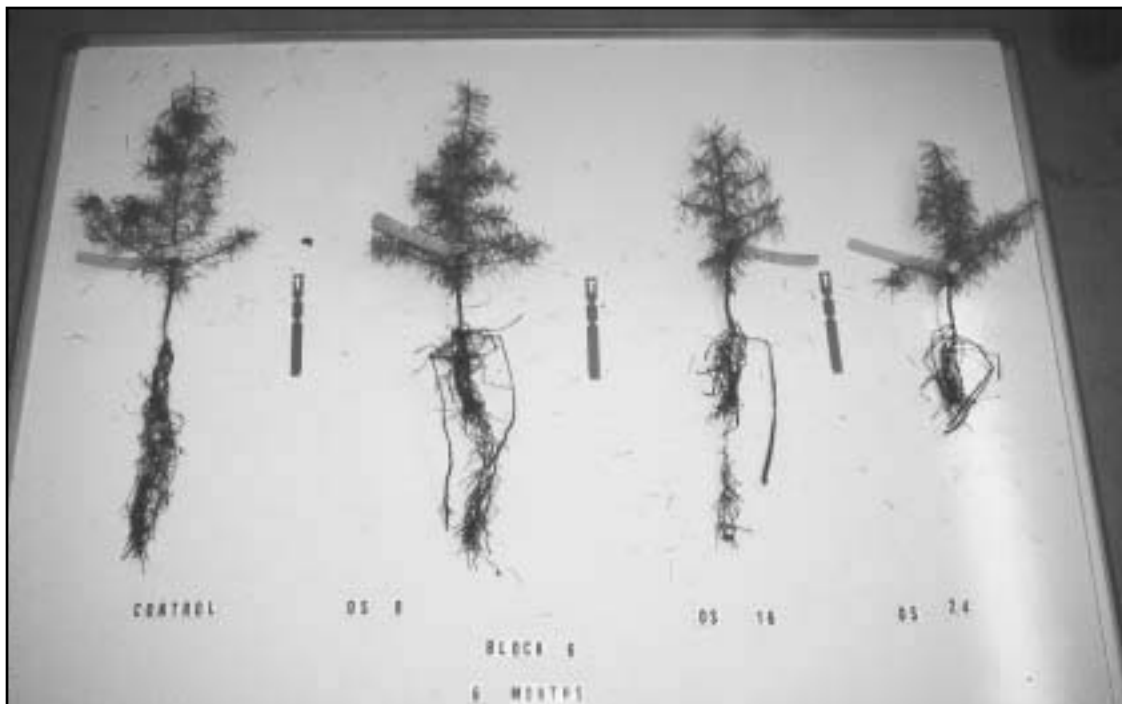


Figure 2. Example seedlings 6 months following transplant showing decreased root penetration into lower soil zones with increasing CRF rate (from left to right).

Poor seedling root growth documented for Douglas-fir seedlings at the highest CRF rates was attributed to excessive EC levels at the point of CRF application. The associated decrease in osmotic potential of the soil solution reached a point where elongating root apical meristems were desiccated and became non-functional. Thus, although CRF release fertilizer salts slowly over time, EC may still reach damaging levels and impair seedling root and whole-plant growth. This effect may be compounded in containerized seedling production when fertigation is also applied.

Techniques for monitoring EC levels in containerized operations are presented in Tinus and McDonald (1979). A portable EC meter can be purchased for under US\$ 200. Levels may be consistently monitored during the growing season and irrigation water applied to leach excessive fertilizer salts from the growing media as conditions warrant. The ability to monitor and adjust EC levels is a distinct advantage that container nursery growers have to successfully use CRF. When CRF are applied at outplanting, foresters must still consider the potential for detrimental changes in soil EC levels associated with the release of fertilizer salts, but have no opportunity to adjust these levels to prevent plant damage.

APPLICATION OF CRF AT OUTPLANTING

To determine if the same type of restriction in root penetration noted in the controlled experiment occurred when Douglas-fir seedlings were fertilized with CRF at outplanting, an experiment was established on a recently clearcut site in the Oregon Coast Range. This site is characterized by wet, mild winters and hot, dry summers. Douglas-fir seedlings (1+1) were either non-fertilized or fertilized with 2.1 oz (60 g) 19-6-12 (~6-month release) Polyon® (JR Simplot Co) CRF in the bottom of the planting hole. Seedlings were excavated after one growing season in the field.

Fertilized seedlings had significantly less root volume growth during the first growing season than non-fertilized seedlings; in some cases, mean root volume growth for fertilized seedlings was actually negative. Fertilized seedlings were also smaller aboveground as compared to non-fertilized seedlings following excavation. No rainfall was recorded on this site from early July until the end of September. Because nutrient release of polymer-coated CRF is primarily controlled by temperature, fertilizer salts continued to release into the soil solution during

summer. Thus, poor root growth of seedlings fertilized at this relatively high rate (2.1 oz [60 g]) was again attributed to detrimental changes in soil EC levels.

A significant portion of roots, particularly fine roots, are lost when bareroot seedlings are lifted from the nursery (Nambiar 1980). Small seedlings have little capacity to store water. Thus, survival and growth is largely dependent on the rapid extension of roots, which reestablish root-soil contact and absorb water to reduce transpirational water loss (Ritchie and Dunlap 1980; Burdett and others 1983; Sands 1984). Drought stress immediately following outplanting may contribute to transplant shock and result in poor seedling growth or mortality.

Fertilized seedlings became significantly more water stressed than non-fertilized seedlings during the summer. Significant positive linear correlations between root volume growth and pre-dawn xylem water potential (that is, good root growth correlated well with resistance to water stress) were established in July, August, and September. This re-emphasizes the importance of promoting adequate root growth following planting.

IMPLICATIONS TO PNW REFORESTATION PROGRAMS

Under ideal conditions, reforestation productivity may be dramatically enhanced with the application of polymer-coated CRF at outplanting. Positive results seem to be most common on sites with adequate summer soil moisture, where doubling of stem volume compared to controls has been reported (Nursery Technology Cooperative 2001).

Extreme care must be taken, however, when utilizing polymer-coated CRF on drought-prone sites. As soils dry in summer and plants enter dormancy, nutrients from CRF continue to release into the root zone. High soil temperatures accelerate nutrient release. Without precipitation to leach excess fertilizer nutrients from within the rhizosphere, EC may reach levels which detrimentally affect root growth. This, in turn, limits the ability of seedlings to resist drought stress. This may contribute to transplant shock and ultimately result in failed plantation establishment.

There is clearly a balance that must be maintained between providing adequate levels of nutrients and maintaining safe EC levels. Under greenhouse conditions, EC levels can (and should) be consistently monitored and irrigation applied when necessary. In the field, foresters should consider the anticipated drought level of the site when deciding on a fertilizer

prescription. Conservative CRF application rates, the use of CRF with moisture-dependent nutrient release characteristics (for example, IBDU, ureaform), or avoiding field fertilization entirely will help to prevent negative results on drought-prone sites. Forestry applications are a relatively new market for CRF products. Manufacturers of CRF must continue to refine CRF nutrient release technology to provide a product in which nutrient release closely coincides with the developmental requirements of forest tree seedlings.

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A HISTORY OF TRANSPLANTING

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Abstract

A brief history of twentieth century transplanting at forest nurseries is presented, including many historical photographs. Transplanting was the normal method of producing plants for reforestation in the first half of the 20th century, and the operation was all done by hand or with rudimentary horse-drawn machinery. Seeds were broadcast sown, the seedlings grown for 1 to 2 years, harvested, and then transplanted at lower growing densities. Starting in the 1940s, mechanical transplanters were converted for use in forest nurseries. During the 1960s, forest nurseries began to switch to seedlings due to the high labor cost of transplanting; cultural improvements allowed production of seedlings with the characteristics of transplants. Precision sowing allowed ideal seedbed density and undercutting produced seedlings with vigorous root systems and thick caliper. In the last 10 to 15 years, however, transplants have returned to favor because of the demand for a large vigorous seedling that can compete with vegetation on outplanting sites and meet the new “Free-to-Grow” reforestation requirements. A new stock type, the plug + one, was developed by growing a small volume container seedling and transplanting it into a bareroot bed for another year of growth. The 1+1 stock type also gained popularity, and together they comprise up to 90% of the stock types produced in some northwestern US nurseries.

Key Words

Seed quality, seedling density, stock type, age class

INTRODUCTION

Before we begin, a brief discussion of the types of plants produced in forest and conservation nurseries is desirable. A *seedling* is a plant that has been grown from a seed, although this term is sometimes also loosely applied to all nursery stock. Forest and conservation seedlings are traditionally divided into 2 basic stock types (bareroot seedlings and container seedlings) that describe how they were grown. Bareroot stock is typically grown in native soil in open fields, and container stock is grown in containers with artificial growing media in greenhouses or open compounds. A *transplant* is a plant that has been physically removed from its seedbed or container and is replanted in a transplant bed or larger container for additional growth, usually 1 or 2 years.

Bareroot stock types are named using a numerical code: 2 numbers separated by a plus sign. The first

number corresponds to the number of years in the seedbed or seed container, and the second number refers to the number of years in the transplant bed or container. Bareroot seedlings are generally produced in 1 to 3 years (1+0 to 3+0), and transplants (for example, 1+1 or 2+1) can vary considerably depending on the species, climate, and nursery system. The sum of the 2 numbers gives the total number of years needed to produce that stock type (fig. 1). Container transplants use the designation “P” (for plug), followed by the number of years in the transplant bed.

Some of the first forest nurseries were established by the newly formed USDA Forest Service in the early 1900s including the Columbia Nursery (later renamed the Wind River Nursery) in Washington (1906) and the Savenac Nursery in Montana (1908). In the intervening years, there have been 3 basic changes in stock type preferences.

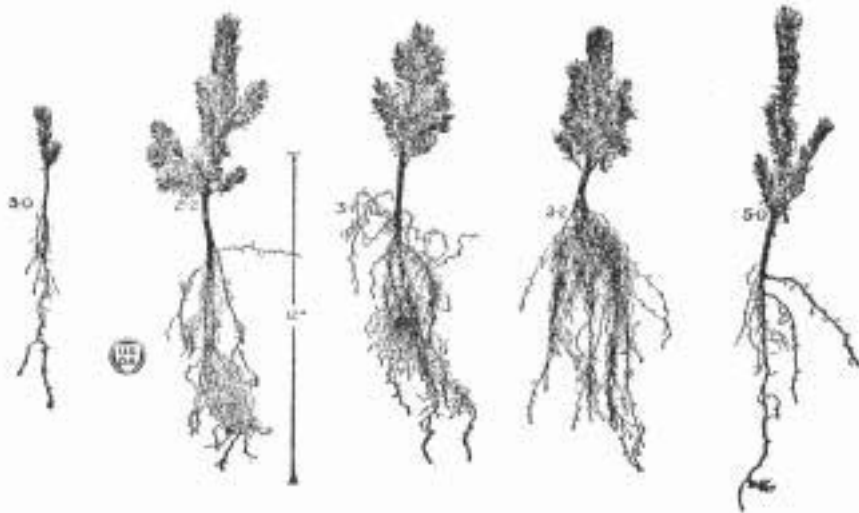


Figure 1. In the first half of the 20th century, transplant stock types (2+2, 3+1 and 3+2) were preferred over seedlings (3+0, 5+0) because transplants have more fibrous roots systems and better shoot-to-root ratios (Tillotson 1917).

1900 TO 1965: TRANSPLANTS ARE PREFERRED

During the early days of forest nursery production in North America, the use of transplanted seedlings was the norm. Transplant stock types had much better root systems and stem diameter (“caliper”) than seedlings (fig. 1), and so were preferred by foresters even though they were much more expensive. The average cost of transplants at \$4.25 per thousand was over 7 times that of seedlings at \$0.60 per thousand (Toumey 1916). In fact, most nursery manuals didn’t even discuss the use of seedlings except as a prelude to transplanting (for example, Yerkes 1929). These stock preferences were backed-up by research trials that proved the superiority of transplants (table 1).

The nursery production cycle started with broadcast sowing of seed and then culturing the seedlings for

the remainder of the growing season. If the seedlings were not large enough, they could be held in the seedbeds for another year or two. Once they reached acceptable size, seedlings were harvested in the spring, processed, and immediately transplanted (fig. 2). The transplants were then grown for another year or two until they were sufficiently large for outplanting. In some nurseries, 1+1 transplants were transplanted for another year to produce a 1+1+1 stock type (table 1).

In these early years, the quality of American grown seedlings was pretty marginal. In fact, late in the 19th century, a number of American foresters, including Gifford Pinchot, sent local seed to European nurseries to have plants grown and shipped back for outplanting. Of course, some of this may have been a trendy method of pleasing distinguished clients such as the Vanderbilt Estate, but there were some understandable reasons for poor seedling quality in American nurseries.

Initial Problems with Seedling Quality

Seed Collection—Even though there was a good understanding of the basic nature of conifer seed in the early 20th century, cone collection practices did not produce high quality seed for the nurseries to sow. One source states “When squirrels begin to cut off cones for storing, collecting should begin at once” (Tillotson 1917). From another source,

Table 1. Results of outplanting trials with different stock types of ponderosa pine in 1915 on the Shasta National Forest in northern California.

Stock Type	Outplanting Survival (%)
1+0	31
2+0	6
1+1	82
2+1	92
1+2	78
1+1+1	99

Modified from Show (1930)



Figure 2. In the first half of the 20th century, seedlings were grown for 1 to 3 years, harvested, transplanted by hand, and then cultured for another 1 or 2 years.

“Furthermore, squirrels hoard only the best cones” (Toumey 1916).

Seed Processing—Seed cleaning operations, such as wing removal, lacked the machinery and finesse of today’s operations. Some quotes from an early nursery manual are revealing. “Another process is to pile the seed 6 to 8 inches deep on a cement or plank floor, sprinkle it lightly with water, and then beat it energetically with leather flails.” “Sometimes the sacks are trampled underfoot for a few moments but this impairs the quality of the seed” (Tillotson 1917). The results would explain why some nursery seedlings did not get off to the best start. After using a grain grading machine (presumably a fan mill), one nursery reported germination test results for yellow pine (*Pinus ponderosa*) seed after 45 days as being 13.5% for the heaviest class, 1% for class 2 and 0.5% for class 3. They didn’t test class 4, since it was mostly debris and broken seed (Tillotson 1917). In another nursery manual, the germinative capacity of ponderosa pine from 3 sources averaged 37.0%, 61.9%, and 44.6% (Toumey 1916). By today’s standards, none of these seeds would be acceptable for anything but the trash can.

High Sowing Density—Another problem was the belief that high growing densities yielded the best seedlings (fig. 3). Two publications of the day support the practice of very high seedbed densities.

“The young plants often do best when growing in rather dense stands of 75 to 150 per square foot” (807 to 1614/m²)(Yerkes 1929). “In general, coniferous seed should be sown in sufficient quantity to produce from 50 to 200 seedlings per square foot” (538 to 2152/m²)(Toumey 1916). The reason for these high sowing densities was probably frost heaving and other environmental factors.

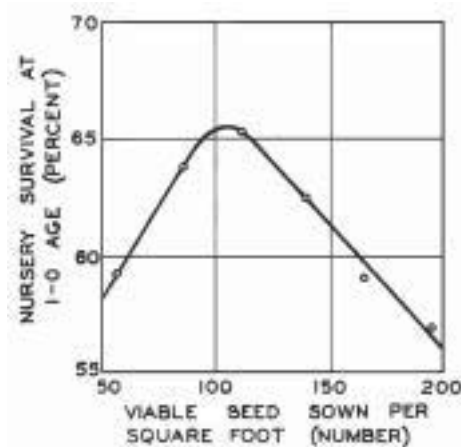


Figure 3. Early nursery managers had the mistaken belief that seedbeds should be densely sown (~ 100/ft² [1076/m²]) to produce the best quality seedlings (modified from Stoeckeler and Slabaugh 1965).

Nursery location, facilities, and cultural factors—

Lack of roads and transportation dictated that nurseries be located close to the larger outplanting operations. As a result, these nurseries were often in climates and soils that were marginal at best. In addition, nursery cultural practices such as irrigation and fertilization were rudimentary by today's standards (fig. 4).

Considering all these factors, it is no wonder that the seedlings from early forest nurseries were not of the highest quality.

1965 TO 1985: CHANGE TO SEEDLINGS

The second phase in the history of transplanting began when high labor costs made transplanting too expensive, and new nursery equipment made it possible to produce a seedling with the physical characteristics of a transplant. In addition, advances in seed collection and processing produced seed with high germination rates which was then sown with new precision seed drills. Nursery managers realized that lowering seedbed densities to an average of 20 to 25 seedlings/ft² (215 to 270/m²) produced seedlings with more stem caliper and fewer culls. Great advances were made with undercutting machinery. The New Zealand Root Pruner featured a thin, serrated blade which oscillated back and forth to precisely cut seedling roots (fig. 5). These new root culturing procedures of undercutting and wrenching produced seedlings with dense fibrous root systems that were previously only available with transplants (Van Dorrser and Rook 1972.). To confirm their quality, outplanting trials of root cultured 2+0



Figure 4. Early fertilization consisted of applying a liquid manure slurry to the seedbeds.

seedlings showed good survival and growth. This trend to seedling production was reflected in contemporary nursery manuals. For example, *Reforestation Practices for Conifers in California* has an entire section on nursery production, but transplanting is not even discussed as a cultural practice (Schubert and Adams 1971).

Some bareroot transplants were still produced during this time period, primarily 1+1s and 2+1s, which were used on difficult outplanting sites (table 2). In particular, transplants were popular for sites with dense brush competition and severe animal browsing. A new stock type, the container transplant, was invented during this period, and the "plug + 1 (P+1)" would soon gain wide acceptance with foresters and other seedling customers. The P+1 was first produced at the Ray Leach Nursery in Aurora, Oregon, in 1971, but the real promoter of this new stock type was Phil Hahn at the Georgia-Pacific container nursery in Cottage Grove, Oregon. Originally conceived as a way to hold over container



Figure 5 A/B. The New Zealand root pruner (A) featured a thin oscillating blade (B) which precisely prunes roots and produces a seedling with transplant characteristics.

seedlings in bareroot beds, Phil continued to experiment with cultural regimes and scheduling (Hahn 1984). Outplanting trials were very encouraging and soon other nurseries began to follow suit. The Plug + 1 has continued to grow in popularity and is one of the reasons for the resurgence in the popularity of transplants in recent years.

1990 TO PRESENT: THE RETURN TO TRANSPLANTS

In the past 10 to 15 years, transplant stock types have been regaining their popularity with nursery customers in the Pacific Northwest. Stock production statistics from the Washington Department of Natural Resources Webster Nursery are illustrative. In 1987, the 2+0 seedling was by far the most popular stock type, with transplants accounting for only 10% of total production. Seedlings had lost their majority by 1997 and, 5 years later, the trend had completely reversed with transplants being the favored stock type (table 3).

There are several reasons for this recent change in planting stock preference (Landis 1998).

Plant Competition and Animal Browsing

Legal restrictions on the use of site preparation herbicides and increasing problems with deer and elk predation helped fuel the demand for larger and

larger stock types. Seedling customers felt that plants with large, fibrous root systems, thick stem caliper, and shoots with more lateral branching had a better chance of surviving and growing on these tougher outplanting sites.

“Free-to-Grow” Reforestation Requirements

The Pacific Northwest states passed new forestry legislation that required all plantations be above the height of the competing vegetation within a relatively short time, typically 5 years. This meant that, instead of just surviving, outplanted stock had to grow rapidly; large transplants had an initial height advantage over smaller seedlings.

TRANSPLANTING METHODS

Currently, all transplanting is done by machine, and the equipment and techniques are discussed in detail in the other papers in this Proceedings. The 1+1 is the most common bareroot transplant, and plug+1s continue to increase in popularity. Container-to-container transplants are a relatively new innovation and are rapidly gaining acceptance by nursery managers and their customers.

Transplanting equipment and techniques have also undergone some interesting changes during the last century.

Table 2. Stock types used for reforestation in the Lake States.

Species	Easy to Average Outplanting Sites	Difficult Outplanting Sites
Balsam fir	2+2, 3+0, 4+0	2+2, 2+3, 3+2
Eastern hemlock	2+2	2+2, 2+3
Jack pine	2+0, 1½ + 0, 1+0	1+1, 2+0
Red pine	2+1, 3+0, 2+0	2+2, 1+2, 2+1
White pine	3+0, 2+0, 2+1	2+2, 1+2
White spruce	2+2	2+2, 2+3, 3+2

Source: Stoeckeler and Jones 1957

Table 3. Stock type trends at the Webster Forest Nursery, Olympia, WA.

Stock Type	1987	1997	1992
2+0 Seedlings	90%	48%	10%
Transplants: 1+1 and P +1	10%	52%	90%

Source: Ramirez 2002

Table 4. Comparison of transplanting production efficiency using different methods.

Transplanting Method	Persons/Crew	Rate/Person/Hr	Source
Transplant Boards (see fig. 2)	20	1016	Stoekeler and Slabaugh 1965
Transplant Boards & Lining-Out Plow (see fig. 6)	15	1250	Aldhous 1975
Self-propelled 2-row Transplanter (see fig.7)	2.5	1500	Stoekeler and Jones 1957
7-Row Transplanter with Tractor (see fig. 8)	9	1875	Hanks 1962

Hand Transplanting

Initially, all seedlings were transplanted by hand and there were 2 basic techniques (Toumey 1916).

Hole or “Dibble” Transplanting—Using a notched board as a spacing template, holes were dug at regular intervals with a hand trowel, dibble, or planting hammer and the seedlings planted one by one. The workers moved backwards down the bed, keeping each line of transplants parallel to the last.

Transplant Boards—The next innovation in hand transplanting was the transplant board, and there were several variations (Stoekeler and Jones 1957; Stoekeler and Slabaugh 1965). Each involved trimming the roots of the harvested seedlings and “threading” them side by side into regularly-spaced notches in the transplant board. Originally, threading was done in the open fields, but progressive nursery managers soon erected tents (“coops”) to house the threaders and keep the seedlings out of the direct sun. The next step in the process was to open a furrow with a hand trencher that was deep enough so that the seedling roots could be oriented vertically against the cut face (fig. 2). Another worker covered the roots with soil up to the seedling root collar to complete the process. At Bessey Nursery in Nebraska, a 20-person crew was used (10 threaders, 5 planters, 3 trenchers, 1 seedling carrier, and 1 foreman), and this crew could transplant 150,000 to 175,000 seedlings per day (table 4).

The next improvement in the hand transplanting process was to use a plow drawn by a horse to open the furrow. Once the furrow was opened, crews used transplant boards to situate the seedlings against the cut surface. As before, another crew member tamped soil against the seedlings to finish the process. When hand trenchers were used, rows of transplants were oriented across the bed (fig. 2) but, with the advent of the plow, long rows were made parallel to each other (fig. 6). In one nursery, 5 rows of transplants were oriented 9 inches (22 cm) apart to produce a transplant bed 36 inches (90 cm) wide, with an 18 inch (45 cm) alley between each bed to allow for

tractor cultivation (Aldhous 1975). A crew of 15 could transplant 8000 to 12,000 seedlings per day (table 4). This process became known as “lining-out” and this term is still used instead of “transplanting” in most ornamental and horticultural nurseries.

Hand transplanting required a large crew, which was not a problem in the first half of the 20th century; government nurseries used cheap labor from work programs such as the Civilian Conservation Corps. In the 1940s and 1950s, however, the increasing cost of hand labor was becoming excessive and so more mechanization was utilized (Hanks 1962). By the

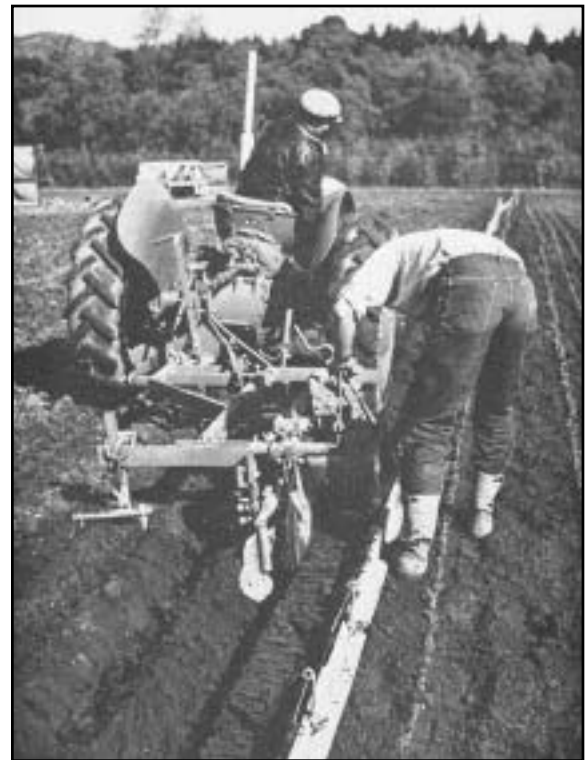


Figure 6. A “lining-out plow” was modified to increase the efficiency of transplanting with transplant boards, and the rows ran the length of the bed (modified from Aldhous 1975).

mid 1950s, one nursery manual stated that hand transplanting had almost disappeared (Stoekeler and Jones 1957). At the current time, hand transplanting is only used for very small numbers of transplants, or in smaller nurseries that cannot afford to purchase transplanting machines.

Machine Transplanting

The first machine transplanter was developed by the Holland Transplanter Company in Holland, Michigan, for transplanting celery in 1927. By 1940, these transplanters had been modified with a deeper planting shoe for use with pine seedlings in a Michigan nursery. This first trial proved the feasibility of machine transplanting in forest nurseries and found that transplanting costs could be cut in half, compared to transplant boards (Hildebrand 1943).

The 2-row Holland transplanter was self-propelled with a gasoline engine and contained 2 planting units (fig. 7). Each unit consisted of a coulter and shoe that opened a furrow. A worker placed seedlings into the pockets of a revolving disk that was situated between the 2 packing wheels. As the disk revolved, the seedlings were released upright in the furrow that was immediately closed by the packing wheels. The tongue on the front of the machine supported the engine, and also contained a steering shoe. At the end of the bed, the transplanter would be rotated and

realigned for another pass (fig. 7). Running the transplanters back and forth along the beds would produce beds of 10 rows that were spaced 9 inches (23 cm) apart (Hildebrand 1943). These 2-row machines were able to plant seedlings at a rate of 11 to 14 ft/min (3.4 to 4.3 m/min), which translated to 30,000 seedlings in an 8-hour day (Stoekeler and Jones 1957).

In the 1940s and 1950s, more modifications were made to machine transplanters to allow all rows in the bed to be planted at once. This innovation also resulted in a standard bed width that could be straddled by the tractor and equipment. The Bradley transplanter was a 5-row machine pulled by a remodeled tractor that was geared down to the relatively slow speeds necessary for best operation of the planting wheels. Since all the rows were evenly spaced, the beds could be cultivated with other equipment (Slavin and Locke 1949). A 6-row transplanter with a deeper shoe was the next improvement (Landquist 1959) and, by this time, newer tractors with slower speeds were commercially available (fig. 8). In 1961, the Bessey Nursery in Nebraska developed a 7-row transplanter (Hanks 1962) that had an average production of 135,000 seedlings per day (table 4). Most transplanters are modifications of commercial units and can transplant 6 to 8 rows per bed, depending on the species and target seedling specifications.



Figure 7. One of the first machine transplanters that was modified for tree nurseries was self-propelled and transplanted two rows at once.

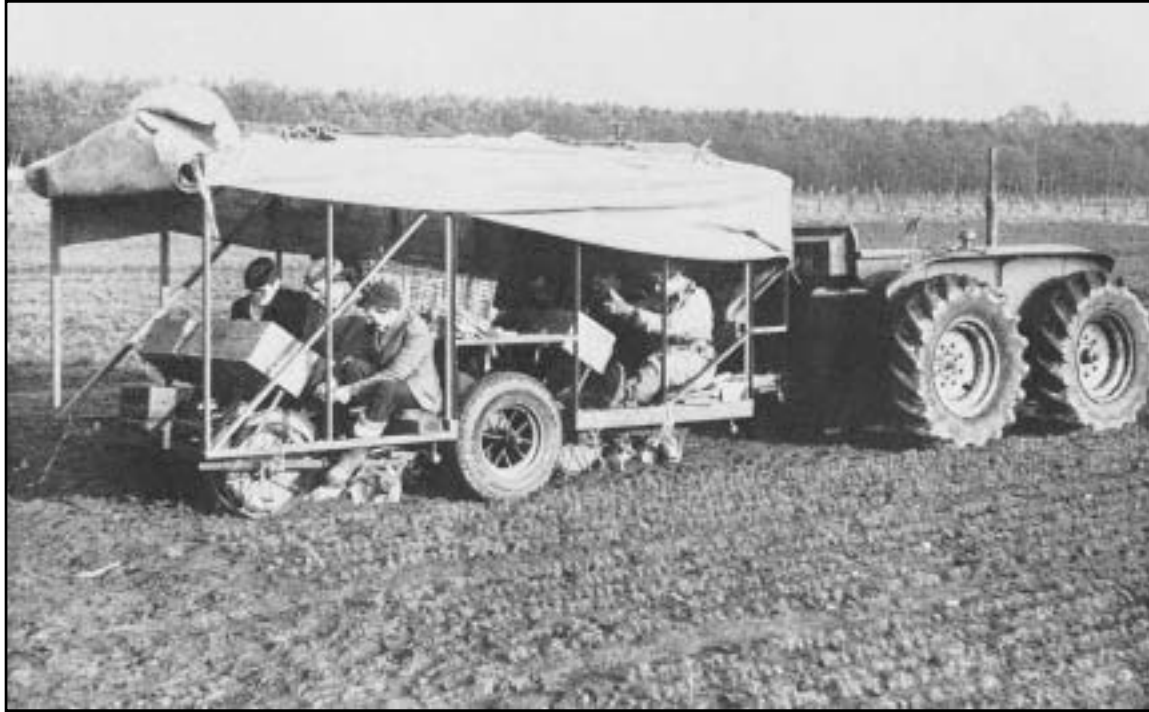


Figure 8. By the 1960s, full-bed transplanting machines could plant 6 to 8 rows at one time. These units were the progenitors of modern transplanters (modified from Aldhous 1975).

SUMMARY

In the first half of the 20th century, transplants were the preferred stock type because seed and seedling quality was marginal. Hand transplanting was the most common technique because of cheap labor. Starting around 1940, machine transplanting became the rule due to the rising cost of labor and the modification of existing agricultural equipment. Seedlings began to replace transplants as the desired stock type in the 1960s to 1980s because new root culturing and precision sowing techniques produced seedlings with the fibrous roots and stem diameters of transplants. In recent years, transplant stock types, especially 1+1s and plug+1s, regained popularity in the Pacific Northwest due to the need for larger plants to meet new outplanting challenges.

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ROOT PHYSIOLOGY AND PHENOLOGY: THE KEY TO TRANSPLANTING SUCCESS

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Ritchie G.A. 2003. Root physiology and phenology: the key to transplanting success. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 98–104. Available at: <http://www.fcnanet.org/proceedings/2002/ritchie.pdf>

Abstract

This paper presents a summary of several key aspects of root physiology that directly affect success of nursery transplanting. Three transplanting systems are considered: container to container (C:C), container to bareroot (C:BR), and bareroot to bareroot (BR:BR). While differing in detail, each of these systems involves growing a starter plant, transplanting it, and growing it longer in a transplant bed or larger container.

The aspects of root physiology discussed are: root system hydraulic conductance, phenology and growth, stress resistance, root cold hardiness, shoot/root interconnectedness, and root pathogens. The paper discusses each of these aspects of root physiology and explores where they might be affected by, or limiting to, the process of growing transplants.

Key Words

Root hydraulic conductance, root cold hardiness, stress resistance, root pathogens, seedling storage

INTRODUCTION

I wish to thank the organizers of this conference for inviting me out of retirement to, once again, probe the mysteries of roots—this time as they relate to the operation of producing nursery transplants. As you know, production of transplants for reforestation is rapidly eclipsing production of 1+0 or 2+0 bareroot stock throughout much of the Pacific Northwest US and western Canada. This is because, in spite of their higher production costs, transplants have consistently delivered better field performance across a wide range of sites. It is in concert with this development that a major portion of this meeting has been devoted to a review of nursery transplanting: its history, equipment and culturing methods, and related aspects of seedling physiology.

Root physiology cannot be considered in a vacuum. As this paper develops it will become clear that roots are intimately connected to, and utterly dependant upon, other parts of the plant. To attempt to address root physiology without these important connections would be misleading and inappropriate.

I will not burden you with an exhaustive review of the literature on root physiology. Rather, I intend to

share with you an on-the-ground account of how an understanding of certain key aspects of root function can directly affect the success of your transplant production operations. This summary is drawn largely from my nearly 30 years' experience as a researcher in the field of seedling physiology and seedling production. As such, it reflects both personal biases and interests.

This paper will address the subject of root physiology and phenology as it relates directly to the operation of nursery transplanting. It will not address root system morphology, plant culture, or nursery equipment, as these topics will be reviewed by other speakers.

TRANSPLANTING SYSTEMS

We will focus on 3 transplanting systems.

Container to Container Systems

In container to container (C:C) systems, seeds for starter plants are sown into small containers and cultured in a greenhouse or cover house where the seedlings are protected from the elements (stage 1). Following a prescribed period of time, often 1

growing season, the starter plants are removed from these small containers and transplanted into larger containers where they are grown on to outplantable size (stage 2). This can be done either indoors or outdoors.

Throughout the C:C process, plants are grown in sterile, artificial growing medium in containers made of Styrofoam, plastic or other materials. Stage 1 is almost always conducted indoors in a greenhouse or coverhouse where light intensity is well below ambient and where the grower can exert precise control over container volume, soil moisture, soil temperature, nutrition and other factors. In stage 2, if conducted outdoors, some loss of control over some factors (for example, soil temperature) is experienced. In the C:C system the seedlings are not intentionally bare rooted. The process of transplanting from small to large containers may or may not be automated.

Container to Bareroot Nursery Bed Systems

In container to bareroot nursery bed (C:BR) systems, starter plants are sown and cultured in the same manner as described above. However, they are then transplanted into an outdoor bareroot nursery where they undergo the second stage of development. Such systems produce stock often referred to as “Plug+1s” or “Mini-plugs”.

Again, stage 1 is done in containers in a greenhouse in sterile medium under very tight environmental control. Light intensity is normally considerably lower than ambient. In stage 2, plants are grown in natural soil under natural environmental conditions and natural light intensities. There is still the opportunity to control some conditions such as soil moisture. But many other important factors, such as temperature and light, are not controllable. Sometimes the transition from stage 1 to stage 2 in the C:BR system can cause considerable transplant shock (Haase and Rose 1993) and even photodamage (Demmig-Adams and Adams 1992). In the C:BR system, roots are generally not intentionally bare rooted.

Bareroot to Bareroot System

In the bareroot to bareroot (BR:BR) system, stages 1 and 2 are both carried out in an outdoor bareroot nursery. Seed is sown in spring in intensively prepared seedbeds at relatively high densities, where starter plants are grown for one or more years under intensive culture. In winter or early spring, they are

lifted, graded and generally stored in a cooler at slightly above freezing, or a freezer at slightly below freezing. In spring, following storage, they are transplanted back into the nursery at a much lower growing density. Here they are cultured for an additional year or two before being lifted for field planting. These are often referred to as 1+1 or 2+1 stock.

In the BR:BR system, both stages of growth are conducted under semi-natural outdoor conditions under full sun. There is only minimal control of root volume, no control of soil temperature, and some control of soil moisture (water can be added to the system, but not removed). Seedlings are always bare rooted between stages 1 and 2.

Despite many differences, these three systems all involve two stages. In stage 1, a starter plant is produced. This is lifted but may or may not be graded or stored. In stage 2, the starter plant is transplanted and cultured into a field-plantable seedling. It is then lifted, graded and packed for field planting.

ROOT PHYSIOLOGY AND PHENOLOGY

In this section we will visit several key physiological and phenological attributes of seedling roots and indicate where and when they might be affected by, or limiting to, various stages in the process of growing transplants. The factors we will consider are: hydraulic conductance; phenology, dormancy and growth; cold hardiness; stress resistance; shoot/root interconnectedness; and root pathogens.

Hydraulic Conductance

Hydraulic conductance expresses the ability of a root system to extract water from the growing medium. Water uptake also includes nutrient uptake; hence, this is a critical function of roots. Hydraulic conductance is affected by 3 main factors (Carlson and Miller 1990). First is the temperature of the soil and root system. As temperature decreases, the viscosity of water increases and root activity decreases. Second, is the volume of the root system. All other things equal, greater root volume leads to greater hydraulic conductance. The developmental state of the root system is also critical. This is because unsuberized (white) roots have greater conductance than suberized (brown) roots. As growth rate increases, the ratio of unsuberized to suberized root surface area increases and so does hydraulic conductance.

To maximize hydraulic conductance after planting, it is important that the roots begin growing rapidly.

This improves root to soil contact, gives a higher proportion of unsuberized (growing) roots, and allows roots to probe new moisture reserves in the soil. So, in transplanting, achieving good hydraulic conductance requires that starter plants be grown with adequate root volume to support its foliage area. For starter plants to begin growing new roots soon after transplanting, planting should be done when soil conditions favor root growth. These conditions are outlined below.

Dormancy, Phenology, And Growth

In seedling shoots, phenology is under control of the dormancy cycle (Romberger 1963; Perry 1971). Briefly, the dormancy cycle comprises 4 stages. In spring and early summer, active growth is occurring in the shoot tips and cambium. By late summer, a period called “quiescence” develops during which growth is impeded by external conditions. This is followed in fall by the induction of dormancy, or winter “rest”. During rest, growth will not resume until after the shoot has been exposed to a prolonged period of low temperature—a phenomenon called the chilling requirement. Once this period has elapsed, usually by late winter, dormancy weakens and quiescence returns. Growth resumes as a response to rising spring temperatures.

The important point here is that roots do not adhere to this schedule. Roots exhibit no innate cycle of growth and dormancy as do shoots. Rather, they are opportunistic growers, growing and stopping in response to environmental conditions. For example, if the temperature suddenly rises to 68 °F (20 °C) during November, when shoots are dormant, roots would suddenly begin to grow. (This can be confirmed at the nursery by lifting seedlings in November, bringing them into a warm greenhouse and potting them. Remove the seedlings after 2 or 3 weeks and observe the proliferation of new, white root tips).

The most important environmental factor controlling root growth may be soil temperature. As a general rule, for tree seedlings native to this region, no root growth occurs when soils are below about 46 °F (8 °C) (fig. 1). Above 46 °F, roots begin to develop white tips and some elongation may be apparent. Between about 54 °F (12 °C) and 68 °F (20 °C), root growth increases linearly with temperature then plateaus or even declines in some species above 68 °F. The second most important factor is probably soil moisture content or soil water potential, which interacts strongly with soil temperature (fig. 2).

When soil moisture becomes limiting, not only does the root growth temperature response tend to flatten out, but the optimum temperature for root growth can fall (Teskey and Hinckley 1981; Kuhns and others 1985). Root growth of container crops is very strongly controlled by container volume up to a point (Endean and Carlson 1975) (fig. 3). In a bareroot nursery, this effect is much weaker, but root growth can be manipulated somewhat by managing sowing or transplanting density. Aeration of the soil or growing medium is also very important to root growth. Poor aeration leads to root deformities, root thickening, reduced fibrosity, and increased risk of pathogens.

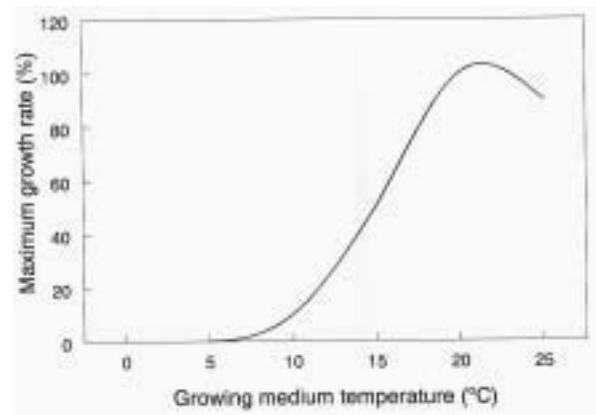


Figure 1. Generalized diagram illustrating how root growth is affected by the temperature of the growing medium for seedlings of many tree species.

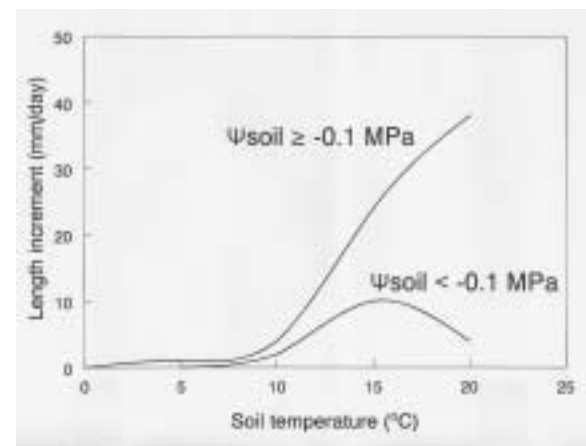


Figure 2. The dependence of root growth on soil temperature is strongly mediated by soil water potential (redrawn from Kuhns and others 1985).

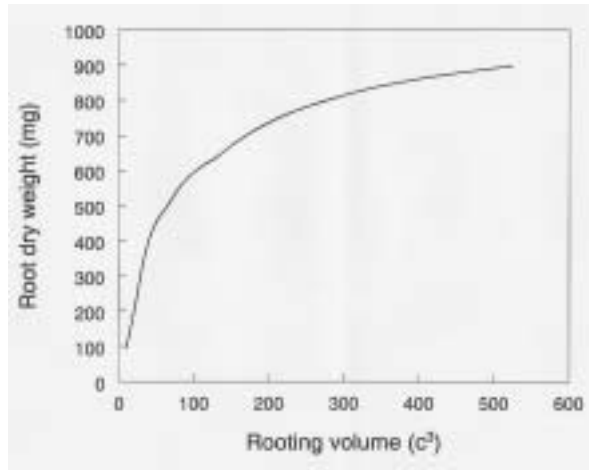


Figure 3. Effect of container rooting volume on root dry weight of lodgepole pine seedlings after 20 weeks (Endean and Carlson 1975).

The above physiological responses have many practical implications. Soil temperature, while generally well controlled in container systems, is not controllable in the bareroot nursery. Therefore, if transplanting occurs before soil has warmed, little or no root growth can be expected. Similarly, soil moisture is under good control in container systems. In the bareroot nursery, it is possible to add water through irrigation, but it is generally not possible to remove it. During rainy periods this can lead to water logging of nursery soils and poor aeration for root systems. In container systems, poor container design, poorly draining medium, and over watering can have the same negative effect on root development. Limited soil volume in container systems can lead to inadequate root fibrosity and “pot binding” of starter plants. Both of these situations can lead to poor performance following transplanting.

Cold Hardiness

Cold hardiness can be defined as the ability of a plant to resist sub-freezing temperatures. Cold hardiness is a trait normally associated with seedling tops. However, root systems also display a seasonal rhythm of hardening and de-hardening (Lindström and Nyström 1987; Colombo and others 1995). This rhythm reflects temperature conditions within the soil, which are far more stable and less extreme than those above ground. As might be expected, roots do not attain the same level of cold hardiness as shoots, but both reach peak hardiness at roughly the same time (fig. 4).

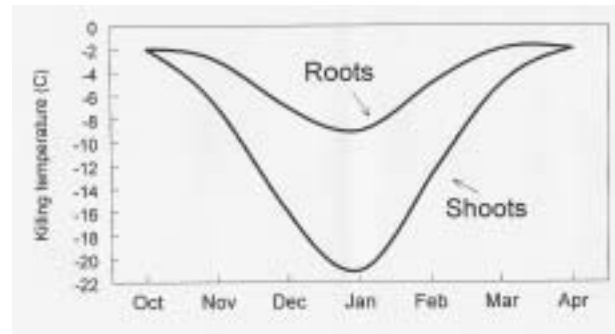


Figure 4. Generalized plot of root and shoot cold hardiness for Douglas-fir seedlings.

When roots are exposed to temperatures approaching their hardiness limits, several negative impacts can occur. First, root growth potential (RGP) and top growth can be substantially reduced. Stomatal conductance decreases, leading to a reduction in photosynthesis, which can further impact root growth (see below). Furthermore, the susceptibility to root pathogens, particularly in storage, can be increased when roots are suffering from cold injury.

These phenomena can have major implications in transplant production. While it would be unusual for seedlings growing in the bareroot nursery to suffer from cold damage, container stock that is exposed to cold weather, or that is over-wintered outdoors, can be killed by cold injury to roots (Lindström 1986; Lindström and Stattin 1994). It has also been suggested that lifting for freezer storage, if done too early, can predispose seedlings to root damage in storage (GA Ritchie, unpublished data).

Stress Resistance

Stress resistance is similar to cold hardiness. It can be defined as the ability of a root system to resist stresses associated with lifting, handling, drying, and other nursery operations. Interestingly, stress resistance in roots has a very strong seasonal periodicity (Hermann 1967; Ritchie 2000), reaching a peak in mid-winter (fig. 5). During times when roots are active, their stress resistance is very low, so that a slight disturbance can have serious consequences.

This phenomenon has important implications in BR:BR operations during the time that seedlings are being lifted, handled, packed, and stored (Ritchie 1986). It's probably not an exaggeration to say that this phenomenon, more than any other, defines the

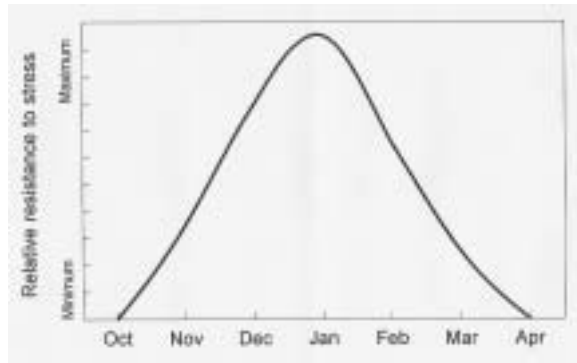


Figure 5. Seasonal changes in root system stress resistance for Douglas-fir seedlings.

biological “lifting window” for bareroot stock. It is much less important in container stock, however, because the roots remain protected by a plug of soil (assuming that the plug remains on the roots) and suffer much less direct exposure to stress. This is one of the key advantages of container stock and is the main reason that fall planting and late spring planting are often more successful with this stock type than with bareroot stock. In northern regions where the BR lifting window (nominally late November through March) is closed owing to frozen ground, containers are often the preferred stock type.

Root/Shoot Interconnectedness

Roots depend on shoots and shoots depend on roots. Neither can be considered without the other. This point will be illustrated with 2 examples. The first involves production and transport of photosynthate. Figure 6 summarizes results of a series of experiments done with Douglas-fir seedlings (Zaerr and Lavender 1974; Ritchie and Dunlap 1980; Philipson 1988). The seedlings were planted into pots containing moist growing medium, then placed into an environment conducive to rapid root growth. Controls behaved as expected, initiating and elongating numerous new roots. Seedlings that were girdled (ring of bark and phloem removed from around the lower stem) produced few or no roots in the same environment. An interpretation of this result was that some factor that is transported from the crown to the roots through the phloem is necessary for root growth. In a second treatment, seedlings were defoliated before potting. These seedlings also failed to produce roots, suggesting that this “factor”, or some component of it, originated in the foliage. If the seedlings were held in darkness during the

rooting period they also failed to produce new roots. These results taken together strongly implied that new root production in these seedlings depends on photosynthate that is being produced in the foliage and transported through the phloem to the roots. This was tested in an experiment (van den Driessche 1990) in which Douglas-fir seedlings were grown in an atmosphere that was scrubbed of CO₂. Since plants are constantly producing CO₂ through respiration, it was impossible to remove all of it from the air. Scrubbing most of it resulted in a near complete cessation of root growth in these seedlings.

The conclusion is that Douglas-fir seedlings rely strongly on current photosynthate for new root growth. Therefore, anything that interferes with photosynthesis, or transport of photosynthate, will reduce root growth. Such factors may include cold damage, photodamage, inadequate nutrition, leaf pathogens and mechanical or insect-related damage to stems. It should also be noted that similar experiments with Sitka spruce gave different results (Philipson 1988), so all conifers may not respond in the above manner.

The second example involves carbon source:sink dynamics within the plant (see Kramer and Kozlowski, p 380-389). Carbon sources include the photosynthesizing foliage, as well as stored starch and sugar contained in the foliage, stem, and roots. Carbon sinks are located in the meristematic tissues—the developing buds and cambium, and the growing roots. Carbon sinks compete with each other. Generally, the more actively a tissue is growing, the stronger a sink for carbon it becomes.

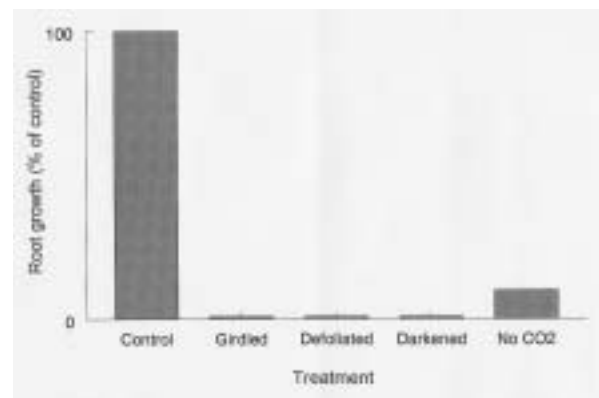


Figure 6. Summary of several experiments with Douglas-fir seedlings in which root growth was measured following various treatments to the tops of the seedlings (after Zaerr and Lavender 1974; Ritchie and Dunlap 1980; Philipson 1988; van den Driessche 1990).

After transplanting, carbon sinks in the developing buds and emerging shoots will overpower the root sinks, causing a temporary reduction in root growth below its potential. However, soon the emerging foliage will begin to photosynthesize and become a net carbon source exporting to the roots. Then, with warming soil and an abundant source of currently produced photosynthate, root growth will resume at a near-optimum rate.

Root Pathogens

No matter how well the transplant production processes are managed, root pathogens can trump success at nearly every point (Hamm and others 1990). Some important root pathogens encountered in this area are *Fusarium* sp., *Pythium* sp., *Phytophthora* sp., and *Cylindrocarpon* sp. The main points of vulnerability in C:C are non-sterile container media, equipment, trays, and greenhouses. In BR, ineffective nursery fumigation procedures are very important, as is cleanliness of equipment and facilities. Improper storage can have serious pathogenic consequences in both BR and C systems. In general, when stock is carrying a root pathogen load, cold storage (storage above 32 °F [0 °C]) promotes the colonization of stock by the pathogen during storage. Given time, the pathogen can completely destroy cold stored seedlings. In contrast, frozen storage (below 32 °F), while it does not kill pathogens, will arrest their development. A useful rule of thumb is: cooler for short term storage (less than one month); freezer for long term storage.

SUMMARY

Transplanting systems discussed here involve container to container (C:C), container to bareroot (C:BR) and bareroot to bareroot (BR:BR). All three systems involve two growing stages interrupted by a transplanting step. Root physiology and phenology can be affected by, or limiting to, each of these.

Root hydraulic conductance, the root system's ability to extract water and nutrients, is affected by soil temperature, root system surface area/volume ratio and developmental state. Achieving good conductance requires that the plant commence root growth soon after planting. Roots have no internal dormancy cycle, as do shoots, but respond to environmental conditions. Soil temperature, moisture content, rooting volume and aeration are key variables controlling root growth. Roots attain some degree of cold hardiness in winter, but do not harden as much as shoots. Lack of root hardiness can limit

C:C and C:BR production and control the date of lifting for freezer storage. Root system stress resistance varies seasonally, being greatest in mid winter. The degree of stress resistance largely defines the "lifting window" for BR stock, but is less important in container stock where roots are protected by an intact plug. Pathogens such as *Pythium*, *Phytophthora*, and others can derail success at any step in transplant production. Main points of vulnerability to pathogens include un-sterile growing medium and trays, inadequate nursery bed fumigation, and improper storage temperatures.

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PRODUCING QUALITY TRANSPLANT SEEDLINGS: BAREROOT TO BAREROOT AND CONTAINER TO BAREROOT

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Crockett T. 2003. Producing quality transplant seedlings: bareroot to bareroot and container to bareroot. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 105–107. Available at: <http://www.fcnanet.org/proceedings/2002/crockett.pdf>

Abstract

Webster State Nursery was established in 1957. The stock types and species grown here have changed over the years. Whereas 2+0s were once the main stock type grown, Webster now produces approximately 90% transplanted seedlings. This paper is an overview of the current cultural practices used to grow 1+1 and P+1 seedlings at Webster Nursery.

Key Words

Transplant culture, fertilization, irrigation, *Pseudotsuga menziesii*, *Pinus ponderosa*, *Pinus contorta*

STEPS TAKEN TO PROMOTE SOIL HEALTH

We rotate crops throughout the nursery field system, with a field planted for up to 3 years in a conifer crop, then fallow for 1 or 2 years. The total acreage at the nursery is 274 acres (111 hectares), allowing the flexibility to produce approximately one third of the area in conifer seedlings and the remainder open fallow.

Proper timing of irrigation applications can reduce disease levels by removing the optimum conditions for many diseases to thrive; the conditions include a combination of heat and moisture. We make certain that the soil surface is dry during the hottest hours of the day. This requires irrigation at 5:30 each morning.

We monitor the soil moisture daily, taking a composite of 6 inch (15 cm) core samples from each field location. These samples are weighed moist, dried in an oven for 2 hours, weighed again, and the difference between the two divided by the dry weight to calculate the percentage moisture available to the plants. Comparing these percentages to a calendar table prepared for Webster's soils, we begin the growing season near field capacity and end with moistures that stress the crop appropriately based on stock type and species. The actual amount of irrigation water applied to the plants any given day is based on the soil sample results from the prior afternoon and the temperature forecast for the current day.

We are using farming techniques that promote rapid soil drainage through deep tillage. Recent purchase of a chisel plow gives the nursery the opportunity to rip the ground open 20 inches (51 cm) deep as the first step of soil preparation. We subsoil at the beginning of each rotation to a depth of 30 inches (76 cm).

YEAR ONE OF 1 + 1

Soil preparation is the most important individual process to the final plant, ultimately determining root quality. This is a true statement for all stock types. Site preparation methods and timing are unique to every soil type. Understand your site and investigate and experiment with different soil farming methods and implements.

Sow 1+1 seedlings as early as you can properly prepare the soil. This enables these seedlings to take advantage of as many of the growing weather days as possible. We attempt to sow our 1+1 crop in early to mid April. Our particular region (southwest Washington) provides 90 to 100 growing days per season. Here we don't expect or hope for more time than that.

In order to limit water stress, we maintain a constant range of 12% to 15% for the 1+0 seedlings throughout the entire first growing season. We apply 75 lb of ammonium sulfate per acre (86.6 kg/ha) in 2 separate applications during the growing season: the

first scheduled for early June and the second early July. The first application is made at the first sign of true needles and the second just prior to the second flush. You must monitor the stock and understand their growth patterns and stages of development.

We apply a one-time application of herbicide to the 1+0 for 1+1 crop shortly after sowing. We have not found it necessary to apply fungicide to most of the 1+0 crop for many years. The exception is those species that originate in eastern Washington (pines and larch). These species contract needle diseases due to the extra moisture found here in western Washington. We rotate fungicide chemical families in the treatment of those diseases. We monitor this crop daily in hot periods and at least weekly in cool weather. No insecticides have been applied to 1+0 crops for more than 15 years.

YEAR TWO OF 1+1

Starting in early December, following the chill hours requirement (400 hours < 42 °F [5.5 °C]), the 1+0 plants are lifted, sorted, packaged in bags, and frozen (28 to 32 °F [-2 to 0 °C]) throughout the winter season.

Transplant as early as you can properly prepare the soil. We try to start in April and be finished by mid-May. If you cannot finish consistently within this time frame, consider purchasing more transplant machines to increase your daily production. We average 85,000 seedlings transplanted per day, per 6 row planting machine. Additional growing days increase the likelihood of a seedling reaching a specified size.

We maintain a cultural schedule for each stock type grown. This schedule is updated prior to the current growing season. The schedule is a quick glance guide for all of us at the nursery. What is the next scheduled activity and approximately when are we planning to apply that activity? The cultural schedule also serves as a permanent record verifying that this activity is complete.

The schedule is an excellent tool, but you must monitor your crop and recognize stages of the plant growth cycle. Apply your activities by these observations as well as the calendar. I apply approximately 8 light applications of fertilizer per growing season to the 1+1 crop. Most of them are 100 lb/ac (112 kg/ha). If you are not certain when to apply fertilizer, early is better than late. Once past the growth cycle, they won't be capable of using the fertilizer and thus it is wasted.

We design our irrigation schedule to compliment the unique characteristics of each stock type and species. For example, 1+0s require light watering nearly every day of the growing season; 2+0s require deeper, but less frequent irrigations. In terms of species, Douglas-fir requires water to move through the root zone, followed by drying; western redcedar grows best when maintained near field capacity.

Pesticides currently applied to the 1+1 seedlings include a single application of herbicide following transplanting and prior to bud break. We schedule fungicide applications to the pine and larch species based on the anticipated appearance of needle diseases. No insecticides are currently applied.

PLUGS TO P+1

The soil preparation, transplant timing, and so on, are basically the same as 1+1 plants. There are several things to be aware of when planning for container stock transplanting. Don't assume that the plants grown outside your control will be of the quality you are expecting. Have the size expectations and quality specifications spelled out in a contract. Visit the facility where the plants are to be grown prior to accepting a contract. Examine the greenhouses for cleanliness, determine the soil mix contents, and verify the soil supplier. Ask about their water source and their water-monitoring program. Above all, be aware that when you bring plants from a source outside your facility you also bring the risk of disease and weeds that you may have never encountered before.

As with 1+1 plants, when planning the field location of P+1 species, consider the following: 1) moisture needs are unique for each species; 2) some species will require multiple pesticide applications; and 3) species will have unique fertilizer requirements (both in rate and formula).

FINISHING THE CROP AT WEBSTER NURSERY

Douglas-fir, White Pine, Lodgepole Pine, Ponderosa Pine (2+0 and Transplants)

Once the plants have grown to near the specified target size, we begin culturing to encourage root growth and discourage stem height growth. These activities include: 1) reducing the amount of irrigation water available to the plants in accurately measured increments; 2) root wrenching to 10 to 12 inch (25.4 to

30.5 cm) depth at varying times throughout the middle to late growing season.

All 1+0 Plants

We maintain a moisture stress free growing environment throughout the growing season (keeping soils at a 12% to 15% moisture range). No other activities (no root wrenching, and so on) are performed.

Western Redcedar, Western Hemlock

We maintain the same moisture stress free growing regime as mentioned for the 1+0, but with deeper water applications so the soil always stays near field capacity.

True Firs and Spruce

These species will respond well whether grown with other species with drier or wetter requirements. On our site, however, we do not normally perform any root culturing activities.

For all crops, one of the final activities prior to lifting involves monitoring the number of cumulative chill

hours. Our goal is to attain 400 hours below 42 °F (5.5 °C). We may lift seedlings prior to receiving the required chill hours; we would recommend, however, outplanting them soon (no long-term storage). The chill hour requirement to achieve dormancy is based on research performed by Weyerhaeuser Company.

At the same time that we are monitoring chill hours, we are frost protecting seedlings. We use the same overhead sprinklers that are used to irrigate the crops during the growing season. Crews are called in at approximately 36 °F (2 °C) and turn the water on at 32 °F (0 °C). This forms an ice envelope around the tender foliage and protects it from damage.

IMPROVEMENTS FOR THE FUTURE

1. Scheduled foliar and soil samples to determine any nutrient imbalances.
2. Fertilizer trials throughout the different stock types, for example, looking at slow-release and foliar applications.
3. Scheduled soil sampling to determine disease levels prior to sowing or transplanting.
4. Additional root culturing, with the goal of improving root-to-shoot ratios.

TREE SEEDLING TRANSPLANTERS

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Windell K. 2003. Tree seedling transplanters. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 108–116. Available at: <http://www.fcnet.org/proceedings/2002/windell.pdf>

Abstract

Short summary tables of tree seedling transplanter manufacturers and some of the models they sell are presented. These tables include manufacturer contact information.

Key Words

Bareroot seedling transplanters, containerized seedling transplanters

INTRODUCTION

The Missoula Technology and Development Center was requested to conduct a market search for bareroot and containerized tree seedling transplanters. The intent was to distribute this information to the attendees of the Joint Annual Meeting of the Forest Nursery Association of British Columbia and the Western Forest and Conservation Nursery Association held in Olympia, Washington. The primary manufacturers of nursery type transplanters found were Mechanical Transplanter Company, Holland Transplanter, Egedal, and Lännen. Although Bartschi-FOBRO makes some units for sale in Europe, they are not readily available in the US or Canada. Therefore their transplanters have not been included in the summary table.

In the process of conducting the search for nursery transplanters, other machines were identified that would be more appropriate in a reforestation setting (field and forest) rather than a nursery setting. Rather than just toss the information, it was included. Mechanical Transplanter Company, Holland Transplanter, Egedal, Whitfield Forestry Equipment, Tree Equipment Design Inc, and Phil Brown Welding Corporation make these type of transplanters. One company, Silver Mountain Equipment Inc, is also listed in the Vendor Information section because they offer a retrofit for other companys' transplanters to make them place the seedlings with greater precision and consistency. You will have to contact them for details.

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DISCLAIMER

The information in the following tables has been assembled in a short amount of time with no chance for review by vendors. There is a very good chance that errors may be present, so just use it as a quick reference. It is suggested that you contact the manufacturer (or distributor) listed in the Vendor Information Section directly to get the latest information on their products.

PRODUCT TABLES (SEE DISCLAIMER)

Gripper Style (Conventional) Transplanters for Nursery Beds

Make	Model	Comments	Base Price US\$
Mechanical Transplanter	Model 500U unit (Close-spacing bed planter unit)	A single unit that can be ganged on a tool bar. 6 inch shoe. Rear drive system.	\$893 (see note 1)
Mechanical Transplanter	Model 525U unit (Close-spacing bed planter unit)	A single unit that can be ganged on a tool bar. Plant spacing as close as 2.5 inches in the row. 8 inch shoe. Direct drive system. (Plant 6 rows as close as 9 inches apart when put in 525 Bed Transplanter.)	\$1305 (see note 1)
Mechanical Transplanter	Model 550LU unit (Large bed planter unit)	A single unit that can be ganged on a tool bar. Plant spacing as close as 3.5 inches in the row. Holds seedlings with up to 18 inch top. Ten inch suction point shoe. Direct drive system. Row spacing on a single tool bar as close as 22 inches. (Plant 5 rows as close as 11 inches apart when put in 55 Bed Transplanter.)	\$1907 (see note 1)
Mechanical Transplanter	Model 580 unit (Large bed planter unit) (fig. 1)	A single unit that can be ganged on a tool bar. Similar to 550LU with larger pocket and wider 3 inch shoe. As close as 22 inch row spacing when ganged on tool bar. As close as 11 inches between rows when mounted on bed planter frame. Handles up to 18 inch tops and 7 inch deep roots. Plant spacing 5.5 inches and up. Direct drive float wheel drive system.	About \$1907 (see note 1)
Mechanical Transplanter	Model CT 5 (Christmas trees)	Mount on a 3-point hitch. Ten inch deep shoe. Comes with 1 seat.	\$1326 (see note 2)
Mechanical Transplanter	Model CT-8 (Mid-sized Christmas trees) (fig. 2)	Mount on a 3-point hitch. Twelve inch deep shoe. Comes with drive system that allows faster forward planting speeds. Comes with 1 seat; 2 optional.	\$2550 (see note 2)
Mechanical Transplanter	Model CT-12 (Heavy duty Christmas trees)	Mount on a 3-point hitch. Fourteen inch deep shoe. Large offset pockets for handling plants up to 30 inches long. Direct drive gauge wheels provide accurate spacing and proper depth control. Cat I or II, 3-point hitch and choice of rubber or steel packing wheels at no extra charge.	\$4437 (see note 2)
Mechanical Transplanter	Model 1980 (mid-sized nursery transplanter) (fig. 3)	Single unit that can be ganged on a tool bar for row spacing as close as 21 inches. Shoe is 4 inches wide and 12 inches deep.	\$4437 (see note 1)
Mechanical Transplanter	Model 2000 unit (Large nursery transplanter)	A single unit that can be ganged on a tool bar. Shoe is 6 inches wide and 12 inches deep. Can handle up to 5-foot tall whips.	\$5995 (see note 1)

Make	Model	Comments	Base Price US\$
Holland Transplanter	Model 1050 unit	A single unit that can be ganged on a tool bar. Plant material may be 9 inches above ground. Accepts plant plugs and bareroots up to 1 inch diameter and 4.5 long. Plant spacing 2.5 inches and greater. Row spacing side-by-side 14 inches and greater. Offset, double gang machine allows row spacing as close as 7 inches. Optional Cat 1, 3-point hitch, or tool bar mounting brackets available.	\$795 to \$895
Holland Transplanter	Model 1500 unit (fig. 4)	A single unit that can be ganged on a tool bar. Plant holder with chain arrangement provides spacing from 12 to 96 inches. Disc holder arrangement provides plant holder arrangement from 3 to 48 inches. Five (5) interchangeable plant holder styles available. Optional Cat 1, 3-point hitch, or tool bar mounting brackets available. Many other options available including multi-row frames and toolbars.	\$720 to \$765 + 2% to 5%.
Holland Transplanter	Model FWD 1500 unit (fig. 5)	Same as Model 1500 but also has a large front wheel drive tire that eliminates sliding in dry, sandy and loose soil conditions by using the front wheel to power the planter.	\$825 to \$870 + 2% to 5%.
Holland Transplanter	Model 1600 unit	A single unit that can be ganged on a tool bar. Same plant holders mentioned in Model 1500. Model 1600 can be mounted on any type tool bar for 3-point mounted multi row planting arrangements where fertilizer attachments are not being used.	\$695 to \$740 + 2% to 5%.
Egedal	Transplanter Type M	Number of rows possible: 4 to 7 Row spacing: 4 and 5 rows from 20 to 25 cm; 6 and 7 rows from 22 cm. Planting distance of 5 to 25 cm possible. Standard 3-point hitch.	\$16,491 to \$19,826
Egedal	Transplanter Type MS	Number of rows possible: 4 to 7 Row spacing: 4 and 5 rows from 25 cm; 6 and 7 rows from 22 cm. Planting distance of 5 to 25 cm possible. Self-propelled. Self-steering.	\$63,153 to \$71,564 Options available.

Note 1 – There are many combinations available from the manufacturer using these basic units. See the price list from Mechanical Transplanter for these package deals.

Note 2 – This Christmas tree transplanter could be used in the nursery for larger stock on larger spacing. For smaller Christmas trees on closer spacing, it would be more appropriate to use a transplanter like Mechanical Transplanter's Model 525.

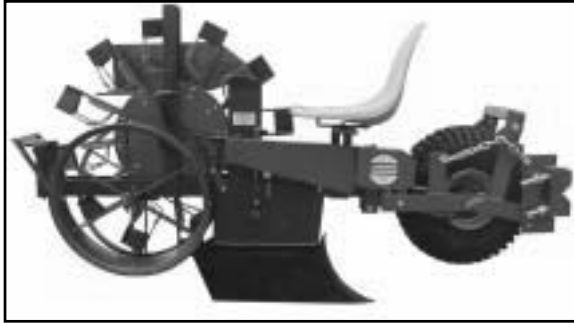


Figure 1. Mechanical Transplanter Model 580.



Figure 3. Mechanical Transplanter Model 1980.



Figure 2. Mechanical Transplanter Model CT-8.

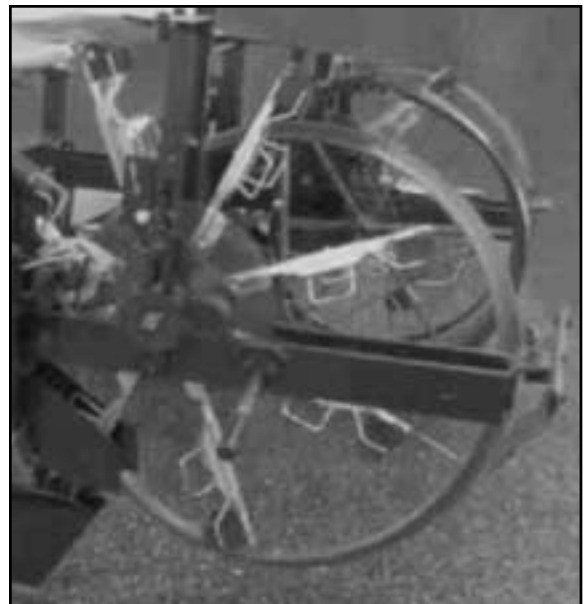


Figure 4. Disc holder arrangement for Holland Transplanter.



Figure 5. Holland Transplanter Model FWD 1500.

Carousel Style (Plug) Transplanters for Nursery Beds

Make	Model	Comments	Base Price US\$
Mechanical Transplanter	Model 4000 Unit (mid-sized metering)	A single unit that can be ganged on a tool bar. Designed to handle all cell type plants. Standard float Wheel Direct Drive System firms the soil, controls the depth and provides accurate, positive spacing. Standard spacing begins at 7.5 inches and a special gear can go from 5 inches and up. Their RD version comes with a packing wheel drive system. They also list a computer-controlled variant called the Model EM4000. It uses a UHMW lined skid plate to do the packing.	\$2387 (see note 3)
Mechanical Transplanter	Model 6000 Unit (large-sized metering) (fig. 6)	A single unit that can be ganged on a tool bar. Same basic design as the Model 4000 but with larger cups. This is their largest carousel transplanter. Their RD version comes with a packing wheel drive system.	\$2423 (see note 3)
Mechanical Transplanter	Model 5000 Unit (Compact metering transplanter) (fig. 7)	A single unit that can be ganged on a tool bar with row spacing as close as 12 inches. Unit comes with a skid plate packing system. The model 5000W has packing wheels instead (extra money). This model requires either a single (\$1398) or dual (\$2310) gauge wheel drive system.	\$2509 (drive system extra) (see note 3)
Holland Transplanter	The Rotary One	Not recommended for forestry applications in nursery if ganging is needed. They are too heavy and long according to Hugh Gerhardt from Holland Transplanter. (However, some info is in the brochure section.)	
Lännen	RT-2 (fig. 8)	Minimum row spacing of 20 inches with one tool bar, 10 inches with tandem frame with 2 tool bars. Plant spacing between 2 and 32 inches possible with the right sprocket combination.	\$2295 base. \$2425 set up for tight spacing.

Note 3 – There are many combinations available from the manufacturer using these basic units.

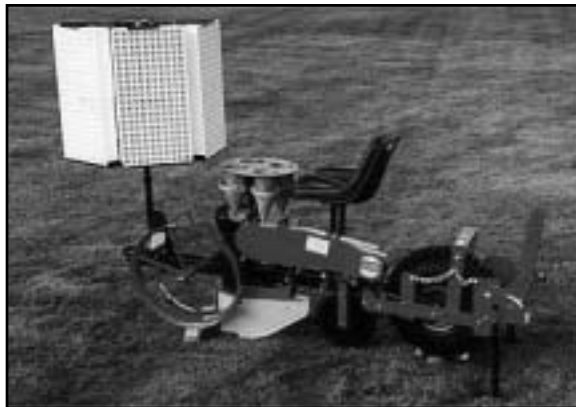


Figure 6. Mechanical Transplanter Model 6000.



Figure 7. Mechanical Transplanter Model 5000.



Figure 8. Lännen Model RT-2.

AUTOMATED TRANSPLANTERS FOR NURSERY BEDS

Make	Model	Comments	Base Price US\$
Lännen	Plantek Automatic	Minimum row spacing with one tool bar 60 cm (24 inches). Plant spacing indefinitely adjustable. Row units from 1 to 8 possible. Output up to 2 plants per second per row. Must use Plantek seedling trays.	\$10,500
Lännen	PlantekSelective	Minimum row distance: 55 cm (22 inches), with a tandem frame 27.5 cm (11 inches). Plant spacing: 10 to 90 cm (4 to 35.5 inches). Electronic control of planting depth. Hydraulically powered. Photocells detect gaps and replace them with new plants. Optional radar control for plant spacing. Must use seedlings grown in Plantek DL 300 trays.	\$11,500

Gripper Style and Hand Transplanters for Outplanting

Make	Model	Comments	Base Price US\$
Mechanical Transplanter	Model CT 5	For Christmas trees. Mount on a 3-point hitch. It is possible to gang 2 together.	\$1326
Mechanical Transplanter	Model CT-8	For mid-sized Christmas trees. Mount on a 3-point hitch. It is possible to gang 2 together.	\$2550
Mechanical Transplanter	Model CT-12	For heavy-duty Christmas trees. Mount on a 3-point hitch. It is possible to gang 2 together.	\$4437
Holland Transplanter	Model 1525 Unit	Price is for a single row planter. Furrow opening shoe is 7 inches deep and 2 inches wide. Choice of Cat 1, 3-point hitch, or tool bar mounting brackets. Optional Cat II, 3-point hitch available. Many other options available. Available in 2, 3, and 4 row models.	\$1450

Make	Model	Comments	Base Price US\$
Egedal	Transplanter Type JT	Number of rows: 1 to 4. Row width: Adjustable from 60 cm. Mounting: 3-point hitch.	\$4986 to \$11,041. Options available.
Egedal	Transplanter Type Hydromatic	Number of rows: 1. Planting distance: 50 to 400 cm. Mounting: 3-point hitch.	\$23,771 to \$28,578. Options available.
Egedal	Transplanter Type B	Number of rows: 2. Row width: 50 to 120 cm. Planting distance: 10 to 30 cm. Mounting: 3-point hitch.	\$5076 to \$5219. Options available.
Egedal	Transplanter Type K	Number of rows: 2. Row width: Adjustable from 24 to 71 inches (60 to 71 cm). Mounting: 3-point hitch.	\$17,556 Options available.
Whitfield (see note 4)	F-85-S (semi-automatic) (fig. 9)	A single unit that will do one row and is mounted on single crank axle. Has a full cab. Heavy-duty use. (3-point hitch and single or double crank axle configurations available)	\$14,800
Whitfield (see note 4)	F-85-HC (semi-automatic)	A single unit that will do one row and is mounted on 3-point hitch adapter. Has half cab. Heavy-duty use. (3-point hitch and single or double crank axle configurations available)	\$10,180
Whitfield (see note 4)	FL-86 (semi-automatic)	A single unit that will do one row and is mounted on 3-point hitch adapter. Has a vinyl canopy top. Heavy-duty use. (3-point hitch and single or double crank axle configurations available).	\$10,440
Whitfield (see note 4)	F 500-S (semi-automatic)	A single unit that will do one row and is mounted on single crank axle. Has a super cab. Heavy-duty use. (3-point hitch and single or double crank axle configurations available).	\$15,300
Whitfield (see note 4)	F-9700-HC (semi-automatic)	A single unit that will do one row. 3-point hitch. Forestland planter for hardwoods.	\$11,200
Whitfield (see note 4)	3204-RF (manual)	A single unit that will do one row. 3-point hitch. Comes with two rear facing seats. Heavy-duty planter.	\$5725
Whitfield (see note 4)	ST-630 (manual)	A single unit that will do one row. 3-point hitch. Side delivery. Comes with one seat. Heavy-duty planter. Frame for canopy has window to see tractor operator for open field use.	\$4500
Whitfield (see note 4)	"L" (manual)	A single unit that will do one row. 3-point hitch. Economy model. One seat forward facing. Light to Medium duty use.	\$3000

Make	Model	Comments	Base Price US\$
Whitfield (see note 4)	SP-3202 (manual)	A single unit that will do one row. 3-point hitch. Two seats. For Pine and hardwood seedlings. Heavy-duty planter.	\$5680
Whitfield (see note 4)	5200 (manual)	A single unit that will do one row and is a tow-type transportable transplanter. Plants hardwoods and evergreens up to 4 feet tall.	\$6680
Whitfield (see note 4)	601 (manual)	A single unit that will do one row. 3-point hitch. Semi-contour model. Medium to heavy-duty use.	\$4638
Whitfield (see note 4)	88-2N (manual)	A single unit that will do one row. 3-point hitch. Two seat model. Medium to heavy-duty use.	\$4500
Tree Equipment Design	One-Seat Model (manual)	A single unit that will do one row and is mounted by 3-point hitch. Used mostly for Christmas trees or small nursery stock.	\$2225
Tree Equipment Design	Two-Seat Model (manual)	A single unit that will do one row and is mounted by 3-point hitch. Hydraulic hillside control, scrapers, and high-backed seats available as add ons.	\$2920
Tree Equipment Design	Shade Tree Model(manual)	A single unit that will do one row and is mounted by 3-point hitch. Makes up to 24 inch trench 14 to 16 inches deep. Optional telescopic row markers with lifting cylinders available.	\$4150
Phil Brown Welding	Tree Planter (fig. 10)	A single unit that will do one row and is mounted by 3-point hitch. They also make a double tool bar for mounting 2 at once.	\$3500

Note 4 – This is not an entire listing of the offerings from Whitfield. Their catalog had not arrived by the time of this report.



Figure 9. Whitfield Model F-85-S.



Figure 10. Phil Brown Welding Tree Planter.

VENDOR INFORMATION

Bartschi-Fobro
1715 Airport Drive
PO Box 651
Grand Haven, MI 49417
616.847.0300
fax: 616.842.1768
<http://www.fobro.com>

Holland Transplanter
510 E 16th Street
PO Box 1527
Holland, MI 49422-1527
616.392.3579
800.275.4482
Fax: 616.392.7996
<http://www.transplanter.com>

Lännen (www.lannenplantsystems.com)

Distributors:

Williamson Greenhouses (RT-2 Sales)
820 Elizabeth Street
Clinton, NC 28328, USA
910.592.6121
Fax: 910.592.2420
e-mail: greenhse@intrstar.net

Automated Transplant Systems / Santa Fe
Nursery (Automatic transplanters, Plantek trays)
PO Box 820
Guadalupe, CA 93434
805.929.3260
Fax: 805.929.4091
<http://www.autotransplanting.com>

Hakmet LTD
881 Harwood Blvd.
Dorion, Quebec, Canada
450.455.6101
Fax: 450.455.1890
email: hakmet@total.net

BAP Forestry Equipment Ltd (Planting tubes)
150 Riverside Drive
Federicton, New Brunswick E3A 6P8, Canada
506.405.1309
fax: 506.458.2200
Mr Blain Phillips
e-mail: bphillip@nbnet.nb.ca

Mechanical Transplanter Company
1150 South Central Avenue
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616.396.8738
800.757.5268
Fax: 616.396.3619
<http://www.mechanicaltransplanter.com>

Phil Brown Welding Corporation
4689 – 8 Mile Road NW
Conklin, MI 49403
616.784.3046
fax: 616.784.5852

Silver Mountain Equipment, Incorporated
(Retrofits other brands of transplanters for more precise planting)
4672 Drift Creek Road SE
Sublimity, OR 97385
503.769.7127
fax: 503.769.3549

Timm Enterprises Limited (Egedal)
PO Box 157
Oakville, Ontario L6J 4Z5 Canada
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Sales: 1.888.769.8466
Fax: 905.878.7888
<http://www.timmerprises.com>
sales@timmenterprises.com

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<http://www.whitfieldforestry.com>

ASPECTS TO MAKE PLUG-TO-PLUG TRANSPLANTING A SUCCESS

OR

"IF YOU THINK THAT SOMETHING SMALL CANNOT MAKE A DIFFERENCE—TRY GOING TO SLEEP WITH A MOSQUITO IN THE ROOM"

STEVE PELTON

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Pelton S. 2003. Aspects to make plug-to-plug transplanting a success. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 117–123. Available at: <http://www.fcnet.org/proceedings/2002/pelton.pdf>

Abstract

Although widely used in bareroot nurseries, transplanting is a new technology to container forest nurseries. The critical aspects required to successfully implement a plug-to-plug transplanting operation in a container nursery are discussed. An increased number of operational steps, technical equipment, and planning are required, but the payoffs to the nursery include improved quality and yield.

Key Words

Plugs, transplanter, mini plugs, containers, forest nursery, gapping, fixing, computer vision

INTRODUCTION

For economic reasons, the goal of forest nursery managers is 100% yield of seedlings from the growing containers. This requires 100% of the cavities to be occupied with a seedling and is seldom attained. Conventional direct sowing always results in a percentage of cavities being blank due to seed germination. This percentage can be decreased by sowing multiple seeds per cavity, but this is not usually practical due to seed volume constraints and the cost of removing the multiples by hand. As well, a percentage of seedlings that germinate are smaller and weaker than the others. These tend to be culled out during the harvest phase, further reducing yield and increasing delivered unit costs. Nursery managers are keen to work with systems that have the potential to yield 100% deliverable seedlings. Recently, integrated systems have been developed in the horticultural sector to address these issues, and the techniques have begun to be adopted by forest nurseries. In this presentation I hope to help you understand the costs, risks and growing implications of using plug-to-plug transplanting to move toward 100% yield.

I wish to demonstrate that, by paying attention to every detail in the plug to plug transplanting process, you can make significant progress to improve yield, quality and your customer's and your bottom line.

WHAT IS PLUG-TO-PLUG TRANSPLANTING?

For the purpose of this presentation I have defined it as "the physical movement of a plant from one growing container to another to enhance seedling performance and yield."

WHY TRANSPLANT?

First off, we should look at the perceived benefits of plug to plug transplanting. Transplanting is well developed in the horticultural sector, and many benefits have been realized.

Space Efficiency

Starting in a small cell and transferring to a large cell realizes significant growing space reduction. Of particular interest are the winter months when considerable fuel savings can be realized. For some

stocktypes, it may be possible to transplant into the destination container and place it directly outside, bypassing greenhouse requirements entirely.

Seed Conservation

Seed conservation issues are important. The system can have little wastage of seed, making high gain seed more economic. Typical seed usage in forest nurseries per delivered seedling is approximately 2.5:1. In some cases with plug-to-plug transplanting, the ratio can be reduced to 1.2:1, realizing significant seed savings to the client.

Plug-to-plug transplanting can also address situations where using low value seed would not be feasible in a conventional sowing situation.

Overall Efficiency

In addition, the transplanting system provides opportunities to move large numbers of seedlings through multiple environments or treatments easily. The high tech field of micropropagation uses plug-to-plug technology extensively for space and flexibility reasons.

On the operational nursery side, thinning can be virtually eliminated. Seedling uniformity can be increased through seedling selection, improving yield and driving down harvesting unit costs.

WHY NOT TRANSPLANT?

Of course there are reasons not to transplant and these need to be evaluated as well.

Complexity certainly is an issue. Plug-to-plug transplanting requires sophisticated equipment that is expensive to purchase, staff, and maintain. The nursery must have enough volume of cavity sizes suitable for plug-to-plug transplanting, for example, 410A (Styro 6S) and larger. To coordinate the process during the optimum crop windows, an increased level of management input is required. This adds up to an element of risk that the nursery manager will have to understand and control in order to deliver a successful plug-to-plug transplant crop.

TRANSPLANTING OPTIONS

Transplanting has been going on for centuries in the horticultural world. Transplanting young plants by hand into fields has been done for centuries with food crops. This “pricking out”, as it is commonly called, means hand selecting the finest seedlings and transplanting them into a new growing environment.

Plug+1s, bareroot 1+1s and 1+2s are examples in the forest nursery industry. In container nurseries, pricking out is used with poor germinating seedlots or with seedlots that germinate over a prolonged period of time, such as Pacific silver fir (*Abies amabilis*) and yellow cedar (*Chamaecyparis nootkatensis*). Seeds are spread in a flat containing growing media and hand transplanted to another container when they have developed. This practice is also used within growing containers when a “double” is transplanted to a nearby blank cell. There are a number of problems with “pricking out” as an operational system. During the process, there is a loss of fine roots which impairs the seedling performance. Also, the task is dependent on human labor which tends to be slow and therefore expensive.

In the past decade, specialized equipment has evolved in the horticultural market to such a degree that nearly all floricultural and horticultural crops are transplanted at least once by machine in their production cycle. However, this practice has only recently been considered for use in container forest nurseries.

There are a number of options for the starting mini cell. Some growers have experimented with cut down 211s (Styro 2s) as a mini plug. Seedlings grown in these plugs work well as a starting point for experimentation and are a viable system for transplanting into a 512 (Styro 15S) or larger cavities by hand.

There are a number of netted plug products produced commercially that are available. Jiffy Plugs® and Ellepots® are examples. These plugs have a net of synthetic material that holds the media in place, facilitating handling. There are many sizes available and some are quite suitable for a plug-to-plug program. Equipment is being developed for a complete transplant system by these manufacturers.

Also available are specialized trays designed for mechanical transplanting. The bedding plant industry has starter trays in many configurations of cell shape, volume, and dimension. Due to their lack of ribs for the prevention of root spiraling, most of these trays have limited use for forest nurseries. The Winstrip, developed by Aart van Wingerden, is a design well suited for forest nursery production, as it has good air pruning for root development and its endless design is intended for transplant machine efficiency. Transplanter manufacturers generally have a starter tray preference that their machines work with most efficiently, and it is best to consult them regarding suitability.

PLUG-TO-PLUG TRANSPLANTING VERSUS CONVENTIONAL SOWING

To look at the aspects of plug-to-plug transplanting versus conventional sowing, we need to compare the steps involved to establish a crop in each system.

Conventional Sowing

Conventional sowing has the following steps: 1) sow in destination container; 2) transport to greenhouse (GH); 3) layout in GH; 4) thin; and 5) grow.

Plug-to-Plug Transplanting

A plug-to-plug transplanting program has the following steps: 1) sow in donor tray; 2) transport to GH; 3) layout in GH; 4) grow 6+ weeks; 5) transport to gapping; 6) gap; 7) transport to GH; 8) grow 2+ weeks; 9) transport to transplant; 10) transplant into destination container; 11) transport to GH; 12) layout in GH; and 13) grow.

Notice there are 13 stages involved in the plug-to-plug program versus 5 in the normal sowing regime. It is important to note that each of these steps is critical to the overall success of the program. A problem in any step will impair the ability to meet order objectives.

CRITICAL ASPECTS FOR PLUG TO PLUG TRANSPLANTING SUCCESS

From this group I have condensed the Critical Aspects required for Plug to Plug Transplanting Success. We will look at each in more detail.

Donor tray design

Donor tray media

Seeding quality

Seedling quality/Growing Regime

Gapping/Fixing

Transplanting

Covering/Gritting

Transport System

Post handling

Staff training

Donor Tray Design

The donor tray must include several important design criteria.

Correct Soil Volume/Surface Area Ratio—A donor tray is required to have small cavities for space saving considerations, but must be large enough to

grow a seedling for up to 12 weeks without impairing subsequent plant growth. For slow growing species, trays with 0.3 to 0.7 inch³ (5cc to 12cc) media volume and a density of 353/ft² to 112/ft² (3800/m² to 1200/m²) are possible. Faster growing species or large seed types require media volumes ranging from 0.9 to 1.5 inch³ (15cc to 25cc) at densities ranging from 74/ft² to 112/ft² (800/m² to 1200/m²). The shape of the cell is important to match the mechanism used by the transplanting machine to extract the plug from the cell. For example, it is preferred to use a square cell over a round cell when the transplant head uses a tweezer type mechanism for removing the seedling.

Pruning for Fibrous Root System—An important factor in plug-to-plug transplanting is development of a mini plug with a fibrous root system that is capable of occupying the destination tray quickly. The donor tray must have a pruning system incorporated into its design. Air and copper are used. An operational issue arises, since most donor tray designs are very shallow, with heights ranging from 1.2 to 2.4 inches (3 to 6 cm) with small surface area. Roots of germinating seedlings will quickly reach the bottom or sides of the plug and get pruned, requiring diligent moisture and nutrition management. Most trays rely on the pruning method to prevent root spiraling, so it is critical the tray is well tested for root form prior to implementing a large program.

Drainage—Shallow trays have a very high perched water table, and this is a difficult aspect to manage. Excellent drainage is a key requirement for the donor tray. Otherwise, the high perched water table will keep the seedling in a water logged situation, resulting in reduced germination, poor nutrient uptake, and root disease.

Compression Factor—The compression factor is the relationship between the number of cavities in the donor tray versus the destination tray. Compression should be a minimum of 3:1, and ideally in the range of 5:1. For example, if the donor tray contains 500 cells and the destination tray 100 cells, this is a compression factor of 5:1. The trays must also be easy to handle for both people and machines. Reference points need to be designed into the tray so machines can handle the tray repeatedly. There can be no variance from tray to tray from year to year. Another desirable design trait is for the tray to be endless. Meaning the distance between a cell within the tray is the same as the distance of the last cell in the first tray to the first cell in the second tray. This design improves efficiency of most transplanters and is essential on others.

Donor Tray Growing Medium

Several parameters should be considered in the selection of growing medium for the mini plug.

Free Draining—The shallow trays have a very high perched water table and tend to retain too much moisture. Ideally the medium should have low capillary action so the perched water table is as low as possible.

Consistency—The medium must flow through filling machines and provide uniform loading. It must have good moisture retention with high air filled porosity and be consistent and repeatable from batch to batch.

Choices include naturally occurring substrates such as peat, coir (ground coconut husks), rice hulls, and composted wood fiber. Artificial substrates include polymer substrates of foam and foam mixes containing natural media. Incorporation of a binding material in the substrate improves the transplanting efficacy, since many forest seedlings do not have a root system capable of holding the plug together. Products such as bentonite and starch based glues are available.

Seeding Quality

One objective of plug-to-plug transplanting is to conserve seed, so singulation and accuracy are important. Seeding target accuracy is 100% cavity fill with a single seed placed in the center of the cavity. It is difficult to place a seed accurately in the center of a very small cell; therefore investment in seeding heads/drums or a dedicated machine may be required. Covering requirements are also more precise with small cells and may involve modifications as well.

Growing Regime

Establishing strong top growth and strong root development is critical to transplanting success. Subjecting young plants to ideal growing conditions during germination and early growth also gives the seedlings momentum that carries forward in the crop cycle. This concept was taught to me by an expert Dutch vegetable grower named Jaap Byl. He demonstrated that the first few weeks in the life cycle of the plant are the most critical. Growing under ideal conditions and maintaining the environment at the exact optimal conditions is the best investment a grower can make in their crop. Compression of the mini tray to the destination tray requires far less growing space. As such, a higher tech facility is more

affordable. Assimilation lighting, energy curtains, efficient transportation systems, boom irrigation, and glass houses are desirable facilities that become more affordable. Also, on the plus side, heating, water, fertilization, and associated tending costs per seedling are reduced during this stage. However, a large concentration of seedlings in a small area increases production risk. Should the facility sustain a failure, an entire crop could be compromised.

Growing mini plugs follows standard nursery practices for fertilizer prescriptions, electrical conductivity, and pH. Most growers have not changed their growing regimes substantially during this stage. The goal is to grow a short bushy seedling with a root system large enough to hold the mini plug together but not root bound in any way.

Gapping or Fixing—What Is It?

Once the young seedlings are a reasonable size and roots have filled the root plug, they are ready for “gapping up”. This is typically between weeks 4 to 8. This process eliminates the “duds” in the donor tray. These include blanks and the small or weak seedlings that have a low probability of making shippable status. Gapping is desired because all transplant machines are mechanical devices which move every plug from the donor tray to the destination tray. If transplanting is done without gapping, there is the need to manually “fix” the destination tray to 100% good seedlings with human labor on the transplanting line. Gapping is the slowest activity within the transplant system and also has narrow timelines where the seedlings are at an optimum stage.

The duds can be identified by human eye, photo optical systems, or computer vision. A simple manual method is to simply extract the dud mini and replace it with a good seedling by hand. This is typically done before the tray goes to transplanting. This is often more effective because it may be difficult to do on the transplanting line in real time. Fondue forks, pins, and computer operated pneumatic devices are used manually or semi-automatically to extract the undesirable plugs.

The horticultural industry has a number of manufacturers of computer based gapping equipment which are designed specifically for this purpose. The equipment is the most technical and expensive portion in the transplant system. Trays to be gapped are brought from the greenhouse and loaded into the machine. A color camera inspects the tray and counts pixels of color which are set by the operator. Most camera systems use luminosity and color ranges

which separate the green foliage of the seedlings from the background noise of the growing media. It is important that the seedling be sufficiently developed so the camera can “see” it. The camera can easily detect the seedlings if they are centered in the cell and have reached the stage of secondary needle development. If seedling foliage extends into the neighboring cell the camera will think the foliage belongs to that cell. This will introduce errors into the process. Cells containing pixel counts below the set point are removed automatically by pin extraction or blasts of air. These machines are capable of inspecting 300 to 400 trays per hour. The tray then proceeds to another machine called the “gapper”. The tray is inspected again, either by laser or computer vision, and the machine determines which cells are empty. The computer maps this information into memory and then operates a mechanical arm to lift a filled cell from a donor tray and transfers it to a blank cell in the destination mini tray. This process takes place at the rate of 1 per second on most machines and repeats until the tray is 100% filled with seedlings. Total production capacity of the machine is determined by the percentage of blank cells, times the cell count, divided by machine cycle time. For example, a 400 count tray with 80% germination (20% blanks) has 80 cells to gap. This will require roughly 80 seconds of machine time, yielding a maximum production rate of 45 trays per hour. Notice the relationship between tray inspection and tray gapping. With this scenario, inspection is quick at 300+ trays/hour, but gapping is slow at approximately 45 trays/hour. Multiple shifts and multiple gapping machines may be required to meet production schedules. After gapping, the mini trays return to the growing area for another 2+ weeks, which allows them to strengthen their rooting and attain sufficient size for transplanting.

Transplanting

The growing medium used, its moisture content, and the mechanism for placing the mini into the destination tray need to be investigated carefully. Quality transplanting is measured using the same rules and key indicators as field personnel use while monitoring planted seedlings in the forest. Raised plugs, “J” rooting, crammed plugs, and poor microsite selection are to be avoided. Transplanters are mechanical devices and, if not set up properly and closely monitored, they can produce the previously mentioned problems within the destination container. A high quality plug-to-plug transplant should be indistinguishable from a sown seedling. Our experience indicates with proper system design, root form is not

impaired and in some stocktypes can actually be enhanced.

Centering the seedling in the destination container is a plus. This allows roots to egress in all directions to form a better plug and increase yield.

Some transplanting machines push the mini plug directly into the medium of the destination tray. In our experience this is not desirable, as many plugs are left exposed, bent, or deformed. The best solution is to prepare a hole slightly larger and deeper than the mini cell and place the mini directly to the bottom of this receptacle. Preparation of the hole can be done with dibble plates or drilling machines. Dibble plates are plates with pins which are pushed into the medium to form the receptacle. There is some compression of medium during this process and this can create an interface which can be problematic to root development. Drilling machines are similar in concept but use spinning drill bits to remove medium to form the receptacle. There are no interface issues with drilling. One dibble machine can be changed for each block size, whereas drilling machines are unique to a block size and therefore considerably more expensive.

Transplant action must be gentle but firm, maintain vertical orientation of the seedling, and minimize soil disturbance. There are many manufacturers of transplanting machines and I will not go into detail here as others are presenting on this topic. I would like to note there are differences in the transplant head design between manufacturers and some are more suitable for forest seedling production than others.

We have compared hand transplanting and machine transplanting results. In every case, the machine transplant blocks yielded a higher percentage of shippable seedlings. We attribute this to the fact that people are inconsistent in their work habits despite supervision and good intentions. Transplanting machines can have problems as well if not set up properly. However, once the operator is familiar with proper setup, the machines are very consistent in their work. In our experience, it is possible to achieve 100% cavity fill of uniform seedlings using plug-to-plug mechanical transplanting.

Covering/Gritting

The physical act of transplanting exposes growing medium on the destination block surface. This needs to be dealt with, otherwise it becomes an ideal environment for algae and liverwort growth. The purpose of covering with grit is to help prevent this growth. The grit heats up with solar input and

becomes too warm for these plants to germinate and grow. Using air jets or a gentle watering prior to gritting is a good way to remove some of the medium. The young seedlings, just transplanted, do not have much lateral stability in their new home. With grit falling on them during the covering process there is a danger the young seedlings can be pushed over. The conventional scalloped rotating drum gritting machines do not work well for this as they tend to throw the dollop of grit at the seedling, pushing it over in the process. A better machine is the conveyor belt type which drops grit in a light curtain across the styroblock. This type of machine uses slightly more covering material per block, somewhat increasing costs.

Transport

As we saw earlier, there are more moves involved in the transplant operation compared to conventional sowing. Therefore, an efficient transportation system is critical for transplanting. Extra transport is required to bring trays to and from gapping, and to and from transplanting. With conventional sowing, some nurseries stack their blocks on wagons and transport these to the greenhouse for layout. This is not possible in transplanting as only 1 layer of styroblocs can be transported at a time, thus increasing the number of trips required for the same number of blocks. Even in a small transplanting program there are a large number of blocks to be moved and the transportation system must be capable to supply them in narrow timelines. Movement must also be non-disturbing as vibration causes problems with seed, mini plugs, and covering material “floating” to the surface of the growing blocks.

Post Handling

Fresh transplants require attention until settled into their new surroundings. The growing environment changes suddenly for the young seedling after transplant, so misting is required on high vapor pressure deficit days. Misting should be continued until roots are well established in the new medium. Growers using controlled release fertilizers in their medium will have to rethink the cultural regime, as the conditions and timelines for controlled fertilizer will change dramatically. Up to 12 weeks of growing time can be removed from growing cycle of the destination trays. This impacts significantly the growing medium temperature exposure and therefore the percentage of release from the controlled release fertilizer.

Staff Training

The increased complexity of the transplant program requires extra planning and management supervision. Each stage of the process is a potential pitfall and each stage needs to have staff fully understand their roles, responsibilities, and ramifications of the task. The machinery involved is some of the most technical in the growing industry and requires a person with a technical “bent” to keep operating at peak performance. Skills in troubleshooting and maintenance need to be developed to a high degree as well.

RESULTS

In the horticultural and floriculture sectors, transplanting technology is a proven production method. However, in silviculture, the method has yet to make large inroads. Forest nurseries are comfortable in evaluating cavity fill and expected yield to determine whether to spend the extra cost to increase cavity fill by hand transplanting. However, the decision to transplant an entire crop mechanically is not as straight forward and must be evaluated carefully. Nursery managers contemplating the process need to fully understand the costs, risks, and growing implications of such a program.

The benefits of a plug-to-plug transplanting program can be maximized with the following growing regimes.

Seedlots with Poor Germination—Sowing multiple seeds per cavity of poor germination stock in a conventional system can be overcome by single sowing the donor tray and using plug-to-plug transplant technology. While expensive in terms of the number of mini growing trays and gapping machine time, the transplant option has proven a better route in my opinion.

Soft Rooted Species—Soft rooted species such as black spruce have performed extremely well. Black spruce seems to prefer growing in a small cell and then being transferred to a larger cell. The act of transplanting encourages root development in the destination tray. We have observed better root and caliper development versus conventional sowing.

Deciduous Species—Deciduous material has performed well in the program. The large flat leaves make computer vision a breeze. These stocktypes tend to suffer with poor germination as a rule as well.

Early Summer Ship Stock—Early summer ship stock requires very early sowing in December to make delivery schedules. In a conventional sowing

program, the heating costs through December and January are extremely high. Sowing in mini trays with a 4:1 compression saves approximately 70% in fuel costs during the phases up until transplanting. Once transplanted, there are further savings associated with the reduced number of blocks required to make order.

Crop Uniformity—A side benefit of gapping is the opportunity to increase crop uniformity. Computer settings allow the nursery manager to select the size of seedlings to be rejected on an order by order basis. Rejecting the bottom 15% improves uniformity substantially.

Packing Efficiency—Finally, the greatest benefit of transplanting is realized at harvest time. Increased uniformity, zero blanks, and few culls mean seedling packing efficiency is increased. There are fewer seedlings to handle and fewer decisions made by the grading crew. Yield increases between 6% and 14% are being realized across all stocktypes, with an average of 10%. This year we have experienced a number of orders where the yield has exceeded 98%.

From the management side, transplanting requires commitment of dollars and management time. Purchasing a transplant machine and expecting it to produce in your existing system is not likely to work. The entire transplant production system needs to be analyzed for productivity constraints, quality check points, and operational issues. The importance of starting the young plants under optimum conditions cannot be over emphasized. Also, it is imperative the transplant equipment is compatible with the donor tray and the destination tray, both biologically and mechanically. Ensuring suitable timelines are available during the production cycle to complete the tasks is an often overlooked problem and must be considered. Also staff must be trained to ensure the equipment operates at peak efficiency.

Most nurseries have evaluated or tried some form of plug-to-plug transplanting and have experienced some

of the issues outlined here. From my experience, travels, and discussions with other nursery managers, the concept is of interest to most forest nurseries. The technology is being explored to increase production per unit area, decrease requirement for greenhouse space, and create new stocktypes. One nursery uses plug-to-plug technology to over-winter mini plugs which are transplanted in spring to produce a 0.5+1 crop for summer delivery. Others are using the technology to conserve greenhouse space with high gain seed. At Pelton, we use the process for many stocktypes including summer ship 1+0 white spruce, 1+0 black spruce, large cavity coastal Douglas-fir and western hemlock, and 2+0 spruce. We also use it for deciduous material and seedlots with low germination.

Currently, I estimate the North American volume at the equivalent of 300,000 styroblocs or 20 to 30 million seedlings. A small number of nurseries in Australia and New Zealand are also using the technology. The practice has yet to get established in Scandinavia, as they tend to use smaller cavities which are not suited to the process.

FUTURE

I believe plug-to-plug transplanting is here to stay. The early adopters have struggled to make the technology a success; second tier adopters will find that as the technology, ease of use, and speed improves in the machinery, the associated costs will come down.

CONCLUSION

I hope I have demonstrated the critical aspects of plug-to-plug transplanting. While more steps are involved, and each of those steps requires more input and expertise compared to conventional sowing, there are real gains to be made in space efficiency, input costs, quality, and yield.

CONTAINER-TO-CONTAINER TRANSPLANTING: OPERATIONS AND EQUIPMENT

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Key Words

Workstation, transplanting conveyor, automatic transplanter, economics

Transplanting can be a large labor user in a tree seedling nursery. Every effort should be made to make it as efficient as possible.

Except for the small nursery with limited production space, the transplanting operation should be set up in a central headhouse area. Having all the materials and workers in one area reduces materials movement and makes supervision easier. A permanent set-up may include the medium preparation and container filling equipment, workstations, transplanting conveyor or an automated transplanting machine. Handling of the containers after transplanting can be done with carts or a conveyor system.

BASICS

Before looking at individual systems, a review of some basic principals is needed. In analyzing an existing operation or planning a new one, many alternatives face the grower. With changes constantly occurring in equipment and methods, an up-to-date review is necessary. It is worth the time it takes to visit other growers, participate in conferences and trades shows, and contact manufacturers and suppliers. The knowledge gained will broaden your view and make evaluation simpler.

Think Simple

Systems and equipment that you understand work best. Fit the equipment to the size of your operation and the tasks that need to be done.

Develop a Flow Diagram

A flow diagram shows the operations that are performed and the movement of materials. Getting

materials (flats, plants, and so on) into and away from the transplanting operations is very important and will create a bottleneck if not handled efficiently.

Compare Equipment on Performance and Capacity

Use manufacturers' operating specifications to select and size equipment. The equipment should meet your production capacity needs, and the size and shape of plug that will be transplanted.

Standardize Your Operations

Limit the number of sizes and types of containers to reduce the inventory that has to be carried and the time needed to make changes to equipment.

Purchase from a Manufacturer That Has a Good Reputation

Check with other growers using the equipment for efficiency, problems and dealer support. Obtain a copy of the warranty.

Keep Employees Informed

Support from employees is important. Ideas and input before changes are made and during the debugging stages will help to make the transition to a new system smooth. Training should also be provided to develop the best techniques.

TRANSPLANTING BY HAND

Efficient workstations can increase production 20 to 30 percent. In setting up the workstation, consider the following.

Workstation Height

The best table height is elbow height. Adjustment should be provided for different size workers. It is best to provide for both standing and sitting positions, as greater efficiency is achieved when workers change position.

Hand and Arm Motion

The reach from the normal arm rest position should be limited to a 24-inch (61-cm) radius to the side and front for women and 27 inches (68.5 cm) for men. The location of the flat that is being transplanted into should be no more than 18 inches (46 cm) from the resting elbow.

Location of Materials

Materials should be located as close to the work area as possible. Walking 10 feet (3 m) to pick up or set down a flat will add about 2 cents to its production cost. Tipping the plug flat toward the transplanter can reduce reaching distance. Prefilled containers eliminate an operation. They can be supplied to the transplanters by belt conveyor or on pallets.

Removal of Transplanted Flats

These can be placed on a cart next to the transplanter or removed with a belt conveyor at the back of the workstation.

TRANSPLANTING CONVEYOR

This piece of equipment, available from several manufacturers, provides convenient workstations for 4 to 8 transplanters. The machine consists of a slow speed conveyor belt that moves predibbled flats past workers who place the plugs. The transplanters stand or sit next to the conveyor with the plugs located within arms reach. A variable speed motor on the conveyor adjusts the speed from 5 to 50 ft/min (1.5 to 15 m/min) to adapt to the type of container, the number of transplants handled, and the experience of the workers. Workers are usually responsible for transplanting into a certain section of each flat.

AUTOMATIC TRANSPLANTERS

The automatic transplanter has been developed over the last few years. It can increase production without additional help. Trays transplanted by machine usually contain more uniform plants. The speed of operation varies by machine. The slowest machines will plant about 2200 plugs/hr whereas the fastest will do up to 25,000 plugs/hr.

A typical transplanter contains several components. The plug tray feeder and conveyor moves the prefilled trays through a plug extractor to the transplanting station. The prefilled flats are dibbled before transplanting. At the transplanting station, the plugs are removed from the plug tray by grippers spaced to fit the transplant tray cell spacing and planted into the transplant flat. Gripper style varies with manufacturer. After transplanting, the flats are usually conveyed to a watering tunnel before going to the growing area.

To be efficient, materials have to be moved to the transplanter and away from it at a constant rate. This requires variable speed conveyors and associated equipment. On the input end, soil mixing and flat filling equipment is needed. For larger operations, a blow-out machine that removes soil from cells that don't have plants, or have weak plants, and a fixing machine that uses vision software to replace those cells is available. This ensures that the transplanted flats will have a full count of uniform plants.

With many models of automatic transplanters available, how do you make a choice? Consider the following:

Plug type – will the transplanter handle tree seedling plugs?

Output rate – select a machine that meets your peak rate needs with some additional capacity for expansion.

Flat size – how easy is it to change from one flat size to another?

Utilities – what are the electricity, water and compressed air requirements?

Plug selection – is a machine with a vision system needed to select only good plugs?

Control system – how easy is it to change the computer program from one plug configuration to another?

Service – what type of support does the manufacturer provide?

Operators – how many people are required to operate the machine?

On the output end, besides the watering tunnel that wets the flats, equipment for bar code labeling or tagging is also available. A system for moving the flats to the growing area is also needed. Carts and conveyors are commonly used. A more efficient system is to use 6 feet wide x 12 to 20 feet long (1.8 m wide x 3.6 to 6 m long) growing trays that are moved on a rail system. This reduces handling cost.

ECONOMICS

Simple payback is a good way to compare different transplanting systems. The projected savings/year are divided by the yearly cost of owning the system. A 2 to 4 year payback is considered good. Payback can also be calculated on a per flat basis. A typical US\$

5000 4-station transplanting conveyor may have a payback of as little as 10,000 flats/yr. A US\$ 60,000 automatic transplanter that will do 250 flats/hr may require that you do a minimum 250,000 flats/yr to get a 3 year payback. Information on the present methods and the savings with the new system are required.

RIMS, A REFORESTATION INFORMATION MANAGEMENT SYSTEM

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Abstract

Washington Department of Natural Resources Webster Nursery successfully met an increased workload with reduced staffing levels after implementing an automated information system. RIMS, the Reforestation Information Management System, supports the entire seedling production lifecycle.

Key Words

Seedling inventory, sowing request, field inventory, orders, nursery management, greenhouse management, handheld computer, Husky, Oracle, client/server, Visual Basic, Crystal Reports, automated tools.

INTRODUCTION

In 1996, Webster Nursery faced an increasingly complex inventory and a 33% workload increase. Many different tools were used to track seedling inventory and sales but were not integrated or sophisticated. Significant staff time was necessary to verify and compile data. Procedures were not well documented. The nursery decided to improve tools, productivity, and efficiency rather than adding staff. Resources were devoted to planning and building an integrated information system.

The RIMS system (fig. 1) has allowed the nursery to meet the increased workload with fewer people. Staff

have more time for crop analysis and improvement, as well as continuing business improvement. The system is comprehensive and flexible. The nursery has continued to allocate resources to add modules and features, implementing a new release annually.

DISCUSSION

Due to the increasing complexity of inventory, a projected workload increase of 33%, the need to know accurate and up to the minute status of seedling orders and inventory movements, and the difficulty in compiling data from the existing data collection systems, demands on staff had increased

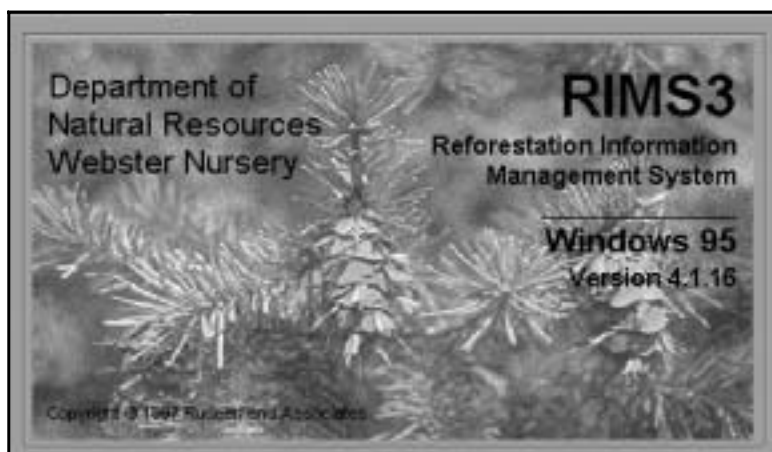


Figure 1.

to unmanageable levels. As part of a comprehensive plan to address these requirements and improve productivity without adding FTEs (“Full Time Equivalents”), Webster Nursery made plans to build better automated tools for information management.

During the summer of 1996, a feasibility study was done to start the process of planning for the information system. Since the cost of building a custom system to automate all important information was very high, and other nursery systems didn’t meet the nursery’s requirements, nursery managers decided to build a custom system in phases.

The nursery’s goal was to have data: 1) entered by its originator; 2) accessible to those who need it; 3) maintained by someone with assigned responsibility; 4) monitored for accuracy and completeness; 5) protected from loss and corruption by good system management methods and tools; and 6) available for varied reporting needs.

Different design teams were formed for the various RIMS modules. Nursery staff were always involved in design decisions. Almost all nursery staff use the system, including office staff, warehouse staff, the bareroot manager, the greenhouse manager, the nursery manager, the seed plant manager, and the warehouse manager. The program manager and division manager view data on screens and reports.

Approximately once every year, a new release of RIMS is developed. Modules and features are prioritized and grouped into affordable releases. The current scope of RIMS includes Sowing Requests; Seed Lot Inventory; Sowing, Verifying, Transplanting; Seedling Locations; Field Inventory Counts; Seedling Orders, Shipments, Payments; Seedling Lift Schedules; Seedling Inventory History; Billings; Customers; Mailing Lists; Reports; and Year End Processes. Husky handheld computers are used to collect data in the field and transfer it to the RIMS database (fig. 2). Handheld applications are integrated with the desktop application.

Benefits include: 1) improved management of data, access to data, and integrity of data; 2) simplified processes and procedures, fewer forms, fewer manual records; 3) reduced inefficiencies such as duplication of effort in processes performed and data handling; 4) consistent and accurate information that is accessible to all staff in a timely manner; and 5) staff responsibilities that focus on data analysis and use rather than data compilation.

Webster Nursery has no IT staff and depends on contractors to develop and maintain RIMS. Costs to date (1996 to 2002) are approximately US\$ 690,000. The system has a relational Oracle database, full featured client/server architecture, a Visual Basic

Code	Type	Species	Zone	Rev Range	City	Age	F	SS	Cdn Type	Avail Bal	Recv Bal	Field Bal	Cooler Bal	Green Bal
PUB-301	F	Douglas Fir	Twin Harbors	5-1000	Alenden, Long	2	3-8			340,000	183,000	503,000	0	0
PUB-302	F	Douglas Fir	Islands	5-1000	Bahn, Friday Hi	2	3-8			60,000	31,000	91,000	0	0
PUB-303	F	Douglas Fir	Islands	5-1000	Bahn, Friday Hi	2	3-8			76,000	33,000	109,000	0	0
PUB-304	F	Douglas Fir	Islands	1000-2000	Bahn, Friday Hi	2	3-8			30,000	16,000	36,000	0	0
PUB-305	F	Douglas Fir	Lower Columbia	5-1000	Carson, Cathlam	2	3-8			25,000	18,000	43,000	0	0
PUB-306	F	Douglas Fir	Lower Columbia	5-1000	Carson, Cathlam	2	3-8			140,000	80,000	306,000	0	0
PUB-307	F	Douglas Fir	Lower Columbia	5-1000	Carson, Cathlam	2	3-8			305,000	171,000	626,000	0	0
PUB-308	F	Douglas Fir	Skagit	2000-3000	Diablo Dam, One	2	3-8			47,000	23,000	68,000	0	0
PUB-309	F	Douglas Fir	Snoqualmie	2000-3000	Crystal Mountain	2	3-8			222,000	116,000	336,000	0	0
PUB-310	F	Douglas Fir	Tuade	2000-3000	Astford, Coupe	2	3-8			25,000	9,000	34,000	0	0
PUB-311	F	Douglas Fir	Tuade	2000-3000	Astford, Coupe	2	3-8			81,000	31,000	62,000	0	0
PUB-312	F	Douglas Fir	Yakima	2000-3000	Berne, Cle Elum	2	3-8			43,000	19,000	62,000	0	0
PUB-313	F	Douglas Fir	Yakima	4000-5000	Berne, Cle Elum	2	3-8			14,000	8,000	19,000	0	0
PUB-314	F	Douglas Fir	White Salmon	1000-2000	Dore Peak, For	2	3-8			23,000	14,000	37,000	0	0
PUB-315	F	Douglas Fir	Fend Oreille	2000-3000	Coe, Deer Park	2	3-8			21,000	8,000	29,000	0	0
PUB-316	F	Douglas Fir	Fend Oreille	2000-3000	Coe, Deer Park	2	3-8			25,000	13,000	38,000	0	0
PUB-317	F	Douglas Fir	Grande Ronde	4000-4800	Anastone, Hood	2	3-8			19,000	16,000	35,000	0	0
PUB-318	F	Douglas Fir	MCO Forts	5-2000	Forts, Near Bay	2	3-8			82,000	39,000	121,000	0	0
PUB-319	F	Douglas Fir	MCO Southwest	5-2000	Beths Ground, Li	2	3-8			117,000	44,000	161,000	0	0

Figure 2.

user interface, Crystal Reports writer, and an interface to Husky handheld computers.

Future enhancement plans include making customer reports available on the web, automating the interface between DNR regions and the nursery (sowing requests, orders), a cost accounting module, additional use of handheld computers, bar coding, growth tracking, and crop trends and goals.

RIMS could be modified to meet the needs of different nurseries.

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SUMMARY

The RIMS system is an automated tool that supports many activities at Webster Nursery, covering the entire seedling lifecycle. Many benefits have been realized. The Nursery plans to continue to enhance the tool to support even more business functions. Staff are willing to share ideas with other nurseries designing information systems.

THE NURSERY MANAGEMENT INFORMATION SYSTEM (NMIS) AT J. HERBERT STONE NURSERY USING MS ACCESS[®]

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Davis D.B. 2003. The Nursery Management Information System (NMIS) at J. Herbert Stone Nursery using MS Access[®]. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 130–132. Available at: <http://www.fcnanet.org/proceedings/2002/davis.pdf>

Abstract

The Nursery Management Information System (NMIS) was designed in the 1970s to support the nursery program at 9 USDA Forest Service nurseries by tracking the seed collection and storage, sowing of seed, culturing of seedlings to specific size criteria, seedling inventory, seedling lifting, grading and culling, packing of seedlings for storage, and shipment and distribution of seedlings to Forests and Districts for planting. NMIS consists of a source (seed) subsystem and a product (seedling) subsystem. The product subsystem works with both bareroot and container products without a need for separate forms and reports for each. Currently an Oracle[®] version of the source subsystem is in use at 5 of the 6 remaining Forest Service nurseries and 1 seed extractory. J. Herbert Stone Nursery has been using a MS Access[®] version of NMIS since October 2000.

Key Words

Seed inventory, seed testing, sowing calculations, seedling inventory, plant inventory, packing, shipping

INTRODUCTION

J Herbert Stone Nursery is in southwestern Oregon near the city of Medford. It produces conifer seedlings and other plant materials for publicly owned lands only. The major clients are the USDA Forest Service, the USDI Bureau of Land Management, and the USDI Bureau of Indian Affairs. The capacity is approximately 24 million bareroot plants per year. More than 340 million plants have been shipped since 1979 to planting sites throughout Oregon, Washington, California, Arizona, Idaho, and Montana. J Herbert Stone Nursery began using the MS Access[®] version of NMIS with the source subsystem in October 2000 and the plant subsystem in December 2000 for entering sowing requests and doing sowing calculations. The lifting, packing, shipping, and billing portions of the product subsystem were used for the first time in January 2002.

NURSERY MANAGEMENT INFORMATION SYSTEM

NMIS consists of a source subsystem for managing and maintaining source material for products and a products subsystem for managing and maintaining

product inventories. Source was originally developed as a means of tracking cones received through processing seed. Source now includes seed as well as other types of plant propagation materials. Products traditionally meant conifer seedlings, but now include plants and seed of native non-conifer seedlings, forbs, sedges, and grasses. NMIS maintains inventories of lots by location, number and type of containers, and density per container. This system allows for tracking a lot even when it might currently be partly in a seedbed, partly in pre-pack storage and partly packed for shipment. NMIS does not require separate subsystems for bareroot and traditional container products by treating all growing containers, both seedbed and traditional greenhouse containers, the same.

Source Subsystem

The source subsystem includes reproductive structure receiving and processing; seed testing; storage; inventory, withdrawals, and shipping; and billing.

Reproductive Structure Receiving and

Processing—Plant reproductive material received for processing can be logged in when received, allowing yield calculations when processing is complete. Each

step of processing can be tracked by activity (extraction, scalping, and so on) and a charge by activity or hourly rate tracked.

Seed Testing—Initial seed testing is performed prior to storage. Germination retesting cycles are defined by species in NMIS to ensure that up-to-date germination information is available for sowing calculations. Each test result remains as new tests are performed, allowing for review of germination history for a seedlot.

Storage—Multiple storage locations are allowed as needed for a seedlot.

Inventory, Withdrawals, and Shipping—Activities can be entered using a ticket form to allow for efficiency of data entry. Tickets also allow documents for seed shipment or retest requests to be produced as soon as the activity data is entered. Information needed for billing, such as client and job code, is entered for activities that require billing.

Billing—Reports for billing can be created as needed using the information entered along with the activity amount.

PRODUCT SUBSYSTEM

The product subsystem includes sowing requests; sowing calculations; sowing; culturing; inventory; ordering; processing; billing; and processing contractor payment.

Sowing Requests—Sowing requests (Agreements) are received from clients and entered into NMIS using the appropriate species product. Each agreement can have multiple job codes for purchase of source material. Multiple agreements from a single source lot can be grouped together into a single Seedling Lot (Agreement Lot) as appropriate.

Sowing Calculations—Sowing calculations are done for Agreement Lots. The sowing calculation form allows entry of multiple nursery factors for both the amount of plants and number of containers. NMIS uses standard calculations (seed test data X nursery factors) to determine the amount of seed to withdraw for a desired amount of plants. NMIS does not need a separate process for bareroot and container plants. The bareroot seedbed is defined, as are all greenhouse containers, by size and number of cells per container. All growing containers are defined in NMIS in advance so that, at the time of calculation for a seedbed, the container is defined as one foot of seedbed (4 ft² [0.37 m²]) having 4 cells (1 ft² [0.09 m²] each) with the desired gross density per cell set during the calculation. For seedbeds, this is typically

around 20. A styrofoam block container with 198 cells, which would have a predefined number of cells per container of 198, would typically be 1.

Sowing—Sowing calibration data is entered into NMIS and loaded into a Husky Hunter 16[®] data recorder for use during sowing. Seed arrives in the field with a bar coded tag which is read with a bar code reader. The data recorder displays the settings for the seed drill. Sowing locations are entered as sowing takes place. At the end of the day, the data recorder is downloaded into NMIS and a daily sowing report created.

Culturing—Culturing information can be entered in NMIS by either lot or location. This allows for tracking treatments to a single lot or part of a lot while also being able to track treatments made to large areas with many lots. Treatments can also be tracked to provide a treatment history of an area.

Inventory—Inventory information is loaded into the data recorder. A lot can be called up by reading the bar code on the tag at the end of the lot or entered by hand. The starting distance, number of plots, and distance between plots is displayed. Inventory counts and, if needed, sizes are entered and either an inventory or a request for more plots is displayed. At the end of the day, the data recorder is downloaded to NMIS and a daily inventory checklist is produced.

Ordering—Orders for packing are entered with client, client contacts, grading specifications, special services, job codes, and amount of request. Multiple orders with different processing specs may be placed for each lot. Orders for partial lots are subtracted from the total inventory remaining and updated on the order form. Orders cannot be placed for a lot with no inventory remaining. Lifting request forms are produced for use during lifting. After an order is entered, an order confirmation report is sent to the client for review. When all orders have been entered, a surplus for sale report is created.

Processing—Processing includes lifting/extraction; pre-pack storage; grading and packing; quality monitoring; and storage/shipping.

Lifting/Extraction—The lifting request report is provided to the supervisor responsible for lifting or extraction of seedlings. It includes locations and how many feet or containers are required to meet the ordered total from each lot. In the case of bareroot plants, the number of feet, and number and type of field container is entered into the data recorder. The data recorder is downloaded into NMIS at the end of each day. This information is compared with the information from the pre-pack storage. After

differences are resolved, the data is processed into NMIS.

Pre-pack Storage—For bareroot seedlings, the number and type of field containers received for pre-pack storage is entered into a data recorder. The data recorder is downloaded into NMIS at the end of each day.

Grading and Packing—Processing order forms are created after lifting and pre-pack data is processed for lots lifted. These forms include the number of field containers in storage, date lifted, client contacts, grading specifications, special services, and amount to pack. Packing labels are created from NMIS for each order on an as-needed basis during packing. Packing information is currently entered by hand into NMIS.

Quality Monitoring—Samples are taken during grading and entered into a data recorder using a bar code reader. At the end of each day, the data recorder is downloaded to NMIS and daily quality monitoring reports by lot, summarized for each grading table, are created. The quality monitoring information is currently used as part of the processing contractor payment.

Storage/Shipping—Storage locations, number of containers, and amount per container can be entered into NMIS. Shipping data is entered into a shipping ticket form recording number of containers (usually

bags or boxes) and amount per container. A shipping document is generated directly from this form.

Billing—Billing is done using information entered earlier. At the time of shipment, all information needed to produce a bill has been entered. A billing review report is created and, after review, a bill is created.

Processing Contractor Payment—J Herbert Stone Nursery uses private contractors to do lifting and packing. All of the information needed to produce a contract payment is included with the lifting and the packing data entry, allowing a contract payment to be made almost as soon as the daily work is completed.

SUMMARY

NMIS has expanded greatly in scope since it was developed for bareroot conifer nurseries in the 1970s. It can track and maintain inventories of source material. It can track and maintain product inventories from sowing request to billing. The decision to create a version using MS Access® required some compromises with what was available using Oracle®. The advantage of the version in use at J Herbert Stone Nursery since October 2000 has been that it could be done without Oracle® programmer assistance, and forms and reports are easy to create and modify.

NURSERY COST-ESTIMATING AT THE NRCS BRIDGER PLANT MATERIALS CENTER

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Abstract

The USDA Natural Resources Conservation Service Bridger Plant Materials Center (BPMC) at Bridger, Montana, has maintained cooperative agreements with Glacier and Yellowstone national parks for restoration research and native seed and plant production for nearly 15 years. Over time it became necessary to develop cost prediction tools to evaluate contractual obligations and allocate project resources. Since conventional nursery cost-estimating systems did not adequately address the increased expense of cleaning, inventorying, storing, and propagating wildland (uncultivated) seeds and plants, BPMC developed cost-estimate matrices based on production difficulty and the size of the seed production field, bareroot stock, or container unit. Production difficulty is determined by personal experience, the experience of other growers, or by numerical rating systems. Seed and plant values are based on Foundation seed prices or commercial and conservation nursery prices adjusted to reflect the additional inputs needed to grow wildland ecotypes for restoration projects. BPMC matrices can be used as templates for other cost-estimating systems and are easily modified as changing economic conditions, emerging propagation technologies, and unfavorable weather influence cost. It is recommended that contracting parties collaborate on the development of cost-estimate matrices, and that these matrices be used as evaluation and planning tools rather than accounting or budgetary systems.

Key Words

Matrix, matrices, restoration, ecotypes

INTRODUCTION

Since the late 1980s, the USDA Natural Resources Conservation Service Bridger Plant Materials Center (BPMC) has maintained cooperative agreements with the National Park Service (NPS), providing restoration research, technical support, and seed and plant production. This work involves the restoration of linear disturbances created by on-going highway reconstruction projects within Glacier and Yellowstone national parks. Funding for restoration activities has been provided by the Federal Highways Administration as part of the comprehensive effort to upgrade the road systems within each park.

Restoration policy within Glacier and Yellowstone national parks mandates the use of only plant species and propagules (seeds and cuttings) indigenous to each respective park. Relatively small, localized collections of propagules are made in the vicinity of each road project and used for seed and plant production. If environmental conditions or topographic

features vary significantly over the length of a given construction project, multiple, separate collections of a single species may be necessary to assure adequate genetic sampling. Furthermore, in order to reduce the potential of genetic drift resulting from repeated off-site production, wildland seeds and cuttings are frequently used as production propagules in lieu of cultivated stock plants. Safeguards, such as the isolation of production fields and repeated cleaning of seed processing machinery (combines and cleaners), are necessary to guarantee the purity and genetic integrity of each lot during production. The additional expense of using non-cultivated propagules for production, and working with numerous, small collections, increases production costs relative to cultivated plants selected for vigor and productivity. The extrapolation of commercial production data, based on large-scale cultivation of superior selections, consistently under-estimates the cost of small-scale production of wildland ecotypes.

At BPMC, the need to estimate the value of restoration products arose from attempts to determine if contractual obligations to the NPS were being met. Additionally, the need to allocate resources for future projects dictated that the value of each product be estimated prior to project and contract development. This planning phase is particularly important in regards to seed and plant production, which often requires 3 to 4 years of lead time. In an attempt to estimate the true value of wildland ecotype production, BPMC developed cost-estimating matrices that assign values or costs to seeds and plants produced by BPMC for restoration projects (Scianna and others 2001). Although this system was conceived and designed for in-house use, the principles are broadly applicable and should be useful as a template for other projects involving ecotype-specific production for restoration and reforestation. Cost-estimating is not an accounting or budget management system. It represents an attempt to provide an approximation of the value of seeds and plants produced directly from native, wildland ecotypes.

DEFINITIONS

Cost-estimating, in the context of this paper, is defined as assigning monetary values to each product offered by a seed grower or nursery. In the case of BPMC, its purpose is to estimate the value of native, ecotype production for evaluating contractual obligations and allocating project resources. A matrix is a diagram or form consisting of a series of intersecting columns and rows. The intercept of each column and row is the value of a given product based on the difficulty of production and size of the seed production field, bareroot stock, or container plant. Large seed production fields of easy-to-grow species are least expensive, whereas small fields of hard-to-grow species are most expensive. Similarly, small, easy-to-grow plants are the least expensive to produce, whereas large, difficult-to-grow plants are the most expensive. Propagules are seeds and cuttings; wildland propagules are seeds and cuttings from uncultivated mother plants.

THE HIGH COST OF RESTORATION PRODUCTION

The cost of producing seeds and plants of wildland ecotypes is higher than cultivated selections for several reasons. Restoration, by definition, implies some attempt to mimic the plant composition and natural diversity inherent to a particular site and

geographic area (Majerus 1997). This is in contrast to mined land reclamation, revegetation, and reforestation projects that emphasize site stabilization or timber production with less emphasis on re-establishing plant communities, preserving population genetics, or maintaining species diversity. The goal of the restoration project and the constraints imposed by restoration policy influence the production costs associated with each project.

Restoration policy requiring the use of propagules taken only from local, native ecotypes increases the cost of production in several ways. Some of the additional expense of producing wildland ecotypes reflects propagule collection, which may or may not be the responsibility of the grower. Individual populations may be located in remote or inaccessible areas, resulting in high travel and collection costs. Seeds of many species ripen indeterminately, a situation exacerbated under non-cultivated conditions that may result in the need for multiple collection trips. In an attempt to adequately represent population genetics or species diversity, high numbers of individual plants may have to be sampled. Even if seeds and cuttings are provided to the grower, propagule production and viability are lower under wildland than cultivated conditions, requiring greater inputs of time and labor during all phases of production. Wildland seeds tend to have less fill and poorer germination rates than cultivated selections. As a result, stand establishment tends to be poor, with thin spots allowing weed establishment and driving up the cost of maintenance. In container production, empty cells require reseeding or culling. Individual plant populations, as defined by geographic, topographic, habitat-type, and climatic conditions, require scouting, sampling, storage, cleaning, production, inventorying, tracking, and shipping under isolated conditions. A lack of commercial incentive has resulted in less propagation research being conducted on uncultivated natives relative to ornamental selections. In many cases, a lack of established propagation and production protocols requires growers to resort to "trial and error" techniques that increase cost. In some cases, specialized harvesting and cleaning equipment are needed that further add to production expenses.

The small scale of production characteristic of many restoration projects also increases the cost of seed and plant production. Production inefficiencies resulting from the handling of multiple small lots or maintenance of small, isolated fields increases per unit cost as described later.

COST ESTIMATE MATRIX

An example of a cost-estimate matrix appears in table 1. Column headings represent the level of production difficulty, whereas rows indicate the size of the seed production field, bareroot stock, or container plant. The point of intercept represents the estimated value or cost of the product.

Establishing Level of Difficulty

The amount of difficulty associated with producing a given species correlates closely with the final cost of production. Any production factor that increases time, labor, and material investment increases cost. These costs are not static over time, however, reflecting inflation, market supply and demand, emerging technologies, regulatory issues, and other factors that influence production costs. Costs also vary in response to weather conditions, insects, diseases, and other environmental factors. Production difficulty, as used here, reflects conditions during cultivation, but does not involve propagule collection. If growers are involved in the collection process, they should bill for collection services separately or integrate the cost of propagule collection into their products.

There are several methods of determining the level of production difficulty, including personal experience, the experience of other growers, inferences based on the commercial value of the same or a closely related

species, and numerical rating systems. At BPMC, we subjectively assign a rating of “low,” “medium,” or “high” degree of difficulty based on our experiences growing a particular species. For species that we have not grown, we rely on our experience growing related plants, or gather information from other growers and references. In some cases, inferences can be made on the difficulty of production based on commercial prices for the same or closely related species. Systems that rate production difficulty based a numerical approach can also be used (table 2). Any number of production factors may be delineated based on their relative impact on production at a given nursery. Production factors are rated on a weighted scale and then tallied to determine if they fall within a numerical range indicating a low, medium, or high level of production difficulty. In the case of slenderbeak sedge (*Carex athrostachya*) in the example in table 2, increased inputs of time and materials are needed for several production factors that result in a “medium” difficulty rating.

For grass seed, production difficulty reflects seed dormancy characteristics, seedling emergence, rate and degree of stand establishment, cultural requirements, stand vigor, speed and degree of seed production, harvesting, and seed processing. Numerous secondary factors are also involved, such as weed management, stand longevity, predisposition to insects and disease, and other factors. Species such as slender wheatgrass (*Elymus trachycaulus* ssp. *trachycaulus*), mountain

Table 1. Cost estimate matrix based on production difficulty and unit size.

Type of Production	Production Difficulty		
	Low	Medium	High
I. Seed Production			
small field (≤ 0.1 ac [0.04 ha]) grass	\$35/lb	\$50/lb	\$100/lb
medium field (> 0.1 to 0.25 ac [0.04 to 0.1 ha]) grass	\$25/lb	\$40/lb	\$75/lb
large field (> 0.25 ac [0.1 ha]) grass	\$15/lb	\$30/lb	\$60/lb
any size field (forbs)	\$50-100/lb	\$100-300/lb	\$300+/lb
any size (shrubs and trees)	NA	NA	NA
II. Plant Production			
<i>A. Bareroot Production (shrubs and trees)</i>			
1+0	\$1/plant	\$2/plant	\$3/plant
2+0	\$1.25/plant	\$2.25/plant	\$3.50/plant
3+0	\$1.50/plant	\$2.50/plant	\$4/plant
<i>B. Container Production</i>			
4 to 10 cubic inch (grass)	\$1/plant	\$2/plant	\$4/plant
4 to 10 cubic inch (forb and shrub)	\$2/plant	\$3/plant	\$5/plant
4 to 6 inch square pots (forb and shrub)	\$3/plant	\$5/plant	\$7.50/plant
1 to 3 gal (3.8 to 11.3 l) (shrubs)	\$5/plant	\$7.50/plant	\$10/plant
> 3 gal (11.3 l) priced separately (shrub)	NA	NA	NA
B&B priced separately (shrub)	NA	NA	NA

All costs in US\$.

Table 2. Seed production difficulty of slenderbeak sedge (*Carex athrostachya*).

Production Factors	Production Difficulty		
	Low (0-33)	Medium (34-65)	High (66-100)
Wildland seed viability	0		
Wildland seed sowing			10
Wildland seed dormancy	0		
Cultural requirements		5	
Seedling vigor	0		
Stand productivity		5	
Stand longevity	0		
Time interval until final product		5	
Harvesting production seed			10
Cleaning production seed	0		
Subtotal:	0	15	20
Total:			35

brome (*Bromus marginatus*), streambank wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus*), western wheatgrass (*Pascopyrum smithii*), and basin wildrye (*Leymus cinereus*) are “low” difficulty because they are easy-to-grow and prolific seed producers. Blue wildrye (*Elymus glaucus*), bluebunch wheatgrass (*Pseudoroegneria spicata*), sedges (*Carex* species), alpine timothy (*Phleum alpinum*), alpine bluegrass (*Poa alpina*), and tufted hairgrass (*Deschampsia cespitosa*) are “medium” difficulty because of one or more production challenges. Richardson’s needlegrass (*Achnatherum richardsonii*), needleandthread (*Hesperostipa comata*), prairie junegrass (*Koeleria macrantha*), and pine grass (*Calamagrostis rubescens*) are considered “high” difficulty to produce, primarily because of stand establishment, seed processing, or seed production limitations. For bareroot and container plants, production difficulty often reflects seed dormancy, germination rate, seedling survival, cultural requirements, and rate of growth. Species such as chokecherry (*Prunus virginiana*), silverberry (*Elaeagnus commutata*), serviceberry (*Amelanchier alnifolia*), and Oregongrape (*Mahonia repens*) have high rates of germination and growth, and are considered “low” difficulty. In contrast, common snowberry (*Symphoricarpos albus*) and Rocky Mountain juniper (*Juniperus scopulorum*) have lengthy dormancy-breaking periods and erratic germination that makes them “medium” and “difficult,” respectively. Although experienced growers know inherently which species are more difficult, and hence more expensive to grow, quantifying production difficulty helps justify cost during contract development and evaluation.

Production Unit Size

As noted earlier, the size of the seed production field, bareroot stock, or container plant is the second factor that has a direct bearing on the price of seeds and plants. The normal production efficiencies associated with economies of scale and large-scale production are not achieved with small lots of wildland ecotypes or cultivated selections. As an example, it may take as long to travel to a small production field and back as it does a large field. The cost of that travel is, therefore, greater per unit of product for a small field because it is distributed over fewer seeds or plants. Additional expenses may be inherent in the production of numerous small lots, such as production inefficiencies arising from the need to physically isolate the same or closely related species during production. In greenhouse production, media, irrigation, and nutritional requirements may vary widely by species. The need to custom culture numerous species often leads to increased manual labor, such as hand watering, that increases cost. Large and older nursery stock requires greater inputs (relative to small, young stock) of time, labor, and materials that drive up the cost of production. Even the temporary storage of container plants at the nursery requires additional inputs of water, fertilizers, pesticides, and labor that increase cost.

Establishing Unit Value

At BPMC, we use current Foundation seed prices as a baseline for determining the value of seed production. Foundation prices reflect the additional cost of isolation and purity mandated by federal and

state seed laws. As an example, Montana standards for Certified basin wildrye allow a maximum of 0.5% of other grass species, whereas the Foundation class only allows 0.1%. Similarly, Certified basin wildrye can have a maximum of 0.5% weed seeds, whereas the Foundation class only allows 0.3% (Handbook of Standards 1995). In addition, Foundation seed prices remain relatively stable over time, whereas Certified and common seed prices tend to fluctuate in response to various market factors. If Foundation prices are unavailable, we base price on the Foundation value of a closely related species or estimate value based on actual time and materials. To determine the additional cost of wildland seed production above Foundation, we collect hourly maintenance and cultivation data for the production cycle of a given species and then adjust price. For plant production, BPMC uses commercial and conservation nursery price data as a baseline, and then adjusts upwards as previously described. Although only an approximation of value, this system allows BPMC to estimate the additional expense of producing plants for restoration projects.

PRODUCTION VALUATION

Based on production difficulty and unit size, the value of each species or lot can be determined and the entire value of production calculated (table 3). This calculation may be based on actual production that year or anticipated production based on historical data. Actual production value data can be used to determine if contract obligations were met for a given contract interval. Anticipated production data

can be used to allocate funds for specific types of production based on restoration needs and project resources. Adjustments can be made to the product mix so that more seeds or plants of easy or moderately difficult species can be grown on a larger scale to meet target production. Adjustments to the product mix must consider the restoration goals of the project as they relate to species diversity and gene preservation factors that may reduce the amount of production possible for a fixed level of funding.

COST INFLATION OVER TIME

A frequently overlooked factor in determining the value of products and services, particularly with multi-year contracts, is cost inflation. Product costs typically increase over time as expenses such as labor, utilities, taxes, and materials increase. Budget and contract managers should develop a strategy to address inflation during contract negotiations. For multi-year contracts in which the same level of funding is available each year, the amount of production should decrease annually to account for inflation. Another option is to average production over the length of the contract to account for inflation, that is, provide a reduced but consistent level of production each year. If a fixed amount of production is needed annually, the cost of that production should increase each year.

The annual inflation rate may be projected from the Consumer Price Index or based on increases in actual expenses incurred over a given time period (Schaefer 2002). The future cost of a product for a given rate of inflation can be calculated by the formula, $X(1 + I)^N$, where “X” is the original amount of money, “I” is the

Table 3. Calculating entire production value.

Species	Field Size (acres)	Production Difficulty	Unit Value Per Pound	Amount of Seed Produced (pounds)	Species Value
BRMA	0.19	Low	\$25	23.00	\$575
BRMA	0.12	Low	\$25	17.00	\$425
BRMA	0.12	Low	\$25	36.00	\$900
BRMA	0.23	Low	\$25	38.00	\$950
ELTR	0.23	Low	\$25	67.52	\$1,688
ELTR	0.12	Low	\$25	62.00	\$1,550
LECI	0.15	Low	\$25	27.00	\$675
AGSC	0.12	Medium	\$40	9.95	\$398
AGSC	0.23	Medium	\$40	22.00	\$880
ELGL	0.23	Medium	\$40	27.50	\$1,100
FEID	0.23	Medium	\$40	2.38	\$95
PSSP	0.23	Medium	\$25	27.00	\$675
ELEL	0.23	High	\$75	9.57	\$718
HECO	0.27	High	\$60	30.00	\$1,800
Subtotal:					\$12,429

All costs in US\$.

inflation rate in percent, and “N” is the number of years. At BPMC, we plan production for an annual inflation rate of 4%. For example, if US\$ 10,000 were needed to produce 10,000 plants in Year 1, the cost of the same 10,000 plants would increase to US\$ 11,698.58 by Year 5 (4 years of inflation) given a 4% annual inflation rate. Similarly, only 8548 plants could be produced in Year 5 if funding remained static with a 4% annual inflation rate. Fair compensation aside, it is only important that the contracting parties recognize the additional cost of doing business over time and then address the issue in some mutually agreeable fashion.

SUMMARY

The cost-estimating system developed by BPMC and NPS represents an attempt to assign values to seeds and plants that more accurately reflect the additional cost of ecotype-specific production for restoration projects. Additionally, cost-estimate matrices provide information indicating why one species is more expensive to produce than another, and why it is more costly than commercial production of a cultivated selection of the same species. This up-front information allows restorationists and budget managers to select species mixes that meet both the biological and economic constraints of the project. The price of seeds and plants of some wildland species could

potentially approach that of commercial selections as production protocols are refined and if the scale of production increased.

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SEEDLING INVENTORY TRACKING

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Kitchen J. 2003. Seedling inventory tracking. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 139–143. Available at: <http://www.fcnet.org/proceedings/2002/kitchen.pdf>

Abstract

A general discussion of seedling inventory tracking objectives and methods is presented, with consideration of future opportunities.

Key Words

Pesticide tracking, seed collection, seed orchard, bareroot, container

SEEDLING INVENTORY TRACKING: WHERE ARE WE NOW?... AND WHERE ARE WE GOING?

I'd like to talk about where we are now in terms of seedling inventory tracking, and about where we may be in a few years. Please bear with me since my point of view is from our company's perspective, and from a Canadian perspective, where the regulatory environment probably makes information tracking more detailed and expensive, and may have a slightly different focus.

When tracking seedling inventory, there are 3 primary goals: 1) track the source, whether from seed collections, orchard production or vegetative propagation; 2) keep the customer informed about crop numbers and progress; and 3) meet regulatory requirements for seed transfer, pesticide use, and meet customer certification needs. There are many secondary goals, such as sales, production planning or budgeting; however, the first 3 goals can not be compromised to achieve secondary objectives.

To track the source, facility maps of various kinds are used, including bareroot fields, container production facilities, and the containers themselves. Container trays should be marked to ensure seedling lots can be tracked without errors. Blocks are often moved, so marking is particularly important. Finally, shipping cartons should be clearly labeled. The value of genetically improved material will continue to rise, and therefore tracking the source material will become increasingly important.

Customers deserve and expect to be kept informed about the progress of their crops, and the number of seedlings to expect when it's time to plant. Keeping close track of contracts is a sure way to get off on the right track. Knowing customer expectations and communicating about expectations regularly is essential. Each nursery will have its own system for this, in order to meet other needs, but it must meet the three primary criteria mentioned. Inventory checks through the season can avert problems for both the nursery and the customer, and customers depend on the information to avoid future unexpected costs, such as brushing. Many models of handheld computers are helpful and all do essentially the same thing—assist the user to organize and collect data.

Keeping the customer informed about the growth of seedlings is not strictly an inventory activity; since both needs depend on the same information, systems can and should be integrated. The growth tracking system is critical for predicting where seedlings will end up, which is a key item for predicting seedling inventory.

Customers can also be kept informed via the internet. This offers the advantage of providing up-to-date information which can be conveniently accessed. This is particularly important when things are changing quickly, such as during lifting, shipping and planting. Third-party websites, such as Plant Wizard, allow nurseries and customers to share up-to-date inventories online. Nurseries and customers utilize the same data source, increasing efficiency of information sharing.

PANEL 8 BAREROOT TRANSPLANTS (TRANSPLANTED 2001)

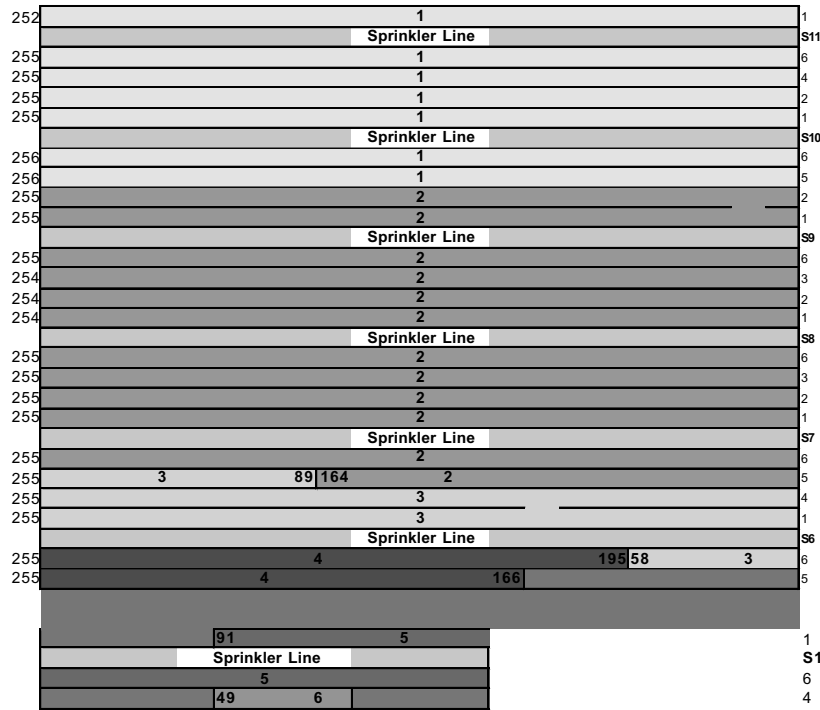


Figure 1. Bareroot panel map for tracking seedlots.



Figure 2. Handheld computer in use for growth tracking.

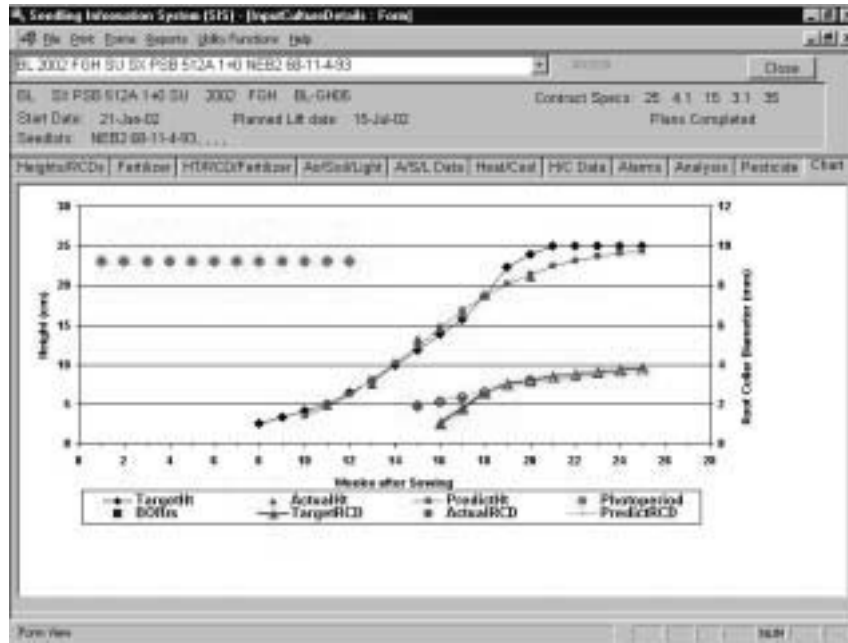


Figure 3. Growth curve is a record of growth and a tool for predicting final inventory.

Regulatory requirements must be met to keep nurseries and customers in business. Customers may need to report on silviculture plans and progress to retain cutting rights. Seed planning is often needed as well, and depends on seedling inventory results. In Canada, customers must have written and approved silviculture plans in place to obtain and retain cutting

rights. They will also need the same plans internally for budget purposes. Only good inventory and data tracking can lead to good seed planning for the future. Source material records are needed to verify that seed transfer rules have been followed, and that appropriate genetic material has been used for the destination. Third party certification needs, such as

PRTA
 (PacifiC Resource Tracking and Analysis)

A Comma Separated Value file can be generated, so that you can work with the data electronically. From Internet Explorer (or Netscape) please right-click on the file name and choose the "save target as" option to download the file to your computer or to a folder on your network. The file can then be opened in MS Excel (Word, Lotus or other program that can read a .csv file).

• Job-S-2002ORDERSUMMARY.csv

Customer: Pacific Inland Resources (PIR)

Customer Orders
 Spring 2002

Order Number	Qty	Type	Size	Age	Barriers	Seedling	Order Code	Requested Qty	Status	Trails	No. of Boxes	No. of Boxes Remaining	Updated
200206081407	50	PS	418	1+0	3.0	39624	1000	8007	128.9 Shipped	120.801	409	0	Nov 13, 2001
200206081408	50	PS	418	1+0	3.0	39624	1000	8007	144.0 Shipped	145.180	477	0	Nov 8, 2001
200206081409	50	PS	418	1+0	3.0	90240	750	801	136.0 Shipped	89.180	0	0	Nov 8, 2001
200206081410	50	PS	418	1+0	3.0	60240	500	801	136.0 Shipped	82.180	0	0	Nov 7, 2001
200206081411	50	PS	418	1+0	3.0	60240	950	801	136.0 Shipped	221.540	740	0	Nov 13, 2001
Spring 2002 Subtotal										470.0	827	0	
Summer 2002													
Order Number	Qty	Type	Size	Age	Barriers	Seedling	Order Code	Requested Qty	Status	Trails	No. of Boxes	No. of Boxes Remaining	Updated
200206081412	50	PS	418	1+0	3.0	60240	950	118.0	Inventory	130.800	934	0	Nov 28, 2002
200206081413	50	PS	418	1+0	3.0	90240	750	111.7	Inventory	111.700	835	0	Nov 28, 2002
Summer 2002 Subtotal										231.7	221	0	
Customer Orders Subtotal										701.7	1048	0	

Shipping History Shipping Request

Please friendly version

Figure 4. Inventory information provided to customer via the internet.

Seedling Properties - 2002 Summer													Current Inventories				
Original Qty	Trace	Seedlot	Sex	Size	Age	Ordered	Required	Internal surplus	External surplus	Inventory	Last Update	Status	Original Owner	Total Owned	IBR1	IBR2	SAMPLE
18,000	0801	01114	OV	410	1+0	6,500	0			18,000	11/13/00	MS2	SAMPLE	18,000	8,900	-	1,000
3,000	0801	01810	OV	415	1+0	2,000	0			3,000	11/13/00	MS2	SAMPLE	3,000	-	2,800	-
2,500	0801	02574	SA	3120	1+0	2,500	0			2,000	11/13/00	MS2	SAMPLE	2,000	-	2,800	-
2,000	0801	01806	SA	4120	1+0	2,000	0			3,000	11/13/00	MS2	SAMPLE	3,000	-	3,800	-
7,500	0801	00863	FDC	4120	1+0	6,500	0			7,500	11/13/00	MS2	SAMPLE	7,500	7,500	-	-
1,500	0801	01859	FDC	410	1+0	1,500	0			1,500	11/13/00	MS2	SAMPLE	1,500	-	1,500	-
8,000	0801	01902	HV	412A	1+0	8,000	0			8,000	11/13/00	MS2	SAMPLE	8,000	8,000	-	-
1,200	0801	00714	HV	410	1+0	1,000	0			1,200	11/13/00	MS2	SAMPLE	1,200	1,200	-	-
Total														34,100	20,900	9,800	1,000

Figure 5. Third party website provides inventory information.

chain of custody and sustainable silviculture, tracking may add further requirements.

Pesticide use reporting of some kind is required in many jurisdictions to retain the right to use pesticides. In other cases, customers may require records for their use. Generally speaking, pesticide use has its own set of regulations. Careful tracking and integration with inventory data may be important for both the nursery and the customer to continue doing business.

There are many secondary objectives for seedling inventory tracking including user-friendliness, keeping operational staff up-to-date with current inventories, knowing what's available for sale, invoicing and financial forecasts. All of these needs can be met, but must not be allowed to compromise the primary goals mentioned above—track the source, keep customers informed, and meet regulatory requirements.

So where are we going in the future? Information will be further automated and integrated between nurseries and customers, nurseries and suppliers, and with employees. The information will become more valuable. We will see new ways of counting, including machine vision and sensing. Bar codes and inexpensive chips will change the way we do things. Our systems will become faster and more flexible;

our customers will expect more information; they'll expect it to accurate and available "yesterday."

User-friendliness is the most important secondary factor; people must be comfortable with systems to get the most from the available information and for the system to function as intended. Providing useful and complete information to operational staff gives them the best chance for success. It is also important to know about available extra stock, or your entire crop if it's been grown for later sale. Invoicing will depend on inventory at some point, and of course



financial forecasts will depend on updated seedling inventory tracking.

Information will be increasingly integrated with: customer systems; seed sourcing systems; and ultimately with field performance—the ultimate goal. We need to ask and challenge ourselves to answer the question, “How will we tie seedling inventory tracking to field performance in the future?” Certainly we will at some point.

The value of seedling pedigree will rise as genetic value in the field rises, and as more valuable material becomes available. This will change the emphasis of what we record, and why.

Ways of counting seedlings will change with the application of current and future technology. For example, computerized machine vision and sensing could be used in the future for plant health monitoring. We may someday use machine sensing to identify and verify source material. I’m sure we’ll see new ways of identifying fields, containers, cartons and maybe even seedlings! Furthermore, is it possible to use production reliability technology so that no counting will be needed?

What are the benefits of good inventory tracking to us as nursery people? While making a cool new spreadsheet may be great fun, we got into the job to grow trees.

Fast and flexible means good things for us too: *More time to do what we love*. We chose the profession because we love to grow things—trees! User-friendly, well designed systems that don’t require us to be computer experts, nor require us to do more things than are necessary, will help us achieve these goals.

So remember, track the source infallibly, keep customers informed, and meet regulatory requirements. Thank you again for the opportunity to speak; and thank you even more for your personal enthusiasm and commitment to high quality forest seedling production.

A FEW USEFUL SOURCES

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Crop Scheduling with Computers: <http://www.na.fs.fed.us/spfo/rngr/fnn/jul-98/cp798.htm#crop>

What is SPAR? (BC): http://www.for.gov.bc.ca/tip/spar/what_is.htm

Nursery Shipping and Administration (BC): <http://www.for.gov.bc.ca/nursery/headqtrs/nsa.htm>

Using the Pivot Table to Summarize Spreadsheet Data: <http://www.na.fs.fed.us/spfo/rngr/fnn/summer01/pivot.htm>

Pesticide Tracking Software: <http://www.na.fs.fed.us/spfo/rngr/fnn/jan-97/ipm.htm#track>

Various forestry IT solutions: http://www.forestnet.com/archives/Nov_2001/tech_update.htm

MANAGING CROP UNIFORMITY IN WEYERHAEUSER NURSERIES

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Abstract

The primary goal during the culture of the 1+1 crop at Weyerhaeuser's nurseries is to achieve seedlings that uniformly meet target specifications. Target specifications are based on a combination of morphological and physiological characteristics that improve outplanting performance. Morphological attributes include height, stem diameter, root volume, root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Physiological attributes include foliar nutrition, water potential, and pathogen load. Other tests which indirectly measure physiology include cold hardiness, root growth potential, and dormancy status. The nursery staff uses these various seedling attributes to create crop development curves for the first and second years of 1+1 culture. They also use in-house research and information from the literature to choose those nursery cultural practices that ensure 1+1 crops follow the target growth trajectory. This results in anticipation of important cultural decisions, choice of the optimal treatment, and, ultimately, the ability to cost-effectively grow and ship a uniform crop that meets the expected targets.

Key Words

Nursery culture, target seedling, bareroot, 1+1 seedling, *Pseudotsuga menziesii*

INTRODUCTION

At Weyerhaeuser Company, Douglas-fir bareroot transplants (1+1) are the principle stocktype used for regenerating newly harvested sites in Washington and Oregon. All 1+1 seedlings are grown by the company at 4 Weyerhaeuser nursery facilities: Mima, Aurora, Turner, and Medford. Mima nursery, the largest facility, is located about 12 miles south of Olympia, Washington. Since Mima supplies about half of the 1+1 seedlings planted on company lands, and the authors are most familiar with this facility, much of the following information comes from Mima nursery.

The primary goal for any nursery is to grow a seedling crop where most seedlings reach some predetermined target specification. The most cost effective means of achieving this goal is to maximize yields through careful planning and intelligent choice of cultural practices. This then minimizes the numbers of seedlings that are discarded at pack. While yield is a significant economic driver for the nursery business, it is not necessarily considered the "bottom line" at Weyerhaeuser. Since the Weyerhaeuser nurseries

grow seedlings for internal customers, there is considerable focus on through-the-system seedling quality. In other words, the nurseries are continually looking for opportunities to improve seedling field performance and thereby significantly increase the company's return on investment and improve the quality of stock for all customers.

At all the nursery facilities, 1+1 seedlings are cultured such that they uniformly meet a combination of morphological and physiological target specifications, or, as defined by Ritchie (1984a), material and performance targets. The morphological, or material, targets can be directly measured and include height, caliper, root volume (or mass), root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Physiological targets, such as foliar nutrition, water potential, and root pathogen load, would also be considered material attributes. However, cold hardiness conditioning, root growth potential, and dormancy status are performance attributes because they are indirect measures that integrate a variety of morphological and physiological elements of a seedling.

Many studies have shown that the aforementioned material targets have a significant effect on field survival and growth. Moreover, the tests of seedling performance have proven to be reliable descriptors of seedling quality. It is obvious that considering all attributes together would provide a more realistic measure of potential for field performance, but it is not clear how to combine all measures into one index.

For many years, considerable research effort focused on understanding how season, environmental conditions, and cultural practices affected material and performance attributes of bareroot seedlings. Weyerhaeuser nurseries have drawn very heavily upon this information to develop best practices. In addition, the nursery business had a seedling testing group that intensively measured seedling characteristics at the end of the growing season and throughout winter. Results communicated to the nurseries guided lifting and packing decisions. Communications to the customers included a description of seedling quality and recommendations for storage duration and handling practices.

Today, the nursery staff is much reduced. Even within 1 nursery such as Mima, it is impractical to evaluate the morphology and physiology of 20 million seedlings from multiple seed lots and families grown in several nursery blocks. Instead, the traits of interest are used to establish a final seedling target that is achieved by describing a target growth trajectory and then using best practices to keep the crop on this trajectory. This approach requires a detailed understanding of seedling development and considerable information regarding the impact of various cultural practices. Obviously targets and best practices change as new technologies are introduced but it is the expectation that this system can be continually improved.

DEFINITION OF TARGET SEEDLING SPECIFICATIONS AND THE TARGET GROWTH CURVE

Height and stem diameter are the primary descriptors for the target Douglas-fir 1+1 seedling at Mima and other nurseries. Height and stem diameter are easily measured and, although there are some contradictory results (Thompson 1984), most studies show that both are positively related to field performance. For example, Newton and others (1993) showed that taller Douglas-fir seedlings exhibited enhanced growth and over-topped the competing vegetation. Long and Carrier (1993) found increased stem

diameter of 2+0 Douglas-fir had a significant effect on tree height at age 5 years. In addition, 2-year survival and height of Douglas-fir rooted cuttings, 2+0 seedlings, and 1+1 transplants were strongly related to stem diameter at time of planting (Ritchie and others 1993).

Average expected height and stem diameter of 1+1 seedlings are constrained by environmental conditions and current operational practices at Mima nursery. However, the actual height and stem diameter targets used by the nursery do not reflect the natural variation in seedling morphology. Instead, they are market driven and based on customer demands. Therefore, to remain competitive, the nursery staff must develop a cultural plan which combines transplant date, years from fumigation, growing density, grading, and other treatments to achieve a uniform 1+1 seedling population that meets target specifications.

A relatively intensive sampling plan is used to track height growth during the first year and height and stem diameter growth during the second year of 1+1 culture. Trees are measured on a predetermined schedule and the data are immediately processed and compared to growth in previous years. The results show if the crop is growing at a rate which will produce the target seedling height and stem diameter or if proactive measures are required to accelerate or slow growth. Most importantly, continually tracking the progression of the crop allows a timely decision to begin dormancy induction treatments that will stop shoot growth and allow seedling tissues to mature.

Target height and stem diameter curves show the very different growth rates over the season. For example, cool air and soil temperatures limit first year seedling growth at Mima nursery for some weeks following germination. However, as summer temperatures began to increase, there is a distinct shift to a phase of rapid shoot elongation. This latter phase continues until the beginning of dormancy induction treatments in late summer (table 1). The development of the 1+1 crop is very similar. For the first few weeks following spring bud flush, shoot elongation is relatively slow. Then, about the same time that the first year seedlings are beginning rapid growth, the 1+1 seedlings start a second flush, and they, too, begin to grow rapidly (table 2).

A description of the target 1+1 seedling at Mima nursery includes other morphological attributes such as root volume (or mass), root fibrosity, root-to-shoot ratio, shoot and root form, and bud development. Unlike height and stem diameter, these measures are only occasionally used for crop tracking. They are

Table 1. Approximate timing of shoot developmental stages and nursery cultural activities during the first year of the 1+1 crop at Mima Nursery.

Date	Stage Shoot Growth	Nursery Activities
Aug - Sep		- Fumigation
Sep - Mar		- Orders received - Planning
Feb - Mar		- Seed stratified and treated
Apr		- Pre-plant fertilization - Soil preparation - Sow - Herbicide treatments - Irrigation
May	Germination ├─ Lag Phase	- Fertilization
Jun		-Fungicide treatments
Jul	├─ Rapid Growth Phase	
Aug		- Shutdown treatments and root culture
Sep	├─ Reduced growth	
Oct	Growth cessation and dormancy	
Nov		
Dec		- Lifting, grading, packing - Freezer Storage
Jan		
Feb		
Mar		

Table 2. Approximate timing of shoot developmental stages and nursery cultural activities during the second year of the 1+1 crop at Mima Nursery.

Date	Stage Shoot Growth	Nursery Activities
Aug - Sep		- Fumigation
Sep - Mar		- Planning
Feb - Mar		
Apr	├─ Lag Phase	- Pre-plant fertilization - Soil preparation - Transplant - Herbicide treatments - Irrigation
May		- Fertilization
Jun		-Fungicide treatments
Jul	├─ Rapid Growth Phase	
Aug	├─ Reduced growth	- Shutdown treatments and root culture
Sep		
Oct	Growth cessation and dormancy	
Nov		
Dec		- Lifting, grading, packing - Freezer Storage
Jan		- Cooler Storage
Feb		
Mar		

primarily used to characterize seedling developmental stages, to determine optimal timing for applying treatments, and to evaluate the effects of specific cultural practices. In other words, cultural practices that maximize root size and fibrosity, optimize root-to-shoot ratio, maintain good root and shoot form, and promote normal bud development are the treatments added to the nursery “tool kit” of best practices.

Physiological targets for 1+1 seedlings include foliar nutrition, water potential, and fungal pathogen load. Foliar nutrient levels are analyzed periodically throughout the growing season. These data and information from the literature are used to establish the seasonal targets for foliar nutrition. The historical data are also used to develop a fertilizer schedule that maintains foliar elements at optimal levels throughout the year. Seedling water potential is monitored with a pressure chamber during the drought stress treatment used to initiate dormancy. To reduce the impact on root growth, target levels of predawn moisture stress are the minimum required to initiate dormancy. Levels of soil-borne pathogens in the soil and on seedling roots are also evaluated at several points during the season. This service is provided by our in-house pathogen testing lab staffed by Dr Will Littke and John Browning. Results are used to develop fumigation plans and to guide seedling handling during lifting and storage.

Seedling quality tests that provide an evaluation of seedling physiology include tests of cold hardiness, root growth potential, and dormancy status. The targets for fall and winter cold hardiness levels are very specific and were established by the considerable efforts of Dr Yasuomi Tanaka and the seedling testing team at Weyerhaeuser (see Tanaka and others 1997 for description of methodology). There are also relatively specific targets for root growth potential. Root growth potential fluctuates seasonally but indicates whether a seedling is in optimal physiological condition (Stone and others 1962). Root growth potential has been used most extensively to develop detailed guidelines for lifting and storing Douglas-fir bareroot seedlings (Ritchie 1987). Finally, dormancy status is measured as the number of days to bud break in a forcing environment and is modulated by a combination of accumulated chill hours in the field and number of hours in storage (van den Driessche 1977; Ritchie 1989). Dormancy status is well correlated with seedling resistance to the stress of lifting, handling and storage (Lavender and Wareing 1972). This test has been used to develop guidelines for duration of storage based on time of lifting (Ritchie 1984b).

SEEDLING DEVELOPMENT AND CROP CULTURE DURING YEAR 1

Since a 1+1 seedling is cultured over 2 growing seasons, there are many opportunities for variable weather to cause a reduction in crop uniformity. Consequently, considerable effort is focused on those nursery practices that most influence crop development and compensate for aberrant environmental conditions. Tables 1 and 2 describe the timing of cultural practices relative to the first and second year development of the 1+1 crop.

Growing a 1+1 crop obviously begins with sowing the seed in the 1+0 beds. As stated by numerous authors, the uniformity of this first year crop is very dependent upon the quality of the seed (Tanaka 1984). At Weyerhaeuser, seed is processed and then tested for purity and germination efficiency (Tanaka 1984). The number of weeks of stratification depends on the origin of the seed source.

The next major limiting factor to a uniform first year crop is disease. Prior to sowing, the seed is chemically treated to reduce damping-off and bird predation. The seed is then sown in the warmest blocks where soil conditions are optimal and drainage is good. However, the most important practice for controlling disease in the first year seedlings is fumigation in the late summer or fall preceding sowing.

Seed is sown by the most experienced staff member using an Oyjörd sower. For uniform germination and subsequent height growth, the seed must be sown over a relatively short period of time at a uniform depth and spacing.

Throughout the 1T and 1+1 growing seasons, the competing vegetation is minimized by controlling weeds in adjacent areas, applying pre-emergent herbicides, and hand weeding. Other crop diseases, such as fungal pathogens and insects, are controlled by applying preventive fungicides and insecticides. Various chemistries with different modes of action are used to prevent build-up of resistance. In addition, timing of applications is based on historical expectations of increased potential for disease as a function of the developmental stage of the crop or other cultural activities.

During the transition from slow to rapid growth, irrigation and fertilization schedules are important for sustaining rapid shoot elongation of first year seedlings. The crop must be irrigated frequently and uniformly to ensure seedlings are not adversely affected by moisture stress. Irrigation uniformity is maximized by maintaining equipment and watering in the morning when wind speeds are minimal.

Fertilizer applications occur as preplant additions to the soil prior to sowing and as soluble fertilizers sprayed over the seedlings during the growing season. Regular sampling during each crop year serves to ensure seedlings have optimal levels of all essential elements.

During rapid shoot growth, first year seedlings are actively initiating and elongating new stem units and, given optimal moisture and nutrients, they will continue to grow late into the fall. Although first year seedlings rarely achieve the target height by late summer, dormancy induction treatments must be initiated at this time to allow a sufficiently long period for development of other target morphological and physiological characteristics. Timely cessation of shoot growth allows an opportunity for roots, vascular cambium, needles, and buds to grow and mature before air and soil temperatures become completely limiting. Maturity of the plant tissues is key to achieving: 1) cold hardiness levels needed to survive potentially early cold events; and 2) stress resistance needed to withstand the trauma of lifting, grading, storage, and transplanting. Dormancy is induced through nutrient stress, root culture, and relatively mild water stress. Since it takes some time before the first year seedlings respond and set bud, seedlings continue to grow and the population “coasts” into the target height specification.

The strategy for lifting the first year seedlings is based largely on timing. Chill hour accumulation in both the field and in storage is used to guide timing of lifting and duration of storage for seedlings (Ritchie and others 1985; Ritchie 1989). These guidelines suggest seedlings become sufficiently resistant to the stress of lifting and storage by about mid-December. This is also the time when seedling roots become increasingly resistant to exposure (Hermann 1967). After lifting, Ritchie (1989) recommended those lots that are first into freezer storage should be last to come out of storage. Therefore, much of the decision about when to lift certain lots is dependent upon the plan for timing of transplant (discussed below). The exception being lots that are most susceptible to cold damage are lifted first. These lots are identified based on elevation and latitude of origin, past experience, or data from Dr. Roger Timmis’ screening of cold hardiness characteristics of Weyerhaeuser improved families.

All first year seedlings are stored in the freezer to arrest pathogen growth and control the rate of dormancy release.

SEEDLING DEVELOPMENT AND CROP CULTURE DURING YEAR 2

The 1+1 year begins with a transplant plan that is largely based around fumigation and time of transplant. Fumigation is an important consideration because not all of Mima nursery’s 14 blocks are fumigated each year. There are many reasons to minimize fumigation. These include the negative impact on the environment, the increasingly high cost of fumigants, and the reduction or elimination of advantageous microorganisms such as mycorrhizal fungi. Dr Will Littke has worked very closely with each Weyerhaeuser nursery to develop fumigation plans that minimize fumigation while maintaining soil-borne pathogens at acceptable levels for production of quality seedlings. Nonetheless, it is well known that newly fumigated soil produces large seedlings presumably because of reduced pathogen load in the soil and higher concentrations of inorganic nitrogen (Hansen and others 1990).

Time of transplant is also very important because transplanting at Mima occurs over about a 6-week period and the seedlings that are transplanted earliest are often the largest by the end of the growing season. Therefore, when developing the transplant plan, the general rule is to transplant first into those beds that have the most years since fumigation. This strategy has one of the greatest impacts on ensuring that all 1+1 seedlings uniformly achieve the target height and stem diameter specifications.

There are, of course, other considerations included in the transplant plan. One is the degree of cold hardiness of certain lots. Cold susceptible lots are transplanted into the warmest blocks and into areas that are relatively well-drained. The latter allows better access in the event that conditions are wet when this stock is removed early in the lifting season. This same strategy is used when a customer requests December or early January delivery of stock. In some cases, a customer may request 1+1 seedlings that are larger than the typical height and caliper targets for the nursery. Although this stock is more expensive, there are several options for growing such seedlings, such as transplanting earlier, transplanting into a recently fumigated field, growing at a lower density, or culling more heavily after lifting.

The development of the 1+1 crop is somewhat different from that of the first year crop, but the principles of crop culture remain very similar. Irrigation and fertilization are very important throughout the year, but become most critical when the seedlings second flush and begin to rapidly grow.

Irrigation is monitored with irrometers and, once more, moisture stress is avoided. The fertilization schedule is based on historical data and continuous crop monitoring of foliar nutrients. The strategy is to match soluble nitrogen addition with the changes in growth rate and prevent deficiencies of any other nutrient element.

Both height and caliper are measured intensively during the 1+1 year to ensure crops in all blocks are following the target growth curves. If seedlings in a block are exceeding the target height trajectory, dormancy induction may be initiated early. On the other hand, if seedlings are behind the trajectory, nitrogen fertilization will be increased and those seedlings may be allowed to continue to grow until the latest possible dormancy induction date. However, as in the first year crop, it is well understood that it is absolutely essential to stop 1+1 height growth early enough in the season to allow sufficient time for growth and maturation of the rest of the plant tissues.

Root cultural activities coincide with the dormancy induction treatments, since this is the time when shoot growth is slowing and root growth is increasing. Root cultural treatments are intended to maximize volume and fibrosity in the portion of the root system that will be lifted and remain intact following root pruning in the packing room.

As the season progresses into the fall and early winter, anxiety mounts over the potential for early winter cold damage. Of course the nursery staff frost protects during most cold events. In addition, the historical cold hardiness data provides a reasonable estimate of the levels of cold 1+1 seedlings can tolerate as long as crops were shutdown sufficiently early. However, in the event of unusually cold weather, air temperature is monitored continuously at all nurseries and the staff can quickly determine if there was a potential for seedling damage. If that uncertainty exists, then nursery research has maintained the capacity to test levels of cold damage in the crop and advise customers if there appears to be significant losses.

Weather permitting, the goal is to lift the 1+1 crop when it is resistant to stress; from mid-December to February. As previously determined in the transplant plan, the most cold susceptible lots are lifted first and transferred to freezer storage where they will maintain optimal physiological condition for approximately 4 months (Ritchie 1989). In addition, customers ordering high elevation lots typically prefer freezer storage and these, too, are lifted earliest. When customers specify cooler storage, the seedlings are lifted no more than a few weeks preceding planting,

thereby minimizing duration of cooler storage and the potential for physiological decline.

SUMMARY

Although we have used Mima nursery as the model for this discussion, these same best practices are shared across the other Weyerhaeuser facilities. Each facility faces its own challenges but evaluation of the crops and management decisions are made using a common strategy. To date, the business has been successful at producing good quality, uniform 1+1 seedlings, and although one can cite good cultural practices, the real key is the vast knowledge and deep commitment of Weyerhaeuser's nursery staff.

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OPEN-POLLINATED FAMILY MANAGEMENT IN NURSERIES

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Carlson W.C. 2003. Open-pollinated family management in nurseries. In: Riley L.E., Dumroese R.K., Landis T.D., technical coordinators. *National Proceedings: Forest and Conservation Nursery Associations—2002*. Ogden (UT): USDA Forest Service, Rocky Mountain Research Station. *Proceedings RMRS-P-28*: 151–158. Available at: <http://www.fcnet.org/proceedings/2002/carlson.pdf>

Key Words

Genetic variation, target seedlings, crop uniformity, bud dormancy, cold hardiness, water stress, RGP

INTRODUCTION

Increasing the genetic specificity of seed sown in forest nurseries has been occurring for several decades. The first step was to collect seed from specific stands identified by geographic location and elevation (Munger and Morris 1936; Wakeley 1944; Isaac 1949). Over the past 25 years, seed orchards have come on line.

Availability of seed from these categories of genetic specificity allows nursery managers to have a fundamental decision in how to sow their seed. Sowing by family offers advantages in both nursery management and reforestation. Nursery management has traditionally only controlled aspects of chemical and physical environment. Sowing by family allows genetics to become a management tool. Reduced variance within family can lead to improvements in uniformity of nursery crops and improved yield of wood having known characteristics in the forest.

THE NATURE OF VARIATION AMONG OPEN-POLLINATED FAMILIES

Given that the relationship shown in Figure 1 is well accepted, the next question is what level of variation will be observed. Weyerhaeuser Company started

sowing loblolly pine by open-pollinated family in 1981. We have done extensive testing of the variation in many traits. Figure 2 shows variation in height growth activity between a slow growing southeastern Oklahoma seed source and a fast growing North Carolina Coastal (NCC) family growing under low or higher water stress conditions. Note that in low stress, both had 100% of the population with 3 growth flushes. Oklahoma source seedlings dropped to 57% of the population having a fourth growth flush while the NCC family had 80% in the fourth growth flush. Neither had a fifth flush. In high stress conditions, the Oklahoma source dropped to 70% of the population in the second flush and then to 0% in the third. The NCC had 93% of the population in the second flush under stress with 8% having 4 growth flushes. It is apparent that there is considerable genetic variation in response to drought, nutrition, and irrigation.

If one were managing the seedlings referred to in Figure 2 in one irrigation unit in a nursery, then one would expect considerable variation in response to water stress used as a management tool. Managing them in separate irrigation units would allow differential irrigation to be used to reduce variation in the seedlings produced. Genetic variation affects the



Figure 1. Genetics and environment control physiological processes which determine rate, timing and duration of growth.

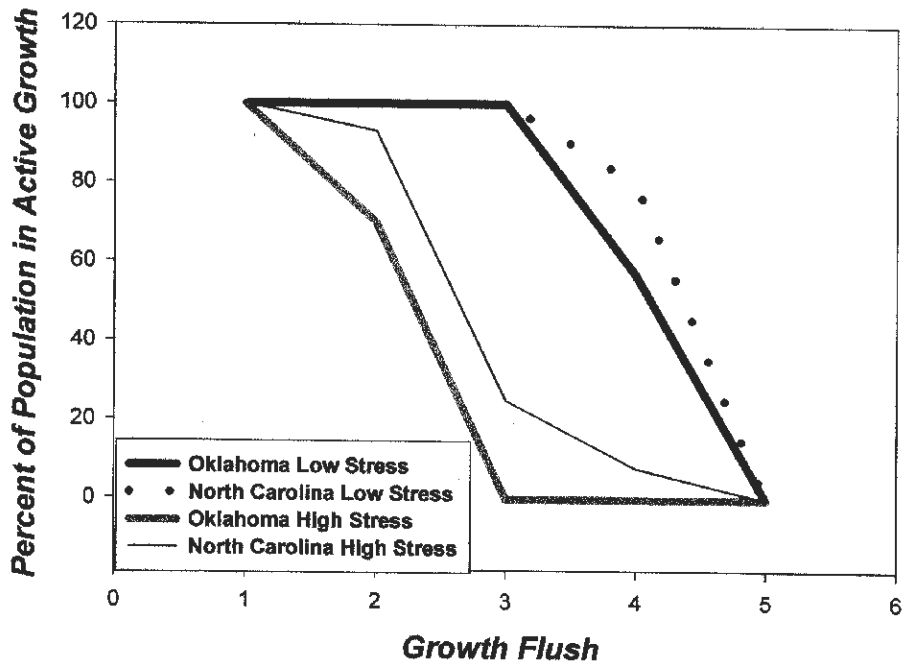


Figure 2. Comparison of height growth response to water stress between a southeastern Oklahoma seed source and a North Carolina Coastal OP family. Low stress seedlings were drip irrigated daily. High stress seedlings were irrigated once at planting then left for the season. Experiment was done under a roof to prevent rainfall from reaching seedlings. Soil was a coarse sand. Water potentials dropped throughout the experiment in the high stress seedlings. They reached predawn water potentials of <-1.2 MPa, whereas low stress seedlings were >-0.3 MPa.

outcome of what nursery managers do. They can improve their products by managing with knowledge of that variation.

Genetic variation occurs in most traits, but one must know if the differences are critical to management. In the early 1980s, it was suggested that differences in bud dormancy status would drive differences in seedling root growth potential (Ritchie and Dunlap 1980). We observed considerable family variation in bud dormancy status (fig. 3) and therefore concluded that we needed to understand if this would cause variation in lifting date and storage responses in root growth potential (Carlson 1985).

Bud dormancy could be released equally well by chilling in a seedling cooler after lifting, or by leaving the seedlings outdoors in the nursery bed (van den Driessche 1977; Carlson 1985). Comparing root growth potential of seedlings receiving their chilling requirement for release of bud dormancy either in storage or outdoors gave very different results (fig. 4). It was apparent that bud dormancy status was not the controlling factor driving root

growth potential. This is an example where considerable genetic variation occurs, but that difference is not critical to nursery management decisions.

Root growth potential (RGP) varies by family and by the temperature at which the test is done (Nambiar and others 1979; Carlson 1986). Figure 5 shows the nature of family variation in loblolly pine RGP at 3 soil temperatures. This points out that the commonly used root growth potential test is a simple index of physiological status at the time of the test rather than an estimator of number of roots anticipated upon field planting where, for example, soil temperatures would differ substantially. Figure 6 shows that similar family variation in root growth occurs under field conditions after planting.

FAMILIES CAN BE SORTED INTO RESPONSE GROUPS

Does genetic variation between families mean that we need to manage each one separately in the nursery? The critical biological variables for nursery

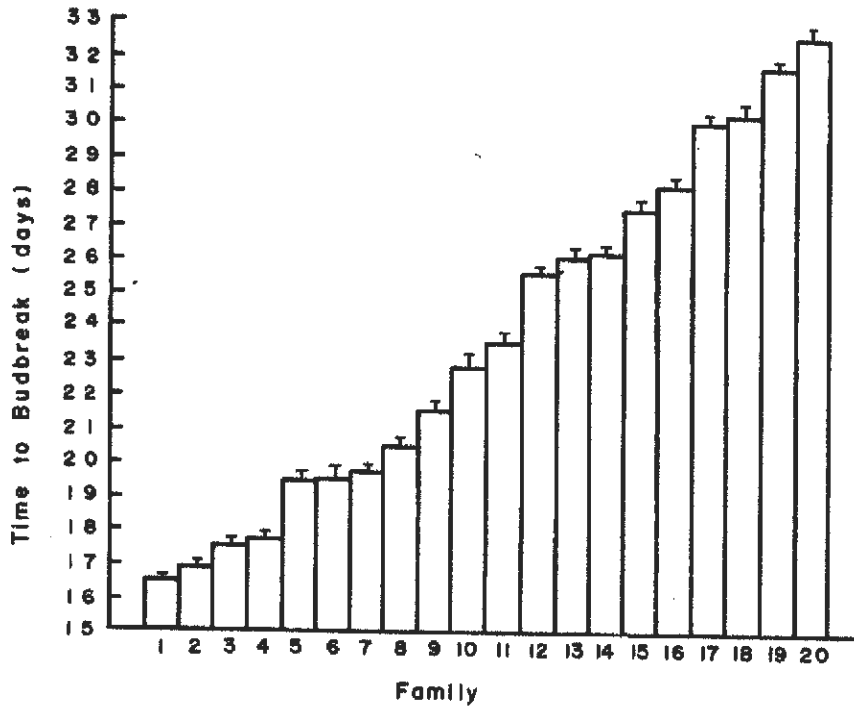


Figure 3. Bud dormancy status of 20 open pollinated families of loblolly pine measured as time to bud burst under warm long day conditions. Differences were highly significant at 207 chilling hours (November 23) but became non-significant as chilling released buds from dormancy at 1234 chilling hours (from Carlson 1985).

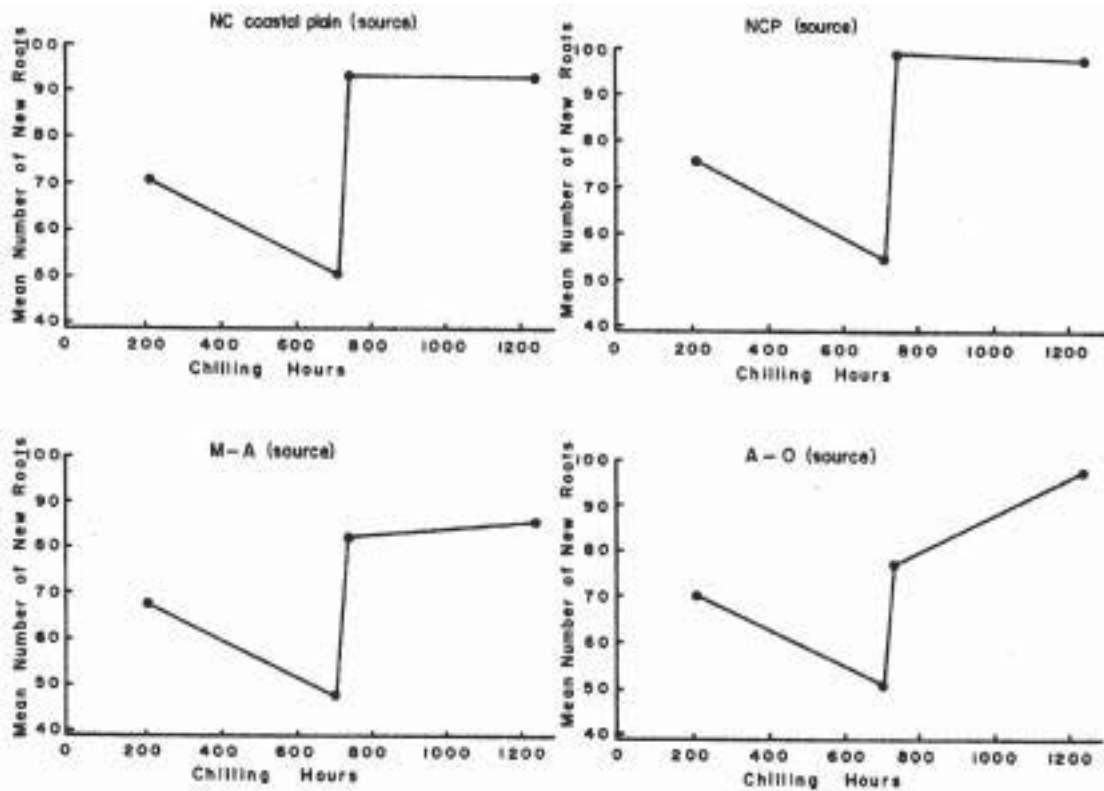


Figure 4. Changes in root growth potential with storage at 2 different points in bud dormancy release as indicated by chilling sums. Results are averaged over families for each seed source but represent the same families shown in Figure 3 (from Carlson 1985).

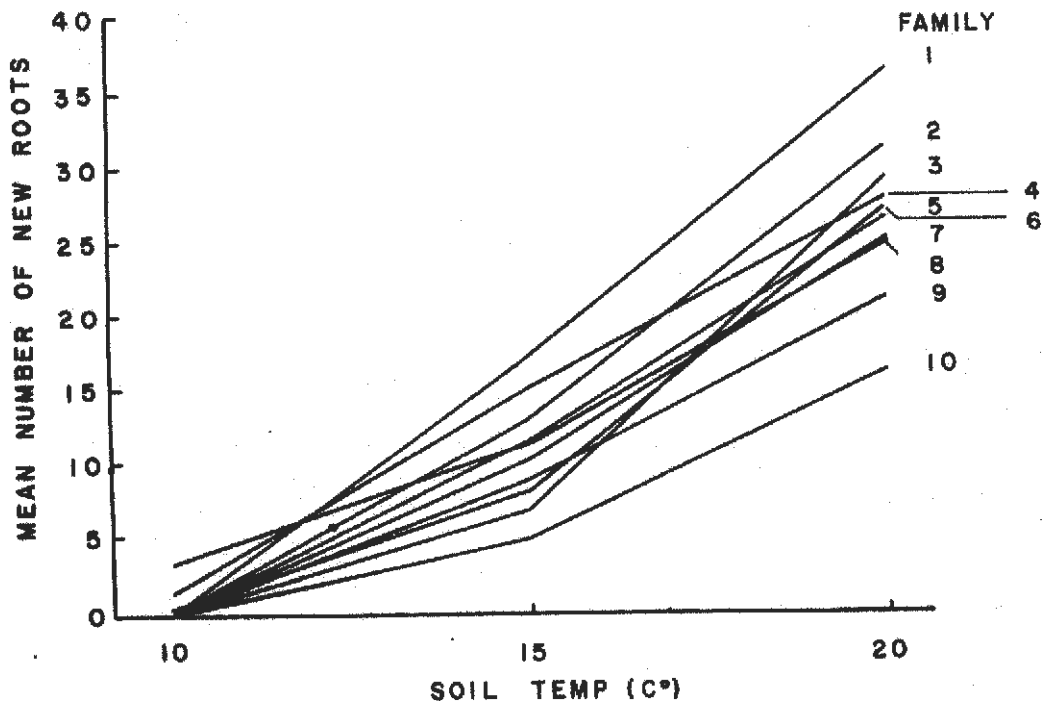


Figure 5. Root growth potential varies with family and the soil temperature at which the test is done.

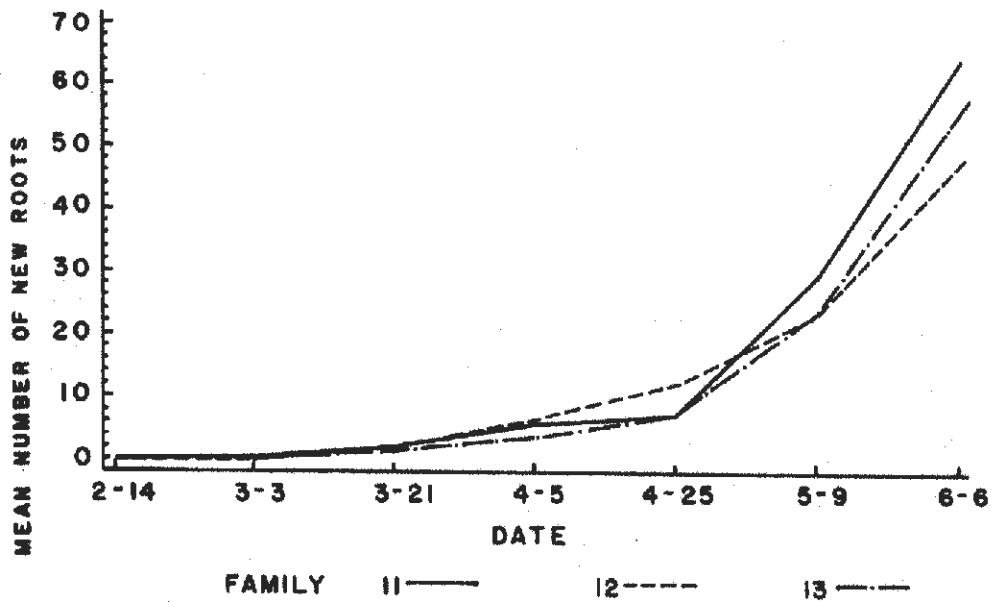


Figure 6. Families also vary in their root growth after outplanting. Ranking changes with time and probably with the soil temperature of the site.

culture are germination rate and height and diameter growth rate. If one considers the alternatives, the choice is to harvest and handle seed orchard produced seed in bulk mixes or as separate families. If you sow a bulk mix, it will have the same range in variation as the group of families would have collectively. We therefore can conclude that all the families will have ranges that are subsets of what would be observed with a mix. For example, take the pattern of shoot growth. Loblolly pine has the capacity to multiple flush in the growing season. The first flush of growth after germination ends in a budset that generally occurs in mid-August (fig. 7). Families differ in what proportion of the family enters another growth flush and when that flush ends. There are 4 types of budset patterns that occur, but most families are in either the "early" or "late" budset groups. These budset pattern groups are typical of nursery management response groups. Whereas there can be many families present in a nursery, they can be separated into a few

management response groups for the variables that affect crop development.

RESPONSE GROUPS CAN BE DIFFERENTIALLY MANAGED TO MEET COMMON TARGETS

These response groups can then be sown in different irrigation units to facilitate differential management (fig. 8). Selection of the location of response groups on the nursery should consider the relative point in crop rotation. Slower developing response groups with more conservative phenology might be selected for sowing in first year post fumigation soil; whereas, the most rapidly developing groups might be targeted for fields that are further along in the soil rotation. Irrigation, fertilization, root wrenching/pruning, and so on can then be differentially applied to guide the response group into the target morphology and physiology.

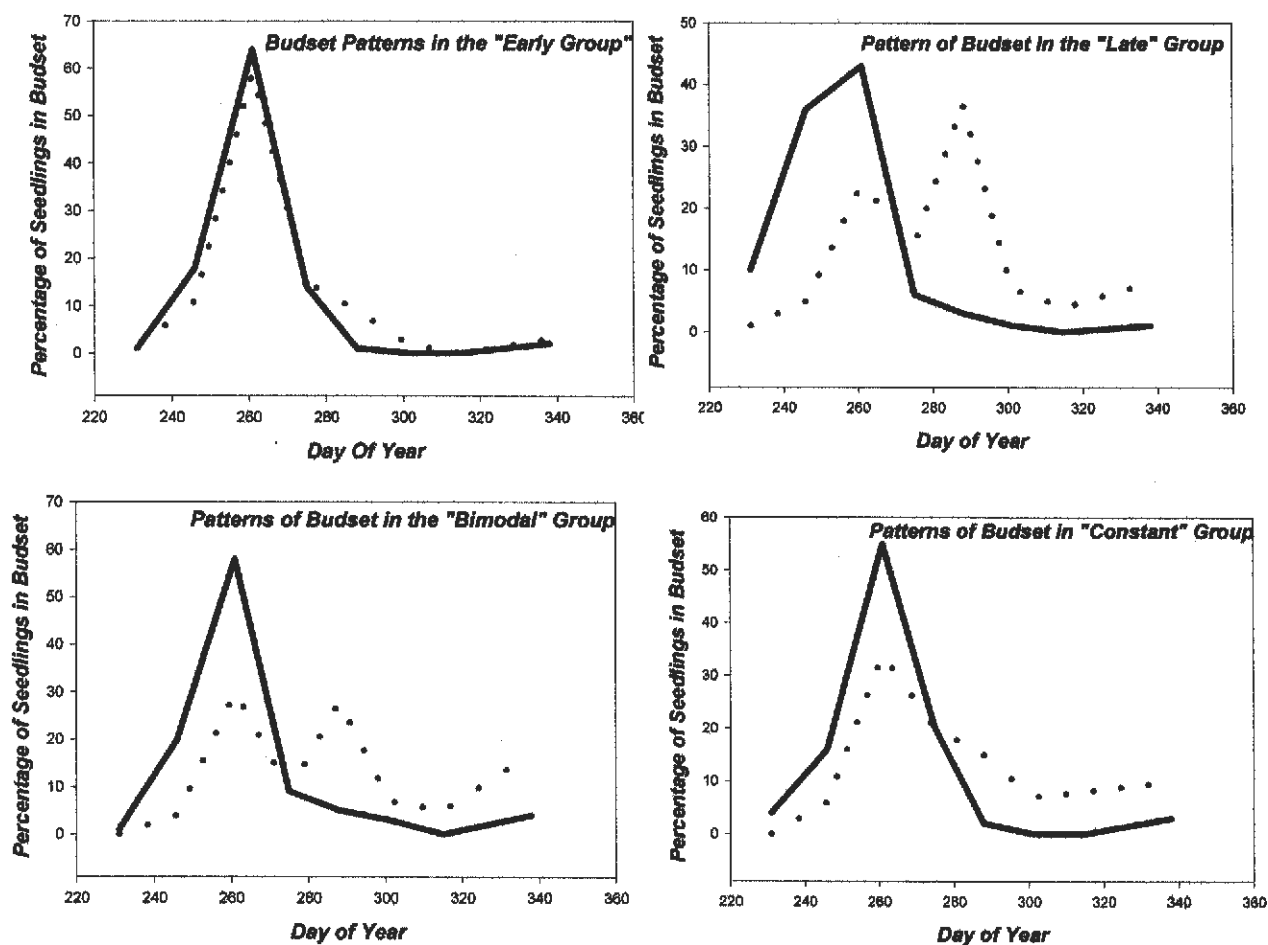


Figure 7. Budset patterns in 1+0 loblolly pine families growing in bareroot nursery beds.

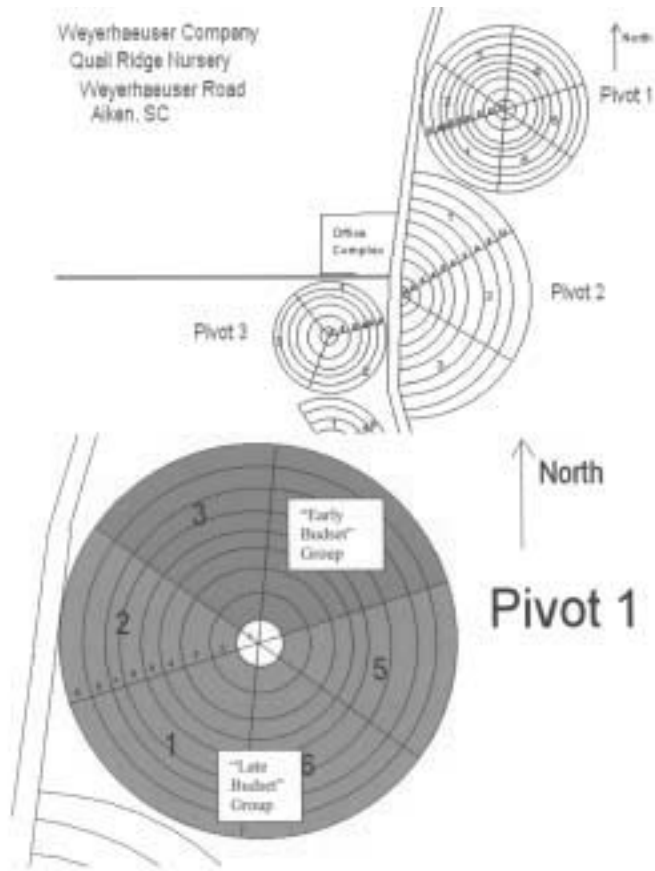


Figure 8. Response groups applied to sowing Pivot 1 of Weyerhaeuser's Quail Ridge Nursery. If a group is very large, it could be an entire pivot in size or it could be as shown here in one or more blocks. Individual families are seldom more than a few units in size. Each unit within a block is 25 to 28 nursery beds wide.

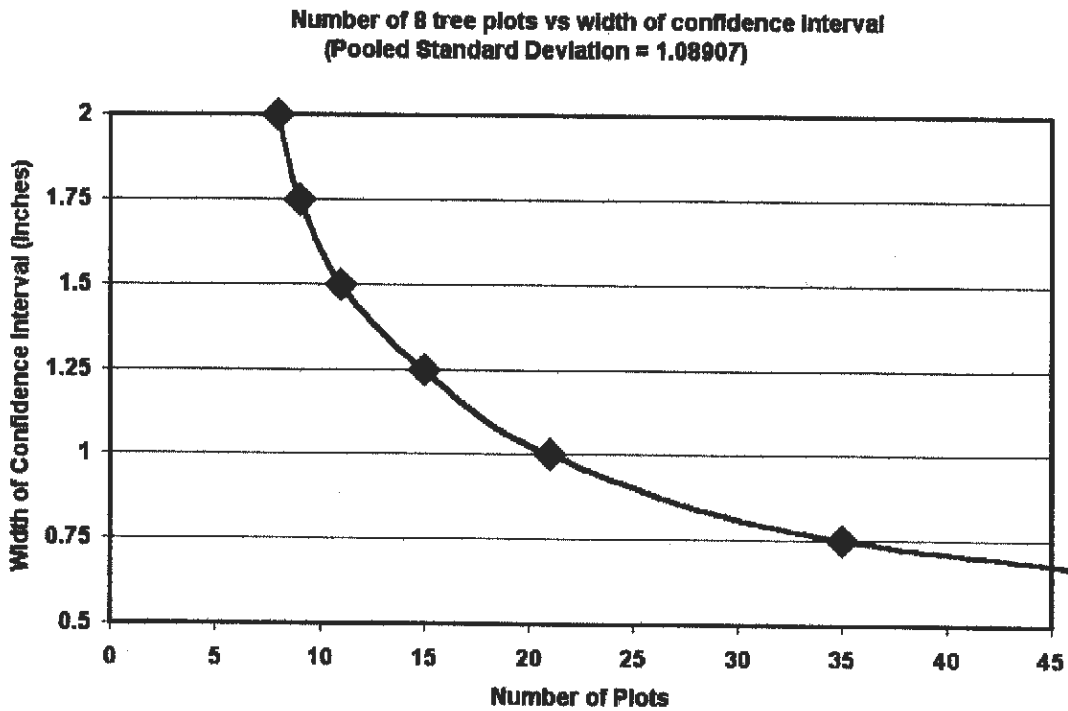


Figure 9. The influence of number of sample plots on width of 95% confidence interval for height in loblolly pine 1+0 bare root seedlings. (Figure provided by John Browning, Weyerhaeuser Company.)

Collaboration of foresters and researchers is necessary to set the criteria for target seedling morphology and physiology (Rose and others 1990). Managing differentially toward a common target is critical to achieving quality goals. Use of target growth curves and seedling sampling through the year can allow growers to make proper decisions on which portions of the crop need acceleration and which need holding back. Stratified sampling of nursery areas should be done understanding the required number of plots/strata necessary to achieve a planned confidence interval around the mean of the variable to be measured. Figure 9 shows a typical relationship for sampling height in loblolly pine.

Growers need to understand size distributions for seedling populations before making a management decision. Cumulative frequency graphs done at each

sampling date allow one to visualize how the population looks against target at any point in development (fig. 10).

SUMMARY

Managing open-pollinated families in conifer nurseries is a positive step in reducing nursery variation. A combination of nursery experience and research can separate the families into response groups that will simplify the process. Once response groups are chosen, all nursery management decisions can be used to help meet targets for each group. This would include selection of the field in which to sow the groups, sowing date, fertilization, irrigation, and root cultural practices. Crop monitoring by stratified sampling can be used to understand crop development and guide management decisions.

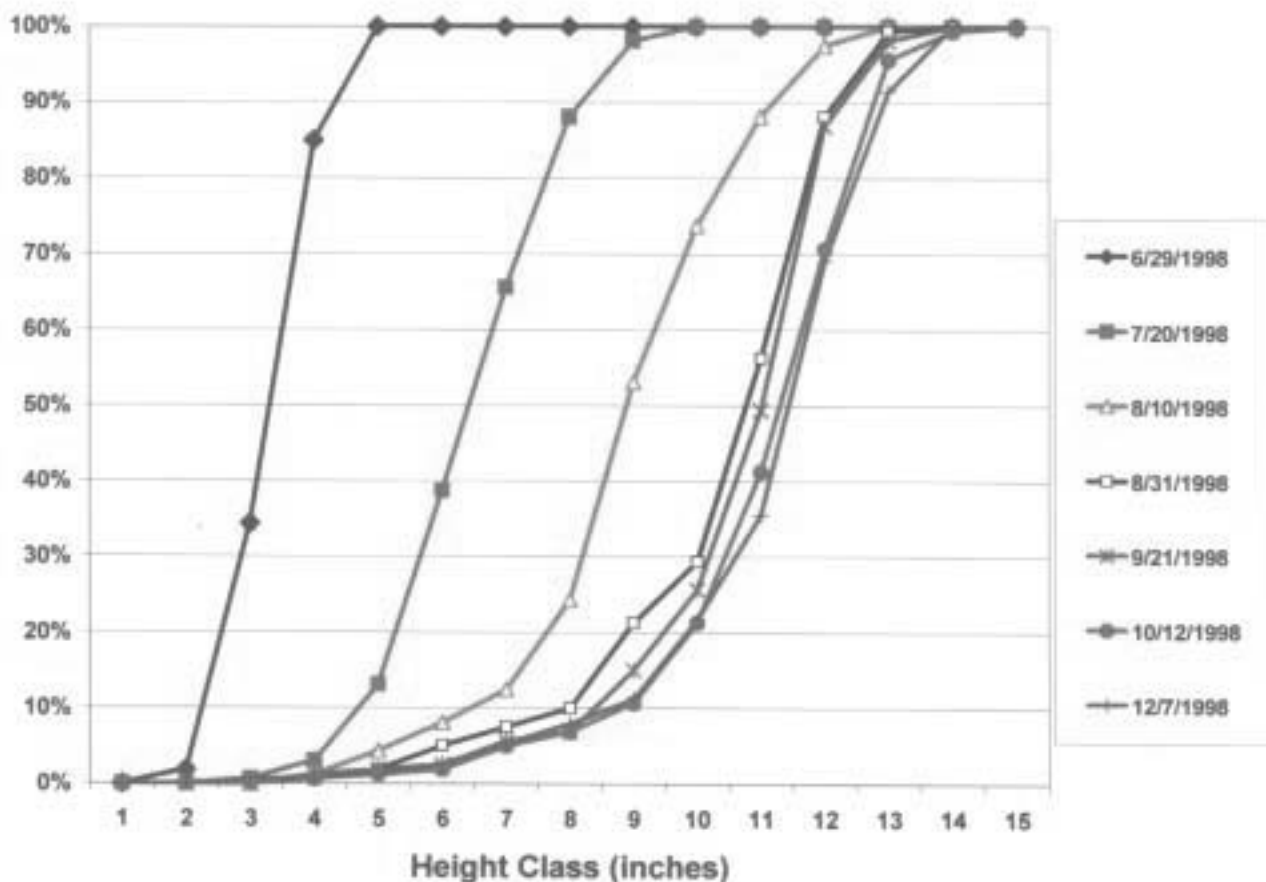


Figure 10. Cumulative frequency distributions for height in a loblolly pine bare root 1+0 seedling crop by sampling date. (Figure provided by John Browning, Weyerhaeuser Company.)

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FALL PLANTING IN NORTHERN CALIFORNIA

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Abstract

Fall planting has become an important part of Roseburg Resources Company forest management program. The current program averages 300,000 seedlings planted in the fall. The majority of sites are high elevation units, which have a small planting window in the spring when enough moisture is available. However, early successes with fall planting have led us to look at other sites which may be suitable. In mediterranean climates, maximizing initial root growth and soil moisture will enhance seedling survival and growth dramatically. Company research has indicated as much as a 50% to 100% increase in stem volume 2 years after planting with fall versus spring planting on high elevation sites. The entire process of preparing for a fall plant is different than for in the spring. Seedling condition, site preparation, soil temperature, soil moisture, storage and transportation issues are all critical factors in determining the success of the fall plant.

Key Words

Outplanting, fallow cropping, seedling conditioning, planting suitability, herbicides, container seedlings

PRIOR TO LOGGING

Our fall planting program begins long in advance of logging. Moisture management is probably the biggest difference between preparing for a fall and a spring plant. In fall, seedlings may have to withstand fairly substantial periods without rainfall after planting. Therefore, we manage our units to retain the maximum amount of moisture possible. Typically we do not fall plant on sites that receive less than 40 inches of annual precipitation.

It is important to evaluate each unit on an individual basis to determine whether or not it is suitable for fall planting. Typically the sites that work best for our program generally have deep soils, good water holding capacities, high site quality, and usually higher elevation. North or east facing slopes also protect seedlings from excessive dry periods post planting. Most of our fall planting program involves higher elevation sites. Snow melt may not occur until late June, or even July, when spring rains have already ended and the only new moisture available is from snowmelt. Temperatures may also exceed 100 °F (38 °C) by the time these higher elevation units open up. Therefore, we felt less stress would be put on the seedlings by planting in fall. Higher site ground with deep soils have also worked fairly well at lower elevations as long as these sites had good water

holding capacities. Well drained sandy soils should be avoided.

At least 1, if not 2, years prior to logging, we are spraying pre-harvest, as a site preparation tool, all vegetation in the understory of stands to be logged. This technique has several advantages. The main benefit is that we are able to use chemicals that more effectively control vegetation. We would not be able to use these chemicals directly prior to, or after planting because of seedling toxicity problems. This allows for more effective control of the woody brush and avoids re-sprouting of brush after it has been disturbed by logging activity. A second benefit is that we seem to be able to use lower rates of chemical than would be required to control open grown brush. This is most likely because the brush is somewhat stressed from the conifer overstory and is not as hardy. In the long-term, controlling the understory brush also allows us to use lower rates of residual herbicides, such as hexazinone, prior to planting because we are only worried about controlling herbaceous vegetation and not woody brush. Application costs are also dramatically less than a release application because applicators do not have to worry about hitting seedlings.

Due to the long-term control achieved with the pre-harvest applications, our logging units are staying clean for 2 to 3 years post-planting. Therefore, there

is significant financial as well as growth implications from the treatments, as we are negating at least one if not more release applications.

LOGGING AND SITE PREPARATION

The timing of logging operations is more critical for fall planting than with a spring plant. For fall planting, logging must occur early in the season. In our region, we try to have fall plant units logged by late April or early May at the latest, when there is still plenty of available soil moisture. Any mechanical site preparation should occur immediately afterward and hopefully be completed by the end of May.

Ripping is a very valuable tool that also compliments the fall planting process. By breaking up any compaction which has occurred on the site, fall planted seedlings have unrestricted space to put on their late flush of roots. The ripping also decreases surface runoff, concentrating most moisture in the rips. Currently, our program is to rip virtually all ground under 30% slope.

FALLOW CROPPING SYSTEM

The combination of pre-harvest site preparation treatments and early logging and site prep will ensure that planting units sit vegetation free throughout summer. This will maximize the amount of soil moisture retained, since there is no transpiration occurring from brush or trees. This is especially critical on better drained soils with limited water holding capacity. On our soils with good water holding capacities, soil moisture can be found at depths of 2 to 3 inches (5 to 7.5 cm) at the end of the growing season on fallow units; on units without the fallow cropping system, soil moisture occurs at depths of 8 to 10 inches (20 to 25 cm).

The fallow system gives added insurance to planting success, especially if a prolonged dry spell occurs after planting. On good soils, there is also the potential to plant even if only a limited amount of rain has occurred on the site.

SEEDLING CONDITIONING

Our fall planting program is entirely focused on container stock. The early initial root growth produced from container stock is critical in dry climates to maximize rooting depth, taking advantage of maximum available soil moisture. Bareroot stock does not have the ability to grow new roots nearly as well as container stock. Container trees also allow for added flexibility to hold seedlings over if adequate fall

planting conditions do not materialize. Nursery managers are also better able to manipulate the growing environment for container stock to prepare it for a fall plant compared to bareroot stock.

Probably the most important factor contributing to increased success of fall planting has come from advances made in the nursery regarding the conditioning of seedlings geared for fall planting. It is most important to know what stocks will be fall planted at the time of sowing, so that the nursery knows what growing regime to use.

Seedlings grown for a fall plant are generally sown earlier than trees for a spring plant, and are usually grown under slightly warmer conditions to accelerate growth rates. The main purpose of this is that the trees will be put under blackout in the greenhouse sooner than trees for spring planting, so they have a longer period to harden off before going out to the field. Trees grown under these conditions will be better prepared for potentially harsh conditions which can occur in the field. It is imperative, however, that the nursery does not blackout the seedlings for too long. Seedlings grown under excessive blackout regimes can go too far into dormancy and shut down caliper growth as well as root growth. The key is to blackout seedlings just enough so they set bud and stop their height growth. However, seedlings should still be able to put on caliper and actively grow new roots.

One treatment which has become more popular in recent years is the addition of slow release fertilizers to the container medium. While significant gains in growth can be achieved, there are several drawbacks. The first is that the nursery needs to pay special attention to salinity levels while seedlings are being grown. If seedlings are not flushed on a regular basis or let to dry down too much, salt levels can increase, damaging or killing roots. The second downfall is the incidence of animal browse in the field once the seedlings are planted. Deer and elk have a special preference for fertilized seedlings. The forester should be aware of potential browse problems and take measures to protect seedlings. Our experience is that big game repellents are a better solution than netting or tubing, even if it has to be reapplied. Netting and tubing tend to deform trees and cause them to lay down under heavy snows.

On the positive side, the replicated field trials outplanted by our company have shown substantial gains in seedling volume with slow release fertilizers planted in fall for the first couple of years after planting. However, these initial differences in growth have dissipated over time. The fertilizer effect is not

as profound, and more lethal, to seedlings with a spring plant. Fall planted trees have a better chance of overcoming fertilizer issues due to the flushing of fall rains, naturally decreasing the salt levels.

TRANSPORTATION AND STORAGE

Transportation and storage play a key role in the success of a fall planting program. When conditions favorable to planting occur, seedlings must be lifted and shipped quickly to capitalize on planting conditions. Seedlings should be shipped at 40 °F (4.4 °C). Seedlings should not be shipped at temperatures lower than this to avoid putting the trees into dormancy. The trees should be actively growing when received.

The problem with storing trees in warmer conditions is that it creates an ideal environment for pathogens and fungi, such as *Botrytis*. Therefore, it is critical to plant seedlings as quickly as possible in fall. Seedlings stored at 40 °F (4.4 °C) have roughly 10 days, in our experience, before fungi problems become evident. Therefore, we try to have our fall planting program completed within 1 week. If you have a small amount of trees to plant, seedlings can be stored on the unit for immediate planting with boxes open in the shade. Seedlings should be packed standing up, allowing for maximum aeration, and be packed without plastic liners or with plastic liners that allow air-flow, so trees can respire. Plastic liners may also cause excessive temperature conditions for seedlings. If you have to cooler store trees prior to planting, seedlings should be stored no cooler than 40 °F (4.4 °C). It should be the goal to get trees out of storage as quickly as possible.

PLANTING

Before seedlings are ordered for delivery from the nursery, it is imperative to have optimal soil moisture for planting. This usually involves at least one good rainfall event. Our rule of thumb is to have at

least 2 inches of rain prior to fall planting before seedlings are lifted. However, this varies somewhat with soil type. Soils that have high water holding capacities, high organic matter, and are of better site qualities usually require somewhat less rain than the 2 inch standard.

It is critical in fall that seedlings be planted quickly. The longer the time in cooler storage, the greater the risk to the seedling. Contracting enough tree planters to complete the planting program within 1 week is our company goal. This usually involves several planting crews and requires adequate supervision. One crew usually requires 2 planting inspectors to ensure a correct planting job is done.

Planting spots must be cleared of all debris and dry soil. Planting spots are scalped until soil moisture is reached. If planting units are ripped, seedlings should not be planted in the bottom of the rips unless the rips have settled over a winter. Otherwise, loose soil on the edge of the rips will fill in the bottom of the rip, burying the seedlings. It is our practice to scalp to soil moisture half way up the shady side of the rip, to create a planting spot that will not cave in but still provide the benefits of uncompacted growing space.

Planting micro-sites is critical in fall. This is especially true if prolonged dry periods follow planting. Planting on the north to east side of any object in the unit will provide higher soil moistures and lower temperatures more conducive to seedling establishment.

CONCLUSIONS

Fall planting can be a valuable tool in a reforestation program. Planning and logistics can be an overwhelming obstacle, but critical to a successful program. Plan early and pay attention to detail. A last minute plan to fall plant will almost surely fail or have unintended results. With proper planning and site selection, the results can be phenomenal.

TRAVELS AMONG THE GWICH'IN

BERT GILDART AND JANE GILDART

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Abstract

Bert and Jane Gildart have been traveling among the Gwich'in people for over 12 years. During the 1991 to 1992 school year, they worked as teachers, then returned for four more summers as summer school teachers. Because their passions had been aroused, they then resumed the type of work Bert had conducted for almost 25 years: specifically, work as a writer and photographer for many national magazines, including Smithsonian. The following represents an excerpt from one of Bert's many stories that he wrote about the Gwich'in Indians and the land upon which they depend: specifically, the Arctic National Wildlife Refuge. This introduction was part of a story that appeared in National Wildlife Magazine, and it provided much of the material the Gildart's used in their slide lecture, "Hunting For Their Future."

Key Words

Arctic Circle, porcupine caribou, native culture

Above timberline, above Arctic Village, Alaska—120 miles (193 km) above the Arctic Circle—my wife, Jane, and I watch with Kenneth and Caroline Frank, a Gwich'in Indian couple, as the first caribou of the season return from summer calving grounds located along the Arctic Ocean. Though Kenneth is a hunter, he restrains himself. Customarily, the Gwich'in permit the first caribou of the season to pass so they won't turn tail and alarm the closely trailing major herd. "We should wait," says Kenneth. "There will be more in a day or so."

For Kenneth and Caroline—and for all the Gwich'in—the return of the caribou is a major event. For many of this most northern of all Indian tribes, spanning 2 nations in about 13 different small villages, the return means that stomachs will be full when it is 70 degrees below zero (-57 °C) and game is not moving. But there is more. Now, when the caribou return, the migration is cause for even more celebration, for it means the Gwich'in have thwarted another year of attempts to undermine their way of life. If petroleum companies have their way, they will



Figure 1. Last summer, the Wilderness Society flew the Gildarts into the heart of the calving grounds for the Porcupine Caribou herd. Although petroleum companies refer to the area as the 1002 Area, it is, in fact, the exact area cow caribou seek out because of the abundance of protein-rich cotton grass. No other Arctic area so completely satisfies the requirements of cows and their calves as does this area, which is located adjacent to the Arctic Ocean.

construct oilrigs in the precise area where members of the Porcupine Caribou Herd have always calved. The Gwich'in are firmly united in their denunciation of these efforts by oil companies, and say so in a variety of ways that represent their concerns for themselves and the caribou.

“Our children draw pride from the caribou,” says Caroline. “The herd reaffirms our way of life.”

“If we are to save our culture and prevent social ills,” says Gwich'in minister Trimble Gilbert, “we must preserve the calving grounds.”

“Our culture is thousands of years old,” says Kenneth. “Is just a few years of oil worth all that? Or will the white man always want to destroy the land and the most beautiful animals on it?”

That night we return to Arctic Village to wait for the herd's return, and dream of the days ahead. Caribou! Magnificently antlered animals. Great aggregates of tawny beasts, flaying the tundra with their hooves,



Figure 2. “An Arctic waste land?” That’s the way some politicians interested in promoting oil exploration in the core calving grounds of the Porcupine Caribou herd have described it. But pictures are worth a thousand words, and Bert and Jane Gildart took exception to such statements made on Tim Russert’s “Meet the Press”.



Figure 3. Moses Sam was a man who had once followed a trade route to the Arctic Ocean, which the Gildarts also followed.



Figure 4. Had Gwich'in matriarch Sarah Abel of Old Crow, Yukon Territories lived another year, her life would have spanned 3 centuries. When she passed away, most thought she was 102. She was born into a stone-age hunting culture and accompanied her parents, who followed the season of the salmon, the pulse of the caribou.

white chests glimmering in these endless Arctic days, streaming along the flanks of Datchanlee Mountain... (The lecture continued, recounting not only the Gwich'in way of life but provided a glimpse into the

life history of caribou. As well, the lecture recounted the annual subsistence cycle of the Gwich'in Indians of northeastern Alaska and northwest Canada.)



Figure 5. For 1 year, the Gildarts lived in this remote cabin in Venetie, Alaska, gathering information for their many stories and stock photographs of the Gwich'in Indians and their concerns about the Arctic Refuge.

STUDY CASES OF NATIVE PLANT PROJECTS FOR MAPUCHE COMMUNITIES IN THE SOUTHERN REGION OF CHILE

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Abstract

Two projects were done with indigenous communities in southern Chile. Both related to native plants propagation. One of them was done with a group of mapuche women that gather native “greens” for flower arrangements. There was a rustic greenhouse built and 60,000 plants were produce in order to make some restoration efforts and assure they will have enough native plants to continue with their business. The mapuche women were trained in plant production and establishment techniques. The other project was done with mapuche communities organized to produce medicinal plants, essential oils, and wild berries. Their interest was to learn to vegetatively propagate 7 native species. This project was undertaken by a whole group of students who decided to make it a classroom project. Seven propagation protocols were established, and simple written material was completed. In this paper, we analyze and share many social and technical aspects of working with indigenous communities.

Key Words

Community-based conservation programs, mapuche, native plant production, indigenous communities

INTRODUCTION

The largest mapuche rural communities are found in the surroundings of Temuco, IX Region and X Region, by the coastal range (37° 35' to 44° south latitude), totalling approximately 250,000. Their total population, however, is approximately a million according to the last census done in Chile in 1992 (INE 1992). From the whole IX region, forests constitute 40% of the area, where 27% are exotic plantations and 73% are native forests. For the X region, the forested areas represent 56% of the total surface, where 95% are native forests and only 5% are exotic plantations (INFOR 1997). In the early days, the mapuche lived in larger communities, which meant they had community crops, vegetable gardens, and forest lands. However, in 1979, a law was promulgated where the land was divided among the different families. In other words, they ended up having large families with a reduced amount of land. This was one of the main reasons for a tremendous destruction of our native forest, because lands needed to be cleared for agricultural practices. Forests were

considered a problem and were burnt and cut down (Catalan and Ramos 1999).

At the same time, in 1974, another law was promulgated that subsidized forestation with exotic species of rapid growth in areas which had always been classified as forest lands and now had clear signs of erosion and degradation. Private companies saw the great opportunity of using this subsidy to reforest large areas, and many times bought the land, at very low cost, from the mapuche. Some of these lands were not eroded, nor had degradation problems. In many cases, these lands had considerable amounts of native forest on them. These forests were classified as bushes in order to comply with the law that permitted the burning of the bushes to convert the land use “to something more productive” (Lara and others 1995). The biodiversity of these forest areas was considered quite high: 443 vascular species, and 44 tree species from 32 different genus and 20 families (Arroyo and others 1996). Currently, some of these species have conservation problems in these locations.

Besides the environmental effects caused by large exotic plantation areas, there was a considerable social impact that now, after almost 30 years, is surfacing. Many mapuche families sold their lands and moved into the cities, where they found no jobs; the cultural shock made it impossible for them to adapt to this new environment. Overall, their decision to sell their lands only made them even poorer (Lara and others 1995; Catalan and Ramos 1999). Their cultural beliefs state that their lands belong to their ancestors and, therefore, they would only find misery if they ever left their lands behind (Quidel 2000). This explains why some of the mapuche communities are asking for their lands back; they want a historical revindication of their rights and properties; they want to “straighten” their lives in the eyes of their ancestors. The forests have been used by the mapuche for centuries to get different products, such as construction wood, fire wood, fruits, roots, seeds, fungus, and medicinal plants. Also, for ritual purposes, they used many forest plants. Just lately, the mapuche have started to recollect fruits, fungus, and foliage to sell in small amounts in order to increase their income. Overall, the situation after 30 years is that the mapuche families had to welcome back the families who had sold their lands, therefore dividing their small properties into even smaller areas, from which it is very hard to make a living. They are surrounded by plantations, which they believe have had a desiccating effect on their streams. They also believe the pest control methods used in company plantations to control insects and mice have poisoned some of their animals.

The government has addressed this issue by creating a new governmental office (CONADI), which has limited funding, to buy some of the original mapuche territory from private owners, mainly forestry companies. This idea has had many problems along the way, and it is not the objective of this study to discuss them here. Overall, the government has had, for years, programs in which the objectives were to promote and generate capacities for small farmers and indigenous communities to become productive in a sustainable way. All of these programs have had a paternalist approach to the participation of the communities, which mainly created dependency from the mapuche people in government programs. Furthermore, these programs limited the creativity of the mapuche, and maintained internal poverty and hopelessness (Velázquez 2002). Currently, there is the willingness to incorporate community-base

methodologies and gender issues that could improve the long running impact of the government programs. But first, we need to understand participation as a process in which the main purpose is to strengthen the capacities and abilities of the local communities; to learn to come up with solutions to their problems with their own knowledge and resources, also known as empowerment (Schmink 1999; Velázquez 2002). There is a world-wide consensus on the need to find new ways of working with local communities to help them to manage their natural resources.

Schmink (1999) states that the scenario of local communities is that they are not only having to deal with government agencies, business interests, and NGOs, but also with significant differences in interest, perspectives, and powers within their own communities. This is very much the case of the mapuche communities in Chile. We also need to add one more factor: the loss of identity they have experienced through the years. Some of the overall effects of these many factors influencing the mapuche communities result in some very complex social issues, such as high levels of alcoholism and intra-family violence.

The mapuche are not conservationist by nature, but they understand how nature works and the natural laws that have to be respected in order to maintain their resources. The mapuche women have an immense knowledge and care for the land and plants. The important role of women in conservation projects, and its promising potential as a conservation agent, has not yet been recognised by the large majority.

This paper will present 2 projects done with indigenous communities in San Juan de la Costa (X region) and in Villarica (IX region). The objective of this presentation is to share our experience of the process of working with local communities, one of them with gender emphasis and the other emphasizing the work of students and mapuche people. Both will be presented as study cases.

STUDY CASE 1: SAN JUAN DE LA COSTA

This is a group of mapuche women, specifically Huilliche (people of the coast) who gathered to start a business together. They have legal status and their name is “Mujeres Follaje de San Juan”. There are 60 of them in total, and they all live relatively close to each other in a total area of 3000 ha. Two years ago, they started collecting and commercializing foliage from native trees, otherwise known as “greens”. The

foliage is used in flower arrangements. In a study done by INFOR (2002), the amount of US dollars received for exporting foliage in 2001 was approximately US\$ 312,000, a very significant amount for these communities. However, as we all expect, the amount received by them was considerably less. A project done by the group of women, the Universidad de la Frontera, and a NGO was proposed to the National Environment Committee (CONAMA), who agreed to finance it. A former student (Juanita) was already working in the NGO, and she was already acquainted with this group of women. Therefore, there was a lot done before we got there in building a trustful and good relationship with the women. While writing the proposal, we decided to go and visit them in order to hear directly from them what their problems were, instead of us guessing them. The main problems stated were: 1) lack of foliage nearby their homes; 2) some species were already showing signs of scarcity (they didn't seem to be regenerating in the forest anymore); and 3) family factors that limited their productive activities.

The main objective of the project was to contribute to the mapuche community forest conservation in San Juan de la Costa. This objective included growing 6 native plants they were interested in for 2 purposes: 1) to help restore some of the ecosystems from where they had been gathering foliage species; and 2) to establish these species near their houses. This would definitely have a positive impact in their family issues, such as lack of time, too many things to do, their husbands not liking them to be gone from the house, little children not been able to walk long distances, and so on. The project was financed for only 1 year and with a low budget. So we also decided to include the development of a thesis in order to do the forest baseline study of the area.

MATERIALS AND METHODS

This study was conducted in San Juan de la Costa (40°22' to 40°32' south latitude), 750 km south from Santiago. The CONAMA project consisted of 5 phases, some of them occurring simultaneously.

Phase I

The objectives of this phase were: 1) to determine what they saw as "the problem"; 2) what solutions they visualized in order to solve this problem; 3) how did they want us to help; and 4) finally, but most important of all, build a trustful and strong relationship with them. As mentioned before, we went to visit them at their homes for a couple of days. Sharing

meals with them and talking a variety of topics besides the conservation issue proved to be a very effective method in building trust.

Phase II

The objective of this stage was to build the greenhouse financed by the CONAMA. All the building was done by the mapuche women. The greenhouse size was 120 m², made with strong plastic, a very simple irrigation system, and wooden structure and benches.

Phase III

The objective of this stage was to characterize the forest ecosystems where the 6 species of interest were found. As part of a thesis, the final product will be the complete site characterization of the areas where these species are grown. This was accomplished by inventorying 300 plots in the 3000 ha. Ten of these plots were done permanently in order to monitor changes in frequency, regeneration, and different aspects of their natural dynamics. Part of the methodology used was to ask some of the women to help Juanita in taking the field data. This would allow them to experience their land with different eyes, and Juanita could learn from them to look at it with mapuche eyes. Details on the inventory methods are not given, because that is not the objective of this paper.

Phase IV

The objective of this stage was to train the women in plant propagation techniques, going through all stages of collecting, to stratification, to production, fertilization, irrigation and finally, to establishment. The methods used were all practical: "learning by doing". We spent 3 days working at their nursery and in the forest. Because of time constraints, some of the contents were given by oral presentations. The most important aspect was to convert all technical aspects into simple words, and let them give examples, so that we could evaluate if they were understanding what we were saying. We also continuously encouraged them to give suggestions on how they could apply what we were explaining, using their own resources.

Phase V

This phase consisted of creating written material for them to help them remember the native plant production course. These materials were done by the students of

the Facultad de Ciencias Agropecuarias y Forestales as part of a plant propagation course they needed to take at the University.

RESULTS AND DISCUSSION

We had 20 of the 60 mapuche women participating in the construction of the greenhouse and in the 3-day training course. The greenhouse was built in a community area which was determined by the women and which had extra space for some outdoor production. There were 60,000 plants produced the first year, mainly from 3 of the 6 species they were interested in (*Lomatia ferruginea*, *Gevuina avellana*, and *Pernetia mucronata*). For the other 3 species, it was decided to do some trials first, because the plants were ferns and therefore harder to produce. The majority of the plants produced (90%) were from seed, collected by the same group of mapuche women from their forests before the project started. The plants were produced in large wooden benches filled with a mix of peat and soil (3:4, v:v). Once they acquired a height of 2 to 4 inches (5 to 10 cm), they were transplanted to polybags (6 inch³ [100 cm³]) filled with the same soil mixture mentioned before. They were irrigated and fertilized manually and periodically. The plants were grown for 7 months.

The 3-day training course was a good opportunity to discuss their seed collecting procedures, what kind of problems they had faced, and ways of improving the seed collection. The course allowed them to practice seeding, transplanting, watering, and fertilization techniques. All of them were analyzed to see if they could be applied considering their resources. The discussion then turned to share other methods they had been using to do certain things in the past and the similarities with the methods being taught. As mentioned by Schmick (1999), adaptation of methodologies to the reality of the community, and to their own ways, really makes a difference in the capacity of the local people to adopt those techniques as theirs.

The last part of the training course covered topics such as conservation relevance, restoration, and plant establishment. Also, basic marketing techniques were discussed in order to find a more effective way of selling their products. Needless to say, it is important to consider many other factors, such as external market behavior and quality product issues. But the main consideration must be the differences between the indigenous world, how they do things, the world they need to sell their products to, and how they want things to be done. This is a limiting factor in most of

the projects done with local communities (Schmink 1999; Velázquez 2002). It seems that one good solution could be found in the niche of organic products where the clients appreciate the uniqueness of their products. The other result is the thesis being done by a student of the University, which will give them the site characterization of their forest resources and an estimate of the amount of greens they have left on their property by the end of the year. This study is crucial in order to plan and design strategies for future restoration projects in that area; it will give us the base line studies in order to prioritise which sections need to be worked in first. Finally, a simply written/illustrated manual was done for the mapuche women to help them to remember the training course.

STUDY CASE 2: VILLARICA

This is an extension course done for a group of 20 indigenous farmers from one mapuche community, and a group of young natives called Grupo Lawenko. They came to ask for some help from the University; specifically they wanted to learn about vegetative propagation of some native plants they were using for medicinal purposes, including essential oils and wild fruits. Their need was taken as a challenge for the students of the nursery and reforestation course given by the University, and it lasted 3 months. The objective was to train indigenous farmers in the production of 7 native plants by vegetative propagation, encouraging the exchange of knowledge between them and the students and, finally, recommending some improvements in their production processes.

MATERIALS AND METHODS

The course was designed in 7 phases, some of which were done by the students, some by the natives, and some by the researchers. The students were organized in 8 different groups, each was responsible for propagating one of the species. Phase I included a visit to the communities in order to know their needs in depth, define the objectives, methods, and their expectations. As stated in the previous study case, it is very important in this first visit to create a strong confidence relationship between the communities, the students, and us. Phase II was done by the students, gathering all the information available on the plant production of the 7 species (*Drimys winteri*, *Peumus boldus*, *Luma apiculata*, *Laurelia sempervirens*, *Ribes magellanicum*, *Ugni molinae*, *Berberis darwinii*) the mapuche had identified as important for them. The third phase consisted of the selection of the propagation methods

to be used. The students had to propose a method to produce plants inside the greenhouse (in a controlled environment) and in a rustic greenhouse made by them with recycled materials. Phase IV included a visit from the mapuche groups to the university, where the students presented their experiments and discussed their methods and materials with the mapuche people. This was done in a way of validating their methods and motivating them to give opinions and criticize their work. The fifth phase consisted of a visit to the community, specifically to 3 greenhouses, in order to see how they were propagating the plants and what problems they were having. Phase VI included the creation of self-instruction written material for the mapuche people, stating the different potential uses, site conditions for growth, and recommendations for the species. The final phase consisted of the evaluation of the experience by students and by the mapuche groups. The evaluation was done by interviewing, in depth, at least one of the students per group and a third of the mapuche people involved in the project.

RESULTS AND DISCUSSION

One of the results was the high motivation shown by the mapuche and students. This motivation was reflected in the efforts the mapuche made in establishing their own experiments as they had seen them at the university, but also including their own modifications. The students' motivation was shown in the efforts they made in building recycled rustic greenhouses, in their attitude towards the mapuche people every time they saw them, and finally, 3 students decided to take this experience and present it at the Latin-American Forestry Students Meeting in Costa Rica in October 2002.

Protocols were determined for producing 7 native species using cuttings in rustic greenhouses. All these protocols were put in a self-instruction written material, the main purpose of which was to remind the mapuche people, in a simple and graphic way, of propagation methods. The perception of the mapuche people was that they really wanted something on paper, hopefully many pictures and very little wording. We realized that only the things that we had explained to them in person made sense when they looked at the manuals. In many cases, we even realized that some did not have the ability to read. From the students' point of view, the results were a higher commitment and understanding of the mapuche culture and a higher interest in continuing this type of work. The mapuche people also expressed their

interest in having students and the university working closer with them as a means of feeling more supported in their activities.

Some of the studies done with indigenous communities state the importance of having the local people doing trials in their own lands and experimenting with different things, even if they are very simple (Velázquez 2002). This would provide them with the feeling of "owning" the results and, therefore, empowering the methods used by them. It would also be a way of assuring the internalization of the new knowledge. Most of the time, the knowledge is not even that new; it would be better to define it as "giving significance" to some of the customs they already had from generation to generation. We feel that this group is ready now for the next step, where they can identify and analyze their production problems and propose solutions for them: the real form of empowerment. The role of facilitators or researchers would only be that of technical support for them, and this would hopefully help end their dependency on eternal help. From the point of view of the educational process of the students, we as professors believe we made a contribution to making professionals-to-be who will be much more sensitive and tolerant of ethnic differences. They understood the 2 basic principals: honest respect and the art of listening.

SUMMARY

We would like to emphasize how important it is, when working with indigenous people, to have a group that is associated in a legal or formal way; they can easily organize better and have a better capacity to negotiate. The role of indigenous women in conservation is more recognized everyday, but we also think that concrete changes that favor these women need to be taken in order to move from "talk to action"; just recognition doesn't help them to increase their quality of life. Honest respect and listening seem to be the 2 most important strategies to work with indigenous groups. Socializing, building trust and confidence as a first phase, is a must in order to have any success in working with them. Understanding that, by bringing the ancestors knowledge, their own knowledge could be the only way for them to adopt new methods. Then we are not only helping them to maintain their culture, but hopefully with their own resources, improve their lives.

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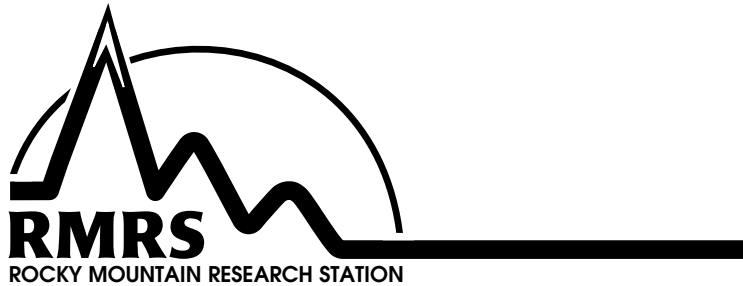
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