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Proceedings of the Southern Containerized Forest Tree Seedling Conference

August 25-27, 1981
Savannah, Georgia

Edited by Richard W. Guilin and James P. Barnett

Proceedings

of the

SOUTHERN CONTAINERIZED FOREST TREE SEEDLING CONFERENCE

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Richard W. Guldin and James P. Barnett

Savannah, Georgia

August 25-27, 1981

Sponsored by:

Southern Forest Experiment Station

Southeastern Forest Experiment Station

Southeastern Area State and Private Forestry

Silvicultural Working Group,
Society of American Foresters

Georgia Cooperative Extension Service

Georgia Pacific Corporation

PREFACE

Research findings provide benefits to society when they are communicated to and implemented by users. This principle was the rationale for the Southern Containerized Forest Tree Seedling Conference. In the 8 years since the North American Containerized Forest Tree Seedling Symposium in August 1974, southern foresters have developed container seedling nurseries and begun large-scale planting programs. By their experience and research, the state-of-the-art has been rapidly advanced. It was time to redefine the state-of-the-art for the 1980s.

The conference objective was to describe and discuss the state-of-the-art of growing and planting containerized tree seedlings for reforestation in the South. The program developed alternative approaches and examined the potential for expanding the use of this regeneration method.

Many individuals and organizations deserve credit for the success of the conference. Each of our speakers did a fine job of covering his assigned topic. We are especially grateful for the presentations of those nurserymen who shared their trials in developing large-scale nurseries and field planting programs, so their successors need not repeat their errors. They have added more to the font of knowledge than they realize and serve as witnesses that planting containerized seedlings is a viable reforestation method. The moderators proved adept at keeping the sessions on schedule, providing insights of their own, and leading the informative discussion periods. The speakers are responsible for the content of their papers and submitted them in camera-ready form.

In addition to our speakers, 4 individuals merit special mention for their contributions to conference planning and arrangements:

John C. Brissette, Southeastern Area State and Private Forestry,
U.S. Forest Service, Jackson, Mississippi

William E. Balmer (Ret.), Southeastern Area State and Private Forestry,
U.S. Forest Service, Atlanta, Georgia

David C. Borem, Georgia-Pacific Corporation, Savannah, Georgia

H. Lamar Merck, Georgia Cooperative Extension Service,
Statesboro, Georgia.

Finally, we acknowledge the support of the Silvicultural Working Group of the Society of American Foresters and the exhibitors. The SAF Continuing Forestry Education and Professional Development Program awarded 16.5 hours of Category 1 credit to each conference attendee.

The South's Third Forest report, published by the Southern Forest Resource Analysis Committee in 1969, stated that developing "year-long planting and seeding schedules for principal forest species" was one of the most important forest research needs to assure adequate future wood supplies. We feel that the authors have made a large contribution toward meeting that need. Through this volume, we transfer a new regeneration technology to you, the reader, hoping that society will be the ultimate beneficiary.

Richard W. Guldin and James P. Barnett
Program Cochairmen

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WELCOME[1/]

Robert D. Raisch[2/]

Good morning! On behalf of the U. S. Forest Service, welcome to the Southern Containerized Forest Tree Seedling Conference. We're pleased to see the diversity of background and interests represented here today! While most of you are from private industry and public agencies here in the South, we do have visitors from the West, Canada and even as far away as Sweden. This conference offers a tremendous opportunity to exchange information; informally as well as in the formal sessions. I hope you'll take full advantage of this time together.

The objectives of this conference are: to describe and discuss the state-of-the-art in producing and planting containerized tree seedlings; to develop alternative approaches; and to examine the potential use of this regeneration method for reforestation in the South! We have an exciting program and well qualified speakers to address the subject matter. However, your participation in sharing information and ideas are essential to insure the maximum benefit from this conference. These three days and the results of the meeting will be what you make it!

Now to join me in this welcome, it is my privilege to introduce a gentleman from our host state! Under his leadership, as State Forester, the Georgia Forestry Commission started one of the first State Tree Improvement Programs and established one of the first seed orchards in the South.

Georgia has consistently been among the top three states in the country in terms of the number of seedlings produced, the number of acres planted, and the number of genetically improved seedlings produced. It is fitting, then, that we meet here in Georgia!

It is a real personal pleasure to introduce my good friend - State Forester Ray Shirley.

1/ Presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Area Director, State and Private Forestry, U. S. Forest Service, Atlanta, Georgia 30367.

REFORESTATION: KEY TO SOUTHERN FOREST PRODUCTIVITY[1/]

John C. Barber[2/]

Ladies and Gentlemen: Greetings! And another welcome to this conference! I am delighted to be here as your keynote speaker and equally delighted that the Society of American Foresters is one of the sponsors of this conference. Such sponsorship and support is one of the many ways that professional societies can help spread new knowledge quickly and get new technology on the ground promptly. Production and use of containerized seedlings is one of the booming frontiers of forest science and technology. We have moved past the pilot test phase and into large-scale operations. But the technology is still relatively new. Some of it is still uncertain in its results, because there has not been time to fully test, debug, and refine all the processes.

To help put containerization in its proper perspective, let's look back at conventional nurseries. Even after many decades of outdoor nursery management, we still see problems. Ask any nurseryman; you can turn your back for a day and return to find that something has arisen to affect both quantity and quality of the stock. Some of us were around when nurseries were trying to gear up for the Soil Bank. The strain and pain of providing 100 million seedlings for Georgia landowners in one year will be long remembered by those involved. That demand, though, provided a much needed stimulus to seed and nursery research. The modern seed testing and research laboratory that serves you well today at Macon was a direct result of those nursery needs.

And where was containerized planting stock then? As a practical means of establishing forest stands it did not exist. Twenty-five years ago when foresters of the Georgia Foresty Commission were establishing seed orchards, they were grafting on containerized stock. The container was a metal or tarpaper pot that bare-rooted seedlings were planted in to produce grafting stock. It was several years later before many people began to look at the idea of producing seedlings in small containers for plantation establishment on a routine basis.

Soil Bank reforestation was relatively easy. The plantations went on abandoned cropland, just where most of the artificial regeneration and much of the natural pine regeneration in the South had taken place for several decades. But when that former crop and pasture land had been planted, reforestation in the South took on a new identity--an identity of expensive stand conversion from usually worthless brush and hardwood to pine. At best, some form of site preparation after harvest was needed to insure success for a new stand. For all practical purposes, the South no longer has abandoned agricultural land that is available for conversion to forest stands. And though we may prepare forest sites very intensively, the planting and growing conditions are different, and the challenge is more complex.

Soil Bank plantations and subsequently established stands are an important part of southern forest productivity, but you have all heard the predictions of supply and demand for forest products, and how the South will be expected to supply increasing quantities of timber to meet national and world needs. It takes only a quick glance at the figures to see why the nation will be turning to the South. Of the roughly 347 million acres of privately owned commercial timberland in the United States, about 170 million is in the South. That consists of slightly less than one-half of the nation's farm and miscellaneous private ownerships and slightly over one-half of the industrial forest land. The public lands in the South are of substantially less regional importance, though they may be quite significant locally.

It is generally agreed that we cannot expect any substantial increases of timber production from public lands in the next several decades, and even on the industrial lands of the South another decade will pass before the substantial investments in site preparation and tree improvement will begin to pay off with wood from high-yielding plantations. Thus as demand for wood and fiber rises we can expect additional pressures to fall on the nonindustrial private lands for harvests to meet those demands.

Another facet of the supply problem will be the decreasing acreage in timber production across the South. Two factors are of great significance. First is the pressure for conversion of forest land to agricultural uses. World food needs will continue to rise and will stimulate U.S. production with the consequent demand for increased acreages in crops. Second, the recent National Agricultural Lands Study makes clear that the South will continue to lose substantial acreages of prime agricultural and forest land to urban development, transportation corridors, and other uses. Shifts of America's population to the sun belt and residential shifts from urban areas to small towns will have their impact. "People" sprawl will usurp and fragment formerly operable agricultural and forest ownerships and will diminish the availability of timber for harvest.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Executive Vice President, Society of American Foresters.

The National Agricultural Lands Study also identifies the South as the region where there are 20.6 million acres of forest land and 26.6 million of pasture land with medium to high potential for conversion to crops. You can be assured that when some of those millions of acres of pasture are converted to crops they will be replaced from our forest land base. The competition for southern land will be food and textile fiber versus lumber and paper. You must also keep in mind that those conversions to crop and pasture will be the most productive forest sites.

So the result of all of this will be that our increased timber supply must come from a reduced land base. In short, we must increase output per acre to offset the loss of forest land to other uses and to meet increasing needs.

There is no question that the opportunity to increase forest productivity lies with the non-industrial private forest owner. He--or she--must first place existing stands under good management, and second, regenerate harvested areas to assure the establishment of productive stands of desired species. The major deterrent seems to be the unwillingness of landowners to make long-term investments. This reluctance means that we are not only failing to manage the stands we already have but, more importantly, are failing to regenerate after harvests.

South Georgia is an example of what's happening all over the South. Steve Boyce and Herb Knight of the Southeastern Station looked at the 1962 and 1972 Forest Survey plots here in south Georgia to see what happened after pine stands were harvested. This was an area with some of the highest stumpage prices in the South. The financial incentive should have existed, but it didn't get landowners interested in timber growing. What Boyce and Knight reported was that of the pine stands harvested only 11% were replanted, and 21% were naturally regenerated, but 68% had reverted to hardwoods. And in later surveys a similar lack of response has been found in Virginia, South Carolina, Florida, Mississippi--more or less all over the South. This information points up an observation that has been made a number of times, that is, high stumpage prices are an incentive for the owner to sell timber but they have little effect on investments in regeneration and management. Recent income tax provisions such as the investment tax credit, changes in capital gain rates, and estate tax revisions are all to the good. But with the high cost of money, the biggest help to be added to all of those will be guaranteed results at reduced costs.

That brings us to containerized seedlings as one of the answers to the problem. There is no panacea for the regeneration of forest stands; there is no simple prescription. Each case must be taken on an individual basis; the regeneration system and the subsequent silviculture must be geared to the site and its productive potential, and of course to the landowner's objectives. Any regeneration system must make both biological and economic sense. It must be efficient not only in terms of cost, but in terms of establishment time. The need for effective reforestation with desired species in the South, primarily softwoods, has been clearly stated. Many of the needed biological methods and systems are known, but the financial resources to do the job have not been identified.

On the biological side, our prescription must look at site conditions in detail so that we can tailor the production of nursery stock, the planting method and the schedule of planting to meet owner objectives, and assure the establishment of a healthy and vigorous stand. There has to be quality control throughout the process from the collection of seed until the planted seedling is free to grow. Successful plantations and improved performance hinge on quality control.

Fulfilling the biological needs of regeneration systems offers many opportunities for us to take advantage of the potential of containerized planting stock. The overall opportunity is that of matching the silviculture with the owner's objectives. We have the opportunity to choose the best species and source to meet management objectives and to give the highest yields with minimal risks. We have the opportunity to plant genetically improved stock that can utilize the full productivity of the site. With quality control to insure survival, we can guarantee stocking at the spacing that will favor optimum growth and financial returns. These are opportunities in the broad sense.

Still other opportunities may exist with containerized seedlings. We hear a great deal about the economies of scale, but let's face it, we will be having an increasing number of small operations because of ownership fragmentation and the unwillingness of owners to harvest more than a small area at a time. Containerized stock may improve the economics of small-scale operation because it usually lessens the investment necessary for site preparation and planting.

Production and use of containerized stock also gives us flexibility to respond to major changes in planting programs. For example, after a major spring fire it would be too late to schedule an extra million of bare-root stock, but there might be time enough to add the million for late-season production in a containerized operation. There is also the capability to extend regular planting seasons, and in some special cases to plant during the growing season.

Probably some of the greatest opportunities will be on the difficult sites, those which are potentially productive but have special regeneration problems such as droughty surface soils, exposed areas, muck soils, competing vegetation, and damage from fire, logging, and surface mining.

I look forward to the time when we will have a fully mechanized planting operation where blocks of containerized stock will be fed into a machine that automatically inserts them into the soil. And does so while traveling over rough sites cluttered with logging slash and other obstructions that prevent the use of any sort of furrow-type machines.

Seven years ago tomorrow a North American Containerized Forest Tree Seedling Symposium convened in Denver, Colorado. It was sponsored by the Forestry Committee of the Great Plains Agricultural Council and many others, including the USDA Forest Service, the Canadian Forestry Service, and the Society of American Foresters. It was an international conference to summarize the state of the art. Some of the forest scientists who contributed to that symposium are here. Again, they will be presenting their research results and experiences. It will be interesting to learn the progress that's been made in seven years. I know that as they have reflected on their 1974 papers and the ensuing discussion in preparation for this conference, they have become acutely aware of the progress made and perhaps even more aware of the problems that still confront us.

Tomorrow we'll see containerized seedling production in operation. We'll see how the process is working and how successful it is thought to be. You will judge for yourselves where the South stands in the ability to grow containerized seedlings and to establish them on forest sites. Those of you from outside southeast Georgia will wonder how things compare with progress back home and whether new ideas on reforestation will work.

I can assure you that when this conference closes Thursday evening, you will at least have been exposed to the state of the art and the avenues of research and opportunity that lie ahead. When you go home, don't put that new knowledge and those ideas on the bookshelves of your mind. Don't wait for the Proceedings even though they'll be available in a few months. Do think how you as a professional forest manager, or research scientist, or nursery manager can take what you learn here and use it to hasten the regeneration of southern forests. Do look at these three days of ideas and information exchange as ways of helping meet future demands of our American society.

Reforestation is the key to southern forest productivity. Our most valued softwood species, and even some desired hardwoods, cannot compete with the lesser valued hardwoods and brush to establish themselves in highly productive stands. We must learn how to follow each timber harvest with adequate regeneration of desired species at proper stocking to assure the future timber supply for this nation. Containerized seedling production and planting systems will be one of the critical elements of our future forest productivity in the South.

A HISTORICAL OVERVIEW OF THE USE OF CONTAINERIZED SEEDLINGS FOR OPERATIONAL REFORESTATION. - HOW DID WE GET WHERE WE ARE TODAY?[1/]

Philip F. Hahn[2/]

Abstract. --A historical review discusses the various container types, their development, their use, and some of their advantages and disadvantages. A brief description is also given on the reasons for containerization and on how we got in this field and to where we are today.

INTRODUCTION

It was about twenty years ago when I first heard about the potential for the commerical use of containerized seedlings in the area of reforestation. The speaker at an Artificial Regneration Short Course spoke very enthusiastically about the past performance of experimentally tested seedlings, and strongly advocated the large scale use of such seedlings. However, at that time even the optimists of containerization couldn't visualize handling millions of seedlings in a nursery and in the field, from an economic and logistic point of view.

Nevertheless, even though it was hard for the optimists to see the application of containerization in a practical sense, they held onto the dream and didn't give up. Their drive for containerization was aided by the increased demand for reforestation during the 1950's and 60's. Most European countries and parts of the United States had a good number of well-developed bareroot nurseries. But areas like the Pacific Northwest and most of Canada were poorly equipped with such facilities. Consequently, the need for an increased amount of seedlings could not be met by the available bareroot nurseries.

In order to fill the immediate needs demanded for artificial reforestation in some areas at that time, the method of aerial seeding was introduced and used on a large scale basis. Helicopters equipped with seed disseminating devices were able to manuever themselves quite rapidly even over the roughest terrain while doing a reasonably good job in distributing the seed on the cutover areas.

Aerial seeding met an immediate need and is still very useful in some areas. However, it is not able to keep up with the new demands of reforestation in a modern forest management program. To further elaborate on this, a drastic change in land management brought on mostly by the increasing timber values during the late sixties induced a need for better reforestation. Besides the value increases in timber, the demand for more timber also increased. A faster timber growth required genetically improved seed for seedlings, well-prepared sites for planting, good seedling distribution on the land, and an intensive plantation maintenance program.

In order to achieve the above factors, an artificial reforestation program was needed. This program required a lot of seedlings. Such seedlings had to be produced rapidly and planted in the field using a system that was as mechanized as possible. Because of these factors, the idea of containerization surfaced more and more.

Experiments with containers continued while aerial seeding was still being practiced. These experiments began to show some advantages over bareroot seedlings in spite of the fact that the seedlings were raised in primitive facilities and often in crude homemade containers. These seedlings often showed good growth rates, high survival rates, and an excellent potential for mechanization.

The early developments made in containerization were centered mostly around the development of various types of containers. These containers came in all shapes and sizes and were made out of a wide range of materials. Some of these containers

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were outfitted with handling equipment. Such equipment ranged from the very simple homemade to the fully automated factory produced machines. During the early stages of containerization, mechanization seemed to be a more important concern than the biological factors needed for good seedling production. In spite of this, containerization did show a great deal of promise and it was soon obvious that containerized seedlings had some application for reforestation.

The early developments that were made did not solve all the problems relating to containerization. As a matter of fact, even today we are still in the stage of sorting out the good features from all the various systems, while trying to apply these properly in the right places.

In certain areas the need for immediate and large scale seedling production triggered rapid container developments. As an example, containerized seedling production grew from less than a million seedlings to a 56 million annual seedling production rate in Oregon and Washington alone during the last decade. Similar rapid developments occurred with an earlier start in Canada and in the Scandinavian countries. Both the Canadians and Scandinavians were pioneers in large scale container developments.

THE SCANDINAVIAN PROGRAM

A major boost to early containerization was the adoption of inexpensive plastic covered greenhouses which were developed in Finland. Such facilities were used in bareroot seedling production in Finland because of their cold Nordic climate and short growing season. These and similar growing facilities later proved to be quite valuable in containerized seedling production. The Scandinavians had the desire to extend their planting season into the summer. Container grown seedlings, with their protected and undisturbed root system, proved to be more suitable for this than bareroot seedlings. There was also a need for mechanization in the Scandinavian countries and elsewhere because of high labor costs and labor shortages. This pushed the containerized seedling production in these countries to 225 million per year by 1974. This pace increased later only moderately because commercial seedling production got considerably ahead of research and development. The paper-pots became the dominant type of containers in the Scandinavian countries when containerization began on a large scale. Later it was used in other European countries and around the world.

This honeycomb shaped and accordian style container was a Japanese invention. The users of this container liked its biodegradable nature and its protection of the root system. The Japanese not only invented a container, they also invented a completely mechanized handling system. This handling system is perhaps the main reason why the use of this container gained popularity and spread so rapidly.

The facilities used for paper-pot seedling production in the Scandinavian countries were generally simple plastic greenhouse structures equipped only with the most necessary environmental control units. The trays were often placed on the ground during the nursery growing stage which caused the containers to disintegrate prematurally if they were kept too long in the nursery.

The multipot (Kopparfors) containers in Sweden helped in overcoming the premature disintegration problem but this unfortunately in turn developed new problems which is often the case in containerization.

CONTAINERIZATION IN CANADA

Canada's need for containerized seedlings materialized relatively earlier than in the United States or in other countries. The reason for this is that Canada's bareroot nursery development was further behind their seedling demand, and the Canadian's did not get involved with aerial seeding either.

The Canadian's labor shortage in the faraway forest areas was traditionally high. Therefore, containerization in Canada seemed to be the natural thing to do, just like it was for the Scandinavian countries. The systems developed in Canada include the following:

Bullet Planting

One of the most outstanding pioneers in Canadian containerization was Dr. John Walter, Director of the University of British Columbia Research Forest. His work dates back to the early fifties.

Dr. Walter invented and developed the bullet method of planting. This bullet planting system was highly mechanized and was fast and efficient. The ease and speed of tree planting was a reforestation dream. It offered a good solution to the labor shortage and high labor costs in reforesting distant cutover areas. For this reason, some companies adopted the system in British Columbia during the late sixties.

Sadly to say, the field results didn't prove to be as good as the system appeared to look. Frost heaving was quite a common occurrence because of the slick and hard container surface. The rigid container restricted the roots in their growth and penetration into the forest soil. This resulted in a poor survival and growth rate.

Newer biodegradable containers are aimed to solve some of the problems in the bullet method, while still keeping its good feature of injection planting. As the initial enthusiasm for the bullet method wore off, the entire system practically faded away. However, the bullet planting system did present a lot of good ideas for the later development of other systems.

The Ontario Tube

While the bullet planting system was gaining some attention on the West Coast, something different was occurring in Eastern Canada. A tube type container was developed in the province of Ontario. The first large scale use of this spiral plastic tube was implemented in 1965.

This planting system was not mechanized like the paper pot or bullet, but some of the homemade type machines used made the system quite efficient. The tubes provided protection for the root plugs during, and shortly after planting which was important on the droughty sites where most of the seedlings were planted. This system gained acceptance in other provinces as well. Some of the disadvantages of the containers, such as root growth restriction, frost heaving, etc., turned people towards a new development in the field of containerization.

Styroblocks

The styroblock was an outgrowth of the bullet system. When the plugs were removed from the bullet container for planting, they performed a lot better in the field. This led James Kinghorn, who is with Pacific Forest Research Centre in Victoria, to the development of the styroblock container. The container and related system did not evolve overnight and, of course, did not solve all the problems relating to containerization either. Nevertheless, it was a new approach that had a lot of promise.

The styroblock, or molded polystyrene container provided good biological conditions for the seedlings during the rearing period. This resulted in an increased amount of improved seedlings compared to previous seedling crops. The better developed seedlings, when planted as naked plugs, survived well and also grew well in the field.

The mechanization process of this system came a little later. After a while, a whole range of nursery handling equipment was developed and built. With the quarterblock handling equipment, the field shipment of containers, and the process of planting directly out of the container became quite efficient. This improvement made the container recyclable from the field also.

Because of the ability of growing hardy seedlings with well-developed root plugs in styroblock containers, it is also possible to extract the plugs at the nursery without jeopordizing the seedling quality. This makes seedling shipment less costly. Extracted seedlings are also more suitable for cold storage if delayed planting is desired.

The styroblocks gained widespread acceptance in the Pacific Northwest and Canada as well as in the whole United States. They are used in other areas also.

The Spencer Lemaire Book Planters

The book planter or ROOTRAINERS as Henry Spencer likes to call his containers were developed in Alberta during the early seventies.

The containers are molded out of thin plastic sheets, while several containers are hooked together in a book form. The cavities are rectangular and slightly tapered with grooves in them for root guidance. (Other containers have root guidance abilities also)

One of the interesting features of the ROOTRAINER is that it provides a root plug inspection without removing the plug. Some other features of the ROOTRAINER include small unit handling, easy packaging, shipping, and planting.

The ROOTRAINER is a thin-walled container without any insulating capacity. Good insulation is often important to produce good hardy seedlings while the roots are protected from extreme weather conditions.

A large number of these containers are used in North America, but most of the use is in the Alberta area.

UNITED STATES DEVELOPMENTS

The first notable developements in containerization in the Pacific Northwest was the development of the Leach Cell System. During the early seventies plug seedling quality and their root system were at a rather low point. It was difficult to keep naked plugs from breaking apart. Taking styroblocks to the field at that time was cumbersome. This prompted Ray Leach to develop a container that would handle a plug in the field, while the seedlings are carried in a planter's bag, without destroying the root plugs. The idea appeared to be a rather good one in the eyes of those old time tree planters who disliked any deviation from the old planting form.

The Leach cells are injection molded out of plastic as a thin-walled container. The cells are fitted in plastic trays where they are secured firmly, but can be removed at anytime. These containers were designed to provide the ability for rearranging the cells in the frame to maximize greenhouse space usage. They are also suitable for extracting and packaging plantable seedlings while the roots are still protected by the plastic cells. These plastic cells have the capacity to be recycled for another use also.

The Leach container system gained widespread acceptance when the Weyerhaeuser Company adapted them into their containerized system in 1973. Besides Weyerhaeuser, the major users of this container are mostly located in the Pacific Northwest.

The initial excitement and acceptance of the container somewhat diminished when cost considerations were closely examined. The initial cost for the container is high, and applying some of the advantages like rearranging cells in the frame to avoid blanks, the extraction of cells for packaging, storing and field planting, and the recycling of the cells for another use all turned out to be labor intensive and costly.

The thin-walled containers didn't provide the good biological aspect for growing and protection. The aspect of freezer storing of the cells turned out to be less desirable than storing naked plugs. Naked plugs have room for expansion. Carrying seedlings in the field while still in the cells made planting slower and more difficult. So, the once highly promoted Leach cells were slowly being replaced by better and less expensive containers.

Besides the major container types just mentioned, there were also other containers developed in Canada and in the United States as well as in the rest of the world. Some of these containers include the hard plastic multipot types, plastic bags, sausage casing types, etc. The list is rather long, and I am sure I couldn't even name them all.

THE MAIN REASONS FOR CONTAINERIZATION

Some of the reasons were mentioned earlier. Besides those, the other important factors or features which were responsible for containerization can be listed as follows:

Growing Facility Features

These were at one time, and are still very important features because:

1. The growing facilities are not tied to specific ground conditions with specific soil qualities for seedling production.
2. A relatively small area is all it takes to build a facility because of its intensive usage.
3. The seedling production is not so dependent on the weather because of the environmental control systems in the growing area.
4. A relatively small facility that has a production capacity of several hundred thousand seedlings and up may be cost effective.
5. The facilities can be located close to the areas where the produced seedlings are used.
6. The overall cost to build a container facility is quite reasonable, in spite of the relatively expensive greenhouse type growing areas.
7. The operation doesn't require large, expensive support buildings for sorting, packaging, and storing seedlings.
8. There is no need for a large assortment of cultivating and lifting equipment.
9. It takes a less expensive watering system and a lesser amount of water than it takes in a similar capacity bareroot nursery.

The factors listed for the growing facility considerations were and are important, but there are many more factors which favor containerization and need to be examined before one embarks on containerization. These factors include:

System Mechanization Features

Components of these are:

1. Environmental controls which include heating, cooling, ventilation, and air enrichment.
2. Light, and photoperiod regulation.
3. Close nutrient supply control.
4. Easy disease and insect control.
5. Good spacing regulation through cavity sizes.
6. Mechanized sowing lines.
7. Good utilization of the facility through thinning.
8. The ability of height, diameter, and root development control through a close monitoring system.
9. Mechanized packaging, shipping, and field handling.

Other features which also favor containerization are:

Uniform Growth Rates

There are few culls in containers because each seedling has nearly the same amount of soil and growing space while generally receiving equal amounts of water and food.

Fast Crop Rotation

It often takes weeks to months in order to produce a crop in containers. This, of course, depends on the species, growing regimes, and the geographical areas.

Seed Utilization

Fewer seeds are needed when producing a crop. The reason for this is because of good sowing and growing controls.

Extended Planting Season

Containerized seedlings are suitable for planting nearly all year-round. However, field moisture conditions must be suitable to support seedling growth.

Field Performance

Experience shows that well produced seedlings have a high survival and growth rate in the field.

Containers for Transplants

Containerized seedlings have proved themselves to be of superior transplant stock when grown for an additional year in a bareroot nursery which produces large seedlings for special sites.

Field Planting

Most containerized systems produce seedlings that are easy to ship and plant manually in the field, or by using mechanized planting equipment.

Cost Comparison

Not all containerized seedlings are cost effective. This is due to the systems and methods used in producing and handling the seedlings. However, containerized seedlings properly produced in well chosen systems are comparable in cost to bareroot seedlings. These seedlings often are less expensive, especially when their total performance is compared which includes growing and planting, and also survival and growth rates.

During the past two decades containerized seedlings have shown many advantages but they also have their disadvantages. Nobody should have the notion that containerized seedlings solve all the problems relating to reforestation.

To expand on this notion:

1. The relatively small containerized seedlings grown in one season or less have a smaller chance in combating heavy animal browse or severe brush competition when compared to the chance that the larger bareroot stock has.
2. Certain species shouldn't be raised in containers because they develop into better seedlings in bareroot nurseries.
3. Most containerized seedlings are bulky when shipped in containers. Shipping seedlings in containers to long distance planting sites (500-1000 km) may not be feasible.
4. Some container types are also difficult to handle when carried into the field.

Some of the advantages and disadvantages listed for containerized seedlings are not necessarily true for all of the different containerized systems.

Since there are many different containerized systems, they can not all be compared to each other straight across the board. Certain systems fit better in one area or condition than other systems. When I talk about a container system I mean more than just the container itself. My feeling or opinion is that the system includes the containers, growing facilities, handling equipment, growing regimes and growing schedules, storage of seedlings, field shipping, and planting methods.

Container systems must be chosen or designed carefully so that all of its components meet a given need while the system is biologically sound and economically feasible. There are some good systems which have been developed and have the ability to be adopted with some modification in most areas. This unfortunately wasn't true when large scale containerization started about 10-15 years ago.

One such total system is the quarterblock growing and planting system which is coupled with the shelterhouse growing facility and mechanized handling equipment. This approach looked at the total package in containerization while closely examining the local environmental conditions, crop scheduling, field conditions, and also biological and economical constraints. Experience proved this system to be quite successful, versatile, and easy to adopt in most areas with some modification. This system strongly considers a highly technical rearing practice, also.

Rearing Practices

Containerization brought a lot of technology to the field of reforestation. It also revolutionized the bareroot nursery system. Closely contolled, scientific rearing practices have taught us a lot about the seedlings need for nutrients, environment, and protection. This technology became useful for all seedling production.

Growing seedlings in containers, despite all the controls the operator has, is not easy to do.

The seedlings need a lot closer attention than they do in a bareroot nursery. A conscientious and good operator has the ability to turn the facility and technology to his favor and is able to produce excellent crops.

Poor planning in the systems development and subpar technical knowledge in growing made containerization a controversial subject. Experience has proven that the previously mentioned advantages for containerization are here. Since this field is new and is still developing, a lot of advantages are not being fully utilized yet.

CONCLUSION

In my opinion the containers are here to stay. Some major systems may fade away as they have already done so in the past and the good systems will go through more refinement. There is no doubt that along the way some more refined and newer systems will emerge.

I don't think the containers will take the place of all bareroot seedlings. However, they have replaced bareroot seedlings completely or partially in a lot of places.

Some species like true firs, hemlock, redwood, etc., are a lot easier to grow in containers than they are in bareroot nurseries. Small plugs of most species when transplanted in a bareroot nursery produce a less expensive and more outstanding transplant than straight bareroot seedlings do.

Plugs have a hard time competing with 1+0 bareroots when only the growing cost factors are considered. If the total costs including field handling and performance are taken into account, well raised plugs will stand the test here, also.

GETTING STARTED[1/]

Robert D. Raisch[2/]

John Barber, in his keynote address, eloquently highlighted the timeliness and the urgency of this conference. If we are to meet the southern reforestation challenge many obstacles have to be surmounted. The entire forestry community will need to use all of the methodology and technology at our command. One of the major challenges facing us in the South is to supply sufficient numbers of quality seedlings to meet current and future needs.

The forest industry has; and continues to enlarge its nursery capacity. The states are also attempting to expand and modernize state nurseries, but funding for the most part has been limited. Currently, many of these nurseries are producing beyond their sustainable capacities; at the cost of seedling quality. With all of our present nurseries, state and industry, producing to capacity southwide, we will still fall short of projected seedling needs.

Container-grown seedlings present opportunities to supplement bareroot seedling stock and meet special requirements. These are the issues and the opportunities we will examine now. Our first technical session will focus on container selection, seed quality and seed germination.

1/ Presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Area Director, State and Private Forestry, U. S. Forest Service, Atlanta, Georgia 30367.

SELECTING CONTAINERS FOR SOUTHERN PINE SEEDLING PRODUCTION[1/]

James P. Barnett[2/]

Abstract.--Greenhouse and field performance data for southern pines are evaluated for a number of containers in each of three general types: tubes, plugs, and blocks. The effects of various containers on root configuration are also discussed. Recommendations for use are made, based on performance and current availability.

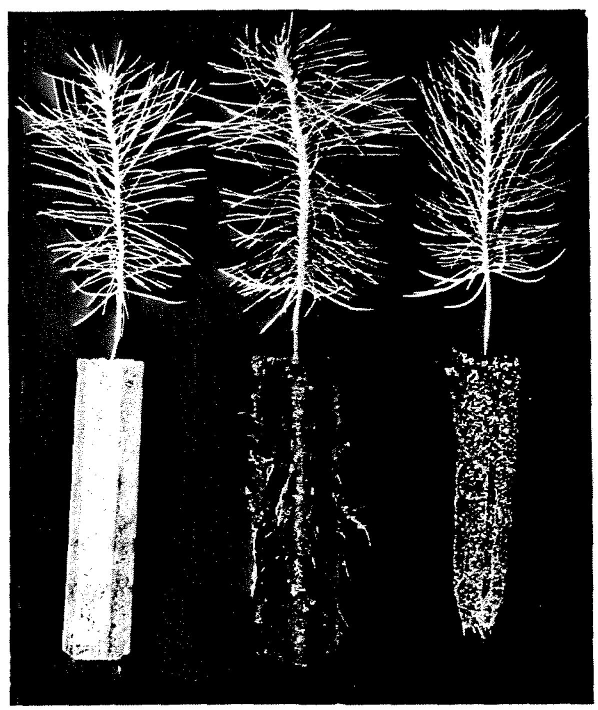
INTRODUCTION

Basic to any container production facility is the selection of an appropriate container system. A wide variety of container products have been developed and tested for growing coniferous species in the last few years. Many of these have been developed for use in the northwestern United States and Canada. As interest grows and operational use of container planting increases in the southern United States, selection of systems appropriate to the cultural needs and planting techniques of southern pines (*Pinus* sp.) becomes of greater concern.

In addition to evaluation of the container systems in use in the northwestern states and Canada, we have sought to find and develop other systems that may be more applicable to southern conditions. We have tested a wide range of systems that are in operational use as well as evaluated a series of products that have potential for use in container planting operations.

TYPES OF CONTAINERS

The many containers that have been evaluated for effectiveness in producing southern pine seedlings fall into three categories: tubes, plugs, and blocks (Fig. 1). Each type has certain merits that must be considered.



(a) (b) (c)

Figure 1.--Loblolly pine seedlings grown in three types of containers: (a) a biodegradable plastic tube, (b) a peat moss-vermiculite molded block, and (c) a plug from styroblock-2.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Principal Silviculturist, USDA-Forest Service, Southern Forest Experiment Station, Pineville, LA 71360.

Tubes

Tubes, such as Paperpots, plastic bullets, and biodegradable plastic containers, require filling with a growing medium, and have an exterior wall that is planted with the seedling. The exterior walls provide rigidity that aids in handling and planting, and give sufficient impermeability to prevent desiccation in soils that are dry near the surface (Day and Cary 1974). Their major disadvantage is that roots emerge slowly after outplanting because initial contact with the soil is made primarily through the bottom of the container.

Many of the early container systems consisted of tube-type products. One of the earliest container materials tested in the South was kraft-paper tubes. Jones (1967) successfully used spiral-wrapped kraft tubes for producing longleaf pine (*P. palustris* Mill.), black walnut (*Juglans nigra* L. and cherrybark oak (*Quercus falcata* var. *pagodifolia* Ell.) seedlings. This tube had a thick wall that decomposed slowly in sandy soils. Square tubes made from a heavy kraft paper were then tested (Fig. 2). This material folded easily for shipment, but degradation of the paper was rapid and this made planting difficult. Both types of kraft paper caused seedling chlorosis because of the utilization of nitrogen in the degradation process. The material was clearly inferior to the paper used in Japanese Paperpots, described later.

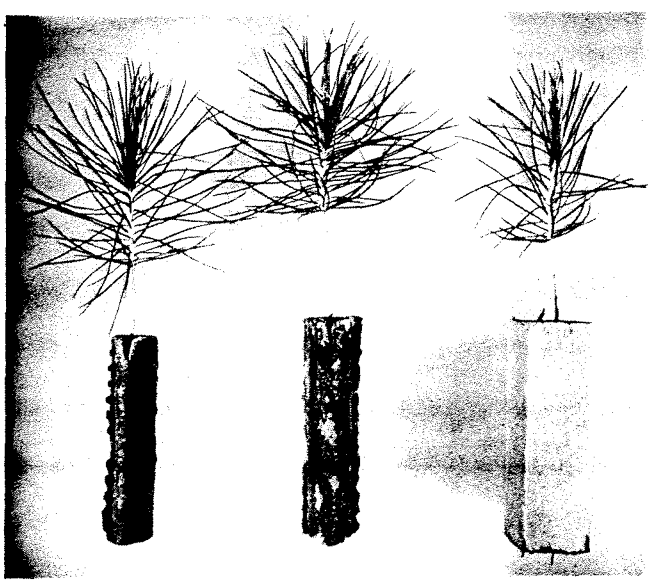


Figure 2.--Six-week-old loblolly pine seedlings growing in two sizes of Gro-blocks and in a square kraft-paper tube.

Walters' plastic bullet and planting gun technique was another early container system (Walters 1961). Although this system has numerous desirable features, such as rapidity of planting (Vyse 1971), results from trials in the heavier soils common in the South show that planting is difficult and root constraint restricting growth is common (Fig. 3). Because of the constraint problem, Walters (1974, 1978) has redesigned his bullet-shaped container. The newly designed container consists of four identical separable sections which assemble to form a plant pot with a square cross section. To my knowledge, this new design has not been critically evaluated in the South.

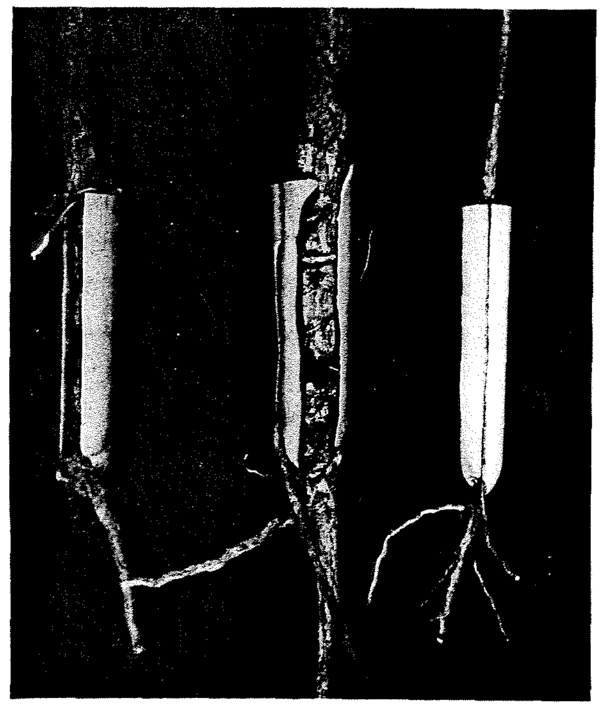


Figure 3.--Loblolly pine seedlings grown in plastic bullets and excavated after 3 years. Various stages of root constraint are shown.

Another plastic material is Conwed's netlike tubing. Made of polypropylene and manufactured in various lengths, diameters, and degrees of flexibility (Schlaeger 1969), early performance was good (Miller and Budy 1974, Barnett and McGilvray 1981). However, polypropylene does not degrade and eventually the roots become severely constricted (Fig. 4). Because of the lack of degradation, plastic tube materials have generally not been satisfactory.

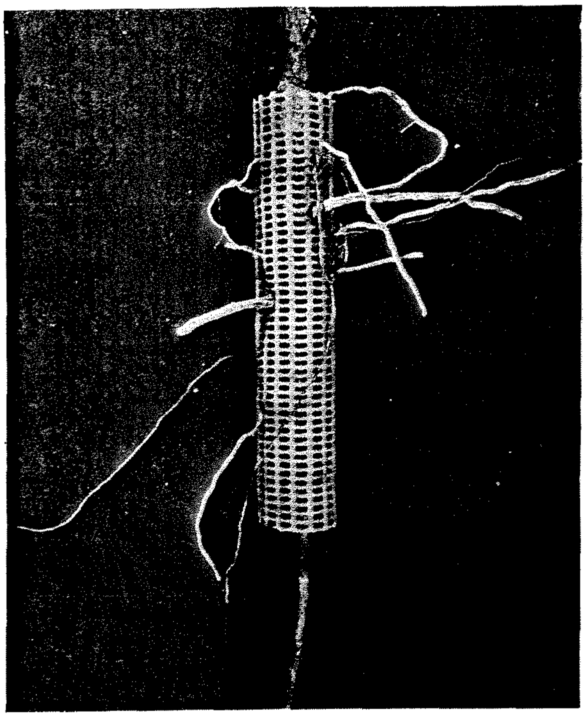


Figure 4.--Conwed mesh-type container showing constriction of loblolly pine roots after about 3 years after outplanting.

Table 1.--Survival and growth at 2-1/2 years of loblolly pine seedlings grown in biodegradable plastic and paperpot containers

Container	Soil type	Survival: June 1975 planting	Survival: August 1975 planting	Height: June 1975 planting	Height: August 1975 planting
		-------Percent-------		---------Feet---------	
Biodegradable	Silt loam	92	93	3.3	2.5
	Sandy loam	91	67	4.1	3.5
Paperpot	Silt loam	96	80	3.4	2.4
	Sandy loam	91	54	4.3	3.3

In the early 1970's Union Carbide Corporation reported that an aliphatic polyester, polycaprolactone, was susceptible to attack and assimilation by microorganisms in the soil (Potts et al. 1972). Because of its low melting point (60° C), polycaprolactone has limited usefulness for packaging materials, but its unique properties have been evaluated as a container for growing seedlings. The rate of degradation can be controlled by thickness of the material and its dilution with various additives (Clendinning et al. 1974). The biodegradable plastic tubes have performed well as containers for growing southern pines. This is attributed to breakdown in the plastic, so that root penetration was more rapid than in the Paperpot comparison (Table 1). Three months after outplanting, the plastic degraded sufficiently to allow good root egress of loblolly pine (*P. taeda* L.) seedlings into surrounding soil (Fig. 5). There is a period immediately after planting, however, when root contact with surrounding soil is limited to the bottom of the tube. Although biodegradable plastic containers have a number of unique characteristics for container growing, the relatively high cost of polycaprolactone has discouraged complete development of this system.

Figure 5.--Biodegradable plastic container showing root penetration of loblolly pine roots 3 months after outplanting on a silt-loam soil.

The Japanese Paperpot system has been widely evaluated in the South. It was originally developed for the sugar beet industry, but has been modified for forestry in Finland. Seedlings are grown in bottomless, hexagon-shaped individual paper tubes which contain plastic fibers and chemicals that increase their durability and resistance to soil microorganisms. Each set of tubes comes in a flat package that opens in a honeycomb fashion for filling with media. Upon watering the glue used to fasten the tubes together dissolves and they can be easily separated for planting. Paperpots vary in diameter and height; the most common types used in the South are designated 315 and 408. Most of the Paperpot material used in the South does not degrade rapidly enough after outplanting to allow root penetration of the tube walls by more than a few roots (Fig. 6). This slow root egress is most likely the reason for generally lower field survival and slower growth after outplanting (Table 2). It also causes some spiralling of the root system because the hexagonal shape tends to become cylindrical after filling. Spiralling is particularly a problem in longleaf pine where root growth is rapid. The Finnish Paperpot distributed by Lannel Tehtaat Oy is reportedly manufactured of materials that allow faster root egress.

Plugs

Plug seedlings are grown in molds, which need to be filled with a potting medium. The rooted seedlings and growing medium are removed from containers and planted together. Plugs provide an ideal biological setting for seedlings because roots are not restrained after planting and rapidly establish themselves in the surrounding soil. Plug seedlings must remain in the container long enough for the root mass to bind the medium so that extraction is easy. Seedlings must be extracted and packaged at greenhouse sites,or containers must be returned from the field. A number of different containers are available that are satisfactory.

The BC/CFS styroblock was developed in Canada by the British Columbia and Canadian Forest Services to overcome problems inherent with plastic bullets. The styroblock is a reuseable rectangular block manufactured of foamed styrene with tapered, rounded cavities in which the seedlings are grown. A number of cavity sizes are available ranging in volume from 2.5 to 8.0 cubic inches. The addition of vertical ribs to the inside of the cavities has greatly reduced the root spiralling problem that is common with cylindrical containers. However, a corkscrew effect can occur at the bottom of the cavity if inadequate air movement results in improper air pruning (Fig. 7).

Figure 6.--Root penetration of loblolly pine through Japanese paperpots 3 months after outplanting in silt loam (left) and sandy loam (right) soils.

Table 2.--Effects of container parameters on development and performance of loblolly pine seedlings

Container [1/]	Container volume	Seedling density	Initial dry weight		Survival at 3+ years	Height at 3+ years
			Shoot	Root		
	In³	Ft²	-----------mg-----------		Percent	Ft
			Planted 4-17-75			
Jap. Paperpot	5.4	154	157	46	87	5.2
Todd Planter (lg.)	4.1	29	301	86	94	5.4
Todd Planter (sm.)	1.5	82	113	41	92	4.5
			Planted 6-17-75			
Jap. Paperpot	5.4	154	165	46	89	4.9
Todd Planter (lg.)	4.1	29	437	111	97	6.3
Todd Planter (sm.)	1.5	82	227	58	99	5.6
			Planted 9-3-75			
Jap. Paperpot	5.4	154	180	42	98	3.9
Todd Planter (lg.)	4.1	29	470	81	97	5.1
Todd Planter (sm.)	1.5	82	237	47	98	4.3
			Planted 11-6-75			
Jap. Paperpot	5.4	154	124	31	83	2.8
Todd Planter (lg.)	4.1	29	213	53	88	3.5
Todd Planter (sm.)	1.5	82	154	34	88	3.1

1/ Container parameters are: Paperpot 315 (1.2 x 6.0 inches), Todd Planter 200 (2 inches square by 3 inches high), and Todd Planter 100A (1 inch square by 3 inches high).

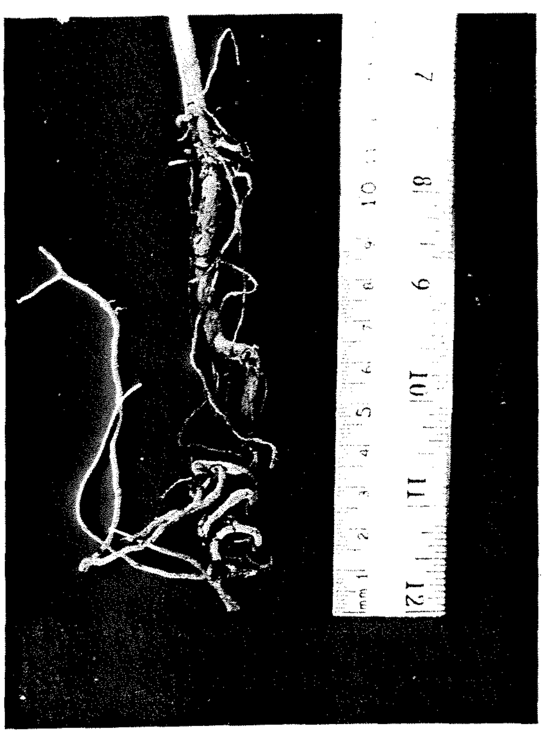


Figure 7.--Root systems of loblolly pine seedlings showing possible deformation at the bottom of the styroplug where vertical ribs do not extend.

Seedlings grown in styroblocks perform well in comparison with those grown in other containers. Growth of slash pine (*P. elliottii* Engelm.) seedlings after outplanting from several containers showed that those from Styroblock-2 equalled or excelled all others except Keyes Peat Sticks (Table 3). An earlier test comparing survival and growth of loblolly pine seedlings from Styroblock-2 containers with those of other container types showed good performance under the stress conditions of summer planting (Table 4).

Other plug systems like RL Single Cells and Spencer-Lemaire Rootrainers have the advantages of plug-type containers and perform well. Each specific container has certain characteristics that make it unique. The RL Single Cells can be handled individually for randomization, removal of blanks, and transport. Rootrainers open to allow checking of the root system and easy removal of the plug.

The Todd Speedling System is another promising system. Its cavities are square and their obtuse taper makes extraction easy (Fig. 8). Another feature that improves seedling quality is low density (number per unit area) in relation to cavity volume--50 seedlings/ft² and 4.6 in³ per cavity. When loblolly pine seedlings were grown in this and several other containers, initial seedling development and

Table 3.--Survival and heights of slash pine (*Pinus elliottii* Engelm.) seedlings grown in various container products 1+ years after outplanting

Container	Survival (1/76) after planting on: 4-26-74	6-25-74	8-28-74	Heights (1/76) after planting on: 4-26-74	6-25-74	8-28-74
	--------Percent--------			---------Feet-----------		
Gro-block	69	57	89	2.4	1.6	1.3
Peat stick	91	94	100	3.2	1.8	1.7
Paperpot (315)	81	76	96	2.1	1.5	1.5
Styroblock-2	89	93	98	2.5	1.6	1.4
Rootrainer (Ferdinand)	83	71	98	2.7	1.6	1.4

Table 4.--Survival and heights of loblolly pine seedlings grown in several types of containers and measured after 30 months in the field 1/

Container	June 21, 1972, planting: Survival	Height	August 24, 1972, planting: Survival	Height
	Percent	Feet	Percent	Feet
Plastic bullets	77	2.7	19	1.3
Kraft paper	55	2.4	47	1.4
Paperpot	64	2.5	49	2.0
Polyloam blocks	52	2.8	12	1.2
Styroblock-2	96	3.0	79	2.2

1/ Except for those in polyloam blocks, all seedlings were grown in a commercial potting medium with relatively low fertility levels.

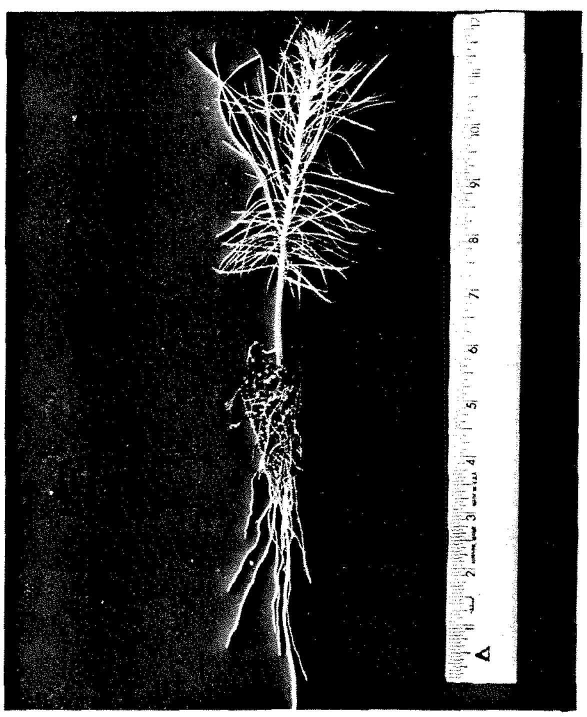


Figure 8.--Root extension of a loblolly pine seedling grown in a small Todd Speedling Tray (2.5 cm or 1 inch square by 7.6 cm or 3 inches deep) 2 weeks after planting into a sawdust bin.

field survival indicate that this system produces seedlings equal or better than others tested (Table 5). Because of the obtuse taper the seedlings are difficult to package once they are removed from the block.

Table 5.--Development and field performance of loblolly pine seedlings grown in various containers and outplanted on several dates

Container	Seedling development: Heights	O.D. top wt.	O.D. root wt.	Field performance (Jan. 1980): Survival	Height
	Inches	---------mg---------		Percent	Feet
		May 22, 1978, Planting			
Jap. Paperpot (315)	8.7	473	78	89	1.6
Tree Planter (ITW)	8.4	558	111	91	1.7
Tree-Start	7.4	429	-- 1/	99	1.7
Styroblock-4	9.3	698	140	94	1.7
Todd Planter (150-5)	9.9	682	133	98	1.7
Gro-block (large)	9.5	603	--	80	1.7
		June 15, 1978, Planting			
Jap. Paperpot (315)	7.6	333	58	27	1.2
Tree Planter (ITW)	5.9	324	68	64	1.4
Tree-Start	7.0	385	--	63	1.4
Styroblock-4	8.0	468	87	61	1.4
Todd Planter (150-5)	7.3	515	116	71	1.5
Gro-block (large)	8.3	424	--	43	1.4
		August 23, 1978, Planting			
Jap. Paperpot (315)	7.7	460	113	77	1.4
Tree Planter (ITW)	3.7	257	145	77	1.4
Tree-Start	8.9	895	--	68	1.0
Styroblock-4	7.1	555	188	67	1.6
Todd Planter (150-5)	6.5	660	224	83	1.6
Gro-block (large)	8.5	678	--	57	1.5
		November 17, 1978, Planting			
Jap. Paperpot (315)	6.5	410	79	25	0.7
Tree Planter (ITW)	6.6	368	114	34	.9
Tree-Start	6.1	782	--	23	.7
Styroblock-4	5.5	513	176	47	.6
Todd Planter (150-5)	4.4	482	158	31	.7
Gro-block (large)	6.5	648	--	20	.6

1/ A dash indicates that no data could be collected on root weights because of the type of container.

Blocks

The block is both the container and the growing medium. Seeds are sown in the block and the entire package is later transplanted into the field. Because blocks are usually rigid enough for mechanized planting, but still allow rapid root egress after outplanting, they have advantages of both tubes and plugs.

Although numerous block-type products have been evaluated, only a few have been available for use in large-scale programs. One type of self-contained block container consists of acrylonitrile-bonded softwood pulp (Schneider et al. 1970, White and Schneider 1972). This product, originally manufactured by American Can Company under the trade name of BR-8, was later made by Famco, Inc., and called Gro-block (Fig. 2). Six-week-old loblolly pine seedlings grown in these soilless blocks and outplanted in July survived better and grew faster than seedlings grown in soil-filled Kraft paper tubes (Barnett 1975). However, when older seedlings were grown in comparative containers, survival and growth of seedlings in Gro-blocks were generally poorer than in other containers (Table 3). This poorer performance may reflect the small size of these Gro-blocks when compared to the other products tested. Gro-blocks are not now commercially available and further development work is needed before the system is a viable one.

Probably the most promising block-type container evaluated has been developed by Keyes Fibre Company. The block consists of a blend of sphagnum peat moss, vermiculite, cellulose fibers, and nutrients. An early design of this product was rectangular in cross-section (1-1/8 x 1-1/4 inches) and 6 inches long. This block, termed a "Peat Stick" was used in several studies with good results (Table 3). Loblolly and slash pine seedlings grown in this block survived and grew better than those in other containers, particularly when outplanted under conditions of moisture stress (Fig. 9 and 10). Survival was maintained at a high level even during June, July, and August, when survival of seedlings grown in Gro-blocks and Paperpots dropped. Heights of seedlings outplanted in Peat Sticks in June compared favorably to those of bare-root seedlings planted in the previous March.

Because of the success with Peat Sticks, the product was redesigned to provide for easier handling, packaging and outplanting. The resulting Kys-Tree-Start has a smaller volume, but has the same properties. The advantages of the Tree-Start includes: (1) simplified greenhouse operations because no filling is required, (2) no root manipulation into undesirable patterns or constraint after outplanting, and (3) adaptability to mechanized planting equipment. After outplanting, root egress occurs from the entire block surface and no unusual patterns of root development are evident that should cause future problems in seedling growth or stability (Fig. 11). The blocks are subject to development of a saprophytic mold during the early greenhouse period and some root cross-over occurs along the back of the 10-block strip if seedlings are held for long periods. Some further development could make this an excellent product, but at the present time insufficient demand exists to keep this product available.

Other Containers

Numerous container materials other than those described have been evaluated (Barnett and McGilvray 1981). Some of these have promise but for some reason have not been produced for commercial use. Our experience with a wide range of containers should provide the information necessary to anticipate the performance of other containers not reported here.

CONTAINERS AND ROOT FORM

When planting any tree you risk having a root system that is deformed, at least to the extent that it will not have the same root configuration as trees grown from seed in place. Recently a Symposium was held devoted to the evaluation of root form on plant development (Van Eerden and Kinghorn 1978). However, there is still no clear determination of effects of root malformation on seedling performance.

Our results with southern pines indicate that the severe constraint of many of the tube-type containers may adversely affect seedling growth. For example, plastic bullets can limit root egress to the extent that growth is stunted (Fig. 3). Other containers can result in root strangulation (Fig. 4) or root spiralling. If, however, these obvious extremes of deformity are avoided, the configuration imposed by the container may not be harmful. Block-type containers seem to impart less of an "oriented" root system than bare-root planting. Root egress from blocks such as Kys-Tree-Starts occurs from the entire surface of the block in a natural manner (Fig. 11).

The effect of plug-type containers on root configuration can vary greatly. Round cavities, like in the Styroblock container, can result in root spiralling if vertical ribs are not incorporated to force root growth downward. These ribs are effective in reducing root spiralling.

Studies have also shown that there are differences among species and soil types in the amount of root malformation. Longleaf pine is more susceptible to root spiralling than loblolly or slash, probably because the lack of stem growth results in more rapid root elongation. Heavy soils can also increase the amount of root malformation by limitint rapid root egress through the punched planting hole wall (Barnett 1978). Root spiralling can occur within the planting hole when holes are punched in heavy clay soils. However, with reasonable precautions in selection of containers and planting techniques, root configuration should not adversely affect seedling growth and development.

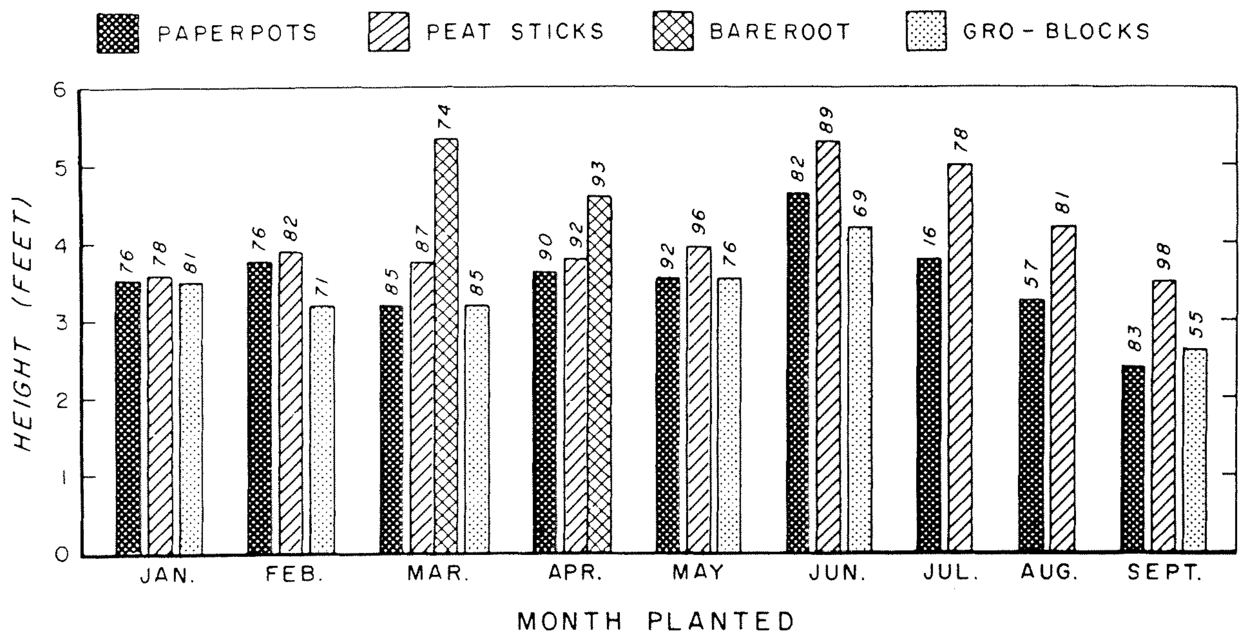


Figure 9.--Heights and survival (above bars) of slash pine seedlings planted during CY 1973 and measured during January 1976.

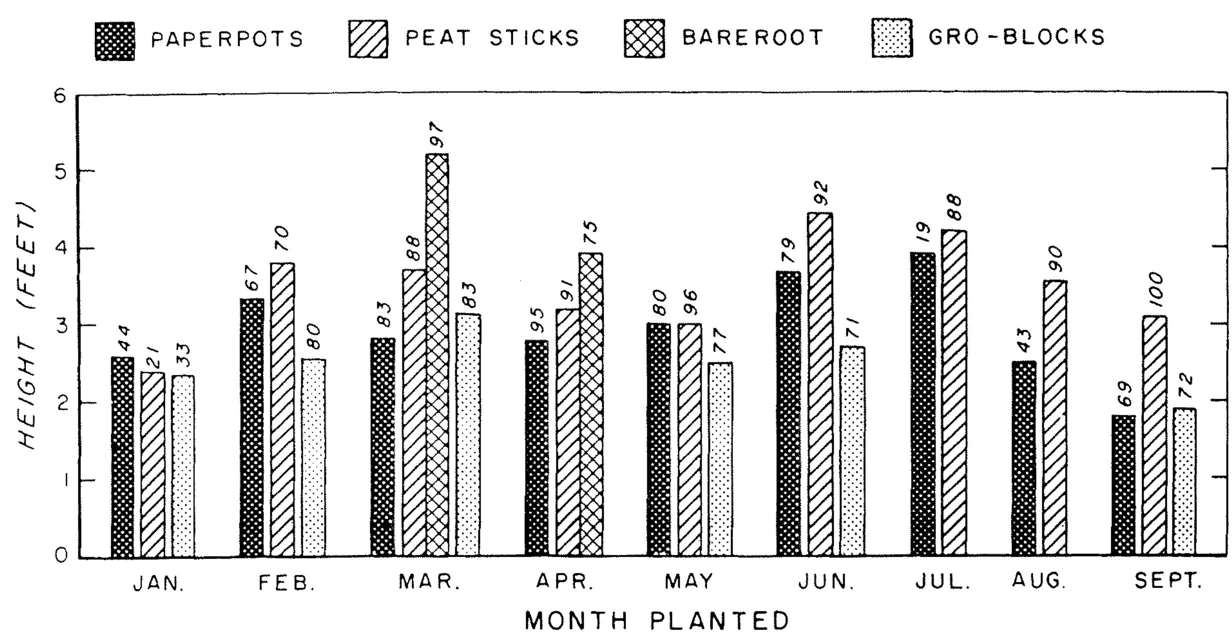


Figure 10.--Heights and survival (above bars) of loblolly pine seedlings planted during CY 1973 and measured during January 1976.

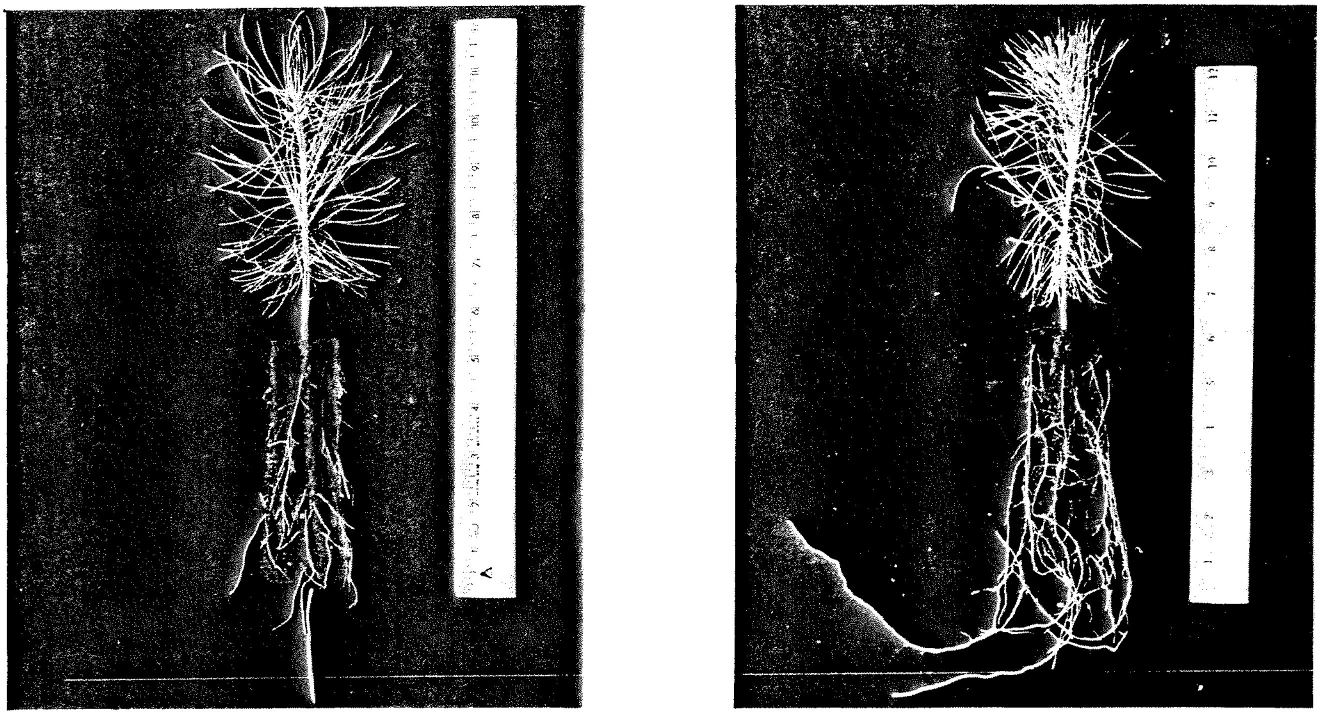


Figure 11.--Development of loblolly pine seedlings in Kys-Tree-Starts 2 weeks (left) and 4 weeks (right) after outplanting into a sawdust bin.

RECOMMENDATIONS FOR THE SOUTH

The choice of container system depends on a number of variables: facilities, size and species of seedlings to be grown, planting techniques and equipment, and personal preference.

Species such as longleaf pine, that are very intolerant, should be grown in containers that allow a smaller number per unit area than most other conifers. Larger containers are also desirable when seedlings of larger than usual size are to be produced. Seedlings grown for hand-planting operations can utilize plug-type containers that could be less desirable for more automated planting equipment.

The recommendations of container systems that follow are based on performance evaluations with southern pines and on commercial availability.

Tubes.--The Paperpot is the best of the tube-type containers now available that have been tested with the southern pines. The Finnish Paperpot is probably superior to the earlier material used in the South since there is less restriction to root penetration in the Finnish product.

Blocks.--The Kys-Tree-Start is the best performing block material tested. Field performance of this material is good and it is easily adaptable to more automated planting equipment. However, at the present time this product is not commercially available.

Plugs.--There are no great differences among the plug-type containers in field performance. Most of the variations in performance are more of a reflection of cavities per unit area than container, *per se*. The differences in the various products are primarily in handling features, i.e., some open for ease of extraction, others can be separated for ease of shipping.

Although a wide variety of container products have been evaluated during recent years, the actual availability of good performing products designed for southern conditions is limited. This reflects the relatively small production of container-grown seedlings in the South. As the quantity of seedlings produced increases, further development and manufacture of the promising container systems will occur.

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YOU REAP WHAT YOU SOW [1/]

E.W. Belcher [2/]

Abstract.--This paper presents methods of evaluating seed quality, identifying losses of quality, and describes five techniques to improve seed quality. These techniques include: water soak, stratification, pathogen control, increased germination temperatures and seed sizing.

INTRODUCTION

An efficient container operation requires a minimum of blanks and multiple seedlings. This efficiency may only be acquired with high quality seed and improved germination techniques (Pawuk and Barnett 1979). The best techniques and resulting seed involve procedures discussed in this report: evaluating seed quality, identifying losses of quality, and techniques to improve seed quality. Recommendations are given on seed handling for container culture.

SEED EVALUATION

The most commonly used evaluation of seed viability is germination. Germination is measured by the percentage of seed which will germinate per 100 seed. The percentage is calculated from standard laboratory tests which are conducted under optimum conditions. The data must be adjusted to prevailing nursery conditions. In the nursery, the adjustment is called survival percent and is obtained from history plot data (Belcher 1964), but such data are limited with container stock.

Experience has shown that the faster the seed germinate, the higher the survival (Rohmeder 1962; Larson 1961). The speed and ability of a seed to germinate identify the seed strength which we call vigor (Hartman and Kester 1975). It is easier to describe vigor than it is to measure it. Declining vigor ultimately leads to low germination and a lowered ability of seedlings to withstand unfavorable conditions. As vigor decreases, the difference between laboratory and field germination increases. This difference is due, in part, to the fact that death is the result of a continuing progression in aging (Justice and Bass 1978, Belcher 1978).

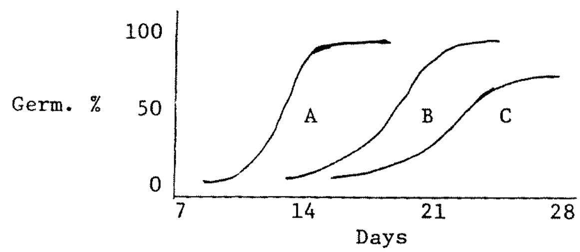

Figure 1.--Germination curve of three selected seed lots.

One method of evaluating seed vigor is by plotting a germination curve (fig. 1). Seed with high vigor (A) germinate rapidly. As vigor decreases (C), so does potential germination and the rate of that germination. Two stratified lots may provide similar total germination (A and B) but one lot may have a delayed germination (B). This delay may be due to weaker seed or seed dormancy, but whatever the cause, fewer seedlings will be produced when subjected to adverse field conditions.

Other methods include the "Coefficient of Velocity" (Kotowski 1926); the "Germination resistance" (Gordon 1973); the Weibull Function (Bonner 1976), accumulative germination by size classes (Wang 1973) and the "Germination Value" (Czabator 1962). "Germination Value" is the easiest to use, and therefore merits a little more discussion.

This index combines the rate of germination with germinative energy. Because of the emphasis on the rate of germination, this index has considerable merit in evaluation of seed for container stock. As an example, this technique is applied to the curves in figure 1 (see table 1).

[1/] Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Ga. August 25-27, 1981.

[2/] Staff Director, National Tree Seed Laboratory, Macon, Ga. The Laboratory is operated cooperatively by Southeastern Area, USDA Forest Service and the Georgia Forestry Commission.

The germination value more clearly expresses the earlier description we presented of the germination curves in figure 1. Maximum output of seedlings at a minimum cost will require high germination values.

Table 1.--Germination data on three selected lots, with germination value

Recording date	Seed lots A	B	C
	Germination %		
7	14	0	0
14	78	14	4
21	82	79	22
28	82	81	69
Germination reported	82	81	69
Germination value	16.3	10.9	6.0

CAUSES OF LOW SEED VIGOR

The causes of low vigor (Heydecker 1972 and Hartman and Kester 1975) are the same causes that lead to low viability. Most of these problems can be avoided if you recognize the causes, described in the following sections.

Physiological

When fruits are collected prior to natural maturity they may produce physiologically immature seed. The earlier the collection, the more immature the seed. Similar instances may occur with extreme adverse weather conditions that may delay or prevent natural maturity.

Mechanical

As the future potential of our forests, tree seed should be considered as fragile as eggs. Unfortunately, the careless slam-bang processing used in many plants is destructive to the seed. Damage ranges from obvious mechanical breaks in the seed coat to subtle impact damage. An impact or blow to the seed results in a bruise. This bruise can result in death if it involves a large enough area or includes the delicate radicle. The result of impact damage may not be evident for six months to a year. I have seen impact damage so great that embryos were broken in half (visualized on radiographs) while no external damage was visible.

Microbial

The air around us is full of fungal spores. The concentration and variety of these spores may be changed by the introduction of infested fruits, seedlings or other living, dying or dead plant material. The rough texture of the seed coat makes a good resting place for microscopic spores, especially those with hooks, barbs, or adhesive qualities. The spores remain until conditions are optimum for their germination. If they are saprophytic, they live only on dead seed and cause no real problem. But, if they are parasitic, such as Fusarium sp., they may spread rapidly and kill seed before, during, and even after germination.

Also, fungal organisms that enter the seed through breaks in the seed coat, insect holes and by other means have been reported in seed tests.3/ Once inside the seed, they initiate deterioration by dissolving the tissue for their own use.

Cytological

"A plant cannot be better than the seed from which it was grown," said Heydecker (1972). Seeds are at their physiological peak at maturity (Justice and Bass 1978). From that point on, vigor declines because of the aging process until death occurs. However, at some point well before death the planting value of seed is questionable. The reduced vigor results in a greatly reduced germination as adverse field conditions are imposed.

Morphological

Strange things happen because of environmental influences during seed production. The longer the developmental process the greater the environmental influence. The greatest influence observed is seed size. Research has shown large seed germinates faster than small seed (Heydecker 1972 and McDaniel 1973) when all else is equal. Delays in field germination subject seed to greater environmental stress and thereby lower stand densities.

Genetics

Delays in germination may be caused by seed dormancy which varies by clone. When bulk seed are sown, the clonal variation is maximized. Sowing individual clones minimizes variation and maximizes plant survival (Wasser 1978). Also, the wrong combination of genetic material can lead to seedlings that germinate well, but which are susceptible to adverse weather or that, in the case of those devoid of pigmentation, cannot survive under the best conditions.

3/ Fungal survey conducted by E. Belcher, R. Anderson and T. Miller, 1979-80 (unpublished)

INVIGORATION

Assuming you have the best seed you can produce, how can you make it produce the maximum number of seedlings? Five methods useful in promoting higher production of container stock will be discussed.

Water Soak

Seeds must become imbibed before they will germinate. If dry seed are planted, the seed must imbibe the moisture from the soil. Imbibition is much slower in soil than in a water soak. Full imbibition of the seed at planting can increase the speed of germination. Faster sprouting will occur with seed that are difficult to germinate by soaking them in aerated water (Barnett 1971). Once seed are planted in a moist condition, they must be kept moist if maximum germination is to be realized. Moist seed placed in a dry environment will decrease in ability to germinate with time until the seed moisture content has reached equilibrium with the existing atmospheric conditions (Forrest 1964).[4/]

Stratification

The most accepted means of promoting germinative energy and the rate of germination is with some interval of stratification. The seed must be fully imbibed to effect stratification. The rate of germination can even be increased for seed which are not normally dormant by a 14-day stratification period, but this treatment may reduce total germination.[5/] Care should be taken not to stratify seed so long that they germinate during treatment. Some species, (such as loblolly pine and Douglas-fir) can be partially dried following stratification and stored for 6 months to a year if conditions are not favorable to sowing (Danielson and Tanaka 1978; Belcher 1981).[6/]

Pathogen Control

Saprophytic fungi are forever present, but because they live on dead and dying tissue they usually may be ignored. On the other hand, a pathogenic fungi such as Fusarium sp. can be disastrous when carried into a seed bed or container via the seed (Pawuk 1978). They spread so rapidly, the devastation may be overwhelming before it's identified. Because of the intensive management of container stock, take some precautions to reduce the amount of fungal spores carried into planting (Carlson 1979). Most of the existing spores can be removed by a vigorous water rinse (Belcher 1981). A partial degree of sterilization can also be obtained by limited soaks in bleach or peroxide (Barnett 1976). Caution must be exercised because these chemicals are toxic to seed tissue and can reduce germination if the seed is soaked too long. More permanent treatment requires the use of a fungicide. If fungicides are used, apply them following stratification rather than prior to it because most fungicides are toxic to seed tissue and can be absorbed into the seed, once dissolved (Pawuk 1979).

Increased Temperature

Each species has an optimum temperature that will provide maximum germination. The best temperature is usually a little higher or lower than the seed experiences in its natural habitat. Nearly all seed will germinate at an alternating 20°-30°C since this is very close to that occuring in nature. Research has shown that constant temperatures often promote faster germination, but as the temperature is increased the weaker seed do not develop normally (Belcher 1966 and Barnett 1979). As an example: loblolly pine germinates well at 20°-30°C in 28 days. At 22°C, loblolly will reach maximum germination in 21 days and at 28°C it will reach maximum germination in 14 days. The germination capacity at 28°C will be less than that at 22°C if the lot has been stored because the weak seed do not survive or germinate abnormally. The germination rate of container stock can be increased by setting a slightly elevated constant temperature until germination can be observed and then changed to an alternating temperature for sturdy growth. Mean constant temperatures should be below 27°C.

Seed Sizing

Seed sizing can be used effectively in a container program because each size can be treated to effect maximum germination of that size. Large to medium-large seed usually germinate the fastest and small seed the slowest. Also, small seed usually contain the most dormancy (Choi and Kim 1969).

Contrary to the argument that sizing may eliminate clones (Silen and Osterhaus 1978), no genotypes are lost unless one or more sizes are discarded. With the present value of improved seed, the loss of clones does not seem likely. The real benefit in seed sizing is a more uniform germination which provides more efficient utilization of improved seed.

CONCLUSION AND RECOMMENDATIONS

A container operation must be flexible enough to respond to changing demands, but there is a point at which the cost is greater than the investment.

4/ Belcher 1967 unpublished laboratory study

5/ Belcher 1969-unpublished laboratory findings with Mississippi longleaf pine

6/ Belcher 1981-manuscript being reviewed

This point usually occurs when production is decreased by poor quality seed and inadequate seedling production. The container operation manager can improve the operation by selecting the best quality seed available. If the seed is not the best, the deficiency should be evaluated. With this knowledge, reclean the seed, replace the seed and/or promote the existing viability.

Once the seed has been upgraded and tested, apply the necessary techniques to promote the germination. A stratification of 14 days or more may be helpful, depending on the species, but if time is critical soak the seed overnight in water. Apply pathogen control if seed mold was identified in the seed test. And finally, maintain a little higher than normal greenhouse temperature until germination begins. Take care to avoid constant temperatures above 27°C.

In summary, you can only reap what you sow. Use the best quality seed possible!

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SEED SOWING STRATEGIES FOR CONTAINERIZED SEEDLING OPERATIONS[1/]

William D. Pepper and James P. Barnett[2/]

Abstract.--Choosing a container sowing strategy was formulated as a linear programming problem. An optimal sowing strategy is achieved by choosing the three fractions of containers sown with one, two, and three seeds to minimize an economic penalty function, which penalizes a sowing strategy if it does not deal effectively with problems caused by blank cells. Mixed sowing strategies, as opposed to the standard strategy of sowing two seeds per cell, were generally optimal.

INTRODUCTION

Because of the relatively high cost of growing seedlings in containers compared with bare-root programs, methods are needed to make all phases of the container operation as efficient as possible. One significant efficiency problem in container growing operations is the blank container. For example, if overall germination is low and a single seed is sown in each container, the number of blank containers will be high, and the cost of carrying these blanks may not be acceptable. In this paper we assume that containers are handled in trays or blocks where individual cells are not removable. Thus, since resowing is infeasible, blanks must be carried or replanted with excess seedlings.

The proportion of blank containers can be reduced by sowing more than one seed in some or all containers. Most published reports of nursery cost analyses for container operations compare the effects of different types of containers for a fixed sowing scheme (Vyse and Rudd 1974; Hallman 1974; Colby and Lewis 1973; Tinus and McDonald 1979). Bohlin and Hultén (1974) compare different nursery strategies, but a given sowing scheme always specifies a constant number of seeds per container. Space and Balmer (1977) published a computer program for evaluating nursery strategies which differ according to their treatment of blank containers.

The cost of producing a given number of seedlings depends upon the germination and survival rate for the seed lot, the cost of seeds, the cost of sowing, the cost of carrying containers, the cost of replanting blank containers, and the cost of thinning excess seedlings.

A frequent choice for reducing blanks is the sowing of two seeds per container. Because this introduces the need for thinning excess seedlings, it necessarily involves an additional expense that may be less acceptable than the cost of carrying blank containers. If neither type of sowing scheme--single sowings only or multiple sowings only--is adequate, then mixed sowing schemes should be considered. For instance, 30% of the containers could receive three seeds, 20% could receive two seeds, and the remaining 50% could receive one seed. In recent work (Pepper and Barnett 1981a, 1981b) we show that mixed sowing schemes are generally more cost-efficient than the standard constant number approach, and we give a method for choosing an optimal sowing scheme when *a priori* estimates of costs and overall germination and survival rates are available. For the nursery manager who wishes to use this method we developed a user-oriented, interactive computer program which determines an optimal sowing strategy for producing a required number of seedlings with a specified number of containers (Pepper and Hodge 1981).

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Authors are Mathematical Statistician and Principal Silviculturist, Southern Forest Experiment Station located at New Orleans, LA 70113, and Pineville, LA 71360, respectively.

METHODS

In this paper we assume that sowing is accomplished by a widely used technique employing a vacuum-operated seeder (Carlson 1979). This type of seeder uses a vacuum to hold single seeds over holes in a template. When the vacuum is released the seeds drop into the cavities. If more than one seed per cavity is needed the operation is repeated. A mixed sowing strategy is accomplished by making additional passes over the trays, or by increasing the vacuum so that more than one seed is held to the hole in the template.

The key quantities in a sowing strategy are total number of seeds, predicted number of plantable seedlings before thinning, predicted number of plantable seedlings after each occupied cell is thinned to one seedling, predicted number of excess seedlings, and predicted number of blank containers. These quantities are computed in terms of germination and survival rates and sowing frequencies and the probabilities may be estimated with the binomial formula

$\hat{P}_{ij} = \binom{j}{i}(\hat{p})^i(1-\hat{p})^{j-i}$, $i = 0, 1, 2, \ldots, j$; $\hat{p}$ = estimated germination and survival rate and $\hat{P}_{ij}$ = estimated probability of producing i plantable seedlings given that j seeds were sown. In practice no more than 3 seeds per cell are sown so that $i = 0, 1, 2, 3$; $j = 1, 2, 3$.

In practice $\hat{p}$ will often represent an overall average germination and survival rate for a composite of seed lots. Naturally, the reliability of the estimate is influenced by the amount of variation within and among seed lots, but will usually not be quantified because of the lack of estimates for these variables. The assumptions for this model are:

1. The germination of a seed and establishment of the seedling form an independent event that does not affect the chance of success for the other seeds in a container.

2. The probability of success is the same for each seed in a given container.

These conditions may not be completely satisfied in some container operations, but Pepper and Barnett (1981a) showed that the assumptions were not seriously violated in a single--and multiple--sowing experiment with loblolly pine seed. The same study showed that thinning excess longleaf pine seedlings has a negligible effect on the remaining seedlings in a container. Throughout this paper we assume that the binomial model is a satisfactory representation of the germination and survival process and that mortality adjustments are unnecessary for seedlings remaining in thinned cells.

It is neither realistic nor necessary to identify all costs that might occur in the production of a container-grown seedling. Rather, we define a function that reflects the penalty when blanks occur and remedial actions are taken.

As a point of departure we consider the extreme case of perfect seed and seedling performance with 100% germination and establishment. In this case a single seed is sown in each cell and all seeds produce seedlings; no thinning is necessary and no blanks occur. Thus, the seed-related cost is not regarded as a penalty. But in reality blanks do occur and we choose a sowing strategy to reduce blanks. The additional number of seeds required and the additional cost of seeds and sowing are considered penalties. The cost of carrying blanks and/or replanting blanks is estimated as is the cost for thinning excess seedlings when the seedlings thinned are not used for replanting blanks.

It was assumed that the cost of sowing is the same for each seed. This assumption seems logical since the seeder must make a pass over the tray of cells for each seed planted per cell.

The cost for thinning was assumed to be the same for each seedling. The validity of this assumption may depend upon the frequency of cells containing excess seedlings. If relatively few cells must be thinned, the cost per seedling for a given cell may be influenced by the amount of time spent walking to that cell. On the other hand, if nearly all cells contain excess seedlings, walking time between cells is not a significant variable, and the cost of thinning should be the same for each seedling. From this it appears that the constant thinning cost assumption will not be erroneous unless there is little thinning to be done. Thus, the final impact of this potential error on the penalty function should be minimal. The thinning cost applies only to excess seedlings not used in replanting blank cells.

The cost of replanting a blank cell consists of the cost of removing an excess seedling from another cell and transplanting it to the blank cell. The mortality of transplanted seedlings is assumed to be negligible.

The cost of carrying a blank cell was defined as the cost of the container plus the cost of the medium. Container costs vary according to the type and the number of times that they can be reused.

The sum of the independent contributions of the cost components described above is the total penalty, including the cost of blanks and the cost of remedial actions to reduce blanks. Our purpose is to present a method for choosing a strategy to minimize the predicted total penalty.

Two options are considered for producing a given number of seedlings:

Option 1. Blank containers are not replanted, but excess seedlings are thinned.

Option 2. Use a sowing strategy for which the predicted number of blanks does not exceed the predicted number of excess seedlings. Remove enough excess seedlings to replant blanks and thin the remaining excess seedlings.

An interactive computer program (CONSOW)[3/] written in BASIC was developed to perform these calculations for both Option 1 and Option 2 problems (Pepper and Hodge 1981). As basic input the user provides an estimate of the overall germination and survival rate, an estimate of the cost components described above and the required number of seedlings per cell. For the specified constraints CONSOW produces a complete list of extreme point solutions, each of which is a candidate for optimality. The value of the penalty function is computed for each of these solutions and the one yielding the smallest value corresponds to the optimal sowing strategy. The mathematical derivations upon which this computer program is based has been described in detail (Pepper and Barnett 1981b).

In our work we assumed resources were available to produce the required number of seedlings, and the objective was to choose a sowing strategy to minimize a penalty function or maximize efficiency in some sense. Many nursery managers might formulate the optimization problem in a different manner. An objective might be to produce as many seedlings as possible with limited resources.

These limitations would probably be reflected in the size of the operation and the availability of money. If they could be expressed as linear constraints, the linear programming approach to optimization would be straightforward. A sowing strategy could be chosen to maximize the predicted number of plantable seedlings subject to the appropriate constraints.

We did not attempt to solve this type of problem. Though we were tempted to set an upper bound on the penalty function making it a linear constraint on seedling maximization, we were hesitant to select arbitrary bounds. It appears that a carefully chosen cost function might be useful for expressing limitations on funds in this type of problem.

RESULTS AND CONCLUSIONS

Choosing a sowing strategy for a container operation can be formulated as a linear programming problem. The independent variables are fractions of containers sown with 1, 2, . . . , n seeds. In practice n will generally not exceed 3. Sowing 3 seeds in each container was never an optimal strategy for problems considered in our applications.

When cost components are used to compute coefficients for the independent variables in the penalty function, it is a relatively simple matter to choose values of the independent variables to minimize penalty. In our experience, for a given container sowing problem the range in penalty values (maximum - minimum) over all admissable sowing strategies has been substantial, and this provided evidence that seeking the optimal solution was worthwhile.

Theoretically, it pays to use excess seedlings to replant blanks. Our work shows maximum gains possible using Option 2 in lieu of Option 1. Actual gains depend on the rate of survival of replanted seedlings. If a high rate of survival is possible, Option 2 seems definitely superior to Option 1, unless the cost of replanting blank cells exceeds the sum of the costs of thinning excess seedlings and carrying blank cells.

With a given number of containers, mixed sowing strategies can theoretically produce a fixed number of seedlings more efficiently than the standard sowing strategy (2 seeds sown in each cell). Basically, this means that mixed sowing strategies do a better job of dealing with problems caused by blanks.

Sensitivity analyses indicate that the superiority of mixed sowing strategies is fairly resistant to changes in price components. When seed viability is high, large price changes would be needed to make standard strategies more efficient than mixed strategies, as judged by our penalty function.

3/ Available from the senior author.

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GERMINATION CHARACTERISTICS

OF SOUTHERN PINE AS INFLUENCED BY TEMPERATURE[1/]

J. R. Dunlap[2/] and J. P. Barnett[3/]

Abstract.--The germination patterns of loblolly (*Pinus taeda*), shortleaf (*P. echinata*) and longleaf (*P. palustris*) were determined under the influence of temperature regimes which alternated between 22°C and two less favorable temperatures, 13°C and 35°C. The germination of loblolly and shortleaf were accelerated with exposure to increasing temperature regimes. The rates of longleaf germination were not significantly changed across any temperature regime; however, uniformity and final germination were optimized by periodic exposure to 13°C. The identification and practical use of temperature regimes to manipulate germination patterns were discussed relative to greenhouse production of pine seedling crops.

INTRODUCTION

The yield of pine seedling crops can be substantially influenced by seed germination patterns. Poor germination results in low yields of seedlings per unit growing area. Slow germination can yield a crop of established seedlings which display wide variation in size and acceptable quality (personal observation). Consequently, seed germination patterns represent a major variable in the successful production of a uniform seedling crop under controlled or natural environments.

Production of containerized seedlings under greenhouse conditions offers the opportunity for partial control of several environmental parameters not afforded an outdoor growing system. One of those environmental parameters with a profound effect on seed germination is temperature (Heydecker, 1977; Koller, 1972). Barnett (1979) and McLemore (1966, 1969) have both shown that the germination of loblolly pine (*P. taeda*) was inhibited at temperatures below 20°C and above 30°C. The rate of germination was also delayed as either extreme was approached (Barnett, 1977).[4/] Similar experiments were conducted with slash (*P. elliottii* var. *elliottii*), shortleaf (*P. echinata*) and longleaf (*P. palustris*) pine (Barnett, 1977[5/]; 1979). Again, dramatic reductions in the rate and final germination took place when treatments were incubated outside a temperature range of 20° to 30°C. The germination of longleaf pine was optimum at 24°C, a temperature slightly less than optimum for the other species tested.

All of the previously described studies were conducted at constant temperatures. Current greenhouse production systems lack total control over temperature as reflected by alternation between daily maxima and minima. The germination patterns of many plant species have been shown to change substantially with the shift from constant to cycling temperature regimes (Heydecker, 1977). Consequently, the germination patterns of southern pine species described by McLemore (1965, 1969) and Barnett (1979) in response to constant temperatures may be quite different under a cycling regime.

The following study was initiated to determine the response of longleaf, shortleaf, and loblolly pine seed to alternating temperatures during germination. This information would provide guidelines for optimizing germination conditions within a greenhouse production system and subsequently enhancing crop yields.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.
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3/ Principal Silviculturist, USDA - Forest Service, Southern Forest Experiment Station, Pineville, Louisiana 71360.
4/ Barnett, J. P. 1977. Temperature effects on germination of southern pine seeds. USDA For. Serv. Res. Rep. SO-1102-1.123, 21 p.

5/ Ibid.

MATERIALS AND METHODS

Three species of southern pine were selected for use in this study. Orchard sources of loblolly (*P. taeda*) and shortleaf (*P. echinata*) seed were supplied by Weyerhaeuser and the Southern Forest Experiment Station, respectively. Both a southern and northern geographic source of each species were collected. A third species, longleaf (*P. palustris*) was supplied from a heterogenous field source collected by the Southern Forest Experiment Station. Consequently, five distinct seed samples encompassing several species and geographical differences were tested.

Seed Preparation

All seed samples were imbibed in distilled water for 24 hours prior to stratification or germination. The loblolly and shortleaf samples were stratified at 4°C for 40 days; longleaf seeds were not stratified. All seed samples were germinated simultaneously in 10 x 10 cm plastic boxes on Kimpak paper moistened with 35 ml of distilled water and fitted with plastic lids. Tests were conducted with three 50-seed subsamples from each major seed source.

Germination Conditions

All species and respective sources were tested under seven different temperature regimes (Fig. 1). The temperatures used to generate this array of regimes were 13°C, 22°C, and 35°C. Each regime was created by alternating between 13°C and 22°C or 22°C and 35°C within a 24-hour time interval. The stress level was varied by exposing seed for 8, 10, or 12 hours to the less favorable temperatures, 13°C and 35°C. One exception was the constant 22°C treatment considered to be optimum for germination which represented a point of comparison for the less than optimal regimes (Anon., 1970). A 12-hour photoperiod was superimposed on each temperature regime (Fig. 1). All germination treatments were imposed to within ± 0.5°C using growth chambers with programmable temperatures and photoperiod.

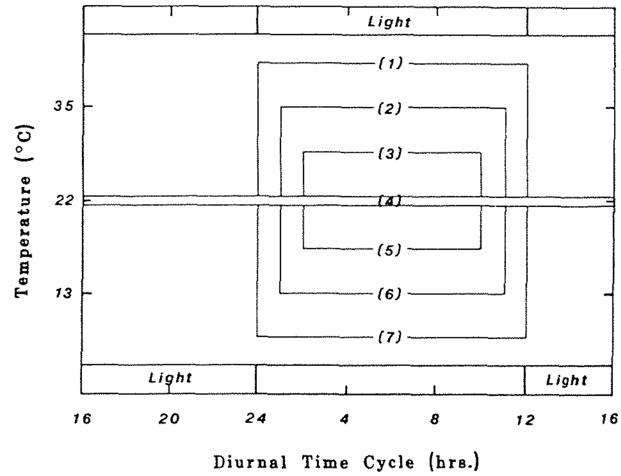

Figure 1.--Treatments used in screening seed responses to different temperature regimes. Solid lines indicate deviation above (1,2,3) or below (5,6,7) constant 22°C (4) relative to time within a 24-hour cycle. Light exposures associated with treatments 1,2,3 and 4 are indicated on the upper edge of the figure; while treatments 5,6, and 7 were represented on the lower portion.

Data Collection and Analysis

Seeds within each treatment were inspected every two days. A seed was considered germinated when the radical had visibly initiated geotropic curvature. The rate of germination (G_{50}) was determined for each treatment by measuring the days from sowing required to achieve 50% of the maximum potential germination. The rate of germination determined in this manner provided a means of comparing relative germination potentials among the various treatments. Mean rates and their respective standard errors (SE) were calculated for each treatment.

RESULTS AND DISCUSSION

Temperatures during a 24-hour day were alternated between 22°C and less favorable temperatures for germination, 13°C and 35°C (Fig. 1). The germination results from all treatments indicated that a 12-hour exposure to either temperature extreme elicited the greatest treatment response. Consequently, only data from treatment 1 (12 hours at 35°C) and 7 (12 hours at 13°C) were used in the study evaluation. Responses to treatment 1 and 7 were compared to the more favorable temperature represented by treatment 4 (constant 22°C).

The reductions in germination previously reported (Barnett, 1979) in response to the temperature extremes examined in this study, 13°C and 35°C, were not observed when alternated with a more moderate temperature, 22°C. The germination of loblolly seed was actually accelerated at the higher temperature regime (treatment 1) in contrast to germination taking place under less severe conditions present in treatment 4 (Fig. 2). Seed incubated under temperatures alternating between 35°C and 22°C (treatment 1) achieved 50% germination almost 3 days before seed incubated under the lower regime in treatment 7. The southern source germinated more slowly than the northern source as indicated by an additional 1 to 1.5 days required to achieve 50% germination (Fig. 2). This delay in the rate of germination could have been attributed to the source difference (Villiers, 1972). However, the limited number of sources screened in this particular study did not permit such an interpretation. Additional investigations have shown that the southern source was expressing a deeper level of dormancy than the northern source which explained the slower germination with equal stratification time (unpublished data). The final germination of either loblolly seed source was unaffected by any of the temperature regimes. The general response of loblolly seed to the various temperature regimes was a relatively constant increase in the speed of germination (G_{50}) with increasing temperatures.

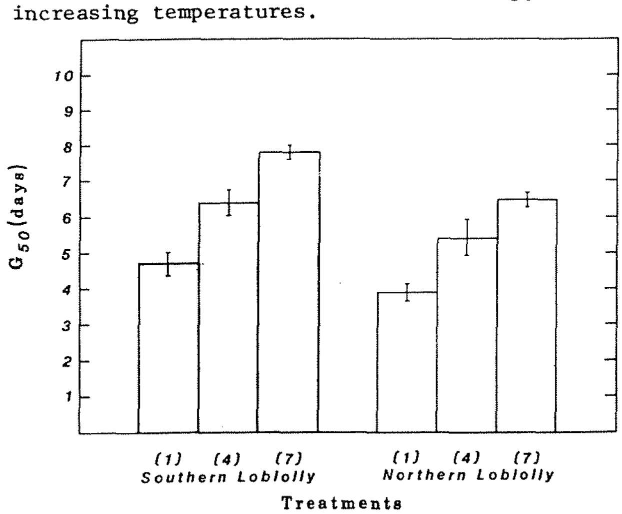

Figure 2.--Rate of germination (avg. $G_{50} \pm$ SE) for a southern and northern source of loblolly pine incubated under temperature regimes 1, 4, and 7.

The germination pattern displayed by both shortleaf sources paralleled the data from similar treatments using loblolly seed. The rate of germination was slower at the lower temperature regime, treatment 7 (Fig. 3). Both sources of shortleaf required approximately 6 days to achieve 50% germination at the lower temperature regime. The same sources incubated at the higher temperature regime, treatment 1, reached 50% germination within approximately 3 days after sowing. The final germination was not affected by any of the treatments.

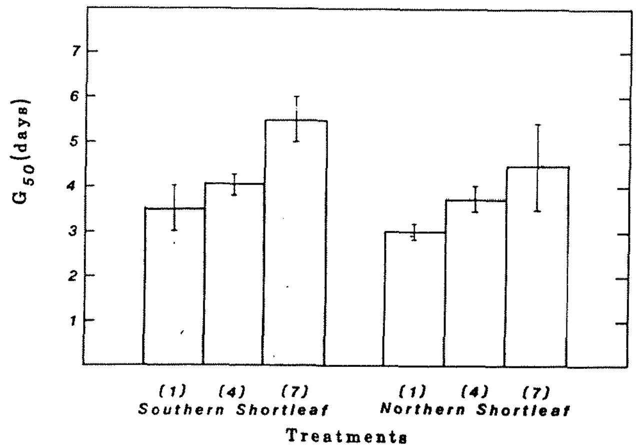

Figure 3.--Rate of germination (avg. $G_{50} \pm$ SE) for a southern and northern source of shortleaf pine incubated under temperature regimes 1,4 and 7.

The germination pattern exhibited by longleaf seed in response to the various treatments was quite different from patterns observed in loblolly and shortleaf. There was a tendency for germination rates (G_{50}) to decrease as the incubation temperature for longleaf seed was increased (Fig. 4). In spite of very little change in the rate of germination, a relatively large increase in the standard error of the mean G_{50} value was observed at higher temperatures. This increase in variation around the mean germination rate reflected a more erratic germination pattern typical of seed incubated under stressful conditions (Barnett, 1977[6/]; Heydecker, 1977). In contrast to only slight changes in germination rates, the final germination percentages after incubation for 28 days were significantly reduced by treatment 1 (Fig. 4). Germination was decreased from a maximum of 90% in treatment 7 (12 hours at 13°C) to 50% in treatment 1 (12 hours at 35°C). Consequently, longleaf responded more favorably to lower temperatures than loblolly and shortleaf.

6/ Ibid.

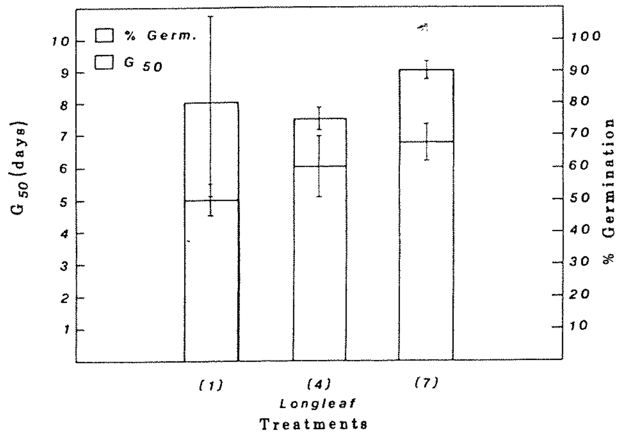

Figure 4.--Rate (avg. $G_{50} \pm$ SE) and final (avg. % $\pm$ SE of total population 28 days after sowing) for a field collected source of longleaf pine incubated under temperature regimes 1,4 and 7.

An earlier study (Barnett, 1979) showed that constant exposure to 35°C and 13°C was detrimental to the germination of loblolly, shortleaf and longleaf pine seeds. Our more recent study has proven that these same temperature extremes were quite acceptable if alternated with less severe temperatures such as 22°C. The alternation of the extremes, 35°C and 13°C, with a more optimal temperature (22°C) actually improved germination patterns relative to incubation at constant 22°C. However, the response varied according to species.

APPLICATION

In the development of a production system for loblolly, shortleaf and longleaf, the grower will require at least two different temperature regimes. This might be accomplished by taking advantage of seasonal temperatures and starting each species during periods when natural temperatures would aid in achieving some optimum regime within the greenhouse. Simultaneous growing of all three species is slightly more complex with regard to germination. However, the grower could take advantage of seasonal temperatures and start the species most suitable for the natural temperature regime outdoors. Species less suitable for germination would be started in the greenhouse under a controlled temperature regime. This procedure would maximize the germination potential of all three species examined in this study. Subsequent growth would take place under controlled conditions using a temperature regime which optimized the simultaneous growth of all three species.

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PRODUCING PLANTABLE SEEDLINGS[1/]

James P. Barnett[2/]

There are numerous differences in growing techniques used in bare-root and containerized seedling production. Container-growing regimes require closer daily control because the volume of medium available to the seedling is small and the environmental conditions present in most facilities can result in the rapid development of disease or other problems.

One critical aspect of starting up a container-growing facility that has not been addressed by our speakers is choosing a qualified "grower" or greenhouse manager. Unfortunately, forestry school graduates are not well trained to grow seedlings under greenhouse conditions and horticulturists are generally not familiar with producing conifers. Therefore, the assignment as greenhouse manager must be made more on interest and potential than current knowledge and ability.

An important element in developing expertise is to give an individual the responsibility and the time to learn the system. Make the position his first responsibility, even though you may have a small operation. Daily inspection and time to live with the seedlings and learn biological responses specific for the species and facilities is essential. If the manager is observant, the specifics of greenhouse culture will develop quickly. By all means, learn from others' experience. Many aspects of seedling culture for the southern pines have been developed to the point that some guidelines are available. However, there is considerable variation in seedling response related to container systems, species, season, and facilities.

In the near future, we hope to publish a "Handbook for growing containerized southern pines." While this will not provide final answers to all questions of rearing containerized seedlings, it will provide assistance to those beginning new container-growing operations.

1/ Presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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RELATING SEEDLING MORPHOLOGY TO FIELD PERFORMANCE OF CONTAINERIZED SOUTHERN PINES [1/]

John M. McGilvray
and
James P. Barnett[2/]

Abstract.--Many initial morphological characteristics are related to field performance of container-grown southern pines. Of these, only seedling height at the time of outplanting has consistently shown a relationship to future field performance. Containerized seedlings appear to have different requirements for outplanting than bare-root seedlings. Although the data are preliminary, some suggestions for containerized loblolly pines are presented.

INTRODUCTION

Containerized seedlings of low vigor or poor quality can survive if soil moisture and other environmental conditions at the time of outplanting are near optimal. However, when less favorable conditions are met soon after outplanting, the morphological and physiological conditions of the outplanted seedlings are closely related to their ability to survive. A number of workers have noted that seedlings that are large and woody survive and grow better than smaller seedlings on difficult sites or where competition is severe (Iverson and Newton 1980, Davidson and Sowa 1974, Walker and Johnson 1980, Barnett 1974). Southern pine seedlings are usually large enough at 12 to 14 weeks to perform well in the field. A few more weeks of growth may be desired when planting is on more difficult sites. Age alone, however, is not a reliable criterion of when to plant, because seedling development varies greatly by season, facility, and cultural treatment.

Almost 30 years ago, Wakeley (1954) established a grading system based on morphology for bare-root southern pine seedlings. This grading system, based primarily on height, diameter, and nature of the stem, is still the best available. However, because there are basic differences in age, development, and cultural regimes between bare-root and container-grown seedlings, grades established for bare-root stock may not be the same as for those grown in containers. Over the past several years we have tried to determine which morphological characteristics of containerized seedlings relate directly to field performance. Data obtained from four preliminary studies, referred to as Studies 1, 2, 3, and 4 throughout this paper, are discussed.

CHARACTERISTICS EVALUATED

A variety of seedling characteristics have been directly related to field performance at one time or another. These include: shoot/root ratio, height, stem diameter, dry weight, chlorophyll content, secondary needles, and mycorrhizal development. The value of these measurements as indicators of performance for container-grown seedlings varies greatly.

Shoot/Root Ratios

Seedlings usually have been reared with the view that a seedling with a shoot/root ratio between 1 and 2 would perform better after planting (Ferdinand 1972, Wakeley 1954). Recent work by Walker and Johnson (1980) with northern species of spruce and pine shows that much higher shoot/root ratios may be better for container-grown seedlings. Regression analyses of their data indicate that the weight obtained 1 year after planting is proportional to initial seedling weight and shoot/root ratio; larger seedlings with shoot/root ratios of up to 7.4 had significantly greater weight increases than smaller seedlings with ratios of 2.0. A similar relationship was found with the southern pines when shoot/root ratios were related to seedling height (fig. 1).

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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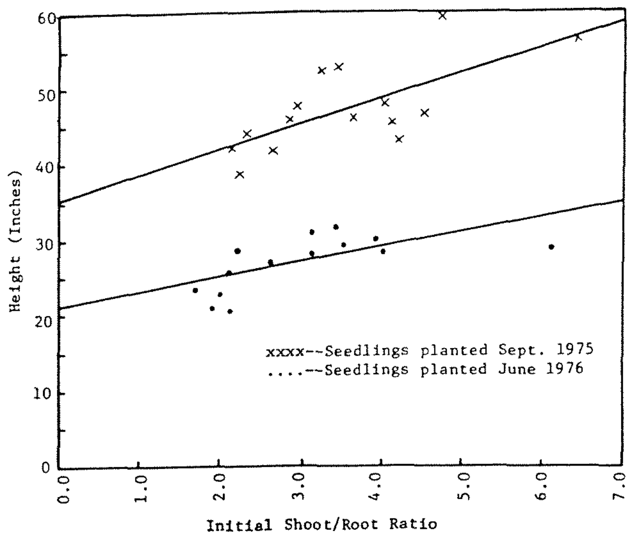

Figure 1.--Initial shoot/root ratio and seedling height relationships 2-1/2 and 3-1/4 years after outplanting (Study 1), based on two separate outplantings of loblolly pines.

It is apparent from the data shown in figure 1 that a so-called "balanced" seedling is not necessary or even desirable with container-grown plants. In our work with container-grown seedlings, higher shoot/root ratios are more a function of larger shoots than variations in root size. Therefore, we have concluded that shoot/root ratio is generally not a meaningful criterion when evaluating containerized southern pine seedlings.

Chlorophyll Content

Chlorophyll content in seedling needles has been shown to give an estimate of stock quality (Sutton 1980). In one of our studies, the chlorophyll content of the needles at planting was correlated to the height of the pine seedlings 1, 2, and 3 years later (Table 1). In this particular study, high chlorophyll content related well to seedling vigor. However, different nutritional regimes were practiced during the greenhouse growing period, and thus differences in seedling quality may have been due to a close relationship between chlorophyll and nitrogen contents. Chlorophyll is generally a nonspecific indicator that is influenced by many factors. When seedlings are grown with abundant nutrients, chlorophyll content will probably not be closely related to field performance.

Mycorrhizae

The visible presence of mycorrhizae on slash and loblolly pine seedlings indicates increased survival of nursery stock (Jorgensen and Shoulders 1967, Shoulders and Jorgensen 1969). The amount of mycorrhizae can have a significant effect on survival and growth of southern pine nursery stock.

The need for mycorrhizal development on container-grown seedlings is probably not as great as with nursery-grown plants because the root system remains intact when planted and initial stress conditions are less. Shortleaf pine seedlings grown in containers and inoculated with *Pisolithus tinctorius* and *Thelephora terrestris* mycorrhizae did not survive or grow better than those that were not inoculated when outplanted on dry sites in the Ouachita Mountains of Arkansas (Ruehle et al. 1981). In fact, performance of inoculated seedlings with over 50 percent root infection was no better than for seedlings grown under a high fertility regime where only 16 percent of the roots showed mycorrhizae.

This apparent less critical need for mycorrhizae on containerized seedlings is fortunate because the high-fertility regimes generally used in production seem to inhibit mycorrhizal development. The presence of mycorrhizae on root systems becomes more important as the planting sites become more difficult. Goodwin (1980) reported that inoculation with *Pisolithus* increased field performance of container-grown loblolly and Virginia pine on an adverse borrow site.

Secondary Needles

The development of fascicle or secondary needles is one criteria used by Wakeley (1954) in his seedling grading system for nursery stock. Our tests with container-grown southern pines show that the presence of secondary needles is an important indicator of seedling development (Barnett 1980). Secondary needles develop when the stem becomes woody and stiff. This condition represents a stage when the seedlings become more hardy and less susceptible to cold and drought damage. Thus seedlings that have secondary needles are more vigorous than those that have not yet reached this stage of development.

Stem Diameter

Stem diameter was shown to be a characteristic closely related to seedling development of loblolly and shortleaf pine in Study 1 (Table 1). Study 2 confirmed the relationship of stem diameter of loblolly pine to seedling growth after outplanting (Table 2). However, diameter was not consistently related to field survival. For example, longleaf stem diameters were correlated with survival in Study 2 (Table 2) but not in Study 1 (Table 1).

Table 1.--Summary of correlation coefficients relating initial seedling development to field performance (Study 1). Seedlings outplanted June 22, 1976

Seedling characteristics	Survival: Feb. 1977	Survival: Feb. 1978	Survival: Feb. 1979	Height: Feb. 1977	Height: Feb. 1978	Height: Feb. 1979
			Loblolly Pine[1]			
Height	0.021	0.238	0.324	0.972*	0.743*	0.738*
Diameter	.168	.361	.455	.913*	.819*	.833*
Root weight	- .345	- .259	- .339	- .078	- .225	- .259
Stem weight	.049	.294	.315	.870*	.646*	.655*
Chlorophyll	.235	.418	.595*	.771*	.915*	.899*
			Longleaf Pine[2]			
Diameter	.079	.046	.020	- .106	- .112	- .162
Root weight	.534*	.522*	.479	- .396	- .435	- .431
Stem weight	- .252	.296	.176	.548*	.590*	.555*
Chlorophyll	- .418	- .566*	.443	.866*	.810*	.798*
			Shortleaf Pine			
Height	.052	.147	.283	.929*	.829*	.784*
Diameter	- .142	- .058	.099	.761*	.760*	.687*
Root weight	.170	.157	.182	- .061	- .021	- .057
Stem weight	.030	.128	.249	.773*	.743*	.666*
Chlorophyll	.281	.193	.302	.913*	.861*	.832*

1/ An asterisk represents statistical significance at the 0.05 level.

2/ Longleaf growth was evaluated by measuring root-collar diameter (inches) rather than height.

Table 2.--Summary of correlation coefficients relating initial seedling development to field performance (Study 2). Seedlings outplanted June 27, 1977

Seedling characteristics	Survival: March 1978	Survival: Feb. 1979	Survival: Jan. 1980	Height: Feb. 1979	Height: Jan. 1980
			Loblolly Pine[1]		
Height	0.441	0.497*	0.481	0.430	0.615*
Diameter	.475	.532*	.522*	.496	.601*
Root weight	.519*	.527*	.514*	.368	.476
Stem weight	.417	.470	.460	.432	.518*
			Longleaf Pine[2]		
Diameter	.320	.317	.346	.670*	.510*
Root weight	.534*	.514*	.495	.196	.222
Stem weight	.131	.149	.207	.292	.384

1/ An asterisk represents statistical significance at the 0.05 level.

2/ Longleaf growth was evaluated by measuring root-collar diameter (inches) rather than height.

These studies indicate that stem diameter, an easily measured characteristic, is indicative of seedling growth, if not survival. The combinations of stem diameter with other easy measureable properties should improve predictions of field performance.

Seedling Heights

The height of a seedling when outplanted is generally a good indicator of subsequent field performance (Walker and Johnson 1980, Iverson and Newton 1980). Our studies with container-grown southern pines confirm this observation (Tables 1 and 2). Not only is height at time of outplanting closely related to subsequent heights, but it is also correlated to incremental growth for a number of years (Table 3). How long this relationship will hold is open to question. Blair and Cech's (1974) work with slash pine nursery stock has shown that Wakeley's Grade 1 and 2 seedlings produced significantly more volume after 13 years than Grade 3 seedlings (fig. 2). In Wakeley's morphological grades, height is a major criterion, with the lower grades exhibiting greater seedling height. Similar results have been published for loblolly and slash pine after 30 years (Wakeley 1969).

Heights and diameters should both be considered when developing predictions of field performance. If containerized seedlings are grown at high seedling densities, heights may be about the same as when grown at lower densities, but stem diameters of the seedlings grown at the lower densities will be larger, and they have been shown to perform better in the field (Barnett 1980).

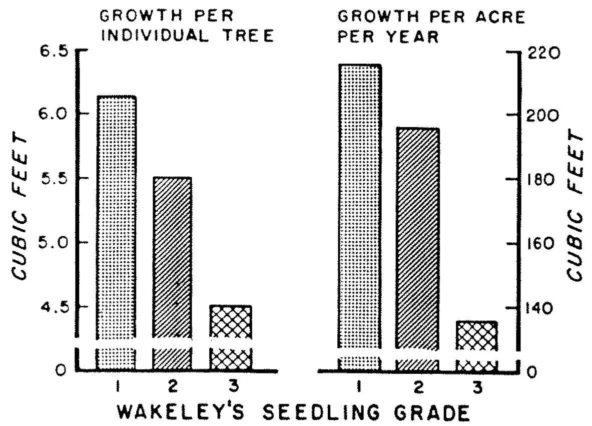

Figure 2.--Volume performance of graded slash pine seedlings after 13 growing seasons (Blair and Cech 1974).

Table 3.--Correlation coefficients of morphological characteristics of loblolly pine seedlings with heights and growth in the field (Study 3). Outplanted February 1976

Seedling characteristics	Height: 1 year	Height: 2 years	Height: 3 years	Growth/year: 1st year	Growth/year: 2nd year	Growth/year: 3rd year
Height	.864*[1/]	.814*	.829*	.490*	.770*	.840*
Stem diameter	.899*	.864*	.832*	.579*	.826*	.842*
Root weight	.700*	.641*	.628*	.386*	.594*	.582*
Stem weight	.890*	.837*	.847*	.536*	.790*	.846*

1/ An asterisk represents statistical significance at the 0.05 level.

Dry Weights

Dry weights of seedling stems at the time of outplanting were correlated with heights in the field over several years (Tables 1, 2, and 3), but were not closely related to survival. Correlations of dry weights of roots at outplanting to survival in most instances did not occur consistently. Only in Study 1 was root weight related to field survival of longleaf pine (Table 1). In Study 2, correlations between root weight and survival occurred with both loblolly and longleaf pine (Table 2). In this study, initial root weights did not relate to seedling height increases. Correlations of both height and growth to dry weights did occur with loblolly pine in Study 3 (Table 3). Differences in response among studies seem related to environmental conditions at or shortly after planting.

SUGGESTED CHARACTERISTICS FOR LOBLOLLY PINE

There is an insufficient amount of data at this time to specify the optimum characteristics of containerized southern pine seedlings to obtain maximum survival and growth when outplanted. Our best information is for loblolly pine, but these data are from studies not designed to provide predictive equations relating initial seedling quality to field performance. However, these data are probably the best available for the southern pines and will give some feel for the relationship between morphology and growth.

There is considerable difference in the ease and reliability of measuring the various seedling characteristics that relate to field performance. Characteristics such as chlorophyll content, dry weights, and shoot/root ratios are not as easy to determine as are seedling heights or diameters. Our results indicate that simplification of measurements may be feasible. For example, seedling stem diameter at the time of outplanting is closely related to initial height (fig. 3). This initial stem diameter is also related to seedling heights in the field 2 and 3 years after planting (fig. 4). Correlations of stem dry weight with height after outplanting are also significant (fig. 5). These correlations are similar to those that relate initial height to field heights 1, 2, or 3 years later (fig. 6).

As long as the type of container and cultural treatment remain constant and provide for good quality seedlings, height at the time of outplanting seems to be the best single morphological indicator of field performance. It is easily measured and is related to field performance. Other visual criteria, such as presence of secondary needles and woody tissue, should also be taken into consideration.

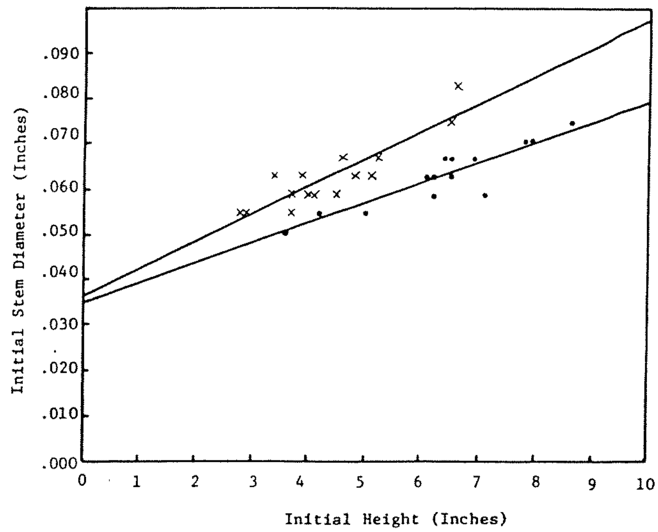

Figure 3.--Initial height and stem diameter relationship for loblolly pine seedlings (Study 1) based on two separate outplantings.

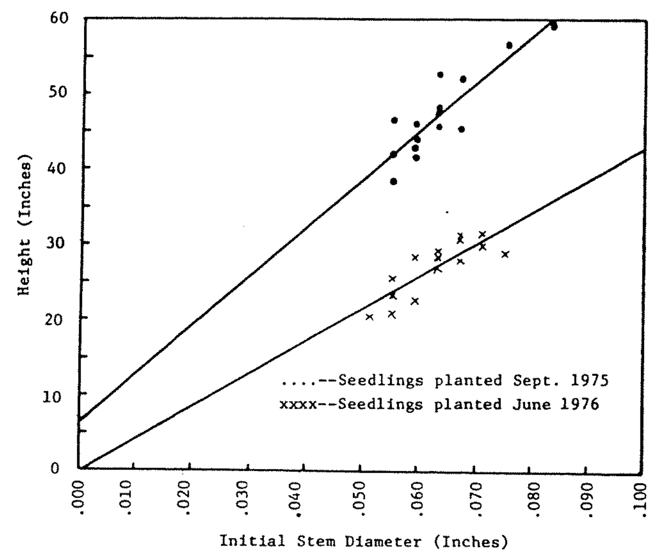

Figure 4.--Initial stem diameter and height relationships for loblolly pine seedlings 2-1/2 and 3-1/4 years after outplanting (Study 1) based on two separate outplantings.

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DISEASES OF CONTAINER-GROWN SOUTHERN PINE SEEDLINGS AND THEIR CONTROL[1/]

William H. Pawuk[2/]

Abstract.--Seed and soilborne diseases caused by *Fusarium* sp. are the most commonly observed diseases in container culture. Airborne diseases are of minor importance. Sound cultural practices and use of fungicides can effectively control disease problems. Fungicides can be chosen that do not inhibit seed germination or ectomycorrhizal development.

INTRODUCTION

Pathogens that cause diseases of southern pine seedlings in bare-root nurseries can cause similar diseases when seedlings are container-grown. Fortunately, not all diseases found in bare-root nurseries have been problems in container seedling culture. The greenhouse environment in which most container seedlings are grown, differs greatly from the bare-root nursery. Consequently, disease development in container nurseries may be more rapid and intensive. Also, the relatively high cost of container seedlings makes disease loss more serious on a seedling-per-seedling basis than in bare-root nurseries.

While the greenhouse environment can create problems, the nursery manager can control the environment much more than when seedlings are grown outside. He can regulate temperature, humidity, soil moisture, and soil fertility to a great extent. Pesticides can be applied effectively to control diseases and insects.

To control disease losses, a thorough understanding of the pathogens and the conditions necessary for infection is essential. This paper discusses the diseases that have been observed in container-grown southern pine seedlings and suggests methods of control.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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SEEDBORNE DISEASES

In the past, seed fungi on sound southern pine seeds have not been considered a problem because most observations indicated the fungi were saprophytic and did not affect germination (Belcher and Waldrip 1972). With the advent of container culture it has become apparent that seedborne fungi can be important causes of seedling mortality. Pawuk and Barnett (1974) associated *Fusarium* infection of container-grown longleaf pine (*Pinus palustris* Mill.) seedlings with retention of infested seedcoats. Cotyledons become infected and the disease spreads to the stem, resulting in mortality. Further studies showed that five species of *Fusarium* that were cultured from longleaf pine seed were pathogenic on longleaf pine seedlings (Pawuk 1978). Mason and Van Arsdel (1978) discovered *Fusarium moniliforme* in abundance on loblolly pine (*P. taeda* L.) seed from Texas seed orchards. It consistently caused top infection damping-off in inoculation trials.

To determine the extent of *Fusarium* infestation on southern pine seed, I sampled 100 seeds from each of 10 seed lots of longleaf, loblolly, slash (*P. elliottii* Engelm.), and shortleaf pine (*P. echinata* Mill.).

All seed lots were infested (Table 1). Slash pine seed was most heavily infested (90.6%), shortleaf (82.5%) and loblolly (78.8%) intermediate, and longleaf the least infested (53.9%). Although longleaf is least infested, disease losses are usually greater in longleaf, perhaps owing to longer retention of seedcoats and its growth habit.

Table 1. Percentage of southern pine seed infested with *Fusarium*, 10 seed lots, 100 seeds per lot 3/

	Slash	Shortleaf	Loblolly	Longleaf
	Percentage			
Range	31-100	23-100	18-100	7-99
Average	90.6	82.6	78.8	53.9

Fungicides applied as seed coatings provide a chemical barrier between germinating seeds and soil fungi. Furthermore, they prevent infection by fungi already present on the seeds. While fungicides may reduce seedling loss (Hamilton and Jackson 1951, Carlson and Belcher 1969), heavy doses often reduce germination (Carlson and Belcher 1969, Peterson 1970).

Because of container production's high costs, fungicides must control diseases without sacrificing quick vigorous germination. Several fungicides were tested for their effect on the germination of slash pine, loblolly pine, shortleaf pine, and longleaf pine seeds (Pawuk 1979). Fungicides were tested at 1, 2, 4, 8, and 16 oz ai per 100 lb. seed applied as a water slurry and the seed dried overnight. Results are shown in Table 2.

Table 2. Maximum fungicide dosages that did not inhibit seed germination of four southern pines

Fungicide	Slash	Loblolly	Shortleaf	Longleaf
	Oz. ai/100 lb. of seed			
Captan 50 WP	16	16	16	16
Arasan 42-S	16	16	16	16
Terraclor 75 WP	4	16	16	8
Demosan 65 WP	4	16	16	8
Truban 30 WP	2	8	16	16
Banrot 40 WP	2	4	2	4
Dexon 35 WP	2	4	2	8
Terra-Coat SD-205 25 WP	2	8	4	16
Mertect 42 F	1	8	4	4
Benlate 50 WP	1	4	2	2
Busan[R] 72 60 EC	0	4	2	4
Terra-Coat L-205, 30 L	0	4	2	4
	Percent			
Control germination	90	86	78	58

Slash pine seed was the most sensitive to fungicides. Longleaf and loblolly were most tolerant and shortleaf was intermediate. Captan and Arasan had the least effect on germination.

3/ W. H. Pawuk, unpublished data.

All other fungicides reduced germination of one or more species. This does not suggest that all other fungicides should be discarded from consideration. Some may be quite effective against disease organisms at levels nontoxic to seed. Furthermore, these tests were conducted in closed germination trays. Germination in the greenhouse may not be so adversely affected as fungicides are washed from the seed with each watering.

For special seed lots, such as those used in breeding programs, disinfecting the seed with hydrogen peroxide may be desirable.

Even good fungicides may not eliminate *Fusarium* entirely. Miller and Bramlett (1978) found that *Fusarium* and *Diplodia* may be present in the megagametophytes and embryos of loblolly and slash pine seed. Slash pine cones and seeds are susceptible to infection before cone maturation.

SOILBORNE DISEASES

This discussion includes diseases commonly referred to as damping-off or root rot that are caused by fungi present in the growing media. It includes those that may in a strict sense be waterborne, that is they are introduced into the soil by contaminated irrigation water.

Species of *Fusarium*, especially *F. moniliforme*, are the fungi most commonly cultured from diseased seedlings and growing media. Attempts to culture *Fusarium* from potting mixes prior to sowing have been unsuccessful. This indicates that it gets established and develops after containers are placed in the greenhouse.

I have cultured *Fusarium* from air and water samples in and around greenhouses, but always at low levels. While these sources cannot be ruled out, spread from infected seedlings during watering is probably the most important source. *Fusarium* can often be seen producing abundant spores on infected seedlings. It spreads to the soil where there is a buildup of *Fusarium* with time. Fortunately, seedlings become more resistant to infection as they mature.

Rhizoctonia has been observed on container-grown longleaf pine seedlings. In all cases it developed during periods when seedling foliage was wet for extended periods. Spread is from seedling to seedling with the mycelium easily seen. The source of *Rhizoctonia* is not known. It is a common soil fungus that spreads in nature by movement of infected soil or plant debris from one area to another. It could easily be brought into greenhouses, as could other soil fungi, by workers or on tools and equipment. *Rhizoctonia* has been observed attacking seedlings in germination trays in the lab.

Water molds such as *Pythium* and *Phytophthora* may enter container nurseries through contaminated irrigation water or by methods previously mentioned. They are favored by wet, poorly drained soils and cause root rot and damping-off of young seedlings. As seedlings mature, they become more resistant, but root development and seedling growth can be reduced.

Sound cultural practices can go a long way in preventing disease loss. Media should be pathogen free from the start. It should be well drained and seedlings should not be over watered. Equal parts of peat and vermiculite can be mixed to make a growing medium that combines high cation exchange capability, good moisture retention, and low pH (Phipps 1974). Commercial media are available but most of these were developed for other crops and have a high pH. Growth may be acceptable but disease development is favored.

Inoculation studies on longleaf seedlings by Pawuk (1981) using *Pythium* and *Fusarium* compared disease development using several media. Best growth was with equal parts peat and vermiculite (Table 3). Less growth, but even better disease control was achieved using pine bark, pine bark-vermiculite, or pine bark-soil. Commercial peat vermiculite, or pine bark-vermiculite mixes, with a higher pH, had the greater disease incidence.

Table 3. Growth and disease development of longleaf seedlings grown on peat and bark media

Medium 4/	Final pH	Dry weight	*Fusarium*	*Pythium*
		mg	-----% loss------	
Peat				
PV-50	5.1	798a 5/	0a	40b
Jiffy Mix	6.2	755a	8bc	94e
Bark				
BV-50	5.2	510bc	0a	24ab
BV-70	4.9	452cd	0a	16a
BV-100	4.6	460cd	2ab	6a
BS-70	5.1	530b	0a	16a
Jiffy 50-50	6.4	420d	16d	68d
Jiffy 70-30	6.4	410d	12c	88e

FUNGICIDES

Several fungicides are available that will control damping-off and root rot if applied correctly. There is no one fungicide cure-all that gives protection against all pathogens.

4/ The number following the medium designation indicates the percentage of peat or bark present.

5/ Means followed by the same letter are not significantly different, Duncan's Multiple Range Test at the 0.05 level.

I have tested several fungicides for control of *Fusarium* and *Pythium*. Best results were with Benlate for *Fusarium* and Truban for *Pythium* at rates recommended on the label. When applied correctly, they give good disease control without phytotoxicity.

During studies with Benlate, applications were made immediately following sowing with no loss in germination. Truban was not tested this way, however.

Fungicides affect mycorrhizal development. Responses vary with fungicides and mycorrhizal symbionts. Not a great deal of work has been done in the area with southern pines, but some data are available. Pawuk and others (1980) tested the effect of several fungicides on the development of ectomycorrhizae on longleaf seedlings grown in pine bark media.

Pisolithus tinctorius ([Pers.] Coker and Couch) was completely inhibited by Terraclor, reduced by Captan and Dexon, not affected by Mertect and Truban, and stimulated by Benlate and Banrot. *Thelephora terrestris* (Ehr.) was greater on seedlings drenched with Benlate, Mertect, and Dexon than on the control. Terraclor and Truban reduce *T. terrestris*. Seedlings drenched with Terraclor had poor lateral root development suggesting that repeated use of this fungicide should be avoided in container nurseries.

Additional tests found that shortleaf pine seedlings grown in peat-vermiculite and drenched with Benlate, formed more mycorrhizal roots than undrenched seedlings (Pawuk and Barnett 1981). *Pisolithus* formed best at the highest level tested, 10 mg per seedling every 2 weeks. Highest Benlate levels also produced the largest seedlings.

Recently Marx and Rowan (1981) reported that drenches of Benlate and Captan increased mycorrhizal development by *P. tinctorius* and *T. terrestris* on loblolly pine in a bare-root nursery. Terraclor had no effect on either symbiont but Benodanil decreased infection by *P. tinctorius*. In this study, two drenches were made in early spring so the effect of repetitive dosages was not tested.

FOLIAGE DISEASES AND RUSTS

To my knowledge, foliage diseases have not been a problem on container-grown southern pine seedlings. This is probably due to the short period necessary to grow plantable seedlings and to the absence of prolonged periods when foliage is wet. The same can be said for the rusts, although seedlings could be infected with *Cronartium* rusts and symptoms would probably not be observed before they were shipped.

The possibility of rust infection should not be overlooked. Spraying with fungicides to prevent rust infection is not necessary. However, during the spring, seedlings should be watered early in the day so foliage is dry by night. This is especially true during wet weather when rust spores are released. I have seen rust infection on slash pine seedlings in an experimental greenhouse in Louisiana. Seedlings were purposely watered in the evening so foliage would be wet during the night to favor rust infection. Infection was only 3 percent compared to 65 percent for seedlings similarly treated and grown in an adjacent open shade house. The low rate of greenhouse infection was probably due to the absence of sufficient inoculum since air movement into the greenhouse was minimal. As long as the foliage remains dry, and greenhouses are closed at night, rust should not be a problem. When container seedlings are grown or held outside, seedlings should be sprayed to avoid rust infection.

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CONTAINERIZED WHITE PINE CULTURAL METHODS AND OUTPLANTING SUCCESS ON THE CUMBERLAND PLATEAU, TENNESSEE[1/]

Ronald L. Hay and Joy K. Keegan[2/]

Abstract.--White pine seedlings were grown in greenhouse culture for 7 and 12 months using combinations of supplemental light, carbon dioxide, and fertilizer treatments. Seedlings with the greatest biomass had received the 24-hour photoperiod and supplemental carbon dioxide. Secondary leaf development was also prolific. The mist foliar applications did not favor root growth.

Outplanting survival after the first field season was least for the 2-0 bareroot seedlings and the 24-hour photoperiod containerized seedlings. Although the natural photoperiod, natural carbon dioxide seedlings were the smallest at outplanting, they survived the best of all treatments.

INTRODUCTION

Why White Pine

East Tennessee is within the commercial range of eastern white pine (Pinus strobus L.), and it is a region in which sporatic logging of white pine during this century has been strongly influenced by the intensity of market demands at the time. The Southern Appalachians were never the loci of extensive white pine logging activity, at least not similar to that which swept the Northeast and Lake States from 1850 to 1910. Still white pine has been here and it forms sizable stems in several forest types.

In the Southern Appalachians white pine occurs generally between 1200 and 3500 feet elevation on cove sites, northern aspects, and along stream bottoms (Fowells 1965, p. 330). On the Cumberland Plateau these truths are even more obvious! Scattered individuals and pockets of white pine grow along the creeks plus on the cool, moist sites of northern slopes. Extensive coverage of large acreages that so enticed the early loggers into the Northwoods is lacking. Rather, white pines are distinctly evident in and above the mixed pine:hardwood canopy as tall, scattered trees or small groups.

Forests on the Cumberland Plateau have long been logged, grazed, farmed or otherwise disturbed and todays stands reflect these abuses, superimposed upon succession and vegetation types. Most stands contain several age classes and several species representing various stages of successional development. White pine is occasionally one of these, but it is not a frequent component of any stand except where CCC plantations have survived the changing plans of man. Mostly the stands are mixtures of oaks, hickories, gum, yellow pines, and an occasional yellow-poplar, all of which are periodically tempered with a surface wildfire.

There are relatively few alternatives available to landowners who initiate forest management on their lands. Some stands have enough structure to justify and permit intensive management without starting afresh, but most stands lack structure. Species conversion is a realistic silvicultural possibility on these sites. White pine has sufficient biological economic and marketing attributes to warrant its use in species stand conversions.

White pine has demonstrated good growth in the Southern Appalachians on a variety of sites (Doolittle 1958). Only yellow-poplar on the very best sites had greater height growth than white pine in a comparison of site indices for 10 species common to the southern mountains. White pine volumes were superior for all site comparisons. Beck (1978) reported that white pine height and basal area growth on good sites were particularly impressive through 25 years, with 4.6 feet of height and 12 square feet of basal area produced per acre per year during the peak years. Volume yields were also good; such growth certainly warrants intensive management.

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With such excellent growth rates possible with white pine, high prices and ready markets complete the future for white pine. While the lower grades of oak lumber were selling for $150 to $170 per thousand board feet f.o.b. millyards on the northern Plateau in Tennessee, white pine lumber, mill-run grade, was selling for $300 to $350 per thousand. The market was so good that buyers parked their trucks at the greenchain to collect all the white pine lumber.

Containerized Culture

It can be a problem to grow white pine seedlings that have acceptable size and quality for outplanting. Some nurseries have grown them for four years as 2-2 transplants, others compromise with 3-0 or 2-0 seedlings. These programs all require substantial investments that raise the cost of seedlings. White pine seedlings at one year do not have sufficient size and they lack secondary needles that are necessary for good outplanting success. Therefore a second year in the seedbed is required, even though problems and costs mount.

Containerized seedling culture has many advantages over nursery culture, at least for some species. It's possible to start seedlings growing in containers and continue those growth processes through outplanting rather than wait for a dormant period to minimize the outplanting shock. Seedlings can be outplanted at a young age, thereby minimizing costs and some problems. The mycorrhizal inoculation possibilities are tremendous and almost unlimited. But white pine seedlings do not grow much different in containers than they do in the nursery bed during the first growing season.

White pine in containers growing under natural photoperiod and temperature regimes do not readily develop secondary leaves (Hay 1981) and they do not attain sufficient size for outplanting (Goodwin 1978). Outplanting failures are common, as influenced by time of planting and environmental conditions (Goodwin 1978). Seedlings that germinate in the spring or early summer will become dormant in autumn requiring an exposure to chilling temperatures before height growth will resume. If white pine seedlings that are suitable for outplanting are to be obtained using greenhouse containerized culture, growth amelioration treatments must produce seedlings with good-sized tops (12-20cm), secondary leaves, good root/shoot ratio, and easily plantable root plugs. Mycorrhizal infection may also be required, depending on the planting site characteristics.

The objectives of these studies were to produce white pine seedlings of acceptable size in less than eight months for outplanting on prepared forest sites using the following techniques:

a. 24-hour photoperiod,
b. carbon dioxide enriched atmosphere,
c. foliar mist spray with 25-10-10 fertilizer.

PROCEDURES

Greenhouse Culture

Treatment combinations of 24-hour photoperiod or natural photoperiod, carbon dioxide (CO_2) enriched or natural atmosphere, maintenance fertilizer (20-20-20) and topdressing (25-10-10) with a foliar mist spray were arranged in a randomized block design. Two sizes of rootrainers, Hillson (175 cubic centimeters) and super-45 (740 cubic centimeters), were used but they were not part of the design. All experiments were conducted in ventilated and cooled, glass greenhouses on the UT-Knoxville campus.

The 24-hour photoperiod was provided by a bank of 40-watt Gro-Lux fluorescent lamps spaced across each bench. The lamps were maintained within 30 to 40 centimeters of the foliage. A black, plastic screen separated the 24-hour and natural photoperiod treatments during the dark period. It was intended that seedlings in the 24-hour photoperiod be given every opportunity to grow at maximum rates, at least in relation to photoperiod.

The dark portion of the natural photoperiod treatment was interrupted by 60 minutes of incandescent light to prevent dormancy. There was no intention nor enough light intensity to aid growth during the dark period for those seedlings.

Carbon Dioxide

Carbon dioxide was supplied to one greenhouse by a propane burner from early November through late March. This period approximated the heat-requiring period; at other times ventilation was required at night. Depending on the intensity of the sun, ventilation was frequently required during daylight hours in the winter. CO_2 enrichment was only effective at night and during the heating season.

The CO_2 generator was initially active from 8:00 p.m. until 10:00 a.m. until a more efficient schedule was developed. To give the seedlings every opportunity to use the enriched CO_2 before ventilation was required, the generator was soon shut off at 5:30 a.m. Later, in an attempt to maximize CO_2 enrichment advantages and still maintain some semblance of a budget, the CO_2 generator was put on a 6:00 p.m. to 10:00 p.m. schedule. This provided a boost in CO_2 concentration for all seedlings in that house as they entered the dark-phase of photosynthesis, i.e., the assimilation of CO_2 into carbohydrates using energy transformed during the light phase. Those seedlings growing under the 24-hour photoperiod treatment clearly had an advantage because they could still transform light energy into chemical energy.

It was not possible to monitor CO_2 concentrations in the greenhouses because equipment sensitive to 300 ppm CO_2 was not available. Being fully cognizant of CO_2 toxicity at high concentrations (5500 ppm on cucumbers - Aoki and Yabuki 1977) and unable to monitor our greenhouse, the CO_2 generator controls were set according to manufacturers guidelines for the air volume in the CO_2 greenhouse. It's possible that greater growth could have been attained with higher CO_2 concentrations. CO_2 toxicity symptoms were not evident on these white pine seedlings.

Fertilizers

Nutrients were added to the growth medium as 20-20-20 liquid fertilizers applied at watering on approximate 10-day intervals. All seedlings received this maintenance fertilizer treatment. Each sampling unit was split and one-half received a foliar mist topdressing of 25-10-10 on 20 day intervals. Every precaution was made to keep the 25-10-10 on the foliage due to the adverse effects that high nitrogen levels in the growth medium have upon ectomycorrhizal development (Dixon et al. 1979).

In all subsequent work, slow-release fertilizers (18-6-12) have been thoroughly mixed with the growth medium prior to filling the rootrainers. Without regard to the potential beneficial growth effects, the ease of operational logistics completely warranted the expense of slow-release fertilizers. Topdressings of water-soluble fertilizers can still be accomplished.

Rootrainers

As greenhouse containers, rootrainers were chosen for many of the reasons that Spencer-LeMaire, Ltd. say they are so good for growing tree seedlings. But which size to use? Much of the greenhouse culture of tree seedlings has been designed to have the seedlings ready for the field within two or three months after germination. White pine growth rates will not permit such a schedule (Goodwin 1978), so some of these seedlings were grown in the greenhouse for 12 months and some for 7 months.

How much root development volume was necessary? The super-45 was the largest rootrainer available and the Hillson was medium-sized. The other component to the question was the growth medium; clearly it's a joint contribution to solving root development problems. A commercially available medium of peat, sand, pea gravel, and shredded pine bark commonly used in ornamental nursery operations for container-grown plants was chosen. It was screened through 1 cm mesh hardware cloth.

At seven months of age, a sample of the seedlings in the Hillson rootrainers was harvested. Those remaining were outplanted on the Cumberland Plateau. The seedlings in the super-45 rootrainers were all harvested at 12 months of age; none of these were outplanted.

Outplanting

Outplanting Sites

The Cumberland Plateau is an extension of the Appalachian Plateau from Kentucky into Tennessee. The western boundary is the escarpment leading to the Highland Rim and the eastern boundary is the Cumberland Mountains, at least in the northern portion of Tennessee where white pine is native. Much of the northern Plateau remains as it was historically, i.e., it's forested, it's relatively isolated in that roads aren't much more abundant than when Boone came that way, and some remnant stands similar to those of E. Lucy Braun's day still contain noteworthy trees with northern affinities such as <u>Fagus grandifolia</u>, <u>Acer saccharum</u> and <u>Taxus canadensis</u>.

The topography on the Plateau proper is gently rolling; soils are underlain by massive sandstone parentrock relatively near the surface. On the western edge, streams have greatly eroded the plateau where some steep, rather spectacular gorges dominate the topography. Upland soils are sand and more sand, shallow, and not highly productive for sustaining tree crops. Sites along the drainages are more productive and support excellent tree growth.

At age seven months, white pine seedlings grown in Hillson-sized rootrainers were outplanted on Pickett State Forest, Pickett County, TN. The outplanting sites, along the Tennessee-Kentucky border on the Cumberland Plateau, had supported mixed pine-hardwoods of medium density and value. These stands were typical for the area, having developed after a history of high-grading, frequent fires, and several years of extensive management under state ownership.

The study sites had been clearcut the previous year, and site-prepared during the autumn before spring outplanting. One site had been sheared and the slash on the second site was pushed into rows, but the stumps were not sheared. Although disking was planned, it was never accomplished due to operational scheduling difficulties. Site I, the sheared site, was a southeast aspect and Site II was a northern aspect. Both had relatively shallow soils with slight humus development, and neither had sufficient chemical or physical properties to be highly productive.

Soil analyses of composite samples selected from various slope positions were uniformly low to very low in phosphorus, potassium, magnesium, and calcium. Ph ranged from 4.6 to 4.8, lacking a pattern as to slope or aspect. These facts were expected considering the geology of the area. This site was typical for this section of the Cumberland Plateau.

Five outplanting treatments were used on each site, in 6 replications each with 25-tree plots, namely,

a) Control--2-0 bareroot seedlings
b) 24-hour light with supplemental CO_2--7-month old containerized seedlings
c) 24-hour light without supplemental CO_2--7-month old containerized seedlings
d) Natural light with supplemental CO_2--7-month old containerized seedlings
e) Natural light without supplemental CO_2--7-month old containerized seedlings.

The trees were spaced 5 x 5 feet (1.5 x 1.5m) in order to satisfy the management objectives concerning the stand after some individuals were harvested for biomass analyses by age 5. The controls were planted on 26 March and the containerized seedlings were planted on 15 May, 1980.

During July in the first growing season, survival of all trees was recorded and a subsample of competing vegetation was made using two randomly selected seedlings as plot centers for a 1 meter radius nested plot. Percent cover and frequency were recorded for grass, herbs, and woody vegetation. Height and root collar diameter were recorded for the subsample seedlings. After the first growing season (November) the same measurements were repeated plus the total height, first-year height increment, and root collar diameter were recorded for each seedling.

RESULTS

Greenhouse

Seedlings used to test the effectiveness of the greenhouse culture techniques were measured and analyzed for height, root collar diameter, biomass of the tops and roots and root/shoot ratio. Table 1 is a summary of the adjusted means. Comparisons between ages should be made with the knowledge that there were differences in rootrainer sizes. However, neither the 7 nor the 12 month seedlings developed root systems that utilized the full-capacity of the rootrainer cavity. Neither did the roots hold the medium together well enough to ease handling during outplanting. This was an early indication that the growth medium was not wholly acceptable for greenhouse containerized seedling culture.

Light

The effects of photoperiod are presented in Table 1. Continuous light caused seedlings to grow more slowly in height than natural photoperiod, yet all biomass variables were significantly greater for the 24-hour photoperiod treatment. Height differences at 7 months were not significant, but after 12 months the seedlings grown under natural photoperiod were significantly ($P < 0.01$) taller. The trend in height growth at 7 months was verified at 12 months.

The 24-hour photoperiod treatment generally produced more than twice as much top and root biomass as the natural photoperiod during both the 7 and 12 month periods ($P < 0.01$). The accrued growth during the additional 5 months of the 12 month treatment produced biomass increases of 300 to 400 percent. Further tests using the same sized rootrainer for varying periods are now underway.

Particularly noteworthy were the changes in dry weight root/shoot ratios. At 7 months the root/shoot ratios were 25.4 and 19.1 percent respectively for 24-hour and natural photoperiods, i.e., the root dry weights were 1/4 and 1/5 as large as the top dry weights.

That's not enough roots! At 12 months, the root/shoot ratio had doubled from 7 months, and the proportions between photoperiod treatments were maintained. The changes in root/shoot ratios were due to proportionally greater increases in root biomass than in shoot biomass.

Carbon Dioxide

The effects of CO_2 enrichment were not as great as those attributed to light. At seven months, the root fresh weight was significantly greater for seedlings grown in the CO_2-enriched house, but there were no differences in root dry weight or in root/shoot ratio. After 12 months, the only significant difference was the root collar diameter of plants with supplemental CO_2. The CO_2 generator did not operate during the last 5 months of the 12 month treatment, due to greenhouse ventilation requirements.

Although there were few significant differences between CO_2 treatments, the evident trends all showed greater growth to have occurred on seedlings in the CO_2 house.

Fertilizer

At 7 months, the foliar topdressing treatment had slowed seedling height-growth, however, by 12 months this difference was not apparent. The topdressing seemed to have negligible effects on seedling top biomass, but after seven months a trend was developing that showed high-nitrogen topdressing to not be conducive to root biomass. After 12 months this trend was confirmed, for root biomass was significantly less ($P < 0.01$) on those seedlings receiving foliar topdressings of 25-10-10. Root/shoot ratio was also significantly less.

Outplanting

Growth, survival, and competing vegetation importance were measured in July and November of the first growing season in the field.

Table 1.-- Growth of eastern white pine seedlings in greenhouse culture for 7 and 12 months using light, carbon dioxide, and fertilizer treatments.

Greenhouse Treatment	Height	Root Collar Diameter	Top Biomass fresh	Top Biomass dry	Root Biomass fresh	Root Biomass dry	Root/Shoot dry wt
	cm	mm	g	g	g	g	%
Photoperiod							
24-hour							
7-mos	7.3	2.3a	2.85a	0.84a	0.77a	0.20a	25.4a
12-mos	9.3y[1/]	3.4	5.77x	2.52x	2.90x	1.30x	53.9x
natural							
7-mos	7.4	1.7b	1.39b	0.38b	0.35b	0.07b	19.1b
12-mos	10.5x	2.8	4.96y	1.41y	1.40y	0.51y	38.3y
Carbon Dioxide							
enriched							
7-mos	7.1b	2.0	2.11	0.64	0.63a	0.15	25.3
12-mos	10.1	3.2x	5.63	2.06	2.08	0.97	46.7
natural							
7-mos	7.6a	1.9	2.14	0.59	0.48b	0.12	20.9
12-mos	9.8	3.0y	5.10	1.87	2.22	0.85	45.5
Fertilizer							
Maintenance (20-20-20)							
7-mos	7.5a	2.0	2.10	0.60	0.62	0.15	24.1
12-mos	9.9	3.1	5.37	1.92	2.35x	1.01x	52.1x
Maintenance +topdressing (25-10-10)							
7-mos	7.2b	2.0	2.15	0.63	0.50	0.13	20.3
12-mos	10.0	3.1	5.36	2.01	1.95y	0.80y	40.0y

1/ The lower case letters indicate statistical significance groupings at the 99 percent level according to analysis of variance. The a-b group was used for seedlings at 7 months and x-y was used for 12-month seedlings.

Survival of the 2-0 bareroot seedlings was least of all treatments. These seedlings were sorted to some uniformity before carefully planting them in March, well within the planting season on the Cumberland Plateau. Current data are not available for comparison with survival of operational plantings in this same area.

Survival of all the containerized seedlings was significantly greater than the 2-0 bareroot stock. Table 2 showed that in July, those seedlings grown with natural photoperiod had greater than 90 percent survival. After the growing season, these treatments still had the highest survival percentages. In November both of the 24-hour photoperiod treatments were grouped with the control ($P < 0.05$) at lowest survival.

DISCUSSION

Somewhat contrasting evidence has been presented on how best to grow containerized seedlings in greenhouses for seven months and how best to maximize survival in the field after the first growing season. The largest, best-developed seedlings in the greenhouse were those growing in CO_2 enriched air using a 24-hour photoperiod, yet these seedlings showed the lowest field survival of all the containerized seedlings. Although all the containerized seedlings were similarly grouped ($P < 0.05$) by Duncan's Multiple Range Test, the 24-hour photoperiod seedlings were also grouped with the 2-0 bareroot seedling ($P < 0.05$). Their performance had not been much better than 2-0 seedlings, and neither one was highly acceptable. Greenhouse culture seedling growth attributes necessary for acceptable field performance in white pine have not been fully assessed nor appreciated.

Table 2.--Survival of white pine seedlings during the first growing season outplanted on prepared sites in Pickett State Forest.

Treatment	Survival July	Survival November
	%	%
2-0 bareroot seedlings	83.6b[1/]	78.4b
Containerized seedlings		
24-hour light w/CO_2	89.2ab	82.8ab
24-hour light w/out CO_2	89.6a	86.0ab
natural light w/out CO_2	92.8a	90.0a
natural light w/CO_2	93.2a	89.2a

1/ Lower case letters refer to those means that were grouped as equal at the 0.05 probability level by Duncan's Multiple Range Test.

Seedling Relationships

The 24-hour photoperiod and CO_2 enriched treatment seedlings had more morphological characteristics similar to the 2-0 nursery seedlings than the remaining containerized treatments, e.g., the secondary leaves. They also survived in the field about as well, but the other greenhouse treatments were superior in first-year survival. It appeared that the extended photoperiod was the major influence upon these seedlings.

Biomass of both tops and roots was especially increased by the 24-hour photoperiod and to a lesser extent by the CO_2-enriched atmosphere. These seedlings appeared to have all the attributes necessary to grow well after outplanting. The tops had good quantities of secondary leaves, height and root collar diameter development were good and there was significantly more root biomass than on those seedlings grown without extra light and CO_2. The only apparent deficiency was the root/shoot ratio, which was low, yet the root/shoot ratios of these seedlings were the highest in the experiment.

By comparison, seedlings that had been grown with natural photoperiod and ambient CO_2 concentrations were less well-developed. They had few secondary leaves, they were significantly smaller at the root collar, had a poor root/shoot ratio, and they were the same height. Most tree planters would not have made them first choice for outplanting. Yet their survival in 1980 was best for all seedlings.

Extended Photoperiod Effects

The natural photoperiod during this study was first decreasing followed by a gradually increasing daylength from December through May 15. The dormancy-inducing effects of the decreasing daylength were broken by occasional interruptions of the dark period. Therefore the natural photoperiod trees continued to grow in height, but they did not accumulate large quantities of biomass.

It's important to note that all containerized trees were outplanted during an increasing daylength. Shortly before the anticipated outplanting, all seedlings were moved to lath shade for several days under natural photoperiod and temperatures. Seedlings that had been grown under the 24-hour photoperiod experienced a sharp decrease in daylength when they were moved to lath shade but the natural photoperiod seedlings only experienced changes in temperatures. About the time the 24-hour photoperiod seedlings had recovered from that shock, they were outplanted.

Although every care was taken to minimize outplanting shock, there was a definite change in environment. There was little or no shade, water came infrequently at first and then not at all, and the temperatures were as high as they could be at that time of year. Even though care had been taken to minimize disturbance to the root plug during outplanting, there had to have been some shock and it would have been more severe on the 24-hour photoperiod seedlings.

Morphology of the 2-0 bareroot controls height growth was normal. The buds produced secondary leaves in the typical uni-nodal height growth pattern. At the termination of active height growth, buds were set for the next year. Height growth morphology of the containerized stock did not always follow this pattern.

When the containerized seedlings began active height growth after outplanting many of them grew rapidly producing primary leaves, even though secondary leaves from the greenhouse period may have already been present. It appeared that rapid growth was correlated with primary leaves production. Unfortunately, it was impossible to analyze the greenhouse growth treatments for this occurrence, but numerous seedlings were observed to have reverted from secondary to primary leaves. At outplanting, secondary leaves were frequent on the 24-hour photoperiod seedlings.

A Probable Scenario

Seedling root growth usually intensifies in early spring, prior to stem growth (Kramer and Kozlowski 1978, p. 102). Both temperature and photoperiod are stimuli influencing height growth timing and amount (Larsen 1965). Containerized seedlings grown with the natural photoperiod were able to respond to the increasing daylength before and after outplanting and they became well established through good root and shoot growth. Survival for these seedlings through the first year (90 percent) was quite acceptable.

Seedlings that were grown in the greenhouse under 24-hour photoperiod did not survive well, perhaps because they did not experience the same sequence of adjustments. It's possible that changes in photoperiod which occurred when the seedlings were moved first from the greenhouse to lath shade and then to the field caused changes in the sequences of root and shoot growth timing and amounts. These seedlings did not become well established shortly after outplanting, rather they experienced a period of adjustment to the new photoperiod and temperature regimen. Before this outplanting shock period was completed, East Tennessee was firmly in the grasp of the hottest, driest June and July ever recorded.

The outplanting sites had been fully prepared early enough in the winter that soil moisture was near maximum when spring arrived. Furthermore, site preparation had been thorough enough that competing vegetation was scarce, thereby permitting maximum soil water availability to all the white pine seedlings. Those seedlings that were ready to grow shortly after outplanting had every advantage. The weather was cloudy, wet and somewhat cool for several days after outplanting. However, in early June the record drought and heat began and lasted all summer. Seedlings that had not begun to grow soon after outplanting experienced survival problems.

In Retrospect

Containerized culture of white pine seedlings with abundant attributes normally associated with strong outplanting successes may not be the complete story. Seedlings were produced in seven months of greenhouse culture that had good secondary leaf development, good root collar diameter, and good biomass of tops and roots. They most closely resembled the 2-0 nursery stock in morphological characteristics, even though they were smaller. However, when these seedlings were outplanted, their survival was the poorest of all the containerized seedling treatments.

In the face of the hottest and driest June and July in recent history, the containerized seedlings that produced the least growth, biomass, and secondary leaves in the greenhouse, yielded 90 percent survival through the first growing season. Perhaps more importance should be given to the physiological growth conditions of seedlings when they are outplanted rather than emphasizing seedling size.

Greenhouse culture techniques should provide a quick boost to seedling growth after outplanting by providing enough biomass plus the right physiological condition at the right time. To obtain these desired results, we may need to reassess our culture programs that emphasize seedling size.

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DORMANCY AND COLD-HARDINESS OF CONTAINERZIED LOBLOLLY PINE SEEDLINGS[1/]

John G. Mexal and William C. Carlson[2/]

Abstract.--Successful regeneration using containerized seedlings is dependent upon matching the physiological state of the seedling to the physical state of the environment. This paper discusses seedling dormancy and cold-hardiness as they impact regeneration success. Methods of inducing cold-hardiness and overcoming dormancy are discussed as well as the consequences of mismatching seedling and environment.

INTRODUCTION

In 1980, the Southeastern nurseries produced over one billion seedlings. Most of these seedlings were produced in bare root nurseries, but an increasing number are being produced in containerized nurseries. Containerized seedlings offer certain advantages unavailable with bare root seedlings. Included in these advantages are: (a) relatively short start-up time; (b) short crop rotation and (c) relatively long outplanting season. The last two factors can allow for multiple cropping in a conventional greenhouse. For southern pines, as many as three crops could be grown in a single year (Barnett, cited in Tinus and McDonald, 1979). Barnett proposes the following outplanting periods for each crop: May-June, September-November, and February-March (fig. 1). However, weather conditions can limit regeneration success during the prescribed outplanting seasons. Regeneration success during the May-June planting seasons is limited by adequate soil moisture and preciptation, and seedlings can be outplanted during this period without special physiological conditioning.

Successful establishment during the other two seasons, however, may be limited by the physiological state of the seedling at time of outplanting. Two physiological criteria which are major determinants of regeneration success during these periods are the levels of dormancy and cold-hardiness attained by the seedlings. The focus of this paper will be the manipulation of these parameters to ensure establishment success.

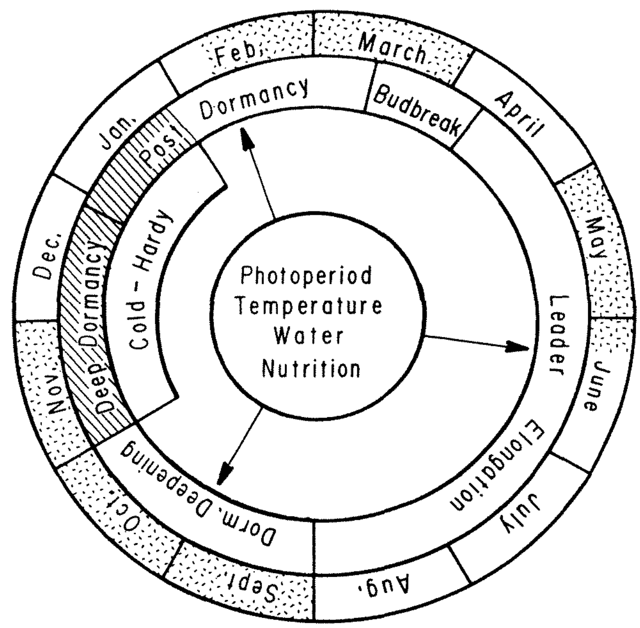

Figure 1. Growth cycle for loblolly pine. Stipled area represents outplanting seasons after Barnett (Tinus and McDonald, 1979).

DEFINITIONS

Cold-hardiness and dormancy are independent but frequently correlated biological processes. In a typical growth cycle, a seedling will become dormant prior to the development of cold-hardiness (fig. 1). Dormancy is the cessation of height growth, which will not resume without exposure to low temperature. In other words, the chilling requirement must be satisfied prior to the resumption of growth in the spring. Seedlings with a satisfied chilling requirement will grow normally and rapidly the next spring (fig. 2A).

[1/] Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981
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However, seedlings without a satisfied chilling requirement will not grow normally if at all the following spring (fig. 2B).

Cold-hardiness is the ability of a plant to survive subfreezing temperatures. The level of cold-hardiness varies seasonally from about -2°C in summer to about -40°C during mid-winter. Cold-hardiness in the fall is usually preceded by the cessation of height growth and loss of hardiness in the spring is succeeded by bud break. Unhardened or dehardened seedlings when subjected to subfreezing temperatures suffer membrane rupture, loss of intracellular water and solutes, rapid desiccation, and death (fig. 2C).

COLD-HARDINESS

Cold-hardiness can be induced by placing the seedlings outdoors in the fall, exposing them to progressively lower temperatures (Mexal, et al., 1979). Lengthening the exposure period from 0 to 6 weeks significantly increased the level of cold-hardiness as well as survival and growth (Table 1). Seedlings left in a heated greenhouse maintained their low level of hardiness (-4.3°C) throughout the exposure period. Failure to acclimate the seedlings has resulted in establishment failures following winter planting (Goodwin, 1974).

Cold-hardiness can also be accomplished by the induction of dormancy through short photoperiod (Mexal, et al., 1979). The photoperiod tested was 8 h and resulted in hardiness levels comparable to outdoor exposure to low temperatures. Growing at low density and subjecting the trees to water stress (-800 to -1700 kPa) has been proven to promote cold-hardiness of containerized Douglas-fir seedlings (Tanaka and Timmis 1974). Fertilization does not seem to impact the ability of a seedling to become cold-hardy; except in the extreme cases (Levitt, 1956, Timmis, 1975, Christersson, 1975). Still, many growers reduce nitrogen levels and fertilize with KCL in the fall to promote "hardiness". However, Hinesley and Maki (1980) failed to demonstrate any benefit to potassium fertilization in the fall. The effects of fall fertilization on cold-hardiness have not been adequately demonstrated.

It is important to understand the differences between the cold-hardiness of shoots and that of roots. Seedling root systems are usually well-insultated from very cold temperatures by the rooting medium, typically, soil. Because of this insultation, root systems are neither required nor capable of attaining the same level of hardiness as the shoots. However, containerized root systems, especially if they are outdoors, can be subjected to lethal temperatures. Seedlings

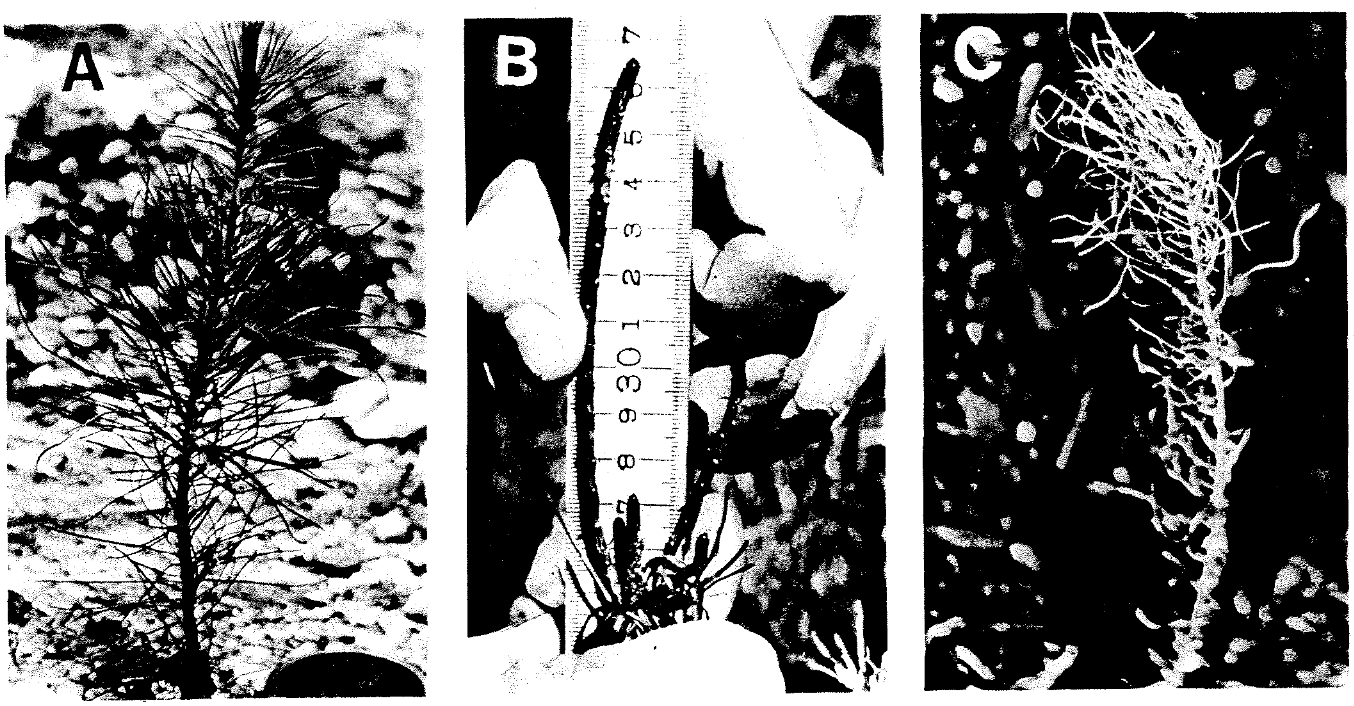

Figure 2. Containerized loblolly pine seedlings: (A) growing normally, (B) growing abnormally due to incomplete satisfaction of the chilling requirement and (C) dead from freezing temperatures.

Table 1. Cold-hardiness and field performance of containerized loblolly pine (Mexal, et al., 1979). All values are significantly different (α= .05) according to Duncan's Multiple Range Test.

Exposure (wks)	Cold-hardiness (LT_{50})[1/]	First year field survival (%)	Height Growth (cm)
0	-4.3°C	28	3.9
2	-6.4°C	52	10.1
6	-13.6°C	76	18.2

[1/] Temperature at which 50% of the seedlings are killed.

often are placed on raised beds to promote root pruning. This allows for circulation of subfreezing air and increases the chance for root damage.

The damaging effects of lethal temperatures on root systems are not immediately obvious as they are in shoots. Seedling mortality, or even morbidity will not be obvious until the shoots are placed in a favorable environment. Significant damage to a container crop occurred in 1980 as a result of exposure to -10°C in early February. Survival for eleven provenances averaged less than 50% when brought into a greenhouse on 15 February; compared to over 90 percent on 24 January (Table 2). If seedlings are to be overwintered outdoors, precautions must be taken to prevent this damage. Precautions as simple as protecting with styrofoam sidewalls should provide adequate root protection for most regions.

DORMANCY

Dormancy is induced in the fall by short photoperiods and cool temperatures. Once a seedling has become dormant it will not resume growth until its chilling requirement has been satisified. The chilling requirement, or the amount of exposure to low temperature which will permit height growth when placed in a favorable environment varies with the species (Table 3) and can vary with the temperature regime. Generally, exposures of 4 to 12 weeks to temperatures less than 5°C completely satisfy the chilling requirement of most species. Loblolly pine requires about seven weeks exposure to natural conditions during November and December to completely satisfy the chilling requirement (Garber and Mexal, 1980). Following exposure for seven weeks, the terminal buds will expand rapidly and uniformly when placed in a growing environment. Partial satisfaction will result in slow budbreak or perhaps no bud break at all.

Table 2. Survival of loblolly pine seedlings grown outdoors and placed in a greenhouse on the dates listed below. Seedlings were exposed to -10°C on February 2, 1980. Survival was measured after 60 days. Number in parentheses represents the number of sources from a region.

Provenance	January 24	February 5	February 15
Alabama/Mississippi (2)	98%	70%	48%
Arkansas/Oklahoma (4)	97%	55%	46%
North Carolina (5)	94%	45%	58%

Table 3. Chilling requirement for dormancy release of conifers.

Species	Exposure Length (wks)	Exposure Temperature (°C)	Source
Picea glauca	4 - 8	≤ 5°	Neinstaedt 1966
Pinus monticola	4 - 5	≤ 5°	Steinhoff & Hoff 1972
P. sylvestris	8 - 10	Natural (Nov.-Dec.)	Jensen & Getherum 1967
P. strobus	8	≤ 5°	Berry 1965
P. taeda	7	Natural (Nov.-Dec.)	Garber & Mexal 1980
Pseudotsuga menziesii	8 - 12	≤ 4.4°	Van den Driessche 1975
coastal			Wommack 1964
mountain		4°	Wells 1979
Tsuga heterophylla	8	≤ 5°	Nelson & Lavender 1979

Failure to break bud and grow the first summer following outplanting will negate much of the benefits of container planting. The effect is short term, however. The chilling requirement of the bud will be satisfied the following winter and subsequent growth will be normal. As an aside it is not known if small containerized seedlings which have not formed a terminal bud have a chilling requirement. However, this does not negate the requirement for cold-hardiness.

While there is information available regarding the natural chilling requirement for loblolly pine, there is no information on the artificial manipulation of the chilling requirement. Van den Driessche (1975) found cold-storage could partially satisfy the chilling requirement of Douglas-fir seedlings; and Tinus and McDonald (1979) stated that most species have the chilling requirement satisfied by four to five weeks of cold storage. Lavender and Hermann (1970) found exposure to low levels of light during storage of Douglas-fir was also important to subsequent growth. This information is not published for southern pines. Yet it is crucial to the development of management strategies for containerized seedlings.

MANAGEMENT PRESCRIPTIONS

Maximum survival and growth of containerized seedlings is the management goal of a container production facility. To attain these goals, careful attention must be given to the cold-hardiness and chilling requirements of the seedlings. Attaining the proper level of cold-hardiness is probably the more important of the two since cold damage can quickly result in death. However, failure to overcome bud dormancy can also negate many of the potential benefits ascribed to a containerized seedling. At the very least, one entire growing season will be lost. The loss may be much greater if competiting vegetation is not controlled, and the seedlings become shaded.

In addition to growth loss, seedling establishment may suffer if the chilling requirement is not satisfied. Ritchie and Dunlap (1980) indicated the root growth potential (RGP) of Douglas-fir seedlings reaches a maximum when the chilling requirement is completely satisfied. Therefore, not only is rapid shoot growth assured by satisfaction of the chilling requirement, but also rapid root growth to ensure survival from summer drought.

Much of the regeneration with containerized seedlings will occur during the fall and winter. To achieve high survival and growth potential, the seedlings should be placed outdoors during September or early October. Water stress and nutrient depletion can be initiated when the seedlings achieve target size, if desired. Outplanting of cold-hardy seedlings can occur throughout the winter. In certain regions, where precipitation is adequate, containerized seedlings can be outplanted during September and early October. The seedlings will acclimate naturally in the field; thereby becoming cold-hardy and also satisfying their chilling requirement.

If the seedling crop does not achieve target size until November or December, outplanting is best delayed until the spring. In that case, the chilling requirement of seedlings must be met prior to outplanting. This is best accomplished by reducing the greenhouse temperature and protecting the seedlings from freezing. Chilling for about seven weeks should satisfy the chilling requirement. Outplanting can occur in March in most regions.

Regeneration success depends on the physiological status of the seedling. Success with containerized seedlings is dependent upon matching the physiological state of the seedling to the physical state of the environment at time of outplanting. Careful attention to the physiological state of the seedling and managing the crop accordingly will ensure regeneration success.

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PRODUCTION PRACTICES FOR GROWING EUCALYPTUS SEEDLINGS IN CONTAINERS[1/]

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and
Mark V. Crow[2/]

Abstract.--Eucalyptus seeds are collected, cleaned and pelletized. The seeds are then sown in either of two container types. After germination they are rearranged, fertilized and grown to a shippable size in 12-14 weeks. The seedlings are packed in wax covered cardboard boxes and are ready to be picked up and outplanted.

SEED ORCHARDS, SEED COLLECTION AND SEED TREATMENT

There are 12 Eucalyptus seed orchards scattered throughout central Florida consisting of four species of Eucalyptus. Eucalyptus camaldulensis (spanish source) and Eucalyptus tereticornis are found in the more northerly orchards while Eucalyptus grandis and Eucalyptus robusta are further South. All the orchards were established in cooperation with the U. S. Forest Service at Lehigh Acres, Florida.

E. grandis and E. robusta seed capsules are collected in early spring and late summer, respectively, while E. camaldulensis and E. tereticornis are collected in late spring. All seed capsules are collected using a bucket truck.

Each seed tree in the orchard is numbered and the U. S. Forest Service, through genetic testing, determines which trees meet the standards for seed collection. After the seed capusles are collected, they are dried in a solar seed drying room in mattress covers or paper sacks, depending on the quantity of capsules.

In the drying room it takes two to three weeks for the capsules to open and release the seeds. The seed and chaff are then separated from the capsules using a cement mixer with a screened top. The smaller particles fall through while the larger ones are held back.

The seed and chaff are then sent to the U. S. Forest Service (Lehigh Acres) for further cleaning. The chaff is separated from the seed using a forced air seed blower. The cleaned seed is then sent back to Herren Nursery for pelletizing.

A small pelletizing machine, developed by Professor W. F. Miller of Cornell University,[3/] is used to coat the seeds. This machine moves a non-stick surface frying pan back and forth as well as in a circular motion. The Eucalyptus seed are placed in the pan, sprayed with Gelvatol[4/] and sprinkled with #140 and #200 sand mix.[5/] The Gelvatol is sprayed on the seeds, then sand is sprinkled on them. This process is repeated until the pelletized seed is about the size of a BB. They are then placed in a force draft oven at 95°F for about one hour to dry. The seed are stored in plastic containers and kept in a refrigerator until sowing.

CONTAINER TYPES

Herren Nursery uses two types of seedling containers to grow Eucalyptus. These are the

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Reforestation Section, Florida Division of Forestry, Collins Building, Tallahassee, FL 32301.

3/ Paper by T. F. Geary & G. Meskimen, USDA Forest Service, Southeastern Forest Experiment Station, Lehigh Acres, Florida 33936.

4/ Gelvatol 40/10 (free sample), Monsanto Corporation, Bircham Bend Plant, Indian Orchard, Massachusetts 01151.

5/ Sand purchased from Standard Sand and Silica Company, Post Office Box 35, Davenport, Florida 33837.

Leach Tube[6/], a small plastic test tube like container, and Styrofoam Tray[7/] with containers molded into the block.

Leach Tube

This tube was developed by Ray Leach in Oregon. It is 4.75 inches long, 1 inch in diameter and tapered at the bottom. It has four small lines down the inside to help prevent root spiraling. The tubes are held upright by a plastic tray which holds 280 tubes. The seeds are sown directly into the tubes held by the tray. After germination they must be separated into wire racks to the proper growing spacing of 25 seedlings per square foot. At Herren Nursery we use 4' x 8' wooden racks covered top and bottom with 1" mesh chicken wire.

Disadvantages: 1. When watering and fertilizing, all of the material does not reach the plants. Only that which hits directly in the tube is usable, the rest is lost in the openings between tubes. 2. After germination plants must be separated from the plastic holder and placed in wire racks at the proper growing spacing.

Advantages: 1. Trees can be separated according to size and placed accordingly in wire racks. Small seedlings can be given more attention and will catch up to larger seedlings. 2. Seedlings pull a little easier from these containers.

Styrofoam Trays

These trays are made of styrofoam material with dimensions 26" x 16.5" x 5". There are 77 cavities per tray and the seeds are sown directly into the cavities. The plug is 5" deep and tapered at the bottom with a diameter of 1 3/8". It has three small lines inside the tube to help eliminate root spiraling. These containers were developed by Tommy Smith of LaBelle Plant World in LaBelle, Florida.

Disadvantages: 1. Large trees cannot be separated from smaller trees. 2. Large area needed to store empty containers.

Advantages: 1. Cavities are already in the proper growing spacing (25/square foot) in the tray. They do not have to be rearranged. 2. Almost all water and fertilizer run-off flows into one of the containers which means less water and fertilizer is needed. 3. Trees can be grown to a larger size.

Presently the Division of Forestry sells container grown Eucalyptus in Leach tubes for $70/M and styro grown Eucalyptus for $80/M.

SOIL MIX

Soil is purchased in compressed bales wrapped in plastic for easy handling and storage. The potting soil is composed of Canadian sphagnum peat moss, vermiculite and perlite. The soil comes premixed at a pH of 5.5. It is placed in a cement mixer. Water and Osmocote[8/] 14-14-14 fertilizer are then added and mixed with the potting soil.

SOWING PROCESS

The soil is packed in containers after it has been through the cement mixer. Each plug is pressed down 1/8" to 1/4" from the top of the container with a special packing tool. A sowing machine using gravity feed drops a pelletized seed in each cavity. The seed is then covered with moist vermiculite and placed in the shade field.

GERMINATION, REARRANGING AND WEEDING SEEDLINGS

After the sown containers are placed in the shade fields, it takes 6-10 days for germination. The freshly sown containers are kept under shade for the first four weeks to keep heavy downpours from thunderstorms from washing the seed or young seedlings from the containers. Four weeks after sowing the young seedlings in Leach tubes have to be rearranged in wire racks at the desired growing spacing of 25/square foot. They are then placed in full sunlight. The styrofoam trays do not need rearranging because they are made at the proper spacing. They are also moved into the full sun four weeks after sowing. Any doubles and weeds are removed at this time.

6/ Leach Tubes and Holders - Ray Leach Cone-Tainer, 1500 N. Maple Street, Canby, Oregon 97013.

7/ Styrofoam Trays - LaBelle Plant World, Post Office Box 398, LaBelle, Florida 33935.

8/ Osmocote - Time release fertilizer - 3 month.

FERTILIZATION

Fertilization with a tractor spray rig begins three weeks after the Eucalyptus are sown. They are fertilized an average of three times per week with a special 15-25-20 liquid mix[9/] until they reach shippable size.

We mix a 25 pound bag of 20-20-20 and a 25 pound bag of 10-30-20 with hot water to make a 21 gallon slurry of 15-25-20. This mix can be applied through overhead irrigation and mixed with water in a boom type sprayer. The concentration should never exceed 500 PPM of nitrogen.

SEEDLING SHIPMENT

Leach tube Eucalyptus are ready to ship when they reach 20 centimeters in height, while stryo Eucalyptus are 30 centimeters when ready for shipment.

Farm tractors pulling flatbed trailers bring in the racks of Eucalyptus from the field to the shipping shed. The racks are unloaded on stands and workers remove the shippable seedlings. Any seedlings too small to ship are placed back in the field. The Eucalyptus seedlings are pulled from the containers by hand. The seedlings are placed on the shipping table in bundles of 25, with 350 packed per box. The lids are put on the boxes and the trees are ready for shipment.

9/ Peters Fertilizer (powder) - Mix 25 pound bag 20-20-20 and 25 pound bag 10-30-20 equals to 15-25-20.

PRODUCTION OF CONTAINERIZED SOUTHERN RED OAKS AND THEIR PERFORMANCE AFTER OUTPLANTING[1/]

William W. Elam, John D. Hodges, and David J. Moorhead[2/]

Abstract.--To test effects of container size and growth media on production and field performance, seedlings of four southern red oaks, Quercus falcata var. pagodifolia Ell., Q. nuttallii Palmer, Q. shumardii Buckl. and Q. nigra L. were produced in a greenhouse using three container sizes (0.5 liter, 0.9 liter, and 1.9 liter) and two growth media (Pro-mix BX and 1:1 Pro-mix BX and fine sandy loam soil).

Twelve-week-old container seedlings were outplanted and field performance was compared to 1-0 nursery stock produced from the same seed lots.

In the greenhouse, stem length and shoot/root ratio increased with container size and leaf surface area was affected by the media.

Third year field data show that both container size and growth media affected seedling performance after outplanting. Seedlings from the small container did not perform as well as those from the larger containers, however, there was no significant difference between the two larger containers. Survival and growth of seedlings produced using 1:1 Pro-mix and soil was better than only Pro-mix. This was probably due to effects on root development after outplanting.

Overall, container seedlings produced using the 0.9 liter container and Pro-mix plus soil media had equal or better survival and growth when compared to the 1-0 bareroot stock.

INTRODUCTION

Production of containerized hardwood seedlings is well behind conifers. Our work with containerized southern oaks closely parallels early work with conifers, i.e. matching species to containers and determining best media and nutrition requirements. Tinus' (1974) work with oaks pointed out that individual species information is necessary for optimum production of quality containerized oak seedlings.

The reasons for using containerized seedlings for regeneration have been enumerated for years; they are essentially the same for hardwoods as for conifers. Some of those most often stated are: poor performance of conventional nursery stock, lengthening the planting season, inadequate natural regeneration, being able to use genetically superior stock, manipulation of species composition and the speeding up of early growth. The importance of rapid early growth to withstand competition has been emphasized and is very important in regeneration of oaks. Survival of planted oak seedlings is often very good but height growth for the first 2 or 3 years may be very poor, often averaging only a few inches per year (Russell, 1971). Some studies have indicated that more rapid early growth with hardwoods may be possible with containerized hardwoods (Johnson 1974; White et al, 1970). This study was done to evaluate the use of containerized southern oaks in the regeneration of hardwood stands with selected species.

[1/] Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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MATERIALS AND METHODS

Seeds of cherrybark oak (Quercus falcata var. pagodifolia Ell.), water oak (Q. nigra L.) and shumard oak (Q. shumardii Buckl.) were collected from selected trees in Noxubee and Oktibbeha counties of Mississippi. Nuttall oak (Q. nuttallii Palmer) seeds were collected from counties in the Delta region of Mississippi.

Stratified seeds were planted in April in three different size containers made from milk cartons. Container sizes were 1.9 liter (23 X 9.8 X 9.8cm), 0.9 liter (23 X 7 X 7cm), and 0.5 liter (23 X 7cm triangular in cross section). Two growth media were used; Pro-mix BX, a commercial potting media, and a 1:1 mix of Pro-mix BX and fine sandy loam soil. All combinations of species, container sizes and media were tested. There were 25 seedlings per treatment and 3 replications. Uniform spacing between plants was maintained. A 50% shadecloth was used in the greenhouse to reduce light intensity, and evaporative pad cooling was used to reduce excessive heat. A Hoagland's solution was used to supply nutrients; watering was by hand and as necessary. Seedlings were kept in the greenhouse for 9 weeks.

Three weeks before outplanting the seedlings were placed outside the greenhouse to acclimate them to full sunlight. Immediately prior to outplanting, 5 seedlings from each treatment were randomly selected and root/shoot ratio, leaf surface area, root weight, and total dry weight were determined. All seedlings for outplanting were measured for height, rootcollar diameter and number of flushes.

The outplanting was a randomized complete block design with 3 replications and 28 plots in each replication. Each plot consisted of 16 seedlings at 8 X 8 ft. spacings with 8 foot border strips between plots. The reps included all species, container size, and media combinations plus plots containing 1-0 nursery produced bareroot stock of the four oak species. The planting area was a somewhat poorly drained, level upland site which was of moderate suitability for the oak species according to the site evaluation technique of Baker and Broadfoot (1977).

Container seedlings were planted in holes drilled with a two-man, powered auger. Containers were removed, the media and root system inserted, packed in and covered with augered soil. Prior to planting the site had been disked to control competition.

Bareroot stock was grown from the same seed lots used for the container stock. They were planted in March using a hardwood planting spade.

Plots were disked twice per growing season to help control competition. Survival, rootcollar diameter and height were measured on all seedlings at the end of each growing season.

RESULTS AND DISCUSSION

Initial Seedling Development

Germination

Germination was not significantly affected by any treatment although after 65 days percent germination was slightly higher in the Pro-mix media. The usual drawn out germination period of water oak was not affected by either media.

After six weeks most seedlings had begun a second flush of growth with the exception of water oak (due to the delayed germination). Averages of morphological data of 12 week-old seedlings are shown by species in Tables 1, 2, 3, and 4.

Height

In general, height increased as container size increased and the Pro-mix medium was slightly better than the combination medium. The media effect is especially evident in Shumard oak (Table 3). Considering all species, Nuttall oak seedlings were consistently the tallest followed in order by Shumard oak, water oak, and cherrybark oak.

Root weight

Overall, treatment differences were small and not highly significant. Measured differences varied by species, Nuttall, Shumard and water oak had greater root weight in Pro-mix while cherrybark oak produced greater root weight in the combination media.

Root-collar diameter

Again, differences between treatments were small with few significant differences. Generally root collar diameter decreased with decreasing container size with the exception of water oak.

Leaf Surface Area

Leaf surface area tended to increase with increasing container size, and the Pro-mix media usually produced seedlings with the most leaf surface. In Shumard oak this difference was great enough to be statistically significant in all container sizes.

Root/Shoot Ratio

Generally, seedlings from the smallest containers grown in the combination media had greater root/shoot ratios than those from other treatments. This may have been due to lack of adequate growth of the shoot system and not better development of the roots.

Table 1. Morophological development of 12-week old cherrybark oak as related to container size and growth media.

Container and Media	Stem Length (cm)	Root Weight (g)	Root-collar Diameter (mm)	Leaf Surface Area (cm^2)	Total Dry Wt. (g)	Root/Shoot Ratio
1.9 liter Pro-Mix	22.80 ab	1.06 ab	4.90 ab	221.93 ab	3.53 a	0.57 bc
1.9 liter Combination	26.00 a	1.41 ab	5.60 a	315.00 a	4.61 a	0.46 c
0.9 liter Pro-Mix	21.60 ab	0.80 b	4.30 b	303.58 a	3.08 a	0.36 c
0.9 liter Combination	22.90 ab	1.52 a	5.50 a	276.50 ab	3.61 a	0.58 bc
0.5 liter Pro-Mix	21.20 ab	1.15 ab	4.70 ab	180.80 ab	2.69 a	0.70 ab
0.5 liter Combination	17.00 b	1.22 ab	4.10 b	143.90 b	2.75 a	0.82 a

Note: Means not sharing a letter in common differ significantly at the 0.05 level by the Duncan's New Multiple Range Test.

Table 2. Morphological development of 12-week old Nuttall oak as related to container size and growth media.

Container and Media	Stem Length (cm)	Root Weight (g)	Root-collar Diameter (mm)	Leaf Surface Area (cm^2)	Total Dry Wt. (g)	Root/Shoot Ratio
1.9 liter Pro-Mix	39.30 a	2.43 a	7.70 a	411.76 a	8.04 a	0.45 b
1.9 liter Combination	46.40 a	2.26 ab	7.20 a	365.64 a	8.18 a	0.42 b
0.9 liter Pro-Mix	44.20 a	2.81 a	7.20 a	418.50 a	8.36 a	0.51 b
0.9 liter Combination	44.90 a	2.04 ab	7.30 a	356.40 a	6.89 a	0.42 b
0.5 liter Pro-Mix	36.12 a	2.10 ab	6.60 ab	280.43 a	6.13 ab	0.52 b
0.5 liter Combination	24.70 b	1.57 b	5.70 b	116.13 b	3.46 b	0.85 a

Note: Means not sharing a letter in common differ significantly at the 0.05 level by Duncan's New Multiple Range Test.

Table 3. Morphological development of 12-week old Shumard oak as related to container size and growth media.

Container and Media	Stem Length (cm)	Root Weight (g)	Root-collar Diameter (mm)	Leaf Surface Area (cm^2)	Total Dry Wt. (g)	Root/Shoot Ratio
1.9 liter Pro-Mix	34.80 ab	2.72 a	6.00 a	470.17 a	7.33 a	0.59 b
1.9 liter Combination	27.90 bc	2.22 a	5.70 ab	290.03 b	5.06 bc	0.82 ab
0.9 liter Pro-Mix	36.10 a	2.61 a	5.60 ab	470.40 a	6.82 ab	0.61 ab
0.9 liter Combination	21.40 cd	2.57 a	5.50 ab	274.80 bc	5.26 bc	0.98 a
0.5 liter Pro-Mix	25.20 c	2.44 a	4.90 b	303.95 b	5.29 bc	0.92 ab
0.5 liter Combination	16.60 d	2.07 a	5.00 b	189.99 c	3.95 c	1.14 a

Note: Means not sharing a letter in common differ significantly at the 0.05 level by Duncan's New Multiple Range Test.

Table 4. Morphological development of 12-week old water oak as related to container size and growth media.

Container and Media	Stem Length (cm)	Root Weight (g)	Root-Collar Diameter (mm)	Leaf Surface Area (cm^2)	Total Dry Wt. (g)	Root/Shoot Ratio
1.9 liter Pro-Mix	23.90 a	1.15 a	4.30 a	203.63 a	3.50 a	0.58 ab
1.9 liter Combination	29.70 a	0.44 c	3.60 a	213.05 a	2.53 a	0.23 c
0.9 liter Pro-Mix	28.60 a	0.87 ab	4.10 a	219.86 a	3.27 a	0.35 bc
0.9 liter Combination	24.30 a	0.68 bc	3.90 a	138.56 a	2.33 a	0.45 abc
0.5 liter Pro-Mix	22.90 a	0.75 bc	4.00 a	189.21 a	2.69 a	0.35 bc
0.5 liter Combination	17.90 a	0.86 ab	4.50 a	114.33 a	2.26 a	0.66 a

Note: Means not sharing a letter in common differ significantly at the 0.05 level by Duncan's New Multiple Range Test.

Total dry weight

Total dry weights of the seedlings were not greatly affected by the treatments. In cherrybark oak and water oak there were no significant differences and only the small container seedlings had significantly lower weight in Nuttall oak. Shumard oak seedlings showed a significant media effect in which Pro-mix produced the heavier seedlings regardless of container size.

Evaluation of the measured morphological variables point out that generally: (1) seedling size increased with increasing container size, (2) seedlings grown in Pro-mix had better shoot growth regardless of container size, (3) seedlings produced in the 0.5 liter containers with the combination media were the poorest, and (4) for practical purposes seedlings produced in the 0.9 liter container appeared to be the most suitable for outplanting purposes since the ease of handling the smaller container overshadowed the advantage of the slightly larger size of seedlings produced in the largest (1.9 liter) container.

Field Performance

Survival and growth data by species are shown in tables 5, 6, 7, and 8 for containerized and bareroot seedlings. Final data were taken after 3 complete growing seasons in the field.

Survival

Although survival was acceptable in all treatment combinations, there was an apparent media/container size effect on survival in all species. In the largest container, seedlings in the combination media had the highest survival in all species. Media effect was not apparent in the .9 liter container with survival about equal across treatments, however in the smallest container the trend is toward higher survival in the Pro-Mix media.

We believe this may be due to the differences in movement of soil water within the media. The pore space of the combination media is smaller and would accomodate capillary movement of water more readily than the Pro-Mix. In the largest container this effect would be more pronounced than in the other size containers. All seedlings were carefully planted so that the media was well covered by soil so we do not think this is due to any type of wicking effect. Differences in root growth of seedlings as affected by media is now being investigated with respect to survival and growth.

Growth

Growth of seedlings in the combination media was superior in all container sizes with the exception of water oak in the smallest container. Overall there is a significant difference in the height and root collar diameter between the small container and the two larger (Tables 5, 6, 7, 8). Between the two larger size containers, seedlings grown in the .9 liter container with the combination media are equal to or superior in growth to the 1.9 liter size (Tables 5, 6, 7, 8) with the exception of cherrybark oak where the large container is best.

Comparison with 1-0 nursery stock

In all species except cherrybark oak the 0.9 liter combination seedlings are larger and growing at a faster rate than the 1-0 bareroot stock after three years in the field. Survival is 98% or better compared to over 90% for the bareroot.

In cherrybark, even the best container seedlings are not as large as the bareroot seedlings after three years although they are growing at a faster rate. Part of this is due to our lack of expertise in producing adequate containerized cherrybark oak seedlings. In producing the seedlings used in this study, we found that cherrybark is much more sensitive to nutrients and media than the other three species. This points up the fact that more species specific work is necessary if we are to produce the optimum containerized oak seedling.

General Summary

Four species of containerized oak seedlings were produced to field test against comparable bareroot stock. Of the three container sizes and growth media tested, based on space, handling, planting ease and quality of seedlings, the best size of the three tested was 0.9 liter. Based on morphological data of 12-week-old seedlings, the best media was a Pro-Mix media; however third year field data shows that seedlings produced in a 1:1 soil and Pro-Mix combination media performed the best after outplanting in terms of both survival and growth. The effect of the media after outplanting could therefore be of more significance than in the greenhouse.

We found that cherrybark oak is more sensitive to containerization than Nuttall, Shumard or water oak. To produce the optimum containerized oak seedlings will require much more testing.

Field results are most encouraging. After three growing seasons the containerized seedlings have survived as well as or better than the bareroot stock. In terms of growth, the container plants are growing at a faster rate and (excluding cherrybark) are now taller and have larger root collars than the bareroot plants.

Cost of producing the container seedlings versus cost of producing bareroot seedlings was not analyzed.

Table 5. Average size and survival of containerized and nursery produced Shumard oak seedlings 3 growing seasons after outplanting.

Container Size & Media	Size at Outplanting Height (cm)	Root Collar (mm)	Size after 3 seasons Height (cm)	Root Collar (mm)	Increase Height (cm)	Root Collar (mm)	Survival %
1.9 L Pro-mix	35.6	5.4	56.9	12.7	21.3	7.3	85
1.9 L Comb.	32.6	4.9	95.0	20.6	62.4	15.7	92
.9 L Pro-mix	40.4	5.3	78.9	17.9	38.5	12.6	98
.9 L Comb.	25.7	5.1	99.3	19.5	73.6	14.4	100
.5 L Pro-mix	23.1	4.9	70.1	13.9	47.0	9.0	98
.5 L Comb.	13.5	4.5	68.6	14.3	55.1	9.8	83
Nursery[1/]	54.8	8.2	88.3	17.6	33.5	9.4	90

[1/] Planted as 1-0 bareroot stock.

Table 6. Average size and survival of containerized and nursery produced water oak seedlings 3 growing seasons after outplanting.

Container Size & Media	Size at Outplanting Height (cm)	Root Collar (mm)	Size after 3 seasons Height (cm)	Root Collar (mm)	Increase Height (cm)	Root Collar (mm)	Survival %
1.9 L Pro-mix	20.6	4.1	120.0	23.3	99.4	19.2	92
1.9 L Comb.	19.3	3.9	198.0	37.7	178.7	33.8	100
.9 L Pro-mix	23.1	4.6	154.8	30.6	131.7	26.0	98
.9 L Comb.	22.5	4.4	209.8	40.5	187.3	36.1	98
.5 L Pro-mix	20.7	3.8	175.8	31.2	155.1	27.4	94
.5 L Comb.	17.9	3.8	164.4	30.3	146.5	26.5	96
Nursery[1/]	45.4	7.2	160.4	31.2	115.0	24.0	98

[1/] Planted as 1-0 bareroot stock.

Table 7. Average size and survival of containerized and nursery produced cherrybark oak seedlings 3 growing seasons after outplanting.

Container Size & Media	Size at Outplanting Height (cm)	Root Collar (mm)	Size after 3 seasons Height (cm)	Root Collar (mm)	Increase Height (cm)	Root Collar (mm)	Survival %
1.9 L Pro-mix	21.0	4.2	59.4	13.9	38.4	9.7	77
1.9 L Comb.	26.6	4.7	89.2	19.9	62.6	15.2	98
.9 L Pro-mix	22.9	4.3	80.6	19.8	57.7	15.5	92
.9 L Comb.	22.8	4.4	81.7	15.6	58.9	11.2	98
.5 L Pro-mix	18.4	4.1	57.5	13.8	39.1	9.7	77
.5 L Comb.	15.5	4.1	61.2	14.6	45.7	10.5	79
Nursery[1/]	44.4	8.1	96.4	22.3	52.0	14.2	98

[1/] Planted as 1-0 bareroot stock.

Table 8. Average size and survival of containerized and nursery produced Nuttall oak seedlings 3 growing seasons after outplanting.

Container Size & Media	Size at Outplanting Height (cm)	Root Collar (mm)	Size after 3 seasons Height (cm)	Root Collar (mm)	Increase Height (cm)	Root Collar (mm)	Survival %
1.9 L Pro-mix	38.7	5.9	186.6	37.5	147.9	31.6	92
1.9 L Comb.	37.3	6.1	222.5	43.9	185.2	37.8	98
.9 L Pro-mix	43.2	6.6	207.8	42.6	164.6	36.0	98
.9 L Comb.	35.5	6.6	219.4	44.8	183.9	38.2	100
.5 L Pro-mix	35.0	6.2	201.2	39.2	166.2	33.0	100
.5 L Comb.	25.9	5.1	202.1	38.5	176.2	33.4	92
Nursery[1/]	87.9	11.5	192.9	41.0	105.0	29.5	98

[1/] Planted as 1-0 bareroot stock.

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BARE ROOT VERSUS CONTAINERIZED SEEDLINGS:

A COMPARISON OF PRODUCTION PROBLEMS AND METHODS[1/]

H. Grady Harris[2/]

Abstract.--Bare root and containerized seedling production methods are compared from a supervisor's standpoint. The accelerated growth rate of containerized seedlings provides the advantage of flexibility in scheduling multiple annual crops, but causes some management problems. Ability to anticipate and attention to detail are required of the greenhouse manager. Advantages of containerized production are extended planting season and flexibility of crop scheduling; disadvantages are high production and transportation costs and logistic problems in field planting.

After more than forty-five years of bare root experience, the North Carolina Division of Forest Resources began operational production of containerized forest tree seedlings in 1976. Containerized production was initiated in an effort to alleviate a recurring shortage of Fraser fir (*Abies fraseri*(Pursh) Poir) seedlings produced for Christmas tree growers in the mountains of the State. A second objective was to extend the planting season for Southern yellow pine species extensively planted in the eastern two-thirds of North Carolina. Since that beginning, crops of containerized fir, eastern white pine (*Pinus strobus* L.), loblolly pine (*Pinus taeda* L.), longleaf pine (*Pinus palustris* Mill.) and slash pine (*Pinus elliotii* Engelm. var. *elliotii*) have been more-or-less successfully produced. Perhaps a comparison of the two production methods will be useful to those interested in containerized production of forest tree seedlings.

Essentially, both bare root and containerized production methods consist of placing viable seeds on a suitable medium and providing water, nutrients, and the necessary cultural practices to favor germination of the seeds and development of the resulting plants into usable seedlings. However, one major difference between these methods becomes readily apparent when considering the establishment of either type of facility.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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The individual planning a bare root nursery thinks primarily of land for the site, because soil quality, available water and location in relation to the field planting area are so important to the success of the nursery. On the other hand, site is not nearly as important when considering the establishment of a containerized facility. The person planning such an operation must choose between a fairly wide variety of greenhouses, environmental control systems, container filling and seeding machinery, containers, and soil mediums. To help insure choices that will allow all parts of the operation to fit together in an efficient system that meets specific organizational requirements, the designer should visit as many existing facilities as possible. Before the installation of the North Carolina Division of Forest Resources was designed, a senior staff forester of the Division visited established operations in seven states and at three Canadian locations.

The greatest difference between these two seedling production system is the accelerated growth rate attained by containerized seedlings. Of course, this increased growth rate results from the optimum conditions for growth that can be maintained in the greenhouse where the seedlings are grown. Some management options unavailable in bare root production results from this accelerated growth, but it may also cause some problems, as will be seen later.

The accelerated growth rate gives much greater flexibility to the containerized operation. More than one crop can be produced annually; if the proper environmental controls were incorporated in the greenhouse, production of a crop can be begun at any time of year. This flexibility affects planning; the greenhouse manager must order supplies for three to five crops if ordering on a yearly basis, whereas, the bare root nurseryman orders for one crop at a time. Thus, the containerized operator has to anticipate to a much greater degree than does the bare root producer.

After planning, construction, and acquisition of the necessary supplies, seedling production can begin. The most important operation in the production process, seeding, comes first. Regardless of the quality of the after care, a high quality crop of the desired quantity of seedlings cannot be produced without a well-planned, well executed seeding operation. Because of its importance, seeding is discussed in some detail.

The bare root nurseryman must place on the bed the proper amount of seeds per hundred feet of bed to give the desired density of seedlings. Because of the long history of bare root production, a wealth of information is available to help this nurseryman calculate the sowing rate and apply the seeds. The practice is fairly standardized, although each individual nurseryman has probably developed his own minor variations from standard practice.

In contrast, the containerized nurseryman is not concerned with the weight of seeds that must be sown; in seeding containers one or more seeds must be put into individual cells so that the number of filled cells is maximized and the number of cells with multiple seedlings is minimized. Procedures are available to assist with the necessary calculations. Balmer and Space (1976) have developed probability tables which are useful in making seeding rate calculations; the same authors have prepared a computer program from which the most economic seeding rates can be derived (Space and Balmer 1977). Tinus and McDonald (1979) recommend use of these methods but also list rules of thumb that have been developed. The North Carolina Division of Forest Resources determines the number of seeds required to result in a probability of 100 per cent that one viable seed will be placed in each cell. Seeding is then carried out using that number of seed per cell. The individual containerized nurseryman will probably decide on the method to use based on the species and the value and quality of seed lots which are required in his operation. Regardless of the method used to determine seeding rate, the best seedlots available must be used for containerized production in order to hold production costs at the lowest possible level.

The containerized nurseryman may use one or more practices not practical in bare root production to improve the results of seeding. If space is available in the greenhouse, extra flats may be seeded and the resulting seedlings transplanted into blank cells. Thinning and transplanting may be used to reduce the number of cells with more than one seedling and to increase the number of filled cells. This practice may not be practical in some operations because of cost. Thinning alone may be used to correct overseeding by eliminating multiple seedlings in single cells. Use of these practices depends upon the value of the crop produced, the value of the seed used, and the cost and availability of temporary labor.

In containerized production, cultural practices necessary for growth and development of the crop are easily carried out. Nutrients are applied with water through fixed or traveling irrigation systems automatically or manually. Competition from weeds and grasses is a minor problem; those weeds that do come in through the ventilation system can be removed by hand during routine inspections; weeds and grasses are prevented from becoming established under the benches by use of a pre-emergence herbicide, or if they do become established, by treatment with contact or systemic herbicides. If pests become a problem, pesticides can be applied directly onto the plants through the watering system. If necessary, the house can be closed. Treatment may have to be applied quickly; natural enemies of the pest are probably not established in the greenhouse and cannot be counted upon to slow the outbreak. Pesticide application should be quite effective because of the closed environment; the risk of environmental pollution is certainly minimal.

However, the bare root nurseryman spends at least four months heavily involved with cultural practices. Irrigation, fertilization, hand weeding, and pest control require a permanent crew and close supervision. In addition, two other practices not commonly used in containerized production, top and/or root pruning, may be used to equalize seedling size and reduce cull percentage.

The bare root nurseryman need not be concerned with light. His seedling crop grows outside in natural light, and requires a full growing season to develop to plantable size. In contrast, supplemental lighting is used in containerized production to prevent shoot dormancy during the dark hours and thus maintain a maximum rate of growth. Although supplemental lighting may not be necessary for optimum growth during the summer in the South (Tinus and McDonald 1979) such lighting may be required for the production of crops begun in early spring or late summer. In the greenhouse of the North Carolina Division of Forest Resources, the supplementary lighting system is turned on as soon as seeding is completed, and remains on until the crop is moved outside, regardless of the season of the year.

Time must be allowed for hardening-off the containerized crop. About as much time is required for hardening-off as is required for growth to usable size. Containerized seedlings may be hardened-off by moving them to the outside benches and reducing the watering-fertilization schedule. In bare root nurseries hardening off follows the natural cycle; in September irrigation and fertilization are stopped, and the seedlings harden-off naturally as the days shorten and temperatures decrease.

Bed inventory of the seedling crop at a bare root nursery requires a considerable effort. A crew of four to six will need perhaps a month to complete the field work; the necessary calculations will require another week or more. Inventory of a containerized crop is much simpler. Individual containers, instead of plots, serve as sampling units. If a good job of seeding was done, and germination was satisfactory, a relatively small number of samples should be needed to produce an estimate within the required limit of error. Even if unexpected variation necessitates an increased number of samples, inventory of a complete containerized crop should require no more than two or three man-days.

Activity reaches fever pitch at a bare root nursery late in the year as lifting season begins. The labor crew has been built up to maximum size as seedlings are lifted, packaged, and stored or delivered. However, no special effort is necessary to package containerized seedlings; they may be transported within the container in which they were grown. Perhaps one or two additional laborers may be needed for loading, but use of portable conveyor makes it possible for small crews to load even refrigerated vans in a short time. The North Carolina Division of Forest Resources has considered removing the containerized seedlings from the containers and transporting them in plastic bags to simplify the transportation problem, but so far such a practice has not been tried because of anticipated labor costs.

A dependable pool of temporary labor is absolutely essential to the successful operation of a containerized facility. A small permanent crew can tend crops growing in the greenhouse or hardening-off outside, but filling containers, seeding, and placing seeded containers in the greenhouse require more people. If containers must be assembled, labor needs are increased. In a summer crop production schedule, if the containers must be assembled, a crew of three to six may be needed above and beyond the permanent crew for about three weeks out of the twelve weeks production period. This fluctuating requirement for laborers causes a problem. If the facility is near an urban area, employemnt of teen-aged high school students may be a solution. In a rural area, temporarily unemployed farm laborers may be available. If possible, locating the containerized operation close-by a bare root nursery may ease the situation. Extra laborers may be hired by the nursery and moved from one operation to the other as needed. Although bare root production requires more laborers, the fluctuation is more seasonal, *i.e*, a maximum crew during winter, a reduced crew in the spring, and a minimum crew during the summer.

The North Carolina Division of Forest Resources has used all the methods listed above in an effort to solve the problem of temporary labor for the containerized operation. The best results have been obtained by hiring two temporary workers for the entire summer and filling the increased need at seeding time by borrowing people from other programs. The containerized facility is about thirty-five miles from the bare root nursery where laborers have been borrowed, and this travel distance reduces efficiency and increases cost. Assuring the availability of temporary labor when needed must receive the highest priority from the containerized nurseryman.

The flexibility inherent in containerized production allows coordination with field planting to a degree unheard of in bare root production. Crops can be timed to mature at the exact time when requested by the planters, or species can be changed with relatively short notice. Enough lead time must be allowed; the planters must realize that 16 or more weeks may be required to change to production of a species whose seed require stratification. Without stratification, production time from seeding to usable seedlings requires at least 12 weeks. Thus the flexibility in production has some limits.

No discussion of containerized production can be complete without some reference to natural disasters. Probably the most common disaster at a bare root nursery is heavy rains washing away the seeds following seeding, but the size of the fields and variation in the rainfall generally prevent a total failure. In containerized production, it seems that the accelerated biological process also mean accelerated possibilities for disaster. Power failure on a cold winter night might wipe out an entire crop; a power failure in late spring may result in excessive heat damage to a crop of cool climate seedlings; a hail storm may destroy a greenhouse and a crop in short order. The chance of losses as described above can be minimized; the containerized nurseryman should evaluate this potential for the area in which his facility is located and take steps to eliminate the chance of unacceptable damage.

What might be concluded from comparing experiences gained in working with both production systems? First, attention to even small details is of paramount importance in maintaining operational production of containerized seedlings. Forgetting the smallest detail can result in unacceptable losses or perhaps even the failure of an entire crop. The containerized production supervisor must impress upon all his staff the need for attention to what might seem to be the most insignificant detail.

The containerized nurseryman must anticipate problems and plan their solution in advance. These problems may be biological, mechanical, or involve human relationships. All three areas are of vital importance in containerized seedling production.

During the production phase, the pressure never lets up on the supervisor of a containerized operation. Because of the machinery involved, the greenhouse must be checked every day. If seed are in stratification, the seed must be turned periodically and the compressor checked. Towards the end of the production cycle, calls can be expected from the field planters. There is literally never a dull moment!

Containerized production does offer some advantages. The planting season can be extended to include all the summer and perhaps the fall, thus spreading out labor requirements. Seedling crops can be closely coordinated with the planters; crop production can be adjusted to utilize labor that may be available for short periods only. Production of various species can be adjusted on a relatively short term basis.

Probably the greatest disadvantage to containerized production is the high per unit cost of seedlings produced. Bare root southern pine seedlings can be produced for one-half or less the cost of containerized seedlings. Also, transportation costs are high, and logistic problems have been noted in providing seedlings to the planters. Lack of moisture may also adversely affect field survival.

Finally, containerized seedling production, particularly on a small scale, is both labor intensive and energy intensive. Such production should not be initiated unless it has been definitely established that the need for and the value of the seedlings produced justifies the capital investment and production costs that will be incurred.

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FULLY CONTROLLED OR SEMI-CONTROLLED ENVIRONMENT GREENHOUSES--WHICH IS BEST?[1/]

STEPHEN E. McDONALD[2/]

Abstract--The general method for deciding what kind of containerized tree seedling growing facility to construct is discussed. Biological, economic, and operational factors are incorporated in the logic together with product needs considerations.

INTRODUCTION

Suppose you are charged with the responsibility to develop a containerized tree seedling facility. How do you decide what kind of greenhouse structure, if any, is needed? In other words, what will be the most cost effective and operationally efficient production facility capable of producing the quality and quantity of trees needed? This is no simple question. Many container operations in the Pacific northwest have failed because, at the outset, the wrong type of facility was constructed.

For the purposes of this brief paper, I will not discuss site selection, market assessment, bare-root production alternatives, or several of the other factors of major importance to containerized tree nursery development. Rather, I will attempt to primarily address how to choose what kind of greenhouse facility to build.

THE RANGE OF ALTERNATIVES

In order to select the right kind of containerized tree seedling structure you have to know the range and general advantages of the alternative facilities. Three categories can be isolated: fully controlled environment (FEC), semi-controlled environment (SEC), and uncontrolled environment (UCE).

Essentially an FEC greenhouse is one that completely encloses the crop. Mechanical heating and cooling equipment keeps the inside of the greenhouse at near-optimium temperatures for the crop. The heating and cooling capability of the structure must be engineered for the climate of the location and the crop to be grown. Added equipment, such as electric lighting, carbon dioxide generators or humidity control, is added as justified.

The SEC greenhouse, on the other hand, is designed to only partially control the environment around the crop. These structures usually consist of a transparent roof with plastic side and end walls that can be removed or rolled-up. In the spring, or in unusually cold weather, the structure can completely enclose the crop. Supplemental heat can be added. Interrupted photoperiod lighting can also be installed. However, for most of the growing season the sides of the structure are open and cooling is by convectional movement of the air from the sides of the structure up through vents in the roof. The roof primarily serves to divert rainfall from the crop so irrigation and fertilization can be controlled.

The UCE growing facility (the term structure or greenhouse cannot be used) usually consists of an asphalt slab graded so excess water will drain from it. Usually shadecloth is stretched over the area, but not necessarily if the climate is cool and cloudy as it is in British Columbia. The blocks of containers may be placed on pallets on the ground or on pallets on sawhorses. Irrigation is often from a portable aluminum pipe system with impulse sprinkler heads on the risers.

1/ Paper presented at the Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Forestation and Tree Improvement Specialist. Cooperative Forestry, Washington, D.C.

In some cases the actual germination of the trees takes place in a special structure designed for the purpose. In other cases it is done outside. Inclement weather is the big worry in a UCE container nursery operation.

Facilities have been developed that exist along an unbroken continuum from nearly completely automatic (FEC) greenhouses to very rudimentary (UCE) facilities. Each category has advantages and disadvantages:

1. Fully Controlled Environment Greenhouses (FEC).

   Advantages
   a. Full environmental control.
   b. Trees can be grown as rapidly as possible.
   c. Can be located just about anywhere.

   Disadvantages
   a. Costly to operate and build.
   b. Equipment must function properly.
   c. Energy intensive.

2. Semi-Controlled Environment Greenhouses (SEC).

   Advantages
   a. Medium-priced and relatively simple.
   b. Some environmental control.
   c. Protection from catastrophic loss due to weather.

   Disadvantages
   a. Must be put in a mild climate.
   b. Still requires a greenhouse structure.
   c. Must grow trees in spring and summer.

3. Uncontrolled Environment Facilities (UCE).

   Advantages
   a. Least expensive to build.
   b. Little equipment to maintain.
   c. Very low energy requirements.

   Disadvantages
   a. No environmental control.
   b. Requires a mild climate.
   c. Risk of catastrophic loss high.
   d. Must grow trees in spring and summer.

So the best production facility for you could be a fully controlled greenhouse or a uncontrolled facility or anything in between. How do you know what to choose?

WHAT IS NEEDED?

The size of tree seedling needed, integrated with the biological requirements of the tree species to be grown and the climate at the proposed site, provides the parameters for greenhouse design. More than one design alternative will probably be viable(Ekblad 1974).

Environmental Requirements

"Environmental requirements" refers to what a tree requires to successfully survive and grow. In a nursery we are obviously interested in rapid, normal growth and development. There are a number of interacting factors important in determining seedling growth rate and morphogenesis. These include temperature, light, moisture availability, nutrition, and humidity. Greenhouse structures and associated hardware can control all part of these. Temperature is probably the most important factor in determining growth rate, provided the others are at some reasonable level. This is basically because temperature has such a marked influence on biological chemical reaction rates. One way to show this is to describe the general interactions between photosynthetic rate, respiration rate, and net assimilation rate at different temperatures (Fig. 1). Respiration can exceed photosynthesis at very high temperatures the plant can actually "starve under high temperature stress. On the other hand at very low temperatures photosynthesis barely exceeds respiration, because the chemical reactions involved are so suppressed, and plant growth can be very slow. In the middle temperature ranges (from 25 to 35°C or 77 to 95°F for most temperate zone plants) the net assimilation rate is greatest and the most plant enery is available for growth. In general a combination of warm daytime and cooler nightime temperatures (lower respiration rates) are best for plant growth, but this varies widely depending on the adaptation of the species or ecotype within species.

Ideally the best day-night temperature combination of the crop should be known. In agronomic and horticultural crop production this is one of the major factors in determining where certain crops are grown. For tree seedlings Dr. Richard Tinus, of the USDA-Forest Service's Rocky Mountain Experiment Station, has developed growth chamber techniques for quickly determining the effects of various day and night temperatures on the growth of tree seedlings (Tinus 1977). He has done this for some timber species and has found optimum temperatures to vary considerably. The data is placed on contour graphs with day

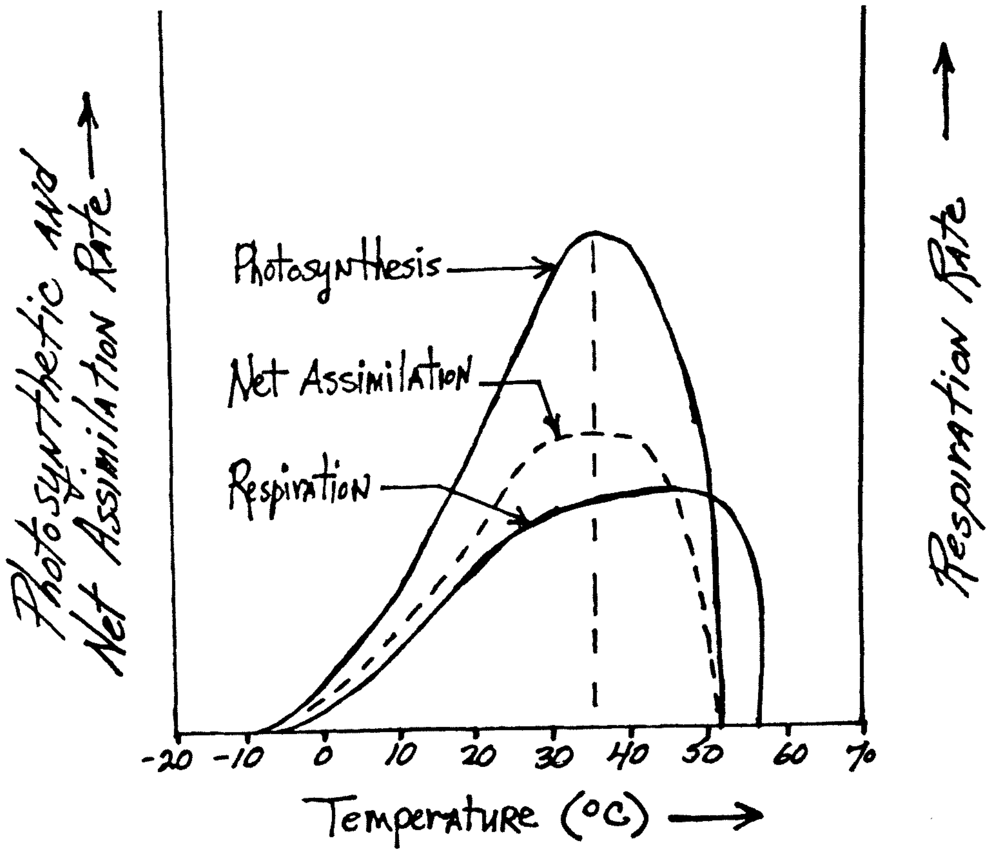

Figure 1.--Effect of temperature on biological chemical reaction rates.

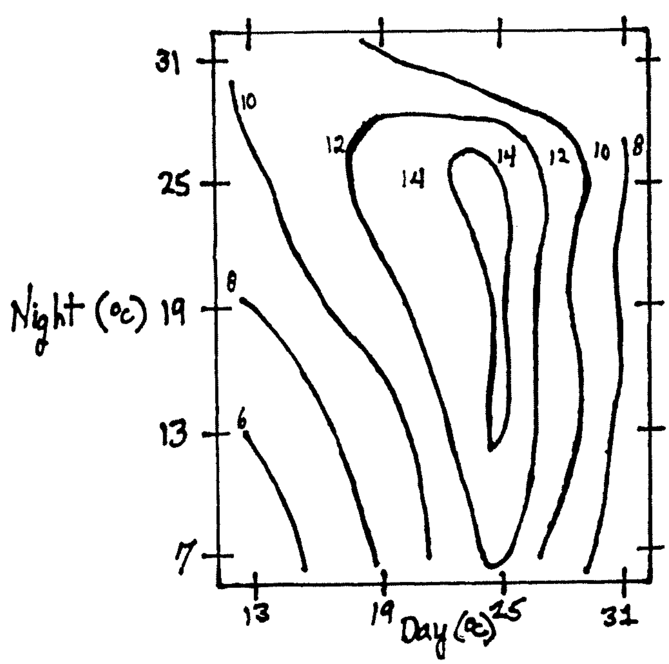

Figure 2.--Heights (cm) of ponderosa pine seedlings as a function of day and night temperature (From Tinus 1977).

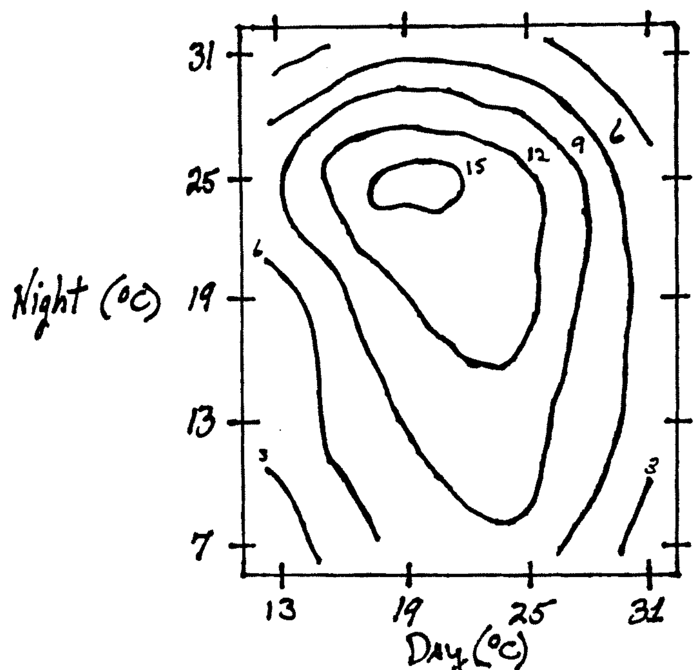

Figure 3.--Dry weights (gm) of ponderosa pine seedlings as a function of day and night temperature (From Tinus 1977).

temperature on the abscissa and night temperature on the ordinate An example is shown in figures 2 amd 3 for a Nebraska source of ponderosa pine (Pinus pondrosa Laws). The height and dry weight graphs are shown. These pine seedlings grew best at day temperatures near 25°C (77°F). However, night temperatures could vary from 15 to 25°C (59 to 77°) with little effect on height. Warm nights (25°C) definitely maximized dry weight accumulation. Graphs of other species, such as blue spruce, are quite different. All the graphs which exist for the various tree species are available in the manual "How to Grow Tree Seedlings in Containers in Greenhouses" (Tinus and McDonald 1979).

Such graphs do not exist for southern tree species. Approximations of suitable temperatures for greenhouse culture of southern pines do exist from past greenhouse experience. Such experience, accumulated by growing repeated crops in an FEC greenhouse, takes years to develop, whereas it can be done in growth chambers in a couple of months.

Where the temperature graphs are especially needed is when SEC or UCE facilities are being planned. These graphs, compared to weather data for a site can tell the planner if such facilities are practical. In both SEC and UCE facilities the temperature is primarily ambient air temperature. Consequently, for either of these types of facilities to be considered, you must have a mild climate where growing season temperatures approximate those suitable for tree growth. Under such circumstances excellent quality trees can be reared in SEC or UCE facilities, but this will normally always take longer and must be done during the growing season.

Once it has been determined that an SEC or UCE facility may be possible at a site, a pilot test is really needed to prove it is true. Then large-scale construction can begin on a firm basis.

Reliability and Operability Requirements

Reliability requirements pertain to assurance of production whereas operability requirements ments relate to design compatiblity with the operation of tree growing and shipment. If the organization or individual developing a containerized tree seedling production facility places a very high value on assured delivery, then reliability requirements will be very important. This will tend to make FEC facilities more attractive or, at the very least, will stimulate considerable study and pilot testing before an SEC facility is built It will also be more important to build reliability features into the structure type selected. Such items can include low and/or high temperature alarms and various other warning systems, redundant control systems, stationing a caretaker on-site, building security fences, etc.

In the Pacific northwest one producer which had successfully grown seedlings at a UCE facility for several years recently expanded the facility. However the expansion was into SEC structures. The reason was concern over the possibility of a catastrophic loss to bad weather.

In an FEC facility the mechanics of the greenhouse must be reliable. Malfunctions can result in rapid, disastrous environmental changes. In SEC units there is a degree of natural buffering in the system. Except in the early spring, where supplemental heat is called-for, an equipment failure can usually be tolerated for a little while.

Operability of a facility will depend on product and raw material flow. Such a system can be designed into the structure with varying degrees of intensity. If labor is cheap or variable (operating) costs of are less concern than inital capital costs, operability can be de-emphasized in the original design are planned for later retrofitting. On the other hand the facility can be designed for almost complete automation. The general wisdom is that the automation angle can easily be overdone, especially at the outset of a development. Certainly raw material and product flow should be designed into a facility at the start, but guard against over-investment in fancy hardware for moving things and minimizing labor until the needs are clearly focused by experience. The main idea is to be able to produce the seedlings needed at the proper time.

Cost Requirements and Considerations

Where the climate permits and slower production of a crop is acceptable, UCE and SEC facilities are very cost effective, especially if risk of loss to bad weather is discounted. However, the must be attuned to the tree species in question. Such facilities deserve real consideration in the south if the crop can be produced when desired.

Controlled environment greenhouses (FEC) are several times more expensive to build and operate than SEC or UCE units. The fast growth, seasonal timing of production and possibility of multiple crops in a year can make them more economic than other types of facilities.

When weighing cost requirements the developer should be mindful of the need of assured production initially. An FEC greenhouse will produce.

Experimentation with SEC growing methods can take place at a site after it is in limited production with an FEC unit.

A word of warning regarding greenhouse accessory hardware purchase is worthwhile at this point. One the major pitfalls in containerized tree seedling nursery development is a preoccupation with mechanical and engineering aspects of the project to the detriment of sound economic and biological reasoning. Consequently, a developer of a container tree seedling nursery should constantly ask two questions:

1. Is this item of hardware required to meet the environmental requirements of the crop?
2. If not, will it save enough labor, maintenance, or other expense to justify its purchase price?

Reconciliation of Requirements

The requirements for the facility--environmental, reliability, operability, and cost--are what define the problem of facility design and allow generation of viable alternative solutions. The alternative solutions will have variability in characteristics (cost, fuel requirements, assurance of production, etc.) that can be rated according to relative importance. Summation of these ratings will indicate the most desirable alternative if the ratings are carefully done. Existence of similar successful facilities in an area can affect the choice considerably. If an existing facility in the area is successful and of the type desired, major construction can usually begin without a pilot test. If no such facilities exist, a pilot test for evaluation is highly recommended. During such an evaluation process it is important that the best possible advice and help be acquired so that later major construction is based on pilot test information that truly represents what will happen in the expanded facility.

THE FINAL DECISION

The answer to the question--"Which is better fully controlled or semi-controlled greenhouses?" "--depends on the developer's goals and circumstances. In other words the requirements can be listed, categorized, and ranked as to relative importance. These elements can then be compared to the viable construction alternatives for the given site/ species/delivery date combination existing. The best construction alternative can then be selected. With that sort of decisionmaking sequence outlined the selection job should be easy-right? Wrong! Even if all the facts about facility requirements and facility construction alternatives are carefully quantified, you, as a developer, must still guage the politics of the situation. A facility of type "A" may be economically and biologically the most cost effective. However, it may not be the best alternative if the company or agency will not accept its appearance or the risk of crop loss associate with it. Facility "B: may be less efficient or more expensive but still be the better selection considering those other factors.

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CAPITAL INTENSITY AND ECONOMIES-OF-SCALE FOR DIFFERENT TYPES OF NURSERIES[1/]

Richard W. Guldin[2/]

Abstract.--Average annual capital costs are estimated for 24 combinations of types of nurseries and seedling containers in 3 southern climatic zones. The optimal nursery expansion strategy is identified and compared with building a new bare-root nursery on a total-cost-per-1,000-seedling basis. The initial construction cost of a new container nursery and its implications for the entire reforestation program are discussed.

The South's Third Forest report (Southern Forest Resource Analysis Committee 1969) called for regenerating 30 million unproductive acres to pine by 1985. This need is in addition to reforesting productive land recently harvested. The report also called for having 60 million acres forested with genetically improved stock by the year 2000. The annual rate of regeneration by direct seeding and planting on all land-including idle farmland, forest land understocked with pine, unproductive upland sites converted to pine, and recently harvested land promptly regenerated--has not exceeded 1.6 million acres since the Third Forest report was issued 12 years ago. Present regeneration rates are barely achieving half the Third Forest goals. Twice as many seedlings are needed. All should be from genetically improved seed.

A major bottleneck to achieving the goal is inadequate nursery capacity. Finding suitable nursery sites and building new nurseries is expensive. Just the construction costs for 2 new industrial bare-root nurseries that began production in 1980 were $1 million and $2 million for annual outputs of 18 and 25 million seedlings respectively. These construction costs are equivalent to $56-$67 per 1000 seedlings annual production capacity excluding land. These 2 nurseries added only 6 percent to total southern nursery capacity. Applying these costs, it would require an additional $55 million to double existing nursery output, assuming that suitable nursery sites are already owned.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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Building new container seedling nurseries could help meet the seedling need. But are they economical? This paper estimates the cost of building new container seedling nurseries and compares the cost to that of building new bare-root nurseries.

NURSERY ALTERNATIVES

Four container nursery alternatives were developed for cost analysis by combining the favorable features and eliminating the unfavorable features of the 6 pilot-scale container nurseries in the South. The container nursery alternatives are identified by the type of seedling germination house used: (1) glass greenhouse, (2) fiberglass greenhouse, (3) timber truss greenhouse, and (4) pole shadehouse. These are alternatives to building new bare-root seedling nurseries. Cost comparisons between bare-root and container nursery alternatives will be made.

The cost of each nursery is influenced by a number of assumptions. Biological assumptions will be addressed in the discussion of each nursery. Several cost estimation assumptions are common to all 5 alternatives.

All capital costs were based on price quotations from nursery equipment manufacturers and wholesalers, or on actual bids for recently constructed facilities across the South. Locally available construction materials were priced at retail outlets in the New Orleans, Louisiana, area. Contingency factors were included. All costs were on a January 1, 1980, basis. An interest rate of 10 percent was used to amortize investments in facility components.

Labor costs were based on man-hours of labor required to perform tasks at existing nurseries, multiplied by standard wage rates of $6, $8, and $10 per hour for unskilled, skilled, and supervisory labor categories. An additional 15 percent of total wages was added for the employer's share of social security, workmen's compensation, and unemployment insurance, based upon Louisiana rates for new nursery businesses.

The quantities and costs of goods and services used to produce seedlings were based upon amounts required by facilities currently in operation and prices quoted by their suppliers.

Direct overhead costs of the nursery operation were included in the total cost estimates. However, no factor was added to any alternative for general administrative expenses of higher echelons of the firm or agency.

Container nursery alternatives

Three major factors must be analyzed before cost estimates can be developed for a container seedling nursery: location of the nursery, type of nursery germination house, and the type of container. Nursery location and type of germination house jointly determine the number of seedling rotations that can be germinated annually in each house. The type of container and the size of the germination house jointly determine the number of seedlings grown per rotation. Thus, all 3 elements together determine annual seedling output as well as influence costs.

Nursery Location

Contrary to the bare-root nursery siting dictum that a site should be chosen which is as far north as possible to lengthen the seedlings' dormant period, container seedling nurseries should be located as far south as possible to maximize the frost-free growing period and minimize wintertime utility consumption. The number of rotations grown annually and output both increase as the length of the growing season increases. Higher outputs spread annual capital costs over a larger number of seedlings.

The South was divided into 3 climatic zones based on the length of the frost-free growing season and the incidence of daily air temperatures exceeding 90 degrees F (fig. 1). Seedling production schedules used in this study assumed that properly hardened seedlings would not be outplanted before the mean date of last frost in the spring nor later than 1 week before the mean date of first frost in the fall. Production schedules also assumed that seedlings could not be consistently outplanted during midsummer because of soil moisture and surface temperature limitations. The climatic criteria used to define the zones were:

	Frost-free length of growing season	Days when daily maximum air temperature exceeds 90 degrees F
	-------No. of days-------	
Zone A	260-310	60-120
Zone B	215-245	60- 90
Zone C	185-215	30- 60

Within any zone, microclimatic conditions may alter actual production schedules and potential seedling outputs.

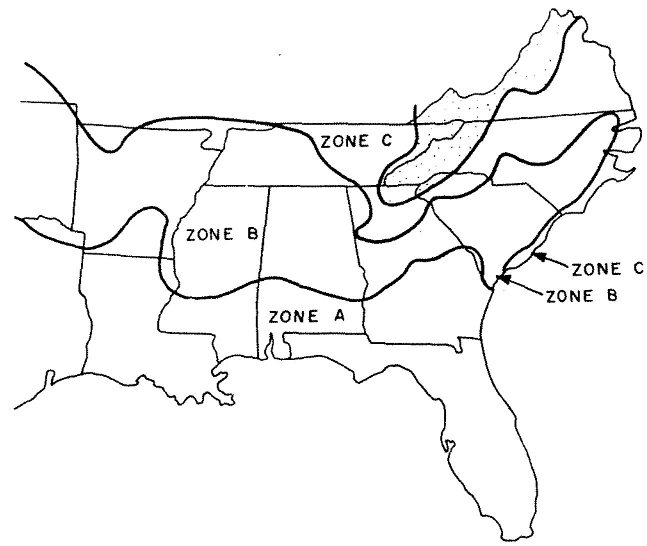

Figure 1.--Southern climatic zones.

Germination Houses

A container seedling nursery requires space in buildings to perform 3 basic functions: filling containers with media and sowing seed; seed germination and initial seedling growth; and hardening seedlings off prior to outplanting. Although one building could be used for all 3 functions, production efficiency increases if separate buildings are available that specialize in each function. A headhouse provides container filling and seed sowing space. Germination and initial seedling growth can occur in either a greenhouse or a shadehouse. Hardening off is most efficiently performed in a shadehouse. Because similar headhouses and shadehouses are used with different germination houses, specifying the type of germination house in this paper identifies the type of nursery.

The 4 types of container seedling nurseries (and germination houses) share several common features. Some of these are biological assumptions, and some induce commonality for cost comparison purposes. The common features are:

Each nursery "replicate" (smallest efficient production unit) has 1 headhouse, 5 greenhouses for germination and 5 shadehouses for hardening off. An exception is the pole shadehouse nursery, which has 1 headhouse and 6 pole shadehouses for both germination and hardening off.

Sufficient CCA type C treated southern pine pallets to fill each greenhouse and shadehouse are included in building construction costs.

Loblolly or slash pine seedlings are grown in 12 to 16 week rotations.

One "greenhouse rotation" is equivalent to 3,240 square feet, ± 2 percent, of usable growing space. Greenhouse sizes were selected to provide this much usable growing space per house, assuming that 67 percent of the gross floor space was usable. Widths of greenhouses currently manufactured were assumed, and greenhouse length was adjusted to provide the usable growing space. Multiplying container cell densities per square foot by the usable growing space per rotation yields the total number of cells per rotation.

Ninety-five percent of the cells produce plantable seedlings. Sowing 2 seeds per cell, thinning and transplanting excess seedlings to vacant cells has attained this percentage of plantable seedlings in existing southern container seedling nurseries. Labor costs include these activities.

One "greenhouse rotation" per week is the maximum headhouse capacity.

Only one-half acre of land is needed for each building. Suitable land with adequate water supply should cost no more than $500 per acre.

Glass Greenhouse Nursery.--A glass greenhouse nursery has a wood-frame headhouse 40 x 60 feet, containing the nursery office, media-mixing, container-filling, and seed-sowing equipment, storage, lavatories, and main utility service station. A forklift truck for pallet handling is included. Each of the 5 gable-roofed, aluminum-framed, glass-glazed greenhouses is 42 x 120 feet. The greenhouses contain complete and fully automated heating, cooling, carbon dioxide enrichment, and lighting systems, an overhead crawling waterer with fertilizer and chemical injector, all utilities and connections, including a telephone alarm system. Each of the 5 pole shadehouses is 44 x 240 feet. They are constructed of shadecloth stretched over a nylon rope grid supported by 3 rows of CCA type C treated poles. Irrigation is the only environmental control provided in the shadehouses. Each shadehouse provides sufficient space for 2 greenhouse rotations while hardening off seedlings prior to outplanting. The shadehouses function as a "surge bin" between greenhouse production and field planting. The total construction cost of this nursery replicate is $596,500, which is equivalent to an annual fixed cost of $78,993.

Fiberglass Greenhouse Nursery.--The same type of headhouse used for the glass greenhouse is used here. Each of the 5 fiberglass-sided greenhouses has a double bowed and trussed roof covered with 2 layers of ultraviolet resistant polyethylene sheeting, held apart by air pressure from a small blower. Each greenhouse measures 34 x 150 feet. The greenhouses contain the same climate control equipment as the glass greenhouse, except for the irrigation system. This greenhouse has a solid-set plastic pipe irrigation system buried in the floor, with threaded removable risers. A fertilizer and chemical injector is provided. The 5 pole shadehouses used for hardening off are of the same construction as the glass greenhouse nursery, but each measures 36 x 300 feet. The total construction cost of this facility is $295,691, which is equivalent to an annual fixed cost of $42,763.

Timber Truss Greenhouse Nursery.--Because annual seedling production levels are lower for this type of greenhouse than the previous 2, less expensive partially-mechanized media-mixing, container-filling and seed-sowing equipment is used in the headhouse. A forklift truck is still included. Timber truss greenhouses measure 34 x 150 feet. They are constructed onsite from standard softwood dimension lumber and poles. Timber trusses are constructed from 2 x 6 lumber to a 4 over 12 pitch using half inch plywood gussets. The trusses are set on 4-foot centers atop two pole walls 34 feet apart. The pole walls are constructed of 4-inch diameter CCA type C treated poles with a double 2 x 4 top plate. The trusses are tied together with sufficient 1 x 4 lumber to make the structure wind-firm for the locality, and covered with a layer of 2-inch galvanized poultry mesh and a single layer of 6 mil ultraviolet resistant polyethylene sheeting. Only irrigation and photoperiod control equipment are provided in the timber truss greenhouse. The pole shadehouses used for hardening are identical in size and construction to those for the fiberglass greenhouse nursery. The total construction cost of a timber truss greenhouse nursery is $167,309. The annual fixed cost is $31,172.

Pole Shadehouse Nursery.--The same type of headhouse used for the timber truss nursery is used for the pole shadehouse nursery. The construction and size of the shadehouses used for germination are identical to those used for hardening in the glass greenhouse nursery. This type of nursery is the least expensive to construct, but provides the least climatological control. Only irrigation is provided in this nursery. The total construction cost of this nursery is $122,608, or an annual fixed cost of $20,925.

Types of Containers

Four types of containers were considered in the study: No. 2 Styroblocks, Kys-Tree-Starts, and 2 sizes of Spencer-Lemaire Rootrainers, Fives and Ferdinands (table 1). The purchase price of the containers, container reusability, and labor requirements for container assembly, filling and sowing, are the 3 factors that affect the cost of containers in growing seedlings.

Table 1.--Physical characteristics and production cost components

Type of container[1]	Cell density	Seedling density	Average cost of labor and materials	Average capital cost of container
	---No./square foot---		---$/1000 seedlings---	
Kys-Tree-Start	150	142	35.83	0.00
Spencer-Lemaire Fives Rootrainers	82	78	22.61	13.56
Spencer-Lemaire Ferdinand Rootrainers	118	112	20.61	8.48
Number 2 Styroblocks	96	91	17.87	2.38

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement approval of the product by the U.S. Dep. Agric. to the exclusion of others which may be suitable.

The No. 2 Styroblocks and the Spencer-Lemaire Rootrainer trays (both sizes of Rootrainer cells use the same tray) could be used for 6 rotations. Both the Fives and Ferdinand Rootrainer cells last only 2 rotations. These lifetimes, based on actual use in southern nurseries, were used to adjust the container purchase price to a container capital cost per 1000 seedlings produced. The container cost per 1000 seedlings enters capital cost calculations along with nursery construction costs. Because Kys-Tree-Starts cannot be reused, their purchase price remains in the labor and materials category and does not enter capital cost calculations.

The Spencer-Lemaire Rootrainer "books" must be folded to form strips of cells which are then inserted into the Rootrainer tray. Seventeen Ferdinand books fill the tray with 102 cells, compared to 13 Fives books that provide only 65 cells. In addition, the trays themselves must be assembled. Neither of the other 2 kinds of containers requires assembly. More media is required per 1000 cells for the Fives Rootrainers, 3.5 cubic inches, per cell, than for the 2.5 cubic inch cells of both the Ferdinand Rootrainer and the No. 2 Styroblocks. The Kys-Tree-Start container is made of molded peat, so requires no assembly, nor media. Only labor for seeding is required. Where Kys-Tree-Starts are used, headhouse capital costs can also be reduced because no media-mixing or container-filling equipment is needed.

Analysis of the cost and operations records of existing container seedling nurseries in the South reveals that labor and materials costs are determined primarily by the type of container selected. The labor and materials cost of a single rotation is independent of the type of germination house and is affected only slightly by the level of headhouse mechanization. The labor and materials component of producing a rotation of seedlings in the various containers was separated from the capital cost component owing to the container purchase prices (table 1). Annual labor and materials costs were divided by annual seedling output to estimate the average labor and materials cost per thousand seedlings.

Bare-Root Nursery

Bare-root seedling costs also have a capital component and a labor amd materials component.

Capital Costs

Capital costs for a new bare-root nursery fall into 3 categories: land acquisition and site preparation, construction of nursery buildings, and purchase of equipment.

Wakeley (1954) outlined the quality and quantity of land required for new bare-root nurseries. He recognized that the best nursery sites are often high-quality agricultural land. A high price is required to bid such land away from crop production. Land costs should include not only the purchase price of the land, but also the cost of the search process and closing costs. If land for the nursery is already owned by the firm or agency, its cost is the net benefits foregone from the prior land use. In addition, if the site selected is not optimal, but the best owned by the firm or agency, there ia an opportunity cost involved in settling for a suboptimal site. Following Wakeley, this study assumed that 3.5 acres would be needed for beds, paths, roads, and administrative areas for each million seedlings annual capacity.

Once acquired, the acres to be used for seedling production must be cleared and leveled, beds laid out, and an irrigation system installed. A green manure crop or other soil management practices may be needed to build up the soil prior to producing the first crop of seedlings.

While site improvements, such as the irrigation system, have an assumed 20 years lifetime, the inherent land value is assumed constant in perpetuity. Therefore, land acquisition costs must be converted to an annual value using the formula for a perpetual annual series rather than a terminable annual series. Costs for land acquisition and site improvements were converted to a basis of annual cost per million seedlings annual capacity basis. When the resulting average capital cost ($3,177 per million seedlings annual capacity) is multiplied by nursery size, annual land capital cost is estimated.

The buildings required are a nursery office, equipment storage and repair garage, a packing building, and a refrigerated seedling storage warehouse. The sizes of the nursery office and equipment garage do not vary as seedling production levels rise, but the sizes of the packing building and refrigerated warehouse do vary with output. All buildings are assumed to have a 20-year life. The cost of buildings by output ranges are:

Million seedlings annual output	Total annual cost of buildings
1.0- 9.9	$13,975
10.0-14.9	$21,046
15.0-19.9	$28,117
20.0-24.9	$38,723
25.0-29.9	$49,330

Equipment required by the nursery includes one or more pickup trucks, tractors, sprayers, seedling lifters, forklift trucks, and wagons. Nurseries producing less than 6 million seedlings have the least amount of equipment. From 6 to 10 million seedlings annual production, equipment costs rise rapidly as production becomes more heavily mechanized. In addition to more equipment, equipment size also increases. Both factors increase equipment costs. Above outputs of 10 million seedlings annually, costs increase at a diminishing rate, due to economies of scale. Both depreciation and operating expenses are included in the equipment costs:

Million seedlings annual output	Total annual cost of equipment
1.0- 5.9	$19,936
6.0- 6.9	$23,923
7.0- 7.9	$27,910
8.0- 8.9	$31,897
9.0- 9.9	$35,885
10.0-14.9	$39,872
15.0-19.9	$43,859
20.0-24.9	$47,846
25.0-29.9	$51,834

Labor and Materials Cost

Cost records for the U.S. Forest Service's W. W. Ashe Nursery were examined. After subtracting capital depreciation, regional office overhead, equipment use, and the costs of the seed extractory, the remaining cost was divided by annual output. The resulting cost, $19.07 per thousand seedlings, includes all labor, salaries, office expenses, seed, fertilizer, pesticides, packing supplies, and other miscellaneous materials essential for nursery operations. This cost is typical of existing southern bare-root seedling production (Guldin 1982).

DISCUSSION

The cost comparison proceeds in 2 steps. First, the most cost-efficient container seedling nursery is developed by selecting the most cost-efficient container seedling nursery and nursery expansion strategy from the 48 possible combinations of containers, germination houses, and climatic zones. Then, the most cost-efficient container seedling nursery is compared to the cost of building a new bare-root seedling nursery over a range of seedling outputs from 1 to 20 million seedlings annually. Finally, the capital cost implications of choosing between containerized and bare-root seedling nurseries is examined.

Choosing Among Container Nursery Options

Seedling production cost, exclusive of the cost of buildings and equipment, is the sum of columns 3 and 4, Table 1.

Type of container	Seedling production cost per 1000 seedlings
Spencer-Lemaire Fives Rootrainers	$36.17
Kys-Tree-Starts	$35.83
Spencer-Lemaire Ferdinand Rootrainers	$29.09
Number 2 Styroblocks	$20.25

The seedling production costs of the first 2 containers are nearly double the $19.07 production cost of bare-root seedlings. They will not be discussed further. The remaining 2 containers have the same cell volume, Table 1, and bracket the 100-cells-per-square-foot optimal density level (Barnett and McGilvray 1981).

The annual capital cost per 1000 seedlings is the sum of column 4, Table 1, for the appropriate container and the annual capital cost of the nursery buildings, land, and equipment. The annual capital cost per 1000 seedlings has been graphed over an annual nursery output range from 1 to 20 million seedlings for each climatic zone and nursery type (figs. 2-4). The sawtoothed discontinuities result from the cost of adding 1 new headhouse, 1 germination house, and 1 hardening house to the most efficient nursery replicate. Costs rise because 80 percent of the new headhouse's container-filling and seed-sowing capacity is not utilized if only 1 germination house is added. Although the headhouse does not directly affect seedling output, excess headhouse capacity increases cost. Adding a minimum of 2 germination houses with a new headhouse lowers the nursery's average annual capital cost per 1000 seedlings considerably.

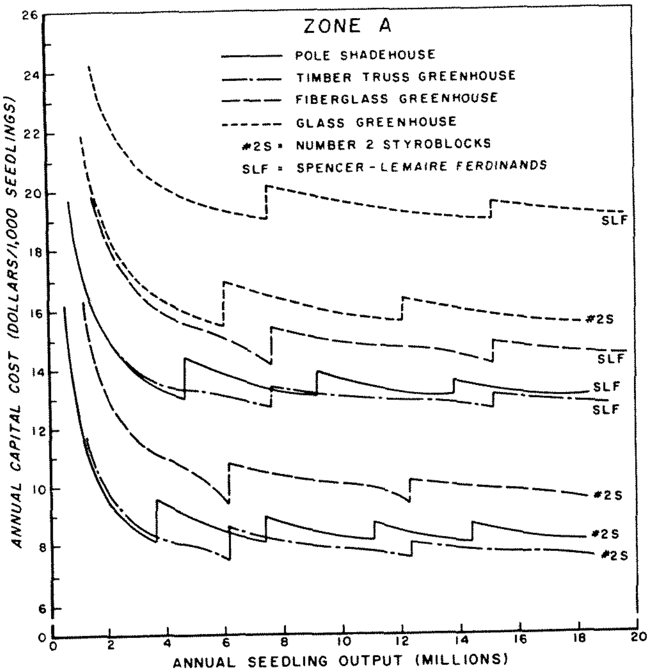

Figure 2.--Nursery annual capital costs in zone A.

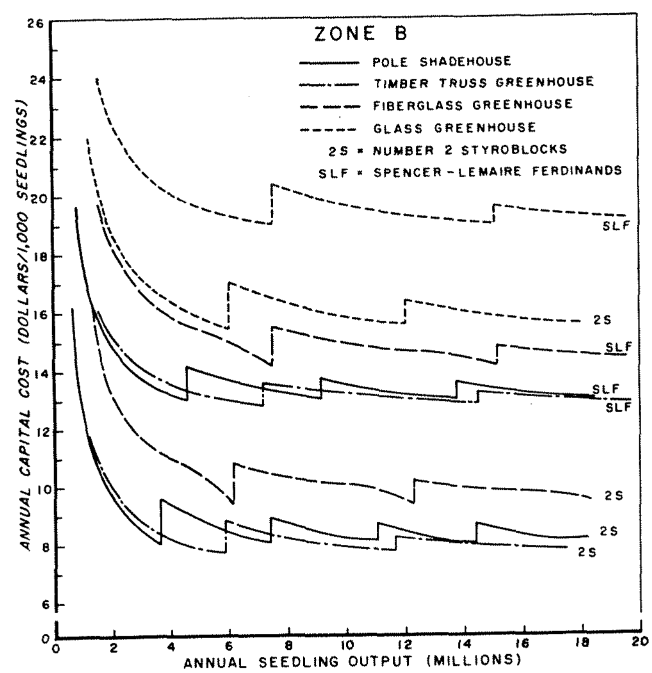

Figure 3.--Nursery annual capital costs in zone B.

Selecting the most cost-efficient type of nursery only requires analyzing average annual capital costs per 1000 seedlings (figs. 2-4) because the average cost of labor and materials for seedling production (table 1, column 3) does not vary with the type of nursery. The pole shadehouse and timber truss greenhouse nurseries have the lowest average annual capital costs per 1000 seedlings

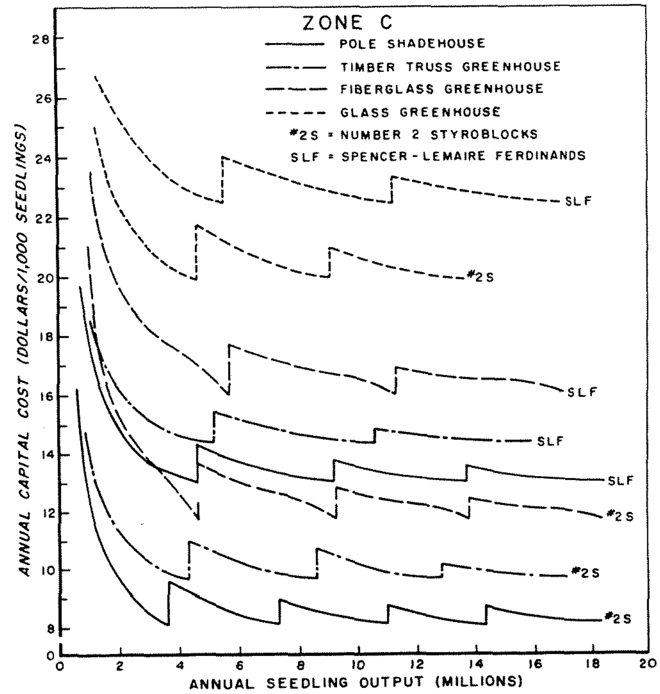

Figure 4.--Nursery annual capital costs in zone C.

($7.50 to $8.50 per 1000 seedlings) in all 3 climatic zones. Although the fiberglass and glass greenhouse options offer greater control of the seedling growth environment, the increased production from these 2 options is insufficient to reduce average capital cost per 1000 to the pole shadehouse or timber truss greenhouse levels. If a controlled environment is required, the fiberglass house is clearly less expensive. However, the cost disparity between the fiberglass greenhouse and the 2 lower capital cost options suggests that multipurpose nurseries, combining progeny testing or other research with mass production of seedlings for reforestation, are cost-inefficient. If a highly-controllable environment is desired, a greenhouse could be built separately from the houses used for mass production of regeneration seedlings. The fiberglass option should not be chosen for the entire reforestation nursery when only limited research space is needed. High-capital greenhouses are not essential in the South to produce quality reforestation seedlings.

The pole shadehouse nursery has the lowest average annual capital cost per 1000 seedlings over the entire output range in zone C (fig. 4). However, the choice of the most cost-efficient type of nursery in zones A and B depends upon nursery size. For No. 2 Styroblocks, a pole shadehouse nursery has the lowest cost up to 3.7 million seedlings annually, and between 6 and 7.5 million seedlings annually. For Spencer-Lemaire Ferdinand Rootrainers, a pole shadehouse nursery is the least expensive option up to 4.6 million seedlings annually and between 7.3 and 9.2 million seedlings annually. In the low output ranges for both containers (up to 3.7 million and 4.6 million seedlings respectively), the pole shadehouse option offers minor cost savings--5 cents to 30 cents per 1000 seedlings. In the higher output ranges for both containers (6-7.5 and 7.3-9.2

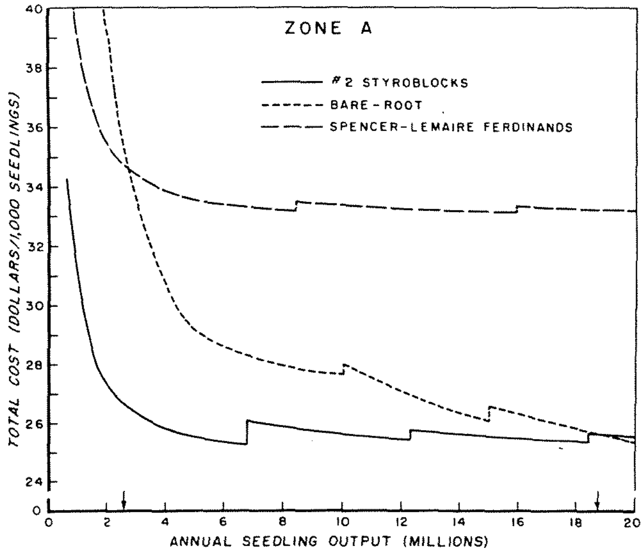

Figure 5.--Seedling total cost in zone A using the optimal container nursery expansion strategy.

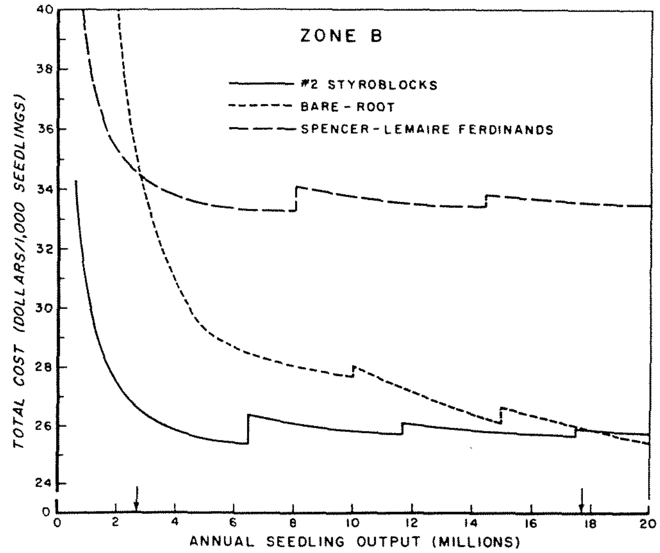

Figure 6.--Seedling total cost in zone B using the optimal container nursery expansion strategy.

million seedlings respectively), the pole shadehouse option is less expensive because an inefficient increase in production level results from adding only 1 timber truss greenhouse to the second headhouse. In these higher output ranges, the pole shadehouse uses available headhouse capital more efficiently. Pole shadehouse savings in these higher output ranges only amount to 10 cents to 40 cents per 1000 seedlings.

These minor cost savings and efficient output ranges for both containers suggest that the most cost-efficient nursery expansion strategy is to combine the pole shadehouse and timber truss greenhouse options through staged construction as seedling requirements rise. The strategy at low nursery output levels is to construct 1 headhouse and up to 6 pole shadehouses for germination. Then, as seedling requirements increase, timber truss greenhouses are added, converting the pole shadehouses from germination houses to hardening houses. Up to 5 timber truss greenhouses could be added before another headhouse is needed. The total cost of growing seedlings using this strategy was calculated and graphed for both types of containers (figs. 5-7).

Most container seedling nurseries presently operating in the South produce between 400,000 and 1.5 million seedlings annually. They are operating in the steeply sloped region of the cost curves. The steepest portion of the curves ends between 2.5 and 3 million seedlings annual output. Existing nurseries will find their marginal cost per 1000 seedlings drop due to increasing returns to scale as outputs are increased to the 3 million seedling threshold. Scale economies derive chiefly from more efficient headhouse utilization. New container seedling nurseries should have annual outputs greater than 3 million seedlings to benefit from economies of scale.

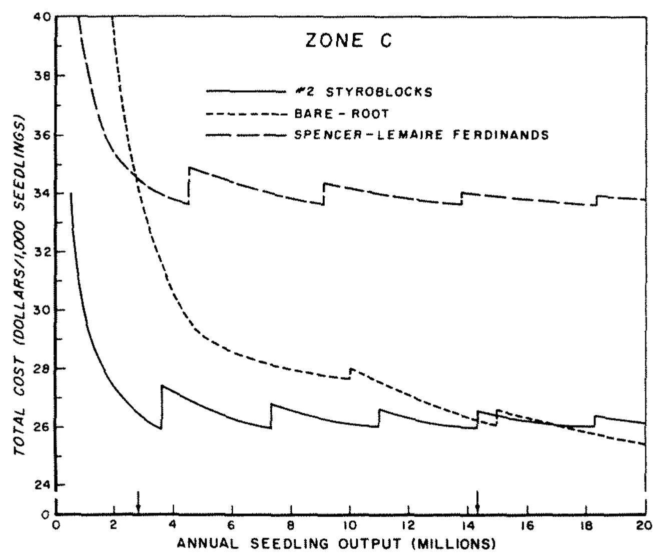

Figure 7.--Seedling total cost in zone C using the optimal container nursery expansion strategy.

Comparison of Container and Bare-Root Nursery Costs

The total cost of growing bare-root seedlings in a new nursery including all capital costs, was calculated and graphed in figures 5-7. Past comparisons of costs for bare-root and container seedlings have been between bare-root nurseries producing 15 to 30 million seedlings annually and container nurseries one-tenth the size. Equitable comparison requires that both types of nurseries must be the same size.

A container nursery using No. 2 Styroblocks can produce seedlings at a lower total cost than a new bare-root nursery of equivalent size for annual seedling outputs of less than 14.3 million in zone C and below 18.7 million in zones A and B. Spencer-Lemaire Ferdinand Rootrainer seedlings are less expensive than growing bare-root seedlings in a new nursery for annual outputs less than 2.6 million seedlings in all zones.

The slopes of the styroblock and bare-root seedling curves are so flat in the area of their intersection that for 2 million seedlings on either side of the intersection, costs vary by 30 cents per 1000 seedling (1 percent) or less. This cost variation is within the presumed margin of error in cost estimation. Hence, in the 4 million seedling output range, bare-root and No. 2 Styroblock seedling costs are essentially equivalent. Under the prevailing cost accounting practices employed by public nurseries, No. 2 Styroblock seedlings could be sold for the same price as bare-root seedlings.

Capital Cost Considerations of Choosing the Type of Nursery

The initial construction cost of a new nursery is not portrayed in figures 2-7. Yet, in an era of high interest rates for private firms and tightening public agency budgets, the level of initial construction costs should be considered. Capital expenditures are often more closely monitored than operating budgets, which may be increased automatically each year via cost-of-living or price adjustment indices.

Capital expenditures for an 18 million seedling per year container seedling nursery constructed in zone B are:

4 headhouses @ $44,240	$176,960
16 timber truss greenhouses @ $11,608	185,728
16 pole shadehouses @ $12,204	195,264
18 acres of land @ $500 (per acre)	9,000
322,750 No. 2 Styroblock "quarterblocks" @ $0.65	209,788
Total	$776,740

This initial construction cost is equal to $43.15 per 1000 seedlings of production capacity. Although this is a relatively inefficient output level (there is only 1 germination house for the fourth headhouse, fig. 6), $43.15 is still nearly $13 less than the $56 per 1,000 seedlings of-production-capacity cost for a recently constructed bare-root nursery in the South. Instead of needing $55 million dollars to meet Third Forest seeding requirements, container seedling nurseries could double seedling output for $38 million.

Also, once constructed, the container facilities would cost $1.20 per 1000 seedlings less to operate.

The $56 bare-root cost does not include land purchase, which could add another $15 to $20 per 1000 seedlings annual capacity to initial capital costs. A public agency forced to purchase land for a new nursery could save between $250,000 and $500,000 or more in initial costs on an 18 million seedling nursery by opting for a container nursery rather than a new bare-root one.

Two additional problems may arise resulting from large increases in seedling production, whether from a container or a bare-root facility--capital investments and labor availability for site preparation and planting. Eighteen million seedlings will plant 24,800 acres at 6 x 10 spacing. The capital required for site preparation and planting machinery may exceed nursery capital requirements. Capital requirements for all components of the reforestation process must be jointly considered to arrive at the best decision.

Year-round planting capabilities of container-grown seedlings may create site preparation scheduling problems. Instead of taking nine months to prepare sites for a three month bare-root planting season, site preparation would probably be performed continuously to keep ahead of planting during an 11-month planting season (3 months planting bare-root seedlings augmented by an additional 8 month planting container-grown seedlings). Site preparation and planting will become year-round tasks for company personnel or local contractors rather than a temporary and intermittant job performed for short periods. If planting contractors migrate following spring warming trends, sufficient local planting labor may not be available for the rest of the season and need to be developed. Labor availability for site preparation and planting should be carefully examined. It may take longer to find and train quality workers for these tasks than it takes to construct a container nursery and produce the first crop to seedlings.

CONCLUSIONS

Seedlings for reforestation can be grown as inexpensively in containers as in a new bare-root nursery. The optimal nursery development strategy in climatic zones A and B is to use pole shadehouses for germination if less than 6 million seedlings are needed. When larger quantities are needed, add timber truss greenhouses for germination and convert the pole shadehouse to hardening houses. In zone C, using pole shadehouses for germination is the best strategy at all production levels. These low-capital germination houses are the most cost-efficient for southern growers. High-capital germination houses do not boost output enough to pay.

The minimum nursery size that captures the majority of economies of scale is 2.5 to 3.0 million seedlings annual output. Below this production level, headhouse capital is underused. Full employment of headhouse machinery dicates the efficient production range of the nursery.

Site preparation and planting capabilities may ultimately restrict nursery size or output levels. Considerably more capital may be needed to raise site preparation output levels than is needed for nursery establishment. Capital and labor requirements for the entire reforestation program must be coordinated and examined as a total package.

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PRACTICAL GUIDELINES FOR DEVELOPING CONTAINERIZED NURSERY PROGRAMS[1/]

Philip F. Hahn[2/]

Abstract.--Practical guidelines are given in an answer form to the often raised questions in developing containerized nursery programs. The guidelines deal with determining seedling needs, choosing the container type and growing facilities, the crop rotations, the location of facilities and size limitations on facilities. Also, a pictorial view is given of an existing facility to illustrate the various components of an operational program.

INTRODUCTION

During my earlier presentation I gave a general overview of the various container nursery programs as they evolved in recent years and also the reasons for containerization. Several other speakers have already discussed the various considerations it takes to begin a containerized seedling production program. For this reason I shall limit my discussion to the questions most often asked when one embarks on the development of an operational container nursery.

HOW DOES ONE DETERMINE SEEDLING NEEDS?

This question needs to be answered first before any planning and designing can begin. The entire program will depend on the amount and type of seedlings needed for a given reforestation program. Such needs are best determined by the land managers and field foresters who are familiar with field conditions, acreages, and reforestation problems.

The seedlings needs must include the amount of seedlings by species, seedling sizes, and their target date for field planting. One must also predict the long term needs and the potential alternatives to these needs.

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WHAT TYPE OR TYPES OF CONTAINERS ARE THE BEST FOR THE OPERATION?

As we all know, there are a large variety of containers in use. These come in many different shapes and sizes, and they are made out of a wide range of material. Each container type has some advantages and some disadvantages. Each may suit a given purpose. Therefore, selecting the right and most suitable container is a very important matter.

Container selection shouldn't be based solely on readily available handling equipment at the nursery, or to suit a given planting method. Containers shouldn't be chosen because that is what someone else is using. Such arbitrary selections could lead to the wrong container and many disappointments later.

Some of the most important considerations for container selection should include:

1. It must suit the species and have the potential of producing the desired seedling size.
2. It must interact well with the growing facility. (This will be discussed later in the section on growing facilities)
3. It must support optimum seedling development in height and diameter growth, root structure, side branch development, lignification of the stem, and good bud initiation and formation.
4. It must provide protection for the roots against extreme climatic conditions to produce a hardy seedling in near natural growing conditions.
5. It must be suited for mechanization at the nursery and during field planting.
6. It should be recyclable for repeated use.
7. It should be lightweight, as durable as possible and low in cost.

Without a doubt these constraints are rather strident. Perhaps none of the containers in use today possess all the listed qualities, but it has been proven that some come closer than others. During my ten years of practical experience in containerization I have had the opportunity to try out most of the container types. This was done under varied conditions from the Northern cold area to the hot tropics. Out of all the container types, the styroblock, or polystyrene container came the closest in meeting the above listed requirements.

WHAT KIND OF GROWING FACILITIES ARE THE BEST?

There is no clear-cut answer to this question. In the past, a whole range of facility types were developed. These facilities range from the open pad to the most sophisticated greenhouses. From practically no environmental controls to the fully controlled growing areas.

Before a decision is made on the type of growing facility, one should consider the following guidelines:

1. The facility type should be well suited to provide the needed environmental controls for growing and for protecting the crop against extreme heat and cold weather, rain, snow, wind, etc.
2. The facility should be as simple as possible for cost savings in building, maintenance, and operation. If possible, all the available natural growing conditions should be utilized to grow a hardy and inexpensive crop. This often depends on how well the crops growing schedule is designed and carried out.
3. The interaction of container and growing facility should be favorable. A practical example may shed some light on this. The shelterhouse developed at Georgia-Pacific interacts well in practically all areas with the styroblock container. The relatively inexpensive shelterhouses equipped with environmental controls, as needed for given locations, provide all the conditions needed for good germination and growing, as well as for crop protection. These shelterhouses may have removable or permanent roof covers. The permanent roof covers are generally equipped for good ventilation with thermostatically controlled fullength roof vents. The sidewalls are either permanently open or, again, fully automated for opening or closing as needed.

Houses with such flexibility have the ability to provide all of the artificial controls needed for growing and protection, which may include heating, lighting, air enrichment, etc., but are quick to open up to take advantage of good ventilation and of the nearly natural growing conditions where this is possible.

The styroblock interacts well with the shelterhouses and because of its good insulating capacity, it protects the roots during hot and cold weather while such weather may be beneficial for hardy seedling growth. This factor is especially important where the stems and buds need to be chilled for deeper dormancy during the hardening phase.

As a general rule, when seedlings are produced in thin-walled containers like paper-pots, Leach cells, book planters, and a whole range of other containers, the seedling roots may then suffer from extreme weather conditions. Such seedling crops may do well in fully controlled greenhouses or in areas where the temperature stays relatively mild. Naturally, in a fully controlled greenhouse, one will end up with an artificial and expensive crop that may have a hard time facing harsh field conditions after outplanting.

HOW MANY CROPS SHOULD BE RAISED PER YEAR?

The answer to this question will greatly depend on local climatic conditions and on tree species. The local climatic conditions because of the environmental controls in the greenhouses may not interfere much with growing the seedlings, but it does determine the field planting conditions.

In areas where field planting is limited to a few months out of the year, regardless of the season, it is perhaps more advisable to stick to a one crop per year rotation. A good example of this is the practice in the Pacific Northwest where crop growing is mostly done during the natural growing season in spring and summer and the trees are planted during the dormant season in winter.

In the areas where trees can be planted from spring through late summer, containerized seedlings come in very handy because they can be planted without being dormant. In a case such as this, even two crops per year can be produced and field planted.

In areas with a moist and warmer climatic condition, like in some of our southern states, it isn't usual to produce 2-5 crops per year with faster developing species.

To illustrate the most extreme possibilities in fast crop rotation I want to sight out experience in the tropics where growing and planting may go on year-round. Here we have produced up to ten crops per year.

Containers are quite suitable for multiple crop rotation but this is often overdone. This may happen in areas where the natural growing conditions and field planting have their limitations. In places like this crops are often grown out of phase with the seasons, thus the crops are raised in expensive growing facilities at high costs. Such crops are often planted out of phase also which results in poor field performance. For better planting scheduling often an entire crop is placed in cold storage for later planting. Such a measure may have an adverse effect on the seedlings and will raise the overall reforestation cost.

HOW ARE GROWING FACILITIES SIZED?

The previously determined seedling needs, container types and sizes, facility types, bench arrangement, and the speed of crop rotation will provide most of the answers to the above question. However, there are also other factors which may play a role in facility sizing and utilization. These come from crop reduction due to seed quality, poor crop quality, and also a variety of other damages. Crop reduction, or fall-down, is difficult to predict ahead of time. But with sowing multiple seed in each cavity with thinning, and with a good rearing and protection program, this can be held to a minimum. With these measures we have averaged well over 90% in usable seedlings during the last ten years at our Cottage Grove facility.

WHERE SHOULD THE GROWING FACILITIES BE LOCATED?

Locating a container nursery is a lot easier than locating a bareroot operation. However, there are still some important factors that need to be considered before a decision is made on a given site. These are:

Climatic Conditions

In spite of the availability of the numerous environmental control mechanisms in containerized nurseries, if possible, one should consider such sites where dependence on control units can be avoided or minimized.

A site with mild climatic conditions that has a lot of sunshine and good air movement naturally would have nearly ideal conditions. Anything close to this should be given preference.

Topographic Conditions and Space Availability

The terrain on the site should be as flat as possible with good drainage. There should be adequate space reserved for support buildings, for storing and handling bulky material such as containers, soil and soil cover, for maneuvering and parking equipment and vehicles. There should always be room left for future expansion even though this may not be in the immediate plan.

Irrigation Water Requirements

There should be an adequate amount of irrigation water available with good water quality. Water quantity and quality can and must be determined before a site is chosen.

The amount of water needed can be calculated. As a general rule, it takes about 10-15 liters of water per square meter of gross growing area for one watering. During the height of the growing season, the seedlings may be watered as many as 2-3 times a week. Naturally, during the early growing stages and during the holding period, a lot less water is required.

The water quality is a very important factor in successful seedling production. Water quality can and must be determined with a complete water test.

Nutrient utilization greatly depends on the pH of the soil medium. The pH of the water, if it is not proper, can easily alter the pH of the soil. Some correction on water pH can be made by using acids or lime. However, even if the corrections are successful, making corrections could become cumbersome in case it has to be done often.

While rearing containerized seedlings, small amounts of nutrients are frequently applied through the irrigation water. Therefore, the mineral content of the water may influence the fertilizer regime. If the nutrient elements in the water are known, corrections for those can be made most of the time and should be made if necessary. However, it could happen that certain elements in the water source are in such an abundant supply that making corrections for them is not feasible. In such a case, the water source should be abandoned.

Labor Source Availability

As a general rule, container nurseries don't require a large year-round labor force. However, there are peak periods during the operation when a sizable work crew is required. Such times include the sowing, thinning, and field shipping periods. Locating a nursery close to a community does eliminate the need of hauling workers in from a distant location or the housing of people near the site.

Power and Fuel Source Availability

Even the simplest or most primitive containerized nurseries have an occasional need for electric power or certain fuel supplies. Occasional power needs can be covered by using in-house generators. Most facilities, however, do require a constant electric power source. In case there is a high risk of losing the crop due to power outages, it is even desirable to have an in-house backup power source.

Besides the need for electric power, other fuels are also needed for heating the greenhouses and for operating equipment. Nearness to a gas line may save cost. However, these types of fuel can be trucked in.

There may be other limiting factors which also need to be considered when a container nursery is located. An important one is the distance to the planting site. This will be covered in the next section.

WHAT IS A GOOD SIZE FOR A CONTAINER NURSERY?

In order to operate a bareroot nursery economically, it has to be relatively large in size, preferably in the several million seedlings per year production range. This is because of the high cost of support buildings and nursery equipment.

Containerized nurseries, on the other hand, can already operate feasibly from a several hundred thousand seedlings per year production capacity. This makes it possible to locate smaller nurseries closer to planting sites that will combat high shipping costs resulting from the bulky nature of containerized seedlings.

Small nurseries might be feasible but not the most economical. Practical experience shows that a nearly ideal size nursery has a capacity of around five million seedlings per year. Such a facility can be run by one experienced nurseryman. By adding one more nurseryman without boosting the equipment and support buildings, the capacity can be increased up to the ten million range.

I could go on and on by stating and answering some of the most often asked questions, but because of time limitations, I would rather show a few slides of an existing facility which shows some of the aspects I have covered so far and perhaps some others would be of interest to the audience.

Slide 1. A distant aerial view of Georgia-Pacific's Cottage Grove Forestry Research Center and container nursery facility.
Slide 2. A close-up view of the plant site itself.
Slide 3. A shelterhouse growing area cluster with ten 50' x 200' shelterhouses, eight 20' x 200' alleys and one 36' x 330' headhouse. Each unit can be operated by itself, but most of the time, when all the houses are filled to capacity, the entire greenhouse cluster is operated as one greenhouse without dividing walls between units.
Slide 4. One 50' x 200' shelterhouse with a permanent roof and equipped with heaters and an irrigation system.
Slide 5. One 20' x 200' alley with a plastic and removable roof cover, with irrigation lines, but without a heater.

Slide 6. The 36' x 330' headhouse. This unit serves as a storage and work area during sowing and later as a growing area also.

Slide 7. Fullength roof vents.
Slide 8. Removable sidewall cover.
Slide 9. Sowing line setup.
Slide 10. Soil loader.
Slide 11. Soil press.
Slide 12. Shutterbox seeding device.
Slide 13. Seed covering device.
Slide 14. Seedling holding benches.
Slide 15. Control house.
Slide 16. Near fully developed seedling crop.
Slide 17. Packaging in containers.
Slide 18. Packaging by extracting seedlings.
Slide 19. Shipping in trucks.
Slide 20. Field planting directly out of the container by using backpacks and dibbles.

CONCLUSION

It is impossible to give a detailed account on guidelines for operational containerized nursery development in a 15-20 minute presentation. However, I am sure that I have covered more useful material in this field in such a short time than there was available to me ten years ago when I was facing the task of developing large scale container nurseries. Since then, I have had the opportunity to go through this process many times under a large variety of conditions and there is no doubt that it was always interesting and challenging.

Today there is a storehouse full of information available on containerization, but unfortunately a lot of it is misused or ignored which consequently makes containers a controversial subject despite all of its many useful applications.

INTEGRATED SYSTEM APPROACH TO CONTAINERIZED SEEDLING PRODUCTION AND AUTOMATED TRANSPLANTING[1/]

Barney K. Huang and David B. South[2/]

Abstract.--Automated methods for producing air-pruned containerized seedlings under controlled environment were studied using the seedling growing and handling tray system to achieve fully automatic transplanting. Results showed that the integrated system provided superior germination and growth rates and relatively uniform seedlings whose yields were significantly higher than those of conventional plantbed seedlings.

INTRODUCTION

Field transplanting and plantbed operations are among the last few farming practices which have not been mechanized in modern agriculture. The need for a practical means for automating these operations has long been recognized. Little progress has been made in mechanization of seedling propagation and planting techniques, and the laborious traditional methods of using bare-root seedlings by hand or with mechanical setters are still used for planting various trees and farm crops.

Container-grown seedlings offer many advantages in growth, control, and mechanical handling (Huang and Splinter 1968, Huang 1971 and 1973, Morrison and Yoder 1975, Huang et al. 1979). The development of an automatic transplanter has further enhanced integrated system approach to containerized seedling production and transplanting. One-row and two-row multiple-drop automatic transplanters were designed to place containerized seedlings at predetermined intervals in the field thus increasing survival rate, eliminating human error in the operation, increasing transplanting efficiency, and reducing labor requirements.

The water injection opener was found to be a very simple and effective means for opening the ground and providing improved soil moisture, aeration and impedance (Huang and Tayaputch 1973). The device is particularly useful to enhance the multiple-transplanting capability of the transplanter. It allows more than one plant to be transplanted in a row for each indexing cycle which increases the operational speed without loss of efficiency.

Production of 1-0 bare-root hardwood seedlings with large diameter root-collars often can be difficult for the southern nurseryman. A short growing season and irregular germination can contribute to this dilemma. The five-to-seven-month growing season is often limiting for the production of large caliper seedlings. Successful production of sweetgum (Liquidambar styraciflua L.) seems to be especially dependent on sowing as soon as the danger of frost has passed. However, because of delays in fumigation or because of wet or cool weather conditions, seeding of hardwoods is often delayed until late May or early June.

Problems can also arise from sowing seeds with low viability of vigor. Germination of seeds of sycamore (Platanus occidentalis L.) and yellow poplar (Lirodeodron tulipifera L.) often is below 30 percent. Such poor germination results in irregular seedling spacing and variable seedbed density. These factors are very crucial to the production of seedlings with large diameters. For sweetgum, 73 percent of the variation in root collar diameter can be attributed to seedbed density (Webb 1969). The recommended density, to produce large diameter sweetgum seedlings are from 54 to 129 seedlings per square meter, while the seedbed densities of sycamore are 43 to 108 per square meter (Formy-Duval 1973). In general, the lower the seedbed density, the larger the seedling. Seedlings with diameters of one centimeter or more are desired because of increased survival and

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1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named, nor criticism of similar ones not mentioned.

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height growth (Ike 1962, Johnson and McElwee 1967, Webb 1969). To achieve the desired density, the nurseryman often will sow heavily in order to ensure an acceptable stand, and then thin to the desired density when the seedlings are two to three months old. This practice not only increases labor costs but also wastes seed.

Emergence can also be a serious problem, especially for small seeded species such as sweetgum and sycamore. Seed of these species should be firmly pressed into the soil (Vande Linde 1973) but not covered with soil since germination is restricted by soil cover (Bonner 1967). Movement of soil and seed due to wind, heavy rains, or irrigation can result in variable spacing and reduced germination. Even after seedlings have germinated, heavy spring rains have often caused high mortality due to erosion and uprooting of seedlings.

It would be desirable to develop a system that would extend the growing season, provide uniform spacing, and protect seedlings during the critical stage immediately following seed germination. The result of such a system would be the production of more large diameter seedlings per unit area than is generally achieved with the conventional production method. A system involving germinant transplants has been developed for forest trees in Canada (Skeates and Williamson 1979). Black spruce (Picea mariana (Mill.) B.S.P.) seeds were germinated in a greenhouse thereby maximizing seed germination and protecting the germinants from adverse environmental conditions. The germinants were placed into 2.5 cm square peat cubes and grown for one to two months in the greenhouse. In June, the seedlings (rooted in peat cubes) were transplanted manually into trenches across the nursery beds.

This paper presents the automated methods for producing air-pruned intact-root containerized tree seedlings under controlled environment using the seedling growing and handling tray system. Germination, growth and yield studies were carried out for southern hardwoods and pine to illustrate the advantages of automated seedling production system and fully automatic transplanting.

SYSTEM DESCRIPTION

The utilization of containerized seedlings in conjunction with proper handling and transplanting techniques offers definite advantages in reduction of labor for total mechanization, efficient use of plantbed space, and undisturbed seedling roots for healthy growth. However, the use of containerized seedlings involves many economical, physiological, and engineering problems such as container cost, efficient means of seeding, germination, emergence, uniform growth of seedlings, growth media, root development, moisture control, efficient means of removing containers, use of degradable containers, handling of individual seedlings, optimum container shape and size, etc. After extensive research into the above indicated problems and into their possible solution, a seedling growing and handling system was developed (Huang 1973). The device also contemplates the automatic transplanting of the seedlings from the device to achieve the systems engineering of the cultural practices.

The seedling growing and handling system consists of a plural-opening seedling growing and handling tray. Figure 1 illustrates the concept of integrating the tray system with pneumatic automatic transplanter to increase the total operational efficiency. The tray can be made from a thin plastic sheet or metal foil at such a low price that it can be either reused or discarded. The tray consists of many conically shaped or pyramid shaped cells tapered upwards with both ends open. Since the plant roots develop toward the bottom of the pot, a larger bottom not only provides a more desirable shape for root growth but also permits a containerized seedling to drop out easily at the time of transplanting. This pot shape also reduces the exposure of growth media to the atmosphere so that the moisture loss can be reduced.

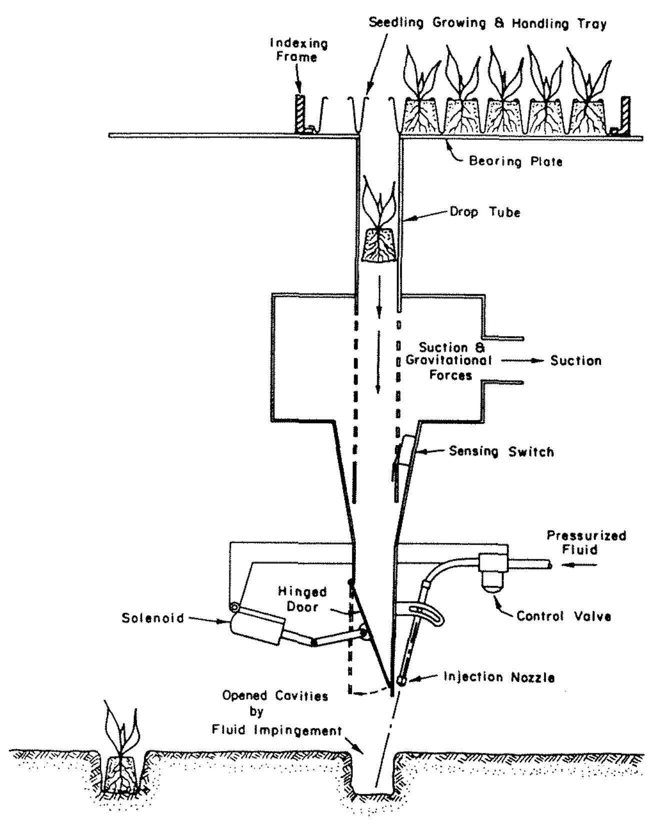

Figure 1.--Operational principle of precision automatic transplanter integrating the tray system with pneumatic transplanting and fluid injection ground opening.

Growing and bulk handling of seedlings for fully automatic transplanting involve (1) filling the plural openings in the growing and handling tray with a growth medium such as soil mix, peat mix, vermiculite mix, growth cubes, etc., (2) planting a seed in the individual opening or placing a preseeded growth medium in each opening, (3) providing an environment conducive to seed germination and plant growth, (4) inserting a bottom plate under the tray at the time of transplanting, and (5) transferring the tray to the indexing frame of the automatic transplanter by pulling out the bottom plate. The tray is progressively shifted by the indexing frame of the transplanter longitudinally and laterally in increments equal to the cell distance. As each containerized seedling is indexed over an opening in the bearing plate, it drops to the ground through a drop tube by gravity and with the aid of suction force. Thus, the containerized seedlings in the tray can be planted directly at the rate of travel of the transplanter and the seedlings are systematically planted at predetermined spaced intervals. The plastic seedling growing and handling trays serve not only as seedling growing and handling containers during plantbed and transferring operations, but also as an indexing grid-cartridge during automatic transplanting. The trays were designed to adapt to the indexing frame of the transplanter. Each tray holds 70 seedlings and the indexing frame carries three trays or 210 seedlings. Figure 1 also illustrates the operational principle of the precision automatic transplanter with a water injection spot opener. The transplanting capacity can be increased by increasing the number of suction-drop tubes. Press wheels are used to support the machine weight, to provide proper coverage of seedling roots with the right amount of soil, and to provide additional compaction to the covering soil. The one-row automatic transplanter used in this study is shown in figure 2.

PROCEDURES

Sycamore and sweetgum seeds were collected from northeastern counties of North Carolina. Sweetgum seeds (collected during October, 1973) were stratified for 40 days at 2 degrees C. Sycamore seeds were allowed to mature on the tree before being collected in January, 1974. Germination percentages for sweetgum and sycamore seeds were 91 percent and 30 percent respectively.

Seeds of each species were sown in plastic seedling growing and handling trays (Summit Plastic Corp., Tallmadge, Ohio) in a greenhouse on March 1, 1974. Each tray contained 70 cells, each with 4 x 4 x 5.5 cm dimensions. Cells were filled with a 3:2:1 volume ratio of loamy soil, peat moss and vermiculite. The temperature in the greenhouse was kept above 19^{o}C and the trays were watered during the day with a mist system at 6-minute intervals before germination and a 12-minute intervals after germination. Fertilizer (23-19-17) was applied twice during the two-month period in the greenhouse.

The nursery study was installed at the Federal Paper Board Company nursery at Lumberton, North Carolina. Soil in the test plots was a sandy loam to loamy sand and contained 56 ppm of available P, 28 ppm of exchangeable K, 272 ppm of exchangeable Ca, 39 ppm of exchangeable Mg, and 6 ppm of Mn. The soil contained 1.9 percent organic matter and had a pH of 2.6. The study area was fumigated with 504 kg/ha of methyl bromide (MC-2) on April 5, 1974.

For the broadcast treatment seed were sown by hand at the nursery on April 29, and the beds were mulched with a thin layer of pine straw. On May 6, 7, and 9, 2-month old containerized seedlings from the greenhouse (fig. 3) were

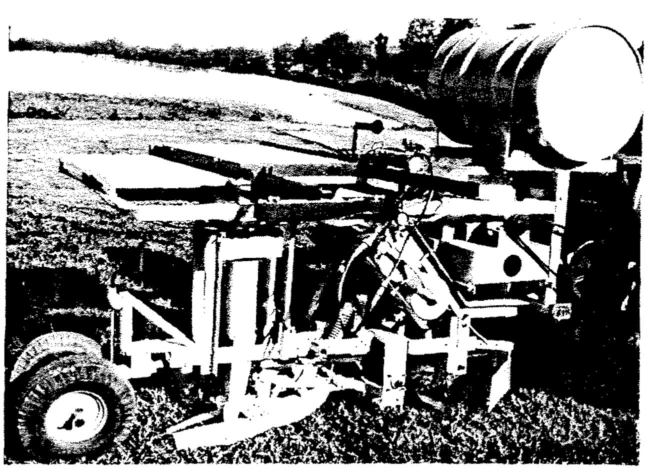

Figure 2.--One-row one-drop precison automatic transplanter for containerized seedlings.

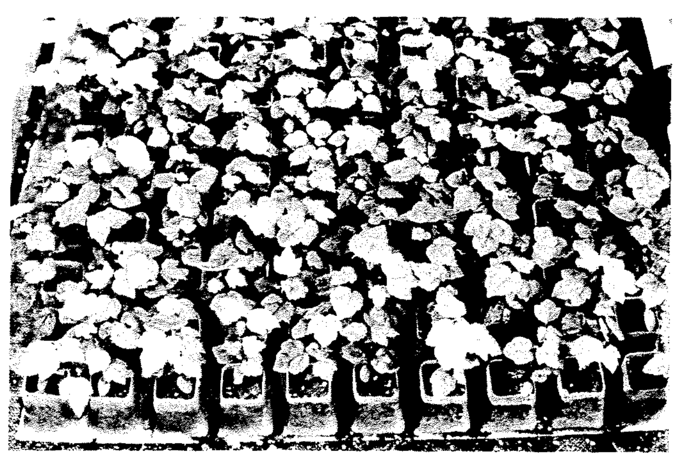

Figure 3.--Seedling growing and handling trays with two-month-old sweetgum seedlings ready for transplanting.

transplanted in trenches 35 cm apart. Seedlings were spaced 2.5 cm apart within each row; this resulted in a density of approximately 129 seedlings per square meter. The transplants were not mulched with pine straw. Plot size for each treatment was 1.2 meters wide by 12.2 meters long. On May 9, heavy rains resulted in considerable erosion of beds in all treatments.

Seedlings were irrigated at the rate of 1.2 cm of water per day until they were approximately 10 cm tall. Fertilizer was applied in 6 applications totaling 390 kg/ha of nitrogen, 118 kg/ha of phosphorus, and 236 kg/ha of potassium. On August 6, the broadcast sweetgum seedlings were thinned to approximately 64 seedlings per square meter.

Heights of seedlings in the plots were measured on June 4, July 9, August 19, October 22, and November 17, 1974, by randomly selecting six codominant seedlings per plot and recording height to the nearest centimeter.

On November 17, root-collar diameters of seedlings from 3 subplots within each plot were recorded. Subsamples were taken at 3 meter intervals, starting and ending 3 meters from the end of the plot. Each subsample was 0.9 meters wide by 1.2 meters long.

The number of man-minutes required for hand-weeding the plots were recorded on June 4, June 20, July 9, and August 6. All variables measured were subjected to analysis of variance.

RESULTS AND DISCUSSION

Seedling production and transplanting tests showed that the seedling growing and handling system achieved the following results.

1. Provided a means of producing a large number of relatively uniform containerized seedlings. The uniformly sized individual root zones allow the seedlings to grow more uniformly throughout the plantbed by restricting root-system expansion of larger plants to slow down the growth since all plants tend to maintain their proper shoot-root ratio. Figure 3 shows the uniformly grown two-month-old containerized sweetgum seedlings ready for transplanting.
2. Provided efficient and minimum use of plantbed space for maximizing uniform seedling production.
3. Eliminated the laborious operation of pulling the seedlings from plantbeds and reduced labor requirements in the seedling handling operations to a minimum.
4. Reduced moisture loss of containerized seedlings in nursery beds by reducing the exposed surface of growth media. This in turn resulted in 2° to $3^{\circ}C$ higher temperature in the growth media and root system giving better plant growth compared to conventional plantbeds, flats, and trays.
5. Provided a seedling with efficiently shaped intact root zones. The seedlings could easily be removed from the larger bottom of the container just before being transplanted. The intact root system once transplanted fanned out to insure good ground contact for excellent survival rates and good growth with minimal shock.
6. Adapted to various types of growth media and cuttings of many varieties of plants could be started. The pyramid or cone design of the tray provides good root orientation for future growth and air pruning effect at the open bottom totally eliminated root-tangling or root-bound problem in containerized seedlings for better growth. It was also shown that air-pruned intact-root tree seedlings do not require long root zones as generall believed to provide vigorous growth after transplanting, thus greatly simplify the seedling handling and transplanter design in tree planting. Figure 4 shows the effect of air pruning on pine root formation at various stages of seedling growth.
7. The adaption of seedling growing and handling system to the automatic transplanter was proved to be excellent which resulted in simplification of automatic transplanter and in improvement of the operational efficiency.

Field tests showed that the automatic transplanter performed effective automatic transplanting with a considerably lower labor requirement. Practical application of the water injection opener showed that the opener provided an effective means for opening precision spot cavities in the ground to improve soil moisture, aeration and impedance for better transplanting performance and plant growth. These new developments made it possible to automate the total containerized seedling cultural operations from plantbed preparation, seeding, handling, to the field transplanting.

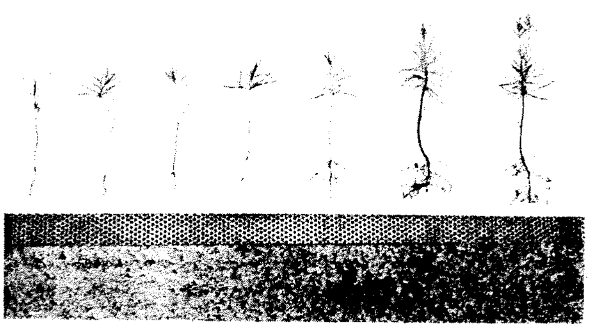

Figure 4.--Effect of air pruning on pine root formation at various stages of growth.

Transplanted seedlings produced more large diameter seedlings, and taller seedlings than the conventional planting as shown in Table 1 and figure 5. There was a three fold increase in large diameter sycamore seedlings and 50 percent more large diameter sweetgum seedlings by using the containerized seedlings. There are two probable reasons explaining why the containerized seedlings were larger than the conventional seedlings. Air-pruned intact-root seedlings generally provide vigorous growth as soon as transplanted and the containerized seedlings were two months older than the conventional seedlings in plots where the seed were broadcast. Height growth curves (figs. 6 and 7) indicate similar growth patterns for both treatments; however, because containerized seedlings were sown earlier in a greenhouse, their growth curves were shifted to the left. In addition, seedlings in conventional plots were probably exposed to greater moisture and nutrient stresses than transplanted seedlings as a result of competition from crabgrass (Digitaria sanguinalis (L.) Scop.). Although the study area was fumigated in the spring with methyl bromide, weeding times on the conventional beds mulched with pine straw exceeded 535 man-hours/ha. The nonfumigated pine straw was apparently contaminated with weed seed. Conversely, beds with containerized seedlings and no mulch required only 42 man-hours/ha of handweeding per hectare (fig. 8). Nonfumigated pine straw mulch has been shown at several nurseries to introduce weeds and increase weeding times (Bland, 1973; South, 1976). Reducing competition from grasses can significantly increase production of hardwood seedlings (South and Gjerstad 1981).

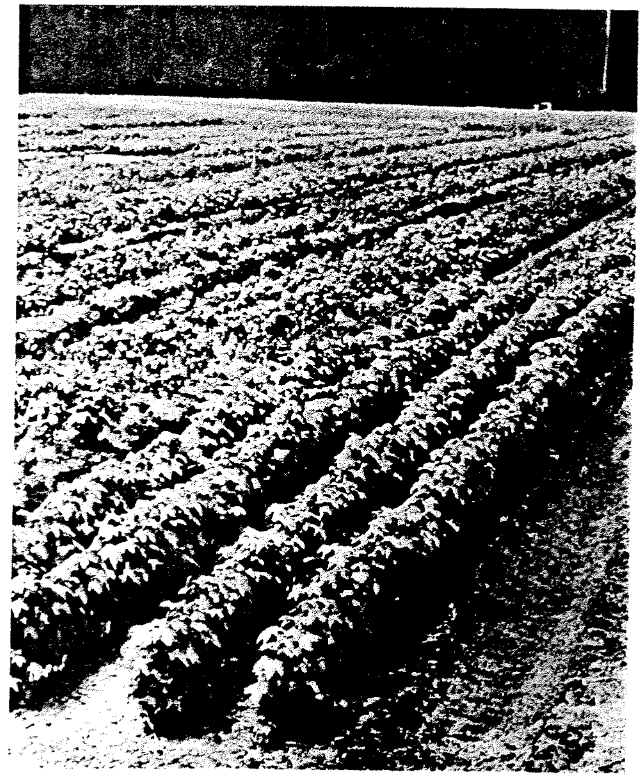

Figure 5.--Growth differences between containerized seedlings in foreground and conventional seedlings in background (July 9, 1974).

Although this study demonstrated that transplanting containerized seedling into nursery beds extends the growing season, insures uniform spacing, and provides protection of seedlings during the critical germination stage, these benefits were not obtained without additional costs. The additional costs of greenhouses, containers, greenhouse maintenance, automatic transplanter (or hand labor for transplanting) would increase seedling production cost of these species.

Presently, the North Carolina Forest Service sells 1-0 sweetgum seedlings for $60 per thousand and 1-0 sycamore for $85 per thousand. With the limited production in North Carolina in 1980 of 200,000 sweetgum seedlings and 27,000 sycamore (a total of less than one hectare), the total worth of both crops would not exceed $16,000. With this low level of production, any large capital investment would be prohibitive. In order to justify such an expense a higher crop value

Table 1.--Seedling production and height growth from conventional and transplanting methods of propagating sweetgum and sycamore at the Federal Paper Board Nursery in 1974.[a]

Species	Propagation method	Total number of seedlings	Number of plantable seedlings[b]	Height of seedlings on 8/19/74
		Number per square meter		cm
Sweetgum	Conventional plantbed	57	17	38
	Containerized seedlings	86	26	48
Sycamore	Conventional plantbed	28	9	58
	Containerized seedlings	44	28	75

a/ All means of variables within species are significantly different at 0.05 level.

b/ Root-collar diameter for sweetgum plantable seedling was greater than 0.79 cm.
Root-collar diameter for sycamore plantable seedling was greater than 1.1 cm.

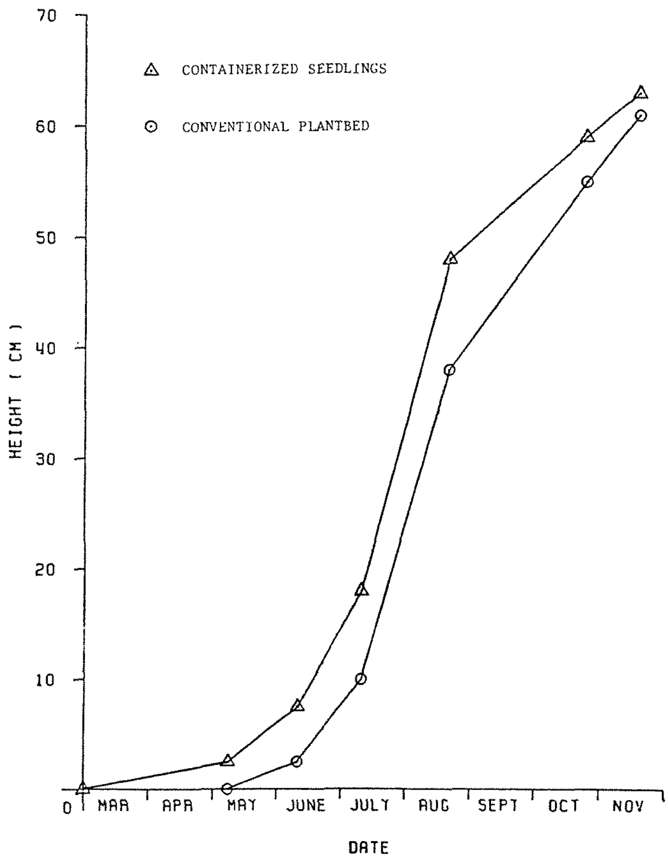

Figure 6.--Average height growth curves for sweetgum seedlings.

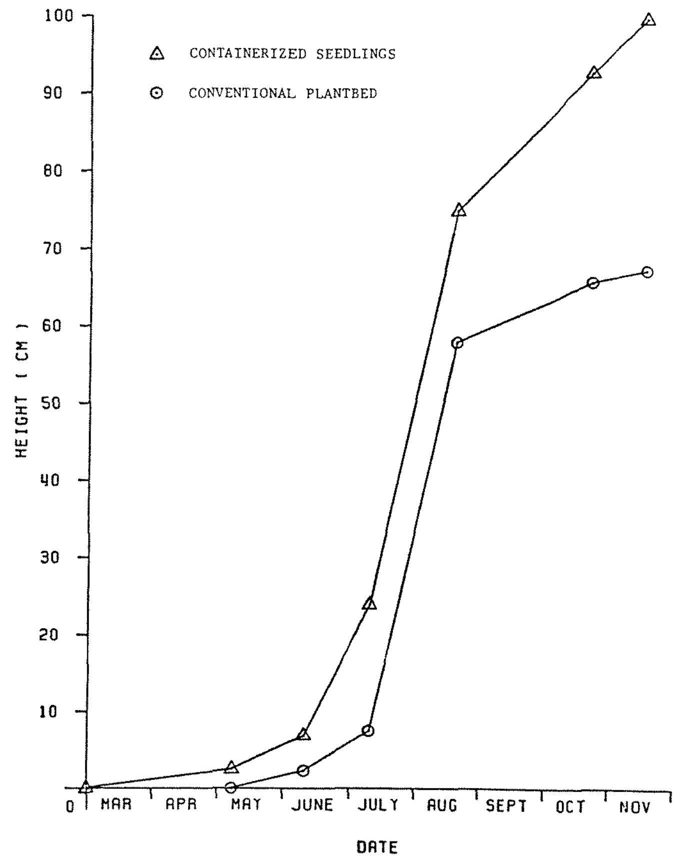

Figure 7.--Average height growth curves for sycamore seedlings.

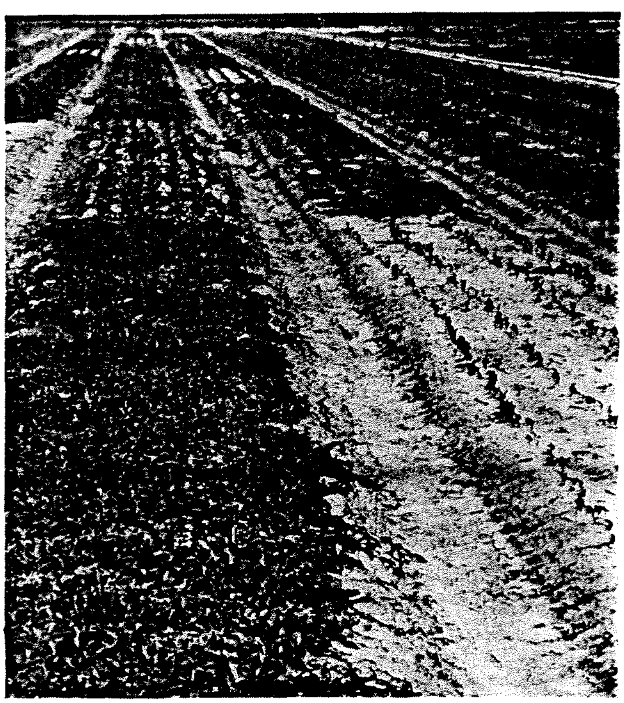

Figure 8.--The pine straw mulched plot (broadcast sown) on the left required the equivalent of 493 more man-hours of weeding per hectare than the nonmulched plot on the right (containerized seedlings).

and/or production of more seedlings would be required. One tree crop in the South for which this system may be applicable is fraser fir (Abies fraseri (Pursh) Poir.). In addition to having limited supplies of seed, this species has low seed germination (3-25%), is slow growing, and has high crop value. One hectare of 3-0 fraser fir seedlings has an approximate value of $400,000. Increasing seed utilization and decreasing the number of years needed to produce a fraser fir transplant would help to offset the additional cost of a germinant transplant system.

This study also demonstrated that the containerized seedling can be automatically transplanted directly from greenhouse into the field especially with water injection spot opener. In this case the above mentioned additional costs of greenhouses, containers and maintenance will be greatly offset by the conventional transplanting costs. Thus, the integrated system approach to containerized seedling production and automatic transplanting would provide a practical means for total tree culture mechanization.

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OPERATIONAL REFORESTATION[1/]

Samuel F. Gingrich[2/]

One of the major forestry problems in the South is the prompt regeneration of pine forests and the establishment of new forests on lands best suited for pine. During the 1950's and early 60's, except for a few years during the soil bank plantings, about one-half million acres of pine were planted annually. By the late 60's and early 70's the annual rate had increased to about three quarters of a million acres. Since 1975 the annual acreage planted has stabilized at about 1.2 million acres. Most of the easy planting, primarily on old fields, was completed by the late 60's when the era of intensive site preparation on cut-over land began. Some of the earlier plantations are now being harvested and although resource statistics may show a slight increase in reforestation acres, the actual forestation of new acres may be decreasing.

Forest resource statistics also show that there are hundreds of thousands of acres in the South, capable of, but not now supporting pine forests. Many of these areas are on difficult planting sites that may have to be man-handled by drainage practices and control of unwanted vegetation before planting. These acres need to be put into production if the South is to meet the projected timber needs of the future. It is a tough assignment and the containerized seedling may play an important role in accomplishing this.

The industrial reforestation programs in the South are impressive but not without serious technical problems that need to be solved. Survival has been low on droughty sites, forest pests such as the tip moth and fusiform rust impose a serious threat in some areas, and site preparation costs are high and going higher.

I prefer to discuss the merits of containerized seedlings rather than compare them with bare rooted seedlings, but the simple fact remains that the operational use of containerized seedlings depends on comparative performance and costs. State forestry agencies and many of the forest industries have made substantial capital investments in nurseries, heavy equipment and seed orchards geared to the production of bare rooted seedlings. One of the facts we have learned in our attempts to have new technology adopted by user groups is that the advantages must be more than a break-even situation because the adoption usually involves a redirection of capital investments and the retraining of personnel.

The literature on the comparative performance of containerized and bare rooted seedlings is inconclusive. Depending on the source of information, differences can be found but in general bonifide experiments have shown no significant differences in terms of survival and early height growth. Most research in containerized planting stock is of recent origin beginning about 10 years ago. Much of the preliminary experimentation and probing, characteristic of new research, has been completed and research efforts should now focus on those technical problems that still remain. Many of these problems deal with operational aspects such as the logistics of the entire production system and improved automation and mechanization. There is some evidence, based on research now in progress, that these problems are being addressed.

There are two areas where containerized seedlings could play an important role in pine regeneration. The first area is those difficult sites that have been avoided in the past. A second possibility is the packaging of a seedling that could perform under conditions involving a minimum of costly site preparation. This will probably mean larger seedlings and a modification of conventional containers, but the cost advantages could be attractive.

The relative merits of containerized planting stock should not only be judged by survival and early growth but also by the eventual stand that will be produced. Small differences in early seedling growth can be quite large when projected into the final stand. For example, if the potential gain from the best containerized growing stock will yield a 5 per cent increase in the number of dominant trees in the final stand, at age 25 the increase in volume would be nearly 6 cords and even more for longer rotations involving the production of sawlogs and peeler logs.

1/ Presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Program Manager, Loblolly Pine Research and Development Program, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Charleston, South Carolina.

One final item at the very heart of operational reforestation is the need for better quality control from nursery to planting site, and specifically the planting operation. Geneticists have found that in many cases where genetically improved planting stock failed to perform as expected, the cause was related to faulty planting and not the quality of the seedling. There may be a tendency to consider improved planting stock as super seedlings capable of performing growth miracles but the cost of producing containerized seedlings justifies the highest level of quality control. Tree planting is costly--but failures are more costly.

In summary, the operational use of containerized seedlings will require that they be used for more than special cases or experimental use. I believe there is a potential for containerized seedlings to provide an option in the planning of reforestation activities but at this time that potential has not been fully developed. Our speakers this morning are well qualified to discuss operational reforestation including the processing and shipping of containerized seedlings, planting, site preparation and the development and testing of automated tree planting machines.

THE PROCESSING, STORAGE AND SHIPPING OF CONTAINER SEEDLINGS IN THE WESTERN UNITED STATES 1/

Thomas D. Landis and Stephen E. McDonald 2/

Abstract.--Container seedling handling systems in the western United States have evolved to reflect the special requirements of individual nurseries. Seedling containers are transported by hand, pallet or conveyor systems. Seedlings are either processed in the growth container or extracted and boxed, depending on management objectives, degree of seedling dormancy and storage facilities.

INTRODUCTION

Before considering this subject, we should consider the physical differences between shippable bareroot and container tree seedlings. Containerized seedlings are bulkier and heavier than comparably sized bareroot seedlings. Container seedlings are sometimes shipped while not completely dormant and planted throughout the season, whereas bareroot trees are normally shipped fully dormant and only outplanted in the spring or late fall.

Container seedling nurseries use a variety of handling systems. Reforestation objectives or customer needs can generate unique requirements, and handling systems have evolved to meet these demands. Size of the planting program, available transportation, distance to the planting site, on-site storage facilities and type of planting tool all influence the evolution of a container seedling handling system.

Because containerized seedlings are relatively new in reforestation, handling systems are continually being improved. Many container nurseries have radically changed their seedling processing each of the last few years in an effort to increase efficiency and incorporate the newest research.

These processing techniques were developed for western conifer species and may not be applicable to other containerized tree seedlings. Refrigerated storage, in particular, may not be adaptable to southern container nurseries until cold tolerance limits are established for southern species.

CONTAINER HANDLING

Handling containerized seedlings at the nursery is complicated by their bulk and weight. Containers must be handled during sowing, after thinning, when transferred from greenhouse to shadehouse, during packing and at outplanting.

Small nurseries simply hand-carry containers between operations or may use motorized vehicles. One way to minimize handling is to process containers right in the greenhouse which is especially suited to houses with portable benches.

Conveyors are often used to improve container handling. Unpowered roller conveyors are used for short distances and motorized conveyors are becoming common in many nurseries. The Gleason Company (Sumner, Washington) has developed an electrically powered conveyor system for handling tree seedling containers. It is available in portable sections and is also compatible with an automated tray filler.

Pallets are also used to transport container seedlings and are moved with pallet jacks or fork-lift trucks. Pallets serve a double function as growth tables in some nurseries.

1/ Presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.
2/ Respectively, Western Nursery Specialist, USDA-Forest Service, Lakewood, Colorado; and Forestation and Tree Improvement Specialist, USDA-Forest Service, Washington, D. C.

PROCESSING AND STORING CONTAINER SEEDLINGS

Two processing techniques are commonly used for western container seedlings: 1) storage and shipping in the container in which they were grown, and 2) extraction from the growth container and storage in boxes.

Storage and Shipping in Growth Container

Container nurseries that ship their seedlings to the field in the growth container usually store their stock in a shadehouse until time for outplanting. This storage may consist of a short period in spring or summer or over the winter. The shadehouse offers protection from overheating, intense sunlight and dessication from sun and wind. When overwintering stock in cold climates, seedlings are placed on the ground with sawdust packed around the perimeter to prevent freezing damage to the root system. Winter dessication can occur if hot drying winds or sunlight increase transpiration when the root system is frozen. Adequate shade and complete snowcover can lessen winter drying losses.

The seedlings remain in the shadehouse until a few days before outplanting when they are graded and prepared for shipping. Some nurseries ship their seedlings on tier racks in delivery trucks whereas other facilities package the containers in waxed cardboard boxes which are stacked in the trucks. Unless the delivery trip is short, the trucks are refrigerated to retard seedling transpiration and prevent overheating.

Shipping container seedlings in the growth container is most commonly used when seedlings are not completely dormant. This technique has the advantage of protecting the shape of the root plug which is necessary for dibble planting. Many foresters believe that this technique reduces seedling transplant shock.

Phil Hahn of the Georgia-Pacific Corporation (Eugene, Oregon) has devised the "quarterblock" system of shipping and outplanting container tree seedlings. Specially constructed styroblocks are shipped to the field in boxes, broken into quarter-sections and planted out of an aluminum backpack. When the quarterblocks are returned to the nursery, they are banded together and reused for the next crop.

Several disadvantages are inherent with the "in container" processing method. Shipping and storage volume is high and seedlings can only be graded for shoot characteristics because the root system is never exposed. Unless the containers are disposable, they must be shipped back to the nursery, cleaned, and sterilized before reuse. Returning containers is expensive and some amount of container damage must be expected.

An intermediate method is unique to Leach "Conetainers" because these containers consist of individual plastic "cells" that are removable from the growth rack. This container design permits the growth cells to be removed from the racks and processed individually. The seedlings are graded, bound together with tape or rubber bands and packed into boxes. The advantages of this method are space efficiency as more seedlings can be packed into boxes, and individual grading so that no empty cells are shipped. The empty plastic cells must still be returned to the nursery for cleaning and sterilization before reuse.

Seedling Extraction and Box Storage

This processing technique involves complete extraction of the seedling from the growth container at the nursery, and developed because of the high costs inherent in shipping and returning containers.

After removal, the seedlings are processed similarly to bareroot seedlings and can be graded for both shoot and root characteristics. The shippable grade trees are accumulated in bundles of 10-25 and the root plugs are wrapped in sheet plastic, saran wrap, or are inserted into plastic bags. Seedling bundles are packed into waxed cardboard boxes, sometimes with a plastic bag liner to retard moisture loss.

The advantages of this processing method include significantly less shipping and storage volume, the ability to grade the root system, no container return problem and the potential for long-term storage.

A disadvantage of this technique is that seedlings must be completely dormant and cold-hardy. This requires careful monitoring of seedling physiology and a cold-hardening period in a shadehouse. Most nurseries using this technique schedule their packing operation during midwinter to insure seedling dormancy. Refrigerated cold storage is required because seedling dormancy must be maintained for several months until outplanting. Planting hoes or shovels rather than dibbles are generally used because the root plug looses its circular form during handling.

Refrigerated Storage

Seedlings shipped in the container are sometimes stored under refrigeration for short time periods, but extracted and boxed seedlings must be stored under refrigeration. Dormant, cold-hardy seedlings are typically stored at temperatures slightly above freezing (33-34°F) for several months. Some nurseries have adopted frozen storage and found that they can store some tree species for up to six months at temperatures of 28°F. By holding temperatures slightly below freezing, the free water in the storage container is changed into ice which almost eliminates storage mold problems. Experience has shown that freezing damage to the stored tree does not occur unless temperatures drop below 25°F.

Storage containers must be sturdy enough to protect the seedlings and support additional weight when stacked. Because high humidity is desirable during storage, waxed cardboard boxes are commonly used and some nurseries use plastic bag liners. These bags are necessary for frozen storage to prevent freezing dessication during long-term storage. Some nurseries even fold over the top of the bag to completely seal the storage box. This practice will eliminate moisture loss but will require constant storage temperatures as temperature fluctuation could stimulate excessive respiration and result in seedling damage.

Refrigerated storage buildings may be located at the nursery, or freezer space can be leased. The performance of storage units should be checked prior to use to insure that desired temperatures can be maintained with minimal fluctuation. Refrigerated vans may be used for storage and can eliminate additional handling between storage and shipping. Many vans are equipped with compressors that run on gasoline or diesel fuel for in-transit cooling or electricity for on-site storage.

Several problems can occur during refrigerated storage of container seedlings. Storage molds, especially Botrytis, are a constant threat to stored seedlings. Botrytis spores are ubiquitous in container nurseries but disease development can be avoided by reducing free moisture on foliage, rouging diseased seedlings during grading and judicious use of fungicides. Freezing injury can be averted by insuring that container seedlings are dormant and cold-hardy before storage. Dessication should not be a problem with plastic wraps and waxed boxes.

Frozen seedling storage introduces some special problems because the trees must be defrosted gradually to prevent injury. Proper unthawing takes 7-10 days at cool temperatures; any attempt to hasten the process will damage the seedlings. Field personnel must be educated in the handling of frozen seedlings so that they can plan for gradual defrosting.

SHIPPING METHODS

As already discussed, the shipping method depends on the seedling and the processing technique. Trees shipped in the growth container will require a rack system in the truck if they are not boxed. Boxed seedlings from refrigerated storage should be shipped in refrigerated vans. Frozen seedlings will have to be protected against rapid temperature increases. Even if trips are short and refrigeration is not available, container seedlings should be shipped in enclosed trucks to minimize overheating and dessication. Refrigerated vans also have the advantage that they may be left at the planting location for on-site storage.

SUMMARY

Containerized seedlings differ from bare-root stock in that they are bulkier and may not be dormant when outplanted.

Container seedling nurseries have developed handling systems which reflect the unique characteristics of their operations.

Seedling containers require frequent handling, and pallet and conveyor systems are commonly used.

Two processing methods are utilized for container seedlings in the west. Nurseries that ship trees in a nondormant condition or do not use refrigerated storage usually leave seedlings in the growth container. The other technique involves removing seedlings from the container, wrapping them in bundles and packing them in cardboard boxes.

Boxed seedlings are held in refrigerated storage, sometimes at temperatures below freezing, until shipment. Seedlings stored in their containers usually remain in a shadehouse until they are shipped in boxes or racks in the delivery trucks.

OPERATIONAL PLANTING OF CONTAINER GROWN SLASH PINE SEEDLINGS ON PROBLEM SITES[1/]

Jerry E. Abbott[2/]

Slash pine seedlings are grown in Kys-Tree-Start containers for outplanting on problem wet sites between May and October. Approximately 1,250 to 1,500 acres per year are hand planted with container trees by contract crews.

INTRODUCTION

Kirby Forest Industries began planting container trees in 1973 with the initial objectives of:

1) Determining the type of container that is best suited to large scale mechanical planting.

2) Extending the planting season.

3) Obtaining better survival and/or growth than possible with bareroot seedlings.

The containers used in these early plantings were Japanese Paperpots, Agritec Polyloam, BR-8 Gro-Blocks, and a pressed peat block. Also, Kys-Tree-Starts were planted starting in 1975.

Trees were grown in lath houses, moved out to a shade area, then machine outplanted.

The present container operation began in 1978 with construction of a greenhouse for production of container trees for operational planting. The current objective of the container program is to establish plantations on problem wet sites. Approximately 750,000 plantable container trees are grown per year for planting between May and October. This number of trees will plant between 1,250 and 1,500 acres per year, which was determined to be the approximate number of these wet site acres.

SEEDLING PRODUCTION

Slash pine seed is soaked overnight in water prior to sowing. Soaking speeds up germination, which is important during summer months when high temperatures can reduce germination (Barnett 1979). In addition, shade cloth is placed over the outside of the greenhouse roof during the summer.

Kys-Tree-Start containers are seeded by vacuum seeder and hand. The vacuum seeder drops twenty seeds at a time. A larger seeder is not practical with this container because the shape of each block (100 containers) is variable.

The Kys-Tree-Start container is a peat-vermiculite mixture that has fertilizer incorporated in the container. This container is no longer being produced, but we have enough to last through our 1982 season. The main problem associated with this container is that the high nitrogen content of the incorporated fertilizer plus a high water holding capacity tends to produce too much top growth in relation to root development. This tendency can be controlled by careful watering, shorter greenhouse cycles, and top pruning. We tried to persuade the manufacturer to eliminate fertilizer from their process, but we were not successful in doing so.

Seedlings are grown for 4-6 weeks in the greenhouse, then moved to a shade area. Shade cloth is placed over the seedlings for 2 weeks until succulent growth has hardened. The shade cloth is then removed for the remainder of the growing period. Ideally, trees grown in these containers would be outplanted at 12-16 weeks of age. If held longer and rainfall prevents control of growth by withholding water, then additional top pruning may be necessary.

Generally, a new crop is started in the greenhouse every 6-7 weeks. Five crops are required to produce the goal of 750,000 plantable seedlings. Production schedules are modified to meet excessively wet or dry conditions.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Tree Improvement & Nursery Operations Manager, Kirby Forest Industries, Inc., P. O. Box 577, Silsbee, TX 77656.

PROBLEM WET SITES

The sites that our container program is designed to replant are flat, poorly drained clays and silt loam over clay soils. They typically have standing water during the normal bareroot planting season to the extent that seedling survival is doubtful.

The site preparation methods on these wet sites differes from our regular site preparation only in that the wet sites are bedded. Normal site preparation consists of either KG, windrow, and burn or chop and burn. Chopping is done with tree crushers or drum choppers. Bedding on chopped areas is delayed for 1-1½ years so that the larger material may decompose. On these tighter soils, it is necessary to disc prior to the bedding operation.

PLANTING

A change from machine plant company operated crews to hand plant contractor crews has, for the present, eliminated our need for a container that is machine plantable. All containers are currently hand planted.

Contractors pick up the container trees from the shade area and transport them to the field. Most use racks with plywood shelves to increase the number of seedlings they can haul. Pick-up trucks with campers or vans are used to prevent wind damage and dessication during transport. Throughout the planting operation, the bulkiness of container trees increases the handling cost.

Production rates for container trees average about 1,000 trees planted per man day. As 500-600 trees are planted per acre, approximately 1.8 acres can be planted per man day. The maximum number of the Kys-Tree-Starts that can be carried in a standard planting bag is 200.

Trees are planted with a standard dibble or one designed to the shape of the container. With the peat container it is important that the entire container be planted below the ground. This prevents drying caused by the wicking effect of the peat container.

SUMMARY

The original objectives of our container program have been modified based on changes in our method of operation and experience with container trees. Our program is designed specifically for problem wet sites that are difficult to get established with bareroot seedlings in the normal planting season. Survival of 300 trees per acre after two years is the generally accepted minimum; however, on certain sites that have been replanted several times, somewhat lower stocking would even be acceptable. Generally, plantations are replanted or interplanted if less than 300 trees/acre survive, or where mortality has occurred in spots.

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METHODS OF SITE PREPARATION AND PLANTING

FOR CONTAINERIZED LONGLEAF PINE SEEDLINGS IN NORTH CAROLINA[1/]

Donald F. Robbins and H. Grady Harris[2/]

Abstract.--Various site preparation and tree planting methods using longleaf pine (*Pinus palustris* Mill.) containerized seedlings were tried on an operational basis in the North Carolina sandhills area. The most effective methods were furrowing or bedding followed by hand tree planting; V-blading with machine planting was successful where conditions were not too severe. Operational use of containerized seedlings of this species was discontinued in 1979 because of consistently poor survival resulting from lack of moisture.

INTRODUCTION

The Forestation Section of the North Carolina Division of Forest Resources began planting longleaf pine (*Pinus palustris* Mill.) containerized seedlings commercially for private forest woodland owners in August, 1977. The purpose of this operational planting of containerized seedlings was to extend the tree planting season and to see if survival problems were less than those that had been encountered with bare root stock.

Due to other commitments in the greenhouse, the month of August had been the earliest date on which containerized longleaf seedlings became available for tree planting. When this planting began the first year, rain was plentiful and adequate survival made the operation fairly successful. Various methods of site preparation and planting were tried; lack of experience was very evident and many problems developed. Planting of longleaf containerized seedlings was continued during the summer and fall months through fiscal year 1979-80 in the sandhills section until weather conditions finally caused such severe survival problems that all such planting was halted.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Forestation Forester, Central and Nursery-Tree Imporvement Forester, respectively, North Carolina Division of Forest Resources, Raleigh, North Carolina 27611.

SITE PREPARATION METHODS

A narrow "Taylor-front mounted plow" V-blade and also homemade, wide V-blades mounted on the front of an International TD-15 and a Case 1150 crawler tractor were used. These V-blades created shallow "scalping" furrows that were between four and eight feet wide and approximately three to four inches deep. In the past, the best survival results had been obtained with longleaf pine bare root stock using these V-blades to create the shallow furrows and following with machine tree planting. Therefore, personnel were anxious to try this method with the containerized seedlings. The V-blade and machine tree planting was done in a one-pass operation.

Fire plow "scalping" to create a narrow shallow furrow was tried. These fire plows were pulled with regular fire control International TD-9 crawler tractors. The "scalping" was done as a separate operation and then followed up with tree planting.

K-G blade and piling was also tried as a site preparation method. In most cases this method was used on sandy areas where the hardwoods were so large that the fire plow or the V-blade method could not be used.

Fire alone was also used in an effort to prepare some areas for planting.

Bedding was also tried at Bladen Lakes State Forest as a site preparation method.

Planting of open fields where no site preparation work was carried out was attempted. It was feared that competition from the weeds would give serious problems as had been the case in the past, but it was desired to see if the situation would be any better using containerized seedlings.

TREE PLANTING METHODS

Both an International TD-15 and a Case 1150 crawler tractor were used to pull a Reynolds F400 machine tree planter. Both of these tractors did the V-blading and machine tree planting in one operation as was mentioned above. Most of this machine tree planting was done in open fields with a heavy weed cover where competition from the weeds was anticipated. This method was also attempted on some scrub oak areas.

An International Diesel 674 rubber-tire tractor was used to pull a two-seated Whitfield tree planter. A Ford farm tractor was also used to pull a small one-seated machine tree planter. These machine planting methods were mainly used in open fields that required no site preparation. They were also used on areas that had been previously furrowed with the fire plow. These methods were successful as long as the furrow was shallow. If the fire plow furrow was too deep then problems were encountered in getting the machine planter to operate correctly. The rubber-tire tractors could also be used in areas that had been prepared by K-G blade and piling providing that a good site preparation job had been accomplished.

Hand planting was attempted with North Carolina Forest Service homemade planting bars. These bars were made out of 1-1/4 inch square steel stock with a sharp edge that creates a square hole in the ground so that the plug of the containerized seedling can be planted. This method worked real well providing that very loose sand was not encountered and that the ground was not too hard.

Hand planting was also tried using the conventional tree planting bar that is used to plant bare root stock. These bars did not work as well as the homemade bars except on hard clay soil where it was easier to make the planting hole with the conventional bar than it was with the homemade bars.

The Finnish tree planting tool called the "Potapookie" was also used in hand planting. This hand tree planting tool was the only one tried that would work on the very loose sandy soils where the hole would fill up as fast as the conventional and homemade bars were pulled out of the ground. A problem did develop with this tool in some cases when dropping the plugs down into the chute caused damage to some of the seedlings.

PLANTING PROBLEMS

As long as sufficient rain fell both before and after tree planting on deep, sandy, dry sites, reasonable survival of the containerized seedlings was obtained. However, just as soon as rainfall was insufficient after tree planting, or soil moisture fell too low, severe survival problems became apparent. In many cases seedlings would be dead within one to two weeks after tree planting without rain. It was very discouraging to the crews to go out and do the best possible tree planting job that could be accomplished and then have the lack of rain for one to two weeks kill the trees. In many cases, when replanting was necessary and the soil moisture was still low, the replanting failed.

It was found that in machine tree planting with both tree planters used, it was extremely difficult to hold onto the seedlings during planting because there was really nothing to grip. This problem had not been encountered with bare root stock so long as the root collar was at least 1/4 inch thick. However, with the plugs of the containerized seedlings there was not much to hold onto. This fact created problems in getting the seedling into the trench made by the tree planter.

It was discovered that in machine tree planting it was extremely difficult to regulate the proper depth of the seedlings. If the seedlings were planted too shallow in loose sand, the plug would be left high and dry as a result of just one rain washing the sand away from the ridge that was created by the packing wheels. On the other hand, if the seedlings were too deep the needles would be completely covered up by the sand from the packing wheels. In other words, there was less margin for error than had previously been encountered in planting bare root stock by machine. Much better handling and depth control of the seedlings was obtained using planting bars.

Adequate temporary field storage facilities in which to keep the trees after they were picked up from the nursery just prior to tree planting were not available. The nursery had an ideal situation in that the seedlings were stored on benches and an irrigation system was installed so that they could be watered as needed. However, in the field in the areas where tree planting was scheduled such facilities were nonexistent. Therefore, the trays of seedlings were placed on the ground under trees in areas where a hose for watering was available. This watering became a daily problem in that it was difficult to tell whether the seedlings were being watered enough or watered too much. In some cases part of the trees dried out and in other cases they were too wet. Securing someone to water the seedlings on weekends or during off-duty hours became a problem.

A logistical problem was definitely encountered all the way from transporting the seedlings from the nursery to actually planting the seedlings in the ground. A large number of these seedlings could not be carried on a pick-up truck and this problem was not really solved by using a tractor-trailer refrigeration van with racks. Because of poor germination and survival, in many instances the trays would only be half full of seedlings. The logistical problem was more severe once the seedlings arrived at the field where it was discovered that the tree planters could only carry about two trays at a time. A cart made out of bicycle wheels was designed and built. This cart made it possible to carry more seedlings, but it was quite difficult to wheel the cart over many of the prepared areas. And, of course, the machine tree planters could not carry as many containerized seedlings as it could bare root stock. It was finally discovered that one man could best carry four trays of seedlings by locking his fingers and carrying two in each hand. On hand tree planting jobs, one man was required to do nothing but carry seedlings to the people doing the tree planting. And, where large contractors were doing tree planting, one man was needed to do nothing but haul trees on a day-by-day basis from the nursery to the contractor. In open fields areas where the pick-up truck loaded with seedlings could be driven right to the tractor, logistical problems were not as severe as they had been in other cases.

Severe problems with the containerized seedlings were encountered when they were planted during the hot summer months on burned, black soil where a wick effect took place. In some cases as a result of this effect, the trees were dead two days after tree planting. It was discovered very quickly that longleaf pine containerized seedlings cannot be planted on black, burnt soil during the hot summer months even with sufficient rainfall.

Survival problems from weed competition were definitely experienced on those open fields that were planted through the summer months with no prior site preparation work. Even the small scalpers on the machine tree planters did not eliminate enough of the weeds to prevent a survival problem. It was determined that some form of "Scalping" was needed on these open fields in order to eliminate enough of the weeds to prevent competition from causing a survival problem.

In some cases planting had to be delayed for a period of a month or more after the trees were picked up from the nursery. The seedlings were growing in the trays throughout this period and the longleaf needles became very long; thus transpiration rate increased, requiring more watering. It was, therefore, decided to prune the needles back as is done with bare root stock to reduce the transpiration rate of the seedlings after planting. The effects of this treatment were unknown; the possibility of doing more harm than good was considered. However, no effect on survival was attributed to this treatment.

While the trees were growing in the trays, the root systems grew out of the bottoms of the containers and this additional growth caused some of the plugs to tear up when they were taken out of the trays and book containers for planting. The seedlings were approximately twelve weeks old when picked up from the nursery and this root problem occurred after the fifteenth week.

CONCLUSIONS AND SUMMARY

As a result of weather problems, no containerized longleaf pine seedlings have been planted in the sandhill section since fiscal year 1979-80. North Carolina Division of Forest Resources personnel are not optimistic at this stage of the game about the practice of planting containerized longleaf pine seedlings on adverse dry, sandy sites in the sandhill area, unless planting can be completed during periods when adequate rainfall is assured. In most cases, this condition would occur during the normal tree planting season when bare root stock would be planted and there would be no advantage in using containerized seedlings. If planting is scheduled during the summer months, it would have to be during a wet summer, which cannot be accurately predicted.

It was determined that the best method would be to furrow or bed the area prior to tree planting and allow the soil sufficient time to settle before attempting the planting. Then hand tree planting would be used when there was adequate soil moisture so that the planters would have the best depth control of the seedlings and the best possible survival would be obtained. Use of the narrow V-blade and machine tree planting in one operation would be attempted on those areas where the sand was not too loose during periods of adequate soil moisture when the temperature was also moderate.

It may appear from this presentation that the Division of Forest Resources personnel have a negative attitude towards containerized longleaf pine seedlings. It is not intended to convey this impression; but it should be emphasized that many, many problems are encountered with this species in this type of planting.

FULLY AUTOMATED PLANTING MACHINE

DEVELOPMENT AND TESTING FOR CONTAINER SEEDLING APPLICATIONS

Jerry L. Edwards

The expanded need for improved methods and techniques of mechanical tree planting calls for the design and building of improved tree planters. This article covers the design considerations necessary for the development of semi-automatic and automatic tree planter for bare root and container seedlings.

INTRODUCTION

Approximately one-third of the United States is covered by Forests. This forested land can be placed into two general classifications, commercial timberland and public timberland. The ownership of the commercial timberland is primarily small private land areas. Nearly sixty percent of the small land holdings are east of the Mississippi River. Probably the most alarming statistic is that the private land holdings are presently estimated to be stocked to less than one-half their potential capacity.

One of the primary objectives of resource managers is to optimize timber production. A potential answer to the understocking dilemna is to increase artificial regeneration and more specifically machine planting of those trees. A method contemplated by managers must take into consideration restraints. The restraints on machine planting of artificial regenerations can be grouped in four general areas: (1) social, (2) economic, (3) technical, and 4) environmental.

1. Social restraints are normally of an internal nature to the system and can be the most difficult obstacle to overcome. The degree of acceptance of a new idea or machine by the labor force can ultimately make or break the effort. The greatest test of a social restraint is how the employee's perceived effect upon himself and other employees by his new activity. In the case of a tree planter, the social restraints may be most effected by the willingness of the employee to endure the arduous conditions related with hand planting.

2. Restraints associated with economics are normally very important to small land owners or land managers. It has been predicted that economic restraints will very shortly be dictating the future of Forest management. Improved engineering solutions, which include tree planters (mechanical), can help. However, they will not be accepted until the American economy recognizes that more money must be put into the development in our renewable resources (Cramer 1974). Small landowners find it extremely difficult to justify or, for that matter, obtain loans for any investment in regeneration equipment since their operation is marginal at best.

3. Technical restraints are the type to which engineers are most accustomed. The mechanical aspects, which result mostly from the biological and environmental factors, closely parallel those found in agricultural. The biological aspects of tree planting are virtually unknown. The development of the seedling up until it leaves the nursery has not been investigated sufficiently (Dyson 1968). Most factors relating to the out planting of seedlings as to the seedling's physiological and morphological development are unknown. A review of literature on existing planting practices implies by omission that researchers have presupposed that without biological information, research and development of mechanical tree planters cannot proceed. Fortunately, development has continued. The unfortunate part is that it has been very slow and the route of development circuitous.

4. Environmental restraints, such as moisture, soil nutrients, temperature, and sunlight, are well documented. Failures, in most cases, can be traced to environmental deficiencies or misunderstanding of the basic plant physiological needs.

Mechanical systems for planting trees must deal with the aforementioned factors; however, the things that seem to cause designers as many difficulties as any are planting site conditions. The soil moisture, topography, and residual vegetation (Lawyer 1978) impose severe restraints.

1/Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.
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The restraints are considered so overwhelming that the land manager is generally reluctant to venture very far into the tree planter development business.

Mechanized planting systems are an attractive alternative to hand planting in most large scale reforestation operations if certain technological problems can be solved. Solutions to many of these problems are not readily apparent and are complicated by the diversity of environmental conditions in which mechanical planting systems must operate. These solutions will require new and innovative designs if mechanized systems are to be widely used.

CLASSIFICATION OF MACHINE CONCEPTS

The first tree planting machine for forestry was based on principles evolved from agricultural machinery. The machines that have developed since then can be broken into the following groups:

Furrow Planters

Continuous Furrow - The device consists of a coulter for making a continuous slit in the soil, following the coulter, a shoe for opening the slit into a furrow for receiving the seedling, and a trailing set of packing feet for firming the soil around the roots.

Many early designers originated, in concept, from transplanting machinces for horticultural nursery, small fruit, or vegetable crops. Even today this is the dominant principle of most tree planting machines used in forestry.

Intermittent Furrow - The planting head maintains only intermittent contact between the planting mechanism and the soil while the machine continues moving at a constant speed. An elongated hole (i.e., intermittent furrow) is made in the soil at each planting spot, this characteristic distinguishes the intermittent from the continuous principle. Soil cutting results from both vertical and horizontal tool motion with intermittent furrow machines.

Although many designs have proven that the intermittent planting principle is a feasible concept, most prototypes have been operationally unreliable or uneconomical when tested in timber land operations.

Spot Planters

Dibble - The name is derived from traditional hand planting techniques where a hole is first made in the soil, the seedling is inserted in the hole, and then the soil is closed around the seedling roots. This principle is distinguished from intermittent and continuous furrow concepts by the more limited contact of the planting head with the soil since all soil cutting or displacement results from vertical tool motion.

At the present time a prototype based on this principle is being tested in Finland that utilizes a sliding gate dibble. The planting head stops to plant while the transport vehicle itself continues forward at a constant speed. The planting stock being used is container seedlings (paper-pots).

Injection - The distinguishing characteristic is that the opening in the soil conforms exactly with the dimensions of the root system being planted and closure of the hole is not required.

There is a prototype based on this principle being tested in Canada. The machine presently being tested is a three-row model. The planting head stops while the transport vehicle continues at a constant speed. The planting stock being used is container type (Walters and St. Jean 1975).

CONCEPTS FOR MECHANICAL TREE PLANTING SYSTEM

In developing new concept and extending old ones, basic guidelines must be set up with respect to the general configuration of the machine. The functional operation of the entire Reforestation Cycle (Lawyer 1978) must be reviewed (see fig. 1) before proceeding to develop the concepts for a machine. The principles of operation of a tree planting machine is on the same order of complexity as typical agricultural or forestry equipment, although some complex controls may be required to ensure the accuracy of certain functions. The machine is considered to be fully automatic and require only one operator, the driver. Plants, either container or bare root stock, in sizes currently used in commercial reforestation. The design takes into consideration that the construction must be substantial enough to withstand operation in the forest environment. Design development does not extend beyond a general description of the working principle of the machine functions.

Planting Stock - The type of planting stock must first be selected (i.e., bareroot, container, etc.) specified as to size, type of container, configuration, maximum physical limits, and special characteristics of the planting stock.

Work Platform - Describes the base on which the planting machine is mounted and may be an integral part of the transport vehicle.

Transport Vehicle - This is the vehicle which provides locomotion to the planting machine.

Ground Speed - Describes the rate of travel of the transport vehicle during the planting operation. "Constant" or "periodic" advance of the vehicle is possible. With periodic advance, the transport vehicle must stop to allow the actual planting operation to take place, while constant does not.

Planting Mechanism - Describes the planting device itself.

Working Principle of the Planting Mechanism - Describes how the planting operation takes place. Two factors are most important in the description--1) the selectivity of the microsite location, and 2) the action of the tool in placing the seedling in the soil. For concepts where other factors are also important, it would be necessary to extend the descriptions accordingly.

Planting Mechanism Motion - Describes the horizontal displacement of the planting mechanism with respect to the work platform over time. With "uniform" motion, the planting tool maintains the same velocity as the transport vehicle at all times. With "variable" motion, the tool velocity varies relative to the transport vehicle during the planting cycle.

Soil-Tool Contact - Describes the interaction of the planting tool with the soil during one planting cycle. With "continuous" contact, the tool is always engaging the soil and with "intermittent" contact, there is a portion of the planting cycle where the tool is not in contact with the soil.

Planting Stock Feed System - Describes the method by which seedlings are moved from the transport racks on the machine to the planting mechanism. Manual machines require a transport operator and at least one other individual to place the plant in its final position in the gound. Semiautomatic machines require a transport operator and at least one other individual to transfer the stock from the transport rack to a mechanism that will then place the seedling in the ground. Fully automatic machines require only one operator, since the machine automatically takes the seedlings from the transport containers and places them into the ground.

Mounting Point of the Planting Mechanism - Describes the location (e.g., front or rear) on the work platform where the planting mechanism is mounted. This position is determined by the location of those components of the mechanism that place the plant in the soil.

Microsite Preparation - Describes the treatment the soil receives prior to planting the seedling. With row scarification, a continual strip is tilled the length of the row, and with spot scarification, only a small area around the plant is tilled.

The concept described here has characteristics of conceptual designs, prototypes, and existing machines. Other factors may be required to describe concepts not yet proposed or developed. Consideration was given to functional and descriptive aspects, and no attempt was made to include size or cost information.

CONCLUSION

Probably the largest deterrent to widespread use of planting machines, both semi-automatic and automatic planters is:

1. The machine's failure to consistently do a satisfactory planting job at a cost competitive with hand planting.

2. The reluctance of land managers, both private and government, to define the long range needs for machine planters and provide the necessary funding to get the development and implementation job done.

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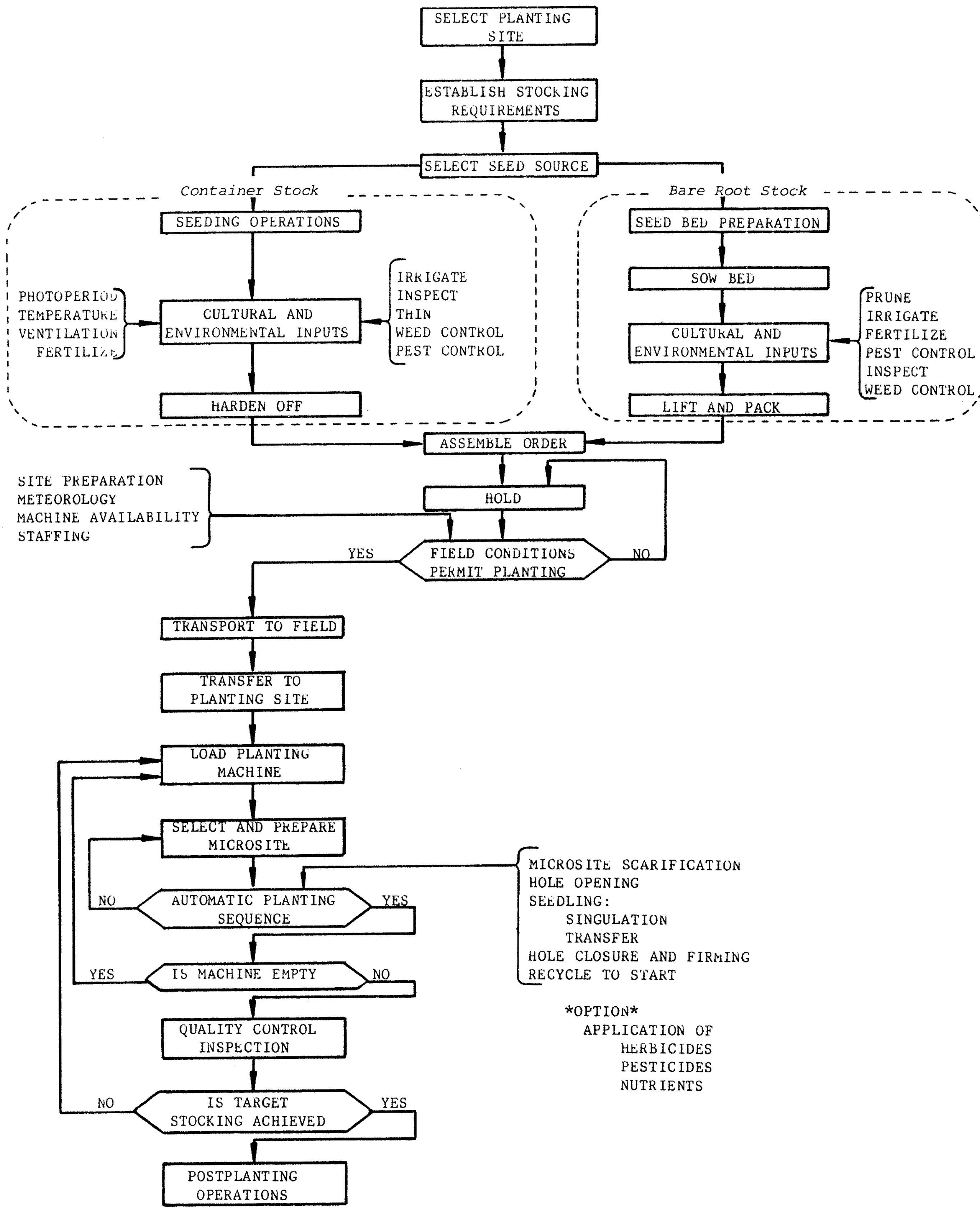

Activities in Reforestation Using Mechanical Planters

FIG. 1

CONTAINER SEEDLING SURVIVAL AND GROWTH: PINE AND HARDWOOD IN NORTH CAROLINA[1/]

O. C. Goodwin, D. L. Brenneman and W. G. Boyette[2/]

Abstract.--After 5 years, loblolly and longleaf pine grown in 2.5 inch^3 containers survived and grew acceptably, with longleaf outperforming 1-0 stock. White pine survival was poorer and growth slower than 2-0 stock. After 1½ to 3½ years, 4 hardwood species grown in 21.5 and 45 inch^3 containers survived and grew well.

INTRODUCTION

The North Carolina Division of Forest Resources began experimenting with growing and out planting container pine and hardwood seedlings in 1972. Extension of the planting season was needed to provide year-round employment for state forestation crews and to help meet the need for the annual planting of 40,000 acres of cutover, private non-industrial land in North Carolina.

The original project called for the production and outplanting of tubelings throughout the year to evaluate techniques used in Ontario, Canada (Goodwin 1974). In the fall of 1973, the study was expanded to evaluate the Spencer-Lemaire book planters (now called Rootrainers) and other containers. Root-plug containers are preferred because roots are not encased in the container when planted and the containers are reusable.

This paper reports on the survival and growth performance of 3 pine and 4 hardwood species. Based on the performance of these pine tests, the Division of Forest Resources started commercial production of loblolly pine Rootrainers in 1976, longleaf pine in 1977, and white pine in 1979. Currently, testing is continuing with commercially important hardwood species.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, George, August 25-27, 1981.

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MATERIALS

Pine

Containers used for southern pine species were the Ontario 3/4-inch diameter, 4-inch long, split-styrene tube; the Spencer-Lemaire Ferdinand 0.8 X 0.9-inch top diameter, 4-inch long Rootrainer; and the half-Styroblock No. 2, 1-inch top diameter, 4.5-inch long container. Each container type has similar dimensions and a volume of 2.5 cubic inches. The 1 X 6-inch Illinois Tool Work (ITW) tube-plug container was used for a white pine test.

Growing media used for pines were fumigated pure peat soil to which was added, per cubic foot, 5 ounces of dolomitic lime and 1 ounce of 10-10-10 pulverized fertilizer with trace elements; and a 1:1 mixture of sphagnum peat-vermiculite to which was added, per cubic foot, 3 ounces of dolomitic lime and 2 ounces of pulverized 10-10-10 fertilizer with trace elements. Two ounces of weathered shredded pine straw were added per cubic foot of growing media as a possible source of ectomycorrhizae inoculum.

Unimproved seed collected from North Carolina sources were used in all tests.

Hardwoods

Containers used for hardwoods were the Ontario 1 X 8-inch split-styrene tube and the Spencer-Lamaire Tinus and Super-45 Rootrainers. These containers are, respectively, 8, 7.25, and 9 inches long and 6.3, 21.5 and 45 cubic inches in volume.

Growing media used for the 1977 tests were a 1:1 peat-vermiculite mix to which 2 ounces of dolomitic lime per cubic foot was added to adjust the pH to 5.5. For the 1979 tests, a 3:1 peat-vermiculite mix was used to which 4 ounces of dolomitic lime per cubic foot was added. Peters 20-19-18 and 9-45-15 water soluble fertilizers were applied with irrigations.

The growing nedium used for all subsequent testing was a 1:1 peat-vermiculite mix to which was added, per cubic foot, 5.0 ounces of dolomitic lime (to adjust pH to 6.5), 7.5 ounces of Osmocote 18-6-12, 2.5 ounces of triple super-phosphate, and 4 grams of fritted trace elements. Fertilizer was added to the media because leaf interception made spray applications unsatisfactory.

For mycorrhizal treatment, 1 part of forest soil, naturally infected by Glomus mossae, was mixed with 8 parts of growing medium for the black walnut, white ash and yellow poplar tests.

For mycorrhizal treatment of northern red oak growing medium, Pissolithus tinctorius inoculum, prepared by Abbotts Laboratories, was mixed at a ratio of 1:10 by volume.

All seeds were collected near where the tests were installed.

SEEDLING PRODUCTION

Pines

All pine container seedlings were grown in the experimental greenhouse at Clayton, North Carolina. Species tested were loblolly (Pinus taeda L.), longleaf (P. palustris L.), and eastern white pine (Pinus strobus L.)(Table 1).

Table.--Container pine production regimes

Species	Grown in greenhouse	Hardened outdoors
	weeks	
Loblolly pine	5 to 12	4 to 6
Longleaf pine	3 to 9	4 to 6
White pine	5 to 16	5 to 6

Seedlings were germinated and grown in the greenhouse until they reached a desired height. They were then moved outdoors to complete their growth and to lignify their stems prior to planting.

Hardwoods

All hardwood container seedlings were grown in the experimental greenhouse at Clayton. Species tested were black walnut (Juglans nigra L.), white ash (Fraxinus americana L.), sweetgum (Liquidambar styraciflua L.), and yellow poplar (Liridendron tulipifera L.) (Table 2).

Table 2.--Container hardwood production regimes

Species	Grown in greenhouse	Grown outdoors
	weeks	
Black Walnut	9	7
White Ash	12-15	3
Yellow-Poplar	11-16	4
Northern Red Oak	7	5

No special measures were taken to harden the seedlings. They were moved outdoors in June where they were held until the lower stems became woody.

For all species except northern red oak, also water-soluble fertilizers, 20-19-18 and 9-45-15, were applied weekly in combination at the rate of 150 ppm N and 22 ppm P while the seedlings were in the greenhouse. With each fertilizer application, the seedlings were irrigated to the drip point. Water-soluble nutrients were not applied to the 1978 northern red oak because fertilizer had been mixed with the growing medium.

TESTS LAYOUT

Pines

Pine tests consisted of 0.5 to 2 acre plots located on recently cutover areas which had been site prepared.

Ten loblolly tests were planted; seedlings were planted in the months of April, July, August and September. Nine longleaf pine tests were planted; seedlings were planted in the months of March, July, August, September, October, and November. All 1-0 stock was planted during the spring following the planting of container seedlings.

Loblolly seedlings were dibble planted at a spacing of 7 X 8 or 7 X 10 feet, longleaf at 5 X 10 feet, and white pine at 7 X 9 feet. Root plugs were removed from the containers and planted approximately ½ inch deeper than the root collar. The tops of the plugs were covered with soil to prevent drying by a wicking-effect.

Care was taken to keep the growing medium moist at all times prior to planting. Generally, soils were moist or rainfall occurred shortly after planting.

Mean survival and growth were determined from measurements of all living pine seedlings in each systematically selected fifth row. Samples of an equal number of 1-0 seedlings were measured in rows adjacent to the container seedlings.

Hardwoods

Hardwood tests were replicated 2 to 4 times in randomized plots of 20 trees with buffers between plots. Tests were planted in July, August, and September. All sites were thoroughly prepared before planting.

Except for northern red oak planted at 7 X 7 feet, seedlings were planted at a spacing of 9 X 9 or 10 X 10 feet. Shovels were used to prepare the planting holes. The same precautions were taken, as with the pine, to keep the media moist at all times and to cover the tops of the plugs at planting to prevent drying by a wicking-effect. Moist soil conditions were a requisite for planting.

Survival and height data were recorded for all trees in each plot.

WEED AND BRUSH CONTROL

Release of pine seedlings was not necessary due to the quality of the site preparation jobs. Because the hardwoods were planted on more fertile sites, they required periodic weeding thoroughout the growing season. Weeding will continue until the seedlings have outgrown the weed competition.

RESULTS

Survival and growth of the various container seedling tests are reported for 5 full growing seasons for the pine and for either 1½ or 3½ growing seasons for hardwoods. The ½ growing season refers to the remaining portion of the season following planting in the summer.

Pines

Loblolly Pine

Survival.--Mean survival of 10 tests after 5 growing seasons was about the same for tubelings and rootrainers, 73% and 75%, respectively, but was considerably lower than for 1-0 seedlings (87%). The best survival of tubelings was 90% for an April planting. (Table 3) (Goodwin 1979).

Diameter Growth.--The mean dbh of the coastal 1-0 seedlings was slightly but consistently larger than the container seedlings (2.6 vs. 2.4 inches). The best dbh growth of container seedlings was 3.0 inches. The mean dbh for Piedmont 1-0 seedlings and tubelings was smaller than that for Coastal Plain tests (Table 4).

Height Growth.--Mean total height growth of the Coastal Plain 1-0 seedlings was 1.7 to 2.9 feet greater than that of the container seedlings. The one exception was the July 25 planted root plugs which averaged 15.8 feet compared to 15.3 feet for the 1-0 seedlings.

Of the container seedling heights, the July planted tubelings had the best height growth being much better than the spring and fall planted tubelings (Table 5).

Longleaf Pine

Survival.--Good survival of the container seedlings was obtained for each of the 6 months that planting was done (Goodwin 1980). Survival was considerably higher for container seedlings than for 1-0 nursery stock. Mean survival was 77% for the container seedlings and 64% for the nursery stock. The highest survival was 93% for an August tubeling planting (Table 6).

Diameter Growth.--Measurements of dbh were not taken because of stiff needles growing on the longleaf trunk at this early age.

Height Growth.--In the tests with direct comparison, the container longleaf seedlings were as tall or taller than the 1-0 seedlings. Mean heights were 6.8 feet for root plugs, 4.7 feet for tubelings, and 3.1 feet for 1-0 nursery stock. Best height growth was for the July and August plantings. Some of these trees were 14 feet tall.

The container seedlings grew more uniform in height than the 1-0 seedlings and they grew out of the grass stage sooner than the 1-0 seedlings.

White Pine

Survival.--Four tubeling tests were installed in 1973 with the planting of 11 weeks old seedlings. Frost-heaving decimated 3 of the tests in the first winter following August, October, and November planting dates. The fourth test, a September planting, had only 44% survival and would have been lower except that the slightly heaved tubelings were pushed back into the soil.

In June, 1976, a test was installed with the planting of 22-week old seedlings grown in ITW and Ferdinand Rootrainer containers. Nursery 2-0 stock was planted the following spring on the remainder of a 7 year old white pine plantation destroyed by wildfire. (Goodwin 1978)

Table 3.--Mean survival of 10 loblolly pine container and 1-0 nursery stock tests in North Carolina after 5 full growing seasons

Date planted	Age (weeks)	Site preparation method	Survival (Percent) Tubelings	Root Plugs	1-0 Stock[1/]
		Coastal Plain Sites			
April 30	19	KG and pile	90	-	92
July 25	13	Disk and bed	63	-	81
July 25	13	Disk and bed	81	-	81
July 25	13	Disk and bed	67	-	80
August 15	9	Chop and bed	78	-	85
August 15	9	Chop and bed	-	85	85
September 27	9	Chop and bed	60	-	94
September 28	9	Chop and bed	-	63	94
Mean survival			73	75	85
		Piedmont Sites			
April 17	18	Disk	83	-	89
July 6	10	Disk	65	-	89
Mean survival			74	-	89

Table 4.--Mean dbh of 10 loblolly pine container and 1-0 nursery seedling tests in North Carolina after 5 full growing seasons

Date planted	Age (weeks)	Site preparation method	Mean dbh (inches) Tubelings	Root Plugs	1-0 Stock[1/]
		Coastal Plain Sites			
April 30	19	KG and pile	1.7	-	2.2
July 25	13	Disk and bed	3.0	-	2.9
July 25	13	Disk and bed	3.0	-	2.9
July 25	13	Disk and bed	2.6	-	3.0
August 15	9	Chop and bed	2.2	-	2.3
August 15	9	Chop and bed		2.2	2.3
September 27	9	Chop and bed	1.8	-	2.4
September 28	9	Chop and bed		1.7	2.4
Mean dbh			2.4	2.0	2.6
		Piedmont Sites			
April 17	18	Disk	1.7	-	2.2
July 6	10	Disk	1.6	-	2.2
Mean dbh			1.6	-	2.2

1/ Planted in February or March following planting of container seedlings.

Table 5.--Mean height of 10 loblolly pine container and 1-0 nursery seedlings tests in North Carolina after 5 full growing seasons

Date planted	(weeks)	Site preparation method	Mean height (feet) Tubelings	Root Plugs	1-0 Stock[1/]
		Coastal Plain Sites			
April 30	19	KG and pile	10.6	-	13.2
July 25	13	Disk and bed	15.1	-	15.3
July 25	13	Disk and bed	15.8	-	15.3
July 25	13	Disk and bed	13.3	-	15.9
August 15	9	Chop and bed	11.9	-	13.9
August 15	9	Chop and bed	-	12.7	13.9
September 27	9	Chop and bed	10.3	-	13.5
September 28	9	Chop and bed	-	10.6	13.5
Mean height			12.8	11.6	14.5
		Piedmont Sites			
April 17	18	Disk	9.8	-	12.2
July 6	10	Disk	11.8	-	12.2
Mean height			10.8	-	12.2

1/ Planted in February or March following planting of container seedlings.

Table 6.--Mean survival and height of 9 longleaf pine container and 4 1-0 seedlings tests on sandhill sites after 5 growing seasons

Date planted	Age (weeks)	Site preparation method	Survival (percent) Tube-lings	Root Plugs	1-0 Stock	Mean height (feet) Tube-lings	Root Plugs	1-0 Stock[1/]
March 27	15	Chop & furrow	85	-	-	2.0	-	-
July 25	7	Disk & bed	84	-	-	8.0	-	-
Aug. 6	9	Disk & furrow	93	93	69	8.4	8.3	3.7
Aug. 15	9	Disk & bed	67	78	-	5.9	6.0	-
Aug. 25	8	Disk & furrow	87	-	-	3.0	-	-
Sept. 26	8	Disk & furrow	78	-	69	1.2	-	1.7
Sept. 28	9	Disk & bed	52	51	-	6.2	6.4	-
Oct. 17	11	Disk & furrow	80	83	67	6.4	6.7	5.2
Nov. 18	11	Chop & bed	79	-	50	1.6	-	1.6
Means			78	76	64	4.7	6.8	3.1

1/ Planted in February or March following planting of container seedlings.

Survival after 4 growing seasons was 63% for ITW seedlings and 41% for Rootrainer seedlings. Survival of 2-0 stock was estimated to be 80%. High mortality of the container seedlings is attributed to the abnormally dry summer after seedlings were planted.

Height Growth.--After 5 growing seasons, the surviving 1973 September planted tubelings averaged 2.1 feet compared to 5.3 feet for the 2-0 stock.

After 4 growing seasons, the ITW seedlings were taller than the 2-0 and Rootrainer seedlings. They averaged 2.2 feet compared to 1.9 feet for the 2-0 seedlings and 1.8 feet for the Rootrainer seedlings. Dense hardwood sprout competetion hindered growth of the seedlings.

Hardwoods

The 1 X 8 inch plastic tubes proved to be unsatisfactory. Although some good seedlings were produced, planting failures resulted from root constriction by the tubes.

Black Walnut, White Ash, Yellow-Poplar

Two tests were installed for black walnut, yellow-poplar, and white ash. Nursery stock was unavailable for the first test which is 3½ years old. Nursery 1-0 stock was planted in the second test which is 1½ years old. Results of both tests are reported.

Survival.--Mean survival for the 1977 test is shown in Table 7 (Boyette, Brenneman, Goodwin 1981).

Table 7.--Percent survival and mean heights of 1977 tests after 3½ growing seasons by species and treatment

Treatments	Yellow-Poplar Survival (Percent)	Yellow-Poplar Height (feet)	Black Walnut Survival (Percent)	Black Walnut Height (feet)	White Ash Survival (Percent)	White Ash Height (feet)
45-in.^{3} Container	60	13.6	83	6.6	83	10.1
45-in.^{3} Container + Mycorrhizae	68	12.8	83	5.9	91	10.1
21.5-in.^{3} Container	44	10.7	90	7.4	77	9.2
21.5-in.^{3} Container + Mycorrhizae	58	12.6	97	6.9	74	9.0

Survival ranged from 44% to 68% for yellow-poplar. High mortality of the yellow-poplar resulted from damage to the tender seedlings when they were hand-released from morning-glory vines. The more woody black walnut seedlings were not damaged.

Survival was good to excellent for both the black walnut (83% to 97%) and white ash (74% to 91%).

Yellow-poplar and white ash grown in the larger container survived best, but black walnut grown in the smaller container survived best.

Mean survival after 1½ growing seasons for the 1979 tests was good with the single exception of black walnut container stock (9%-20%)(Table 8).

Table 8.--Percent survival and mean heights of 1979 tests after 1½ growing seasons by species and treatment

Treatment 1/	Yellow-Poplar Survival (Percent)	Yellow-Poplar Height (feet)	Black Walnut Survival (Percent)	Black Walnut Height (feet)	White Ash Survival (Percent)	White Ash Height (feet)
45-inch^3 Container	91	2.1	9	0.0	100	1.9
21.5-inch^3 Container	91	1.5	20	1.0	87	1.8
1-0 Nursery Stock	100	2.1	88	1.7	98	2.0

1/ No appreciative infection of roots was achieved for mycorrhizal treatments, therefore, data is combined for containers.

Failure to properly keep the black walnut medium moist at all times on the outdoor benches, resulted in drying of the medium to a point where it could not absorb water when irrigated. This condition was caught too late to rectify, and it is believed to be the cause of the high mortality occurring shortly after planting.

Survival of the 1979 yellow-poplar was much better because they were not damaged during the weeding operation. Survival for white ash ranged from 87% to 100%.

Height Growth.--Yellow-poplar and white ash grown in the 45 inch^3 containers were slightly taller after 3½ growing seasons than those grown in the 21.5 inch^3 containers.

Height growth results of the black walnut seedlings were confounded during the second growing season from grazing by a stray cow.

Because the control seedlings had some mycorrhizal infection, despite fumigation precautions, the mycorrhizae results were also confounded.

For the 1979 test, height growth was slightly better for white ash and yellow-poplar grown in the 45 inch^3 container. The 1-0 seedlings were approximately one inch taller than container stock after their first growing season.

Northern Red Oak

Mixing laboratory fermentor-produced inoculum of Pissolithus tinctorius at 1:1 ratio resulted in 5% to 20% of the northern red oak container seedling roots becoming infected with 2 kinds of ectomycorrhizae. One species was identified as Cenoccum grandiforme and the other appeared to be Pissolithus but was not positively identified as such.

Survival.--Survival was fair to excellent after the first growing season for all treatments (79% to 95%) (Table 9).

Table 9.--Percent survival and mean heights of northern red oak container stock after 1½ growing seasons

Treatments	Survival (Percent)	Height (Feet)
45-inch^3 Container	96	1.6
45-inch^3 Container + Mycorrhizae	79	1.6
21.5-inch^3 Container	89	1.5
21.5-inch^3 Container + Mycorrhizae	87	1.7

Height Growth.--After 1½ growing seasons, there was no appreciable difference in heights of oak seedlings of various treatments. They ranged from 1.5 to 1.7 feet tall.

CONCLUSIONS

Tests conducted by the North Carolina Division of Forest Resources, beginning in 1972 and continuing to the present, have demonstrated that southern species of pine and hardwood container seedlings can be successfully outplanted on properly prepared areas in North Carolina.

After 5 full growing seasons, survival and growth of loblolly container seedlings was not quite as good as 1-0 seedlings; however, longleaf container seedlings survived better and outgrew 1-0 seedlings on sandhill sites.

After 4 growing seasons, white pine rootrainers did not survive as well but were equal to or better than 2-0 seedlings in height. White pine tubelings failed because of frost-heaving and did not grow as well as plug seedlings.

After 1½ to 3½ growing seasons, black walnut, white ash, yellow-poplar, and northern red oak survived and grew well where good weed control was maintained.

Containers having volumes of approximately 2.5 cubic inches were satisfactory for pines.

Containers of 45 cubic inch volume produced slightly better results for hardwoods than 21-inch^3 containers although the smaller containers were satisfactory.

Container seedlings can be used advantageously in a forestation program to extend the normal planting season to early fall, to reinforce or replant failures the same season, to plant low areas too wet to plant during the normal season, and to provide longer working periods for planting labor. Container seedlings for the species tested do not show potential for replacing nursery stock for the bulk of forest tree planting in North Carolina.

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MYCORRHIZAL INOCULATION IMPROVES PERFORMANCE OF CONTAINER-GROWN PINES PLANTED ON ADVERSE SITES[1/]

John L. Ruehle[2/]

Abstract.--Container-grown pine seedlings with well developed *Pisolithus tinctorius* ectomycorrhizae can be successfully used in forestation of adverse sites created by surface mining. Results of some current research on coal spoils and borrow pits illustrate the benefits of mycorrhizal technology for forestation of adverse sites.

INTRODUCTION

Conventional artificial or natural techniques often fail to reforest adverse sites created by surface mining and poor soil management. When forestation is the option selected for reclamation, survival of bare-root seedlings planted after routine site preparation is often poor. Efforts to ameliorate adverse sites will be most successful when both physical and biological methods are integrated. Subsoiling to fracture indurate soil surface layers, addition of organic matter to restore necessary physical, chemical and biological factors, and a combination of grass cover and forest tree seedlings colonized with beneficial mycorrhizal symbionts ecologically adapted to adverse sites should be considered in an integrated plan for forestation of adverse sites.

Bare-root pine seedlings have often been used for reclamation of surface mines. Adverse extremes in pH, low nutrient status, high concentrations of toxic substances, elevated surface temperatures, and droughtiness have contributed to poor performance by this type of growing stock. Often mycorrhizal fungi on this type of planting stock are adapted to nursery conditions, but are not ecologically adapted to the adverse site (Marx 1977). Performance of bare-root pine seedlings on such sites was greatly improved when they were "tailored" with *Pisolithus tinctorius* (Pt), a symbiont well adapted to many adverse sites (Marx and Artman 1979, Walker and others 1980).

In certain areas, rainfall patterns are better for planting in summer and fall than in winter or early spring, the best time for planting of dormant bare-root stock. Consequently when off-season planting is desirable, containerized pine seedlings should be considered for reforestation of difficult sites (Barnett 1980). This type of planting stock can be planted in summer when environmental conditions favor seedling establishment. Inoculating container-grown pines with Pt prior to planting also aids survival and early growth on certain adverse sites (Ruehle 1980, Berry[3/]).

MINING SPOILS

In a comprehensive review of the significance of mycorrhizae to forestation of surface-mined lands, Marx (1980) stated that pine seedlings naturally colonized with Pt survive and grow well on mining spoils. Berry[3/] confirmed the value of Pt in a recent study on two strip-mined coal spoils in the South. Pine lines comprised of loblolly, pitch, and loblolly x pitch pine hybrids were grown in containers with Pt. During the 16-week growing period in the greenhouse a comparison set of control seedlings became naturally colonized with *Thelephora terrestris* (Tt) ectomycorrhizae. Seedlings were then outplanted on acid coal spoils in Tennessee and Alabama in mid-July. Treatment plots of 16 trees of each line were randomly arranged in 5 blocks at each site. After two and one-half growing seasons the results were striking (Table 1). On both sites seedlings with Pt ectomycorrhizae had greater survival, height, and root-collar diameter than naturally inoculated seedlings. Volume indexes on plots with Pt ectomycorrhizae were 200 percent greater in Tennessee and 380 percent greater in Alabama than indexes of control seedlings with Tt ectomycorrhizae.

1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

2/ Plant Pathologist, Institute for Mycorrhizal Research and Development, USDA Forest Service, Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30602.

3/ Berry, C. R. (In Process). Survival and growth of pitch, loblolly, and pitch x loblolly pine hybrid seedlings with *Pisolithus* ectomycorrhizae on coal spoils in Alabama and Tennessee.

Table 1.--Survival and growth of loblolly and pitch pines and their hybrids with *Pisolithus tinctorius* after two and one-half growing seasons on coal spoils in Tennessee and Alabama

Ectomycorrhizae	Survival	Height	Root-collar diameter	PVI 1/
	%	cm	cm	(x 10^2)
		Tennessee 2/		
Pt	85	79	3.0	133
NI	81	53	2.0	43
		Alabama 3/		
Pt	66	67	3.0	96
NI	56	43	1.6	20

1/ Plot Volume Index (PVI) computed by (root collar diameter)^2 x height x number of surviving seedlings per plot.
2/ Means of nine pine lines.
3/ Means of six pine lines.

BORROW PITS

Borrow pits created by surface-mining to supply fill for construction of buildings, dams, and highways often become severely eroded and gullied without sufficient vegetative cover. The subsoil exposed in these pits is often less toxic but lower in essential nutrients than coal mine spoils. A combination of cultural practices and planting of containerized pine seedlings colonized with Pt will result in successful reforestation of such areas.

I conducted a study on a borrow pit at the Savannah River Plant near Aiken, South Carolina (Ruehle 1980). In June 1975 the site was graded level, subsoiled to a depth of 1 meter, and double disked to break clods and smooth ridges created by the subsoiler. In September, 30 plots (7.3 x 7.3 m) were arranged with a 6-meter buffer zone separating all plots. Processed sewage sludge was broadcast over 15 plots (approximately 1.3 cm deep); 560 kg/ha of 10-10-10 fertilizer and 2240 kg/ha of dolomitic limestone were broadcast over the remaining 15 plots. All plots were double disked to a depth of 10 to 15 cm to incorporate the amendments and seeded with fescue (Kentucky 31). The following year containerized loblolly pine seedlings (one group inoculated with Pt, one group with Tt, and one group nonmycorrhizal controls) were planted by hand to establish 25 trees per plot.

The effects of the sludge and Pt were dramatic. After 2 years in sludge plots, seedlings with Pt ectomycorrhizae had 265 and 528 percent greater plot volumes than seedlings with Tt or no ectomycorrhizae at planting. As a group, seedlings on sludge plots had 900 percent greater plot volumes than those on fertilizer plots. After 4 years each plot was thinned to 9 to 12 trees with an approximate spacing of 1.7 m between trees. Trees on sludge plots averaged two times more height and root-collar diameter and 17 times more tree volume than trees on fertilizer plots (Table 2). The Pt-sludge treatment was still strikingly superior to other treatments. Trees on Pt-sludge plots averaged 3.4 m in height and 10 cm in diameter compared to trees on Pt-fertilizer plots which averaged 1 m in height and 3 cm in diameter.

Table 2.--Growth of containerized loblolly pine seedlings with specific ectomycorrhizae after 4 years on a borrow pit in South Carolina

Amendment	Mycorrhizal condition at planting	Height	Root-collar diameter	Tree volume 1/ (x 10^3)
		m	cm	cm^3
Sludge	Pt	3.4a 2/	9.8a	35.0a
	Tt	3.3a	8.1b	20.3b
	Control	2.5a	7.6b	16.8b
	$\overline{X}$	2.7	8.4	20.0
Fertilizer	Pt	1.0a	3.2a	1.5a
	Tt	0.9a	3.1a	1.3a
	Control	0.7a	2.2a	0.5a
	$\overline{X}$	0.9	2.8	1.1
Percent differences between groups		2.1* 3/	200*	1718*

1/ Tree volume $(cm)^3$ = (root collar diameter) x height.
2/ Each mean in a column within groups followed by a common letter is not significantly different at the P = 0.05 confidence level.
3/ *Denotes significant differences (P = 0.01 between groups according to Student's t-test.

CONCLUSIONS

This discussion and previous reviews by Marx (1976, 1977, 1980) leave little doubt that *Pisolithus tinctorius* ectomycorrhizae on pine seedlings remarkedly improve our chances for successful forestation of untreated coal spoils. In all of the Institute for Mycorrhizal Research and Development research on coal spoils the Pt inoculum employed was produced in small quantities on highly defined medium under controlled conditions in a research laboratory. For commercial use, large volumes of functional inoculum are required. In 1976 the Mycorrhizal Institute joined with Abbott Laboratories[1] to devise means of producing

1/ Dr. Donald S. Kenney, Section Head, Microbial Products Research, Abbott Laboratories, Oakwood Road, Box 173, Long Grove, Illinois 60047 vermiculite-based vegetative inoculum of this fungus in large fermentors. After 5 years of testing different formulations of inoculum in over 40 nurseries in 33 states and Canada, adequate procedures are now available for commercially producing functional inoculum.

Much of our previous knowledge about afforestation of such sites is only of limited benefit now that federal requirements for current coal surface mining areas involves something approaching "original contour" conditions (Medvick 1980). Although we can now avoid some of the problems encountered in the past on raw spoils, the planting of trees on restored and topsoiled mine surfaces presents a new set of problems we must cope with. Numerous opportunities exist for meaningful research on coal spoils. We need to learn if companion grass cover near pine seedlings will have to be controlled with herbicides to reduce competition with trees, particularly when containerized pines are used. Should we select alternative herbaceous species and adjust their time of establishment in relation to tree planting to improve survival and growth of planted trees? Could other ectomycorrhizal fungi be isolated and used to provide benefits similar to those obtained from Pt for pine seedling survival and growth on topsoiled spoils? It seems our problems are no fewer, they have simply shifted to new dimensions. Research efforts should continue to develop mycorrhizal technology for coal strip mine reclamation.

Our studies on borrow pits, both with bare-root and containerized pine seedlings, make it clear that an integrated program of cultural and vegetative methods is required for amelioration and successful afforestation. Subsoiling, organic amendments, grass cover, and mycorrhizal tree seedlings are all needed in a unified program to transform borrow pits to productive land for trees, wildlife, and watershed management.

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FROST HEAVING OF CONTAINERIZED SUMMER-PLANTED SEEDLINGS[1/]

Frank W. Woods[2/]

Abstract.--*Pinus virginiana* and *Pinus rigida* were planted in early July on strip-mined areas that had been reclaimed in the spring of 1977. Tubelings of both species innoculated with *Pisolithus tinctorius* were slit-planted in undisturbed spoil and in prepared minisites to which amendments had been added and the spoil tumbled. Treatments were replicated on a bare area and an area seeded with grass. Seedling counts made 8 months, and 14 months after planting revealed that: Survival of both species on the bare area was better with minisite preparation than in undisturbed soil; survival on the bare site was greater than on the grassed site; frost-heave was greater in the case of undisturbed soil than in minisites; frost-heave was greater on the bare area than on the grassed area. Three growing seasons after planting, many of the frost-heaved seedlings are still alive. However, most of them have a procumbent habit and have not exhibited a strong apical dominance.

1/ Abstract of paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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A FIELD TEST OF CONTAINERIZED SEEDLINGS UNDER DROUGHT CONDITIONS[1/]

T.E. Amidon, J.P. Barnett, H.P. Gallagher, and J.M. McGilvray[2/]

Abstract.--A total of 8,960 longleaf and loblolly seedlings were planted on two sites in the late summer of 1979 and spring of 1980. The summer of 1980 was exceptionally dry, providing a rigorous test of container types under harsh environmental conditions. Significant differences were found among containers and between sites and species for both the fall and spring plantings. There was a significant container-species interaction in the late summer planting but not in the spring planting. Containerized seedlings survived better than bare root controls for both species.

INTRODUCTION

The major objective of this study was to evaluate the survival and early performance of containerized loblolly and longleaf pine seedlings produced in commercially available containers and prepared by typical operational techniques. Four container types, two soil types, and two planting seasons were considered. Plantings were made in August and September 1979 and March 1980 in both Kurthwood, Louisiana and Jasper, Texas. One growing season survival was used as the primary indicator of performance. Measurements of height growth and root collar diameter of loblolly and longleaf pine, respectively, were also taken. In this region, the 1980 season was characterized by a severe drought causing extensive losses in the spring 1980 plantings and dramatizing the advantages of the seedlings that were planted in the fall 1979 and established prior to the onset of stress in the summer and fall of 1980.

1/ Paper presented at The Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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MATERIALS AND METHODS

Containers

Styroblock 8's (S8)

These styrofoam block containers were supplied by Silvaseed of Roy, Washington. This container has a soil capacity of 8 cubic inches, a depth of 6 inches, a top diameter of 1.55 inches, and a density of 41 cavities/sq. ft. Culture time for both loblolly and longleaf was 20 weeks in this container after an approximate, 2 week germination period. Seedlings were planted 21 weeks from seeding at the Louisiana site, and 23 weeks from seeding at the Texas site in the fall planting. In the spring planting, seedlings in this container were planted 20 weeks after seeding.

Styroblock 4's (S4)

These styrofoam block containers are from the same manufacturer as Styroblock 8, with a soil capacity of 4 cubic inches, a depth of 5 inches, a top diameter of 1.2 inches, and a density of 75 cavities/sq. ft. Culture time for both loblolly and longleaf for the fall planting was 17 weeks after seeding for the Louisiana site and 19 weeks after seeding for the Texas site. In the spring planting, culture time was 17 weeks from seeding for both sites.

Kys-Tree-Start™, K-7 (Kys)

This is a triangular sided compressed block manufactured by Keyes Fiber Company, New Iberia, Louisiana. This container has a 4.5 cubic inch capacity, is 1.25 inches/side, and 5 inches tall. The block was composed of sphagnum peat moss, vermiculite, cellulose fibers, a wetting agent and fertilizer (23, 10, 15 with diammonium phosphate, potassium nitrate, and ammonium nitrate) at a reported pH of 5.5-6.5. This container was only planted in the late summer 1979 due to greenhouse culture problems. Seedlings in this container followed the same greenhouse culture as Styroblock 4's.

Todd® Model #150-50 (Todd)

These are styrofoam block containers supplied by Speedling, Inc., Sun City, Florida, USA. They are pyramid shaped containers with top dimensions of 1-1/2 inch square and a depth of 5 inches, with a container capacity of 3.7 cubic inches and a density of approximately 50 cells/sq. ft. This container was used in the spring planting to replace the Kys-Tree-Start container, and followed the same culture regime as Styroblock 4's.

Greenhouse Culture

All containers (except Kys-Tree-Start) were filled with 1:1 screened peat and vermiculite. They were seeded with cold stratified loblolly seed or unstratified longleaf seed that were surface sterilized by a 24 hour soak in 3% H_2O_2 prior to seeding. Seeded containers were placed under a mist system for two weeks to facilitate germination. Fertilization began when seed coat dropped, approximately 3 weeks after seeding. The fertilizer, Peter's 20-19-18 at 150 ppm N, was applied twice a week, weather permitting. A preventative Benlate treatment of 1 rounded tsp/gal was applied once every 2 weeks. Supplemental light was applied to longleaf seedlings during greenhouse development for the spring plantings.

Seed

Loblolly

International Paper Company improved seed lot, southern loblolly large, Springhill, Louisiana orchard, 1978.

Longleaf

Department of Natural Resources, Columbia Nursery, Columbia, Louisiana, 1970.

Bare Root Seedlings

Both loblolly and longleaf seedlings were sown April 30, 1979 at International Paper Company's Natchez nursery. Loblolly seedlings were lifted and cold stored until time of planting under standard nursery practice. Longleaf seedlings were lifted less than one week prior to planting and cold stored until use.

Crop Specifics

Late Summer Planting (8/79)

Styroblock 8 <u>seeding date</u> (4/6/79)
Kys-Tree-Start and Styroblock 4 <u>seeding date</u> (5/4/79)
<u>Planting date</u> - Kurthwood, Louisiana (8/28/79)
<u>Planting date</u> - Jasper, Texas (9/12-13/79)

Spring Planting (3/80)

Styroblock 8 <u>seeding date</u> (10/15/79)
Todd and Styroblock 4 <u>seeding date</u> (11/13/79)
<u>Planting date</u> - Kurthwood, Louisiana (3/11/80)
<u>Planting date</u> - Jasper, Texas (3/13/80)

Site Description

Kurthwood, Louisiana

Soil series - Susquehana-Sumter-Houston Association (sandy loam). This was a level site with good site index (>80) and a relatively high water table.

Jasper, Texas

Soil series - Letney-Tehran loamy sand. This was a deep sand, dry site, with a 1-8° slope and a low site index (≈70).

Statistical Analysis

The effect of different container types upon survival rate and the growth of the surviving trees was investigated for four combinations of species (loblolly, longleaf pine) and planting season (spring, late summer). Each of the four combinations was analyzed as a standard split-plot design with the site (Texas, Louisiana) serving as the whole-plot factor and the container type as the split-plot factor. Four replications (each an 80 seedling plot) of every treatment combination were performed in each analysis.

The survival proportion (p) in each replication was transformed to $y = \text{ARCSIN} \sqrt{p}$, a standard transformation for proportions, before the analysis was done. The site effect was tested against the whole plot error, while the container and the site by container interaction effects were tested with the split-plot error. Site and container effects were tested at the 0.05 significance level. When there was no site by container interaction, the least significant difference method, at a significance level of 0.05, was used to order the containers by mean survival rate ($\bar{y}$).

Growth measurements were taken on the surviving trees of both species: root collar diameter on the longleaf and height for the loblolly. These measurements were averaged for each replication and used as the response variables in the same type of split-plot design described above.

RESULTS AND DISCUSSION

Container Influence on Survival

Overall survival in the late summer planting in this study showed a highly significant container effect (Table 1). Seedlings grown in

Table 1.--Container survival by site, species, and planting time (%).

	Late Summer						
	Loblolly (a)			Longleaf (b)			Container
Container*	LA	TX		LA	TX		Average
Kys (b)	84	58	(b)	70	38	(c)	63
S4 (b)	80	70	(a,b)	70	66	(b)	72
S8 (a)	85	77	(a)	88	77	(a)	82
Site Average	83 (a)	68 (b)		76 (a)	60 (b)		
Grand Average							72

	Spring						
	Loblolly (a)			Longleaf (b)			Container
	LA	TX		LA	TX		Average
Bare Root	7	43	(b)	1	6	(c)	14
Container*							
Todd (a)	33	60	(a)	8	29	(b)	33
S4 (a)	37	70	(a)	5	31	(b)	36
S8 (a)	23	66	(a)	12	44	(a)	36
Site Average	31 (b)	65 (a)		8 (b)	35 (a)		
Grand Average							35

*Denotes significant difference across species. Lower case letters (a,b,c) indicate statistically significant differences; those with same letter are not statistically different at $\alpha 0.05$.

Styroblock 8 containers survived better than those in Styroblock 4 containers by an overall difference of 10% and in the Kys-Tree-Starts by an overall 19%. A significant site effect was seen with Texas survival lower than Louisiana for all container types (Table 1). No significant site-container interaction was found in this planting.

In the spring planting, no significant differences were found between containers. All containers showed significant increases in survival over bare root controls. Bare root seedlings averaged 14% survival, Todd 33%, and the Styro 4's and 8's 36% (Table 1). A significant site effect was found in this planting with the Texas site yielding better survival. This is the reverse of late summer data in which the Louisiana site performed better.

Survival Differences Between Species

There was a highly significant difference between species, with loblolly surviving better (Table 1). A significant species-container interaction was found in the late summer planting, but none was found in the spring planting. This significant species x container interaction stems from equivalent survival for both species in the late summer planted S8 container, while in the other containers loblolly survived better than longleaf. In the spring planting, loblolly always survived better. Thus longleaf survival was competitive with loblolly when late summer planted in S8 containers.

Analysis of data segregated by species showed significant differences for loblolly between the S8 and Kys containers in the late summer planting (Table 1). No significant difference is seen between S4 and S8 or S4 and Kys in the late summer planting. In the spring planting, there were no significant differences among containers in loblolly survival. However, all containers performed significantly better than bare root seedlings.

Analysis of longleaf survival data showed a significant difference between all 3 containers in the late summer planting with the ordering S8>S4>Kys. In the spring planting a significant difference was noted between the S8 container and the others, with no difference noted between the S4 and Todd containers. It should be noted that these results for longleaf are less certain as there is a site-container interaction in both seasons.

Preplanting Crop Status Effect on Survival

Data indicative of seedling quality were collected by random sampling at the time of planting (Table 2). Measurements were made of height, stem caliper, and top and root oven-dry weight. In longleaf seedlings, no attempt was made for a height growth indicator, rather stem caliper and oven-dry top weight were the only indicators of shoot growth. There are few seedling measurements for the Kys due to limited crop size and inability to retrieve roots for measurement.

Table 2.--Greenhouse seedling characteristics.

Loblolly									
Late Summer					Spring				
Container	Height (mm)	Stem Caliper	Top Weight (g)	Root Weight (g)	Container	Height (mm)	Stem Caliper	Top Weight (g)	Root Weight (g)
S8	210.8	3.0	1.48	0.24	S8	251	3.3	1.42	0.27
S4	206.5	2.6	0.84	0.16	S4	199	2.6	0.70	0.14
Kys	--	--	--	--	Todd	179	2.4	0.66	0.13

Longleaf							
Late Summer				Spring			
Container	Root Collar (mm)	Top Weight (g)	Root Weight (g)	Container	Root Collar (mm)	Top Weight (g)	Root Weight (g)
S8	4.8	2.19	1.82	S8	3.9	1.40	0.19
S4	2.9	0.97	0.67	S4	2.9	0.69	0.10
Kys	2.6	0.70	--	Todd	3.2	0.89	0.13

On average, Styro 8 containers produced seedlings with 93% greater root weight and 113% greater shoot weight than the other containers. Container volume and culture time cannot be separated in this study; therefore, the relative importance of these 2 parameters in the differences between Styro 8 and other containers cannot be attributed to either.

In comparing the Todd and Styro 4 containers, which experienced the same greenhouse culture, there was an interesting species interaction. The loblolly seedlings grew better in Styro 4's, whereas the longleaf seedlings showed better growth in the Todd container (as measured by top weight and root weight). This suggests that the increased seedling density of the S4 container is more detrimental to longleaf development than to loblolly, as the other container characteristics such as depth and soil volume are only slightly different between these containers.

Survival and Rainfall

The 1980 growing season was very dry across the southern United States and provided an extreme situation for testing survival. Rainfall data was obtained from the N.O.A.A. data collection sites in Jasper, Texas and Leesville, Louisiana (≈15 miles from Kurthwood planting site). The summer rainfall totals (June, July, August) were 2.83 and 3.40 inches for Jasper and Leesville, respectively. The rainfall was not evenly distributed with one rain providing over three-quarters of the total at Jasper and two rains providing almost two-thirds of the total at Leesville. At both sites, droughts of over 30 consecutive days without rainfall greater than 0.5 inches were encountered.

Survival data for the later summer planting was segregated into two time periods: (1) from planting to January 1980 and (2) from January 1980 to January 1981 (shown in Table 3). The initial mortality is attributed to transplant shock and the longer term mortality is attributed to the dry 1980 summer. In the Louisiana planting, which had moist soil at planting time, the Styro 4 container appeared more susceptible to this shock mortality than the other containers showing a 7% loss for loblolly and an 8% loss for longleaf. In the Texas planting, which had extremely low soil moisture on the planting date, the Kys container showed the highest mortality during this period with loblolly losing 22% and longleaf 30%. This difference between planting site in transplant shock may reflect the differences in original soil moisture and rainfall during September 1979 to January 1980 at those two sites: Texas, very dry initially with 15.3 inches of rainfall and Louisiana, moist originally with 21.5 inches of rainfall. The very dry Texas site had higher transplant shock mortality for Kys and S4 but not for S8. S8 container seedlings exhibited the least mortality over this period, and appear to be least susceptible to transplant shock.

From the data in Table 3 for loblolly pine, the largest component of loss is associated with the 12 month period during 1980 for the Louisiana site. Analysis of these figures show no significant differences in mortality over this period associated with container, sites, or site x container interactions. Consequently, this mortality is associated with some parameter outside the planting vehicle. The low rainfall during this period is the most likely explanation for this loss.

In longleaf pine no difference between the average mortality during 1980 due to site or site x container interaction effects are evident (Table 3). However, mortality in Kys containers during this period (29%) differed significantly from that of the S8 container averaging 18% with no statistically significant difference found between the S4 container (21%) and either the Kys or the S8 container. No obvious explanation for the high mortality of the Kys container during this period is known; however, this container exhibited poorer greenhouse culture performance, and higher mortality may be a measure of seedling quality rather than a field aspect of container performance.

Table 3.--Losses over time, late summer planting.

	Planting to 1/80			
	Loblolly		Longleaf	
Container	LA	TX	LA	TX
Kys	4%	22%	4%	30%
S4	7%	16%	8%	14%
S8	4%	2%	2%	3%

	1/80 to 1/81			
	Loblolly		Longleaf	
Container	LA	TX	LA	TX
Kys	12%	20% (a)	26%	32% (b)
S4	13%	14% (a)	22%	20% (a,b)
S8	11%	10% (a)	10%	26% (a)

*Lower case letters (a,b,c) indicate statistically significant differences; those with same letter are not statistically different at α0.05.

The lack of significant differences in the loss data for late summer planted loblolly during the 12 month period of 1980 indicates that the significant (16 month) differences were due to planting shock effects during the first four months of field adaptation. Thus the Styro 8 container, either through the virtue of increased soil volume, lower seedling density, or longer culture period, was less susceptible to transplant shock than the Kys container. Analyzing the data, partitioned into these time periods, shows the importance of transplant shock stress in determining loblolly survival differences between containers. Statistically, significant differences in overall survival stem from differences during the initial acclimation period.

In longleaf, statistical differences are seen in percent loss over the period 1/80 to 1/81 with Styro 8 containers suffering less loss than the other 2 containers. This suggests that container parameters influence field performance after the initial transplant shock period for longleaf. Presumably, this effect is associated with the increased container volume and culture time of S8's.

Field Measurements as an Indicator of Container Performance

Field performance of containerized seedlings was assessed by loblolly height measurement and longleaf root collar diameter in 1/81 (Table 4). It was found that the mean height of loblolly seedlings showed a positive correlation with percent survival (R=0.59). This relationship also held for longleaf root collar (R=0.57). Thus, those containers which performed well in terms of survival also performed well in terms of growth. Height of survivors at 1/81 showed a significant site and site x container effect for both species in the late summer planting. The Louisiana site proved better for both species. The site x container interaction stems from a different ranking of the containers between Louisiana and Texas; however, the S8 outperformed the others in both sites in both species.

Table 4.--Mean height and root collar diameter of survivors (1/81).

Loblolly Mean Height (ft.)					
Late Summer			Spring		
Container	LA (a)	TX (a)	Container	LA	TX
			Bare Root	0.9 (a)	0.8 (a,b)
Kys	1.5 (b)	1.1 (b)	Todd	0.8 (b)	0.8 (b)
S4	1.4 (b)	1.3 (a)	S4	0.8 (b,a)	0.8 (a,b)
S8	1.7 (a)	1.4 (a)	S8	0.9 (a)	0.9 (a)

Longleaf Root Collar (in.)					
Late Summer			Spring		
Container	LA (b)	TX (a)	Container	LA (a)	TX (a)
			Bare Root	0.4	0.4
Kys	0.4 (b)	0.4 (c)	Todd	0.3	0.3
S4	0.4 (b)	0.5 (b)	S4	0.4	0.3
S8	0.5 (a)	0.6 (a)	S8	0.4	0.4
				No Significant Difference	

*Lower case letters (a,b,c) indicate statistically significant differences; those with same letter are not statistically different at α0.05.

In the spring planting, no significant site interaction was found for either species. A significant container effect on height measurement was found for loblolly pine with the S8 container differing from the Todd container, but not showing a significant difference between bare root or the S4 container. The lack of significant differences in height of bare root seedlings versus containerized is noteworthy as the bare root seedlings were larger on outplanting. The growth exhibited by containerized seedlings during this period decreased the initial size advantage of bare root seedlings. Longleaf showed no significant site difference and no significant differences in root collar diameter.

CONCLUSION

Data presented indicate that: (1) containerized seedlings surpass bare root seedlings in survival and can yield competitive first year growth with bare root stock; (2) of the containers tested, the Styroblock 8 container showed the best performance for both species in both seasons; (3) late summer planting of containerized longleaf can yield results competitive with loblolly, and both species can yield acceptable survival when planted at this time even when the subsequent year is very dry; (4) longleaf is more sensitive to container parameters than loblolly as indicated by significant differences in survival between containers when comparable data for loblolly fails to show significance; and (5) in late summer planted loblolly, the mortality during the initial stress period (4 to 5 months) differentiated container types, while subsequent mortality was not significantly affected.

ACKNOWLEDGEMENT

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USE OF CONTAINERIZED SEEDLINGS FOR PROGENY TESTING[1/]

J. P. van Buijtenen[2/] and W. J. Lowe[3/]

Abstract.--Nine of the twenty-one WGFTIP members are using containerized seedlings for part of their progeny testing. The main advantages are increased uniformity, quicker turn-around, more plantable seedlings for a given number of seeds, and greater ease of field planting. Growth has been comparable to that of bare-root seedlings.

INTRODUCTION

During the past few years, the use of containerized seedlings for the purpose of progeny testing has increased greatly. About six years ago, progeny tests were established exclusively from bare-root seedlings. Now nine of the twenty-one members of the WGFTIP program are using containerized seedlings for at least part of their progeny testing. Also, all of the progeny testing for the Texas Urban Tree Improvement Program utilizes container grown seedlings. Types of containers used vary greatly, but styroblocks, speedling flats, and Ray Leach tubes are among the ones used most commonly. The N. C. State Cooperative and the Florida Cooperative are making only limited use of containerized seedlings for progeny testing.

ADVANTAGES OF USING CONTAINERIZED SEEDLINGS FOR PROGENY TESTS

Increased Uniformity

This is by far the most important consideration in using containerized seedlings for progeny testing. No matter how well a nursery bed is prepared, the seedlings in the nursery bed are usually far from uniform. Differences in germination, soil texture, low spots in the nursery bed, leakage from irrigation systems, and problems with weeds all contribute to this lack of uniformity. That doesn't imply that containerized seedlings are automatically uniform because they have problems, too. For instance, we have noticed some pronounced edge-effects, but with proper management, very uniform seedlings can be produced. As with any greenhouse operation, very close attention needs to be paid to watering schedules, fertilizer programs, and insect and disease control. Damage can easily occur in less than 24 hours if a problem remains undetected or untreated. Because of the edge-effects and other differences in a greenhouse climate, it is as important to replicate the seed lots for a progeny test in a greenhouse as it is in a bare-root nursery.

Quicker Turn-Around

If a program is managed efficiently, it is possible to collect seed from controlled loblolly pine crosses in the fall, stratify the seed, plant them in a greenhouse in late November, and field plant the seedlings in April. This essentially gains one year, compared to bare-root seedlings, which would be planted in the nursery in April and the seedlings field planted in the next dormant season. The process is more easily attained with species, such as slash pine, that require little or no stratification period. This is a very important consideration in a tree improvement program where a reduction of the generation interval results in an increased gain per unit of time.

More Plantable Seedlings for a Given Number of Seed

Even with the extra care given to progeny test seedlings in the nursery, we generally need to plant between two and three seeds for every plantable seedling desired. In a recent test carried out by the Texas Forest Service, germination percentage in the nursery varied by family and ranged from 31 to 74 percent for slash pine and 38 to 91 percent for loblolly pine. Using containerized

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1/ Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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seedlings in Leach tubes, it is possible to get 99 plantable seedlings out of 100 seeds, although this is quite unusual. Normally, we plan to use 150 seeds to obtain 100 plantable seedlings when using styroblocks or speedling flats. We generally do some transplanting or double seeding. When using controlled crosses of which only a very limited number of seeds are available, the seedling percentage is extremely important. It has been possible in some cases to avoid an extra year of crossing efforts because of the increased proportion of plantable seedlings.

With species for which it is difficult to obtain a high percentage of sound seed, we usually sow the seed in petri dishes or on trays. Only germinated seed are planted in the containers. This practice increases the proportion of good seed that are used and eliminates the need for multiple sowing, thinning, and later transplanting. Also, it is easier to obtain a uniform growing density. Large seeded species, such as the oaks, that present special problems in multiple sowing and transplanting also work well with this system.

Greater Ease of Field Planting for Complex Designs

With certain kinds of containers, particularly movable containers such as the Ray Leach tubes, it is possible to re-arrange the seedlings prior to field planting in exactly the way they need to be set out in the field. This process is not usually weather dependent such as lifting seedlings from a bare-root nursery. Also, it can be completed before the tests are to be planted which enables easier scheduling of personnel and activities. This greatly simplifies and speeds up the establishment of progeny tests in the field. The more complex the design, the greater the benefit of the use of containerized seedlings.

DISADVANTAGES OF USING CONTAINERIZED SEEDLINGS

Difference from Operational Practices

The use of containerized seedlings is another step further away from operational practice. Many years back, when tree improvement started, the philosophy was that progeny tests should be treated exactly like operational plantings. As time went by, we have drifted away from this practice primarily because progeny tests need to be uniform in order to be effective in distinguishing between fast and slow growing families. For the sake of uniformity, progeny test sites are now much better prepared before planting and also receive better maintenance than operational plantings. The use of containerized seedlings carries this one step further which may affect the rankings of the families. One could visualize, for instance, that the ability to regenerate a root system after lifting is an important attribute of a bare-root seedling, while it is not a significant factor for containerized seedlings. This could possibly affect its performance.

Slower Initial Growth

In a number of instances, containerized seedlings appear to have a slower start than bare-root seedlings. This may be partially due to the somewhat smaller size of the containerized seedlings and partially due to the fact that containerized seedlings do not develop side roots in the top six inches of the soil because of the root structure inside the containers. Eventually, they seem to get over this.

Length of Planting Season May Not Be Increased

One of the advantages that is often quoted in favor of the use of the containerized seedlings is that it increases the length of the planting season. This is true if sufficient soil moisture is present and the seedlings are properly hardened off. However, in our experience, the planting season for pine seedlings in containers is distinctly different from bare-root seedlings, but carrying out the planting operation in the proper time slot seems to be even more critical. We find that we can plant pine seedlings only at two periods of the year, in early spring and early fall. First of all, we need to wait until the danger of frost is over. Then we need to plant well before the usual summer drought unless irrigation is available. This means that, in effect, we need to plant our seedlings between March 15 and April 15. In the fall, we have another time slot in which we can plant. In this case, we need to plant after the fall rains have restored soil moisture, but at least one month before the first hard freeze. For practical reasons, in effect, we cannot plant trees until the cone collecting season is over, which leaves a period from the middle of October until the middle of November. The last seedlings planted may get burnt badly by an early freeze, although they usually recover in the spring.

Planting activities start for the hardwood seedlings in the fall when sufficient soil moisture is available which usually occurs in September. This activity can continue through the winter until the middle of April. As with the pine seedlings, the chance of summer drought is our main concern after this time. Dormancy and winter burn do not cause a major problem with the hardwood species.

Because of the extended summer droughts in our area, we are cautious about extending planting activities too late into the spring. In areas where rainfall patterns are more uniform, extension of the planting season into the summer should be feasible. Also, different procedures for hardening of pine seedlings may reduce our problems with winter burn.

PRACTICAL CONSIDERATIONS FOR PRODUCTION OF CONTAINERIZED PROGENY TESTS

When developing a schedule for the production of containerized progeny tests, it is important to determine the desirable field planting time and then develop a management program that will allow acceptable quality seedlings to be produced at the desired date. Factors such as the size and type of the container, greenhouse management, and practical limitations dictated by seed collection and stratification requirements for a species need to be considered. If an improper management regime is used in the greenhouse, the seedlings can be too small at the desired planting time for survival or be unable to compete with existing vegetation at the planting site. Also, the seedling root system may be underdeveloped so that it can not be pulled from the container. By the same token, they can be grown too large for the container which will cause an imbalance between the top and the root system. This usually results in rootbinding that will handicap growth and later performance in the field.

Currently, styroblocks, speedling flats, and Ray Leach tubes are among the most commonly used containers for progeny test production. Early in our containerized program, we attempted to use other types of containers, such as the bag and tube type of containers. Neither of these types of containers performed satisfactorily under our conditions. The main problem that we experienced with both of these containers was root spiraling. Also, with many of the tube type of containers, the tube material did not decompose soon enough when it was field planted so that the root system could penetrate into the soil.

There are several different types of media that are available for use in a container program. Under our conditions, a mixture of 1:1 peat moss and grade four vermiculite is an acceptable growing media. Fertilizer can either be incorporated into the media when it is being mixed or it can be applied by injection through the irrigation system. Either technique or a system that utilizes both methods of fertilizer application is satisfactory. It is important to note that if fertilizer is injected through the irrigation system, you need to continue watering after fertilization has stopped to wash the fertilizer off the leaf surface. If this is not done, it is possible to develop a salt accumulation on the leaves which will damage the seedlings.

Intermittent supplemental lighting at night can be used to increase stem elongation. If supplemental lighting is used, the seedlings will have a tendency to become very spindly. The supplemental lighting needs to be stopped and the fertilization regime changed prior to outplanting so that sufficient seedling caliper can be developed. Many of our southern species will grow fast enough in containers to obtain an acceptable seedling without the use of supplemental lighting.

It is common knowledge that bare-root seedlings need to be planted sufficiently deep. This is also an important consideration with containerized seedlings. The growing plug needs to be planted completely below the surface of the soil. If a portion of the plug is left uncovered, it can act as a wick to dry the root system of the seedling out.

SOME ACTUAL FIELD EXPERIENCES WITH CONTAINERIZED PROGENY TESTS

The Texas Forest Service has not planted containerized and bare-root seedlings in the same test. We do, however, have some tests of both kinds established in the same year. Table 1 gives a comparison of several tests established in the 1974-75 and 1975-76 planting seasons. Tests 1 and 2 contained very similar materials. One planted in 1974-75 from bare-root seedlings, the other planted in 1975-76 from containerized seedlings. The difference in growth, however, cannot necessarily be attributed to the use of containerized seedlings. Plantation 3 was the only other loblolly plantation established in the same year, and had very similar growth to the containerized seedlings. The comparison is somewhat arbitrary, however, since the two tests were planted at two rather widely separated locations.

Table 1.--Plantation summary for bare-root and containerized loblolly pine progeny tests

	1974-75 Bare-Root	1975-76 Containerized	1975-76 Bare-Root
	1	2	3
Survival at age 1 (%)	98.0	98.1	97.1
5-Year Height (m)	4.18	3.89	3.86
5-Year DBH (cm)	5.62	4.71	4.92
5-Year Volume/Tree (dm^3)	3.89	2.50	2.88
Rust Score	.692	.707	.977
Rust Infection (%)	27.5	25.4	37.1
Survival at age 5 (%)	96.6	94.5	94.6

During the 1975-76 planting season, six live oak progeny tests were established in areas outside the natural timber range. Half of the tests used bare-root seedling while the other half were established with containerized seedlings. First year survival for the bare-root tests averaged 64 percent (range 44-86 percent) while the containerized tests averaged 85 percent (range 79-97 percent). First year survival of progeny tests established in this area is very dependent upon test management. However, the use of containerized seedlings has significantly increased the average first year survival.

SUMMARY

During the last few years, the trend has been toward using containerized seedlings for the production of progeny tests. Containerized seedlings have the advantages of increasing test seedling uniformity, more efficient use of seed, a reduction in time required to establish progeny tests, and the simplification of field planting procedures. Possible disadvantages are that in some cases it appears that containerized seedlings have slower initial growth, and the use of containerized seedlings is a different practice from operational regeneration programs.

FUTURE OF GREENHOUSE CONTAINER NURSERY SYSTEMS IN THE SOUTH[1/]

Richard W. Tinus[2/]

Abstract.--Greenhouse container nurseries' contributions in the South include superior seedlings for specialty crops, longer planting season, promoting mechanization, and conserving valuable seed. Future greenhouses must be more energy efficient, and growing systems may change drastically. Past mistakes include lack of clear objectives and a systems approach, overly complicated and expensive structures, using too small a container, and poor administrative decisions and organization. These mistakes can be avoided by applying current knowledge.

ADVANTAGES IN THE SOUTH

The South is the last major tree growing region on the North American continent to embrace the greenhouse container nursery system as a major reforestation tool, probably because nowhere else is the bare root option so cheap and satisfactory. Currently, the greenhouse container nursery is used in this region mainly for specialty crops, such as longleaf pine, sand pine, Fraser fir, oaks, and eucalypts. The number of species grown probably will increase with the demand for diversification in the forest and as more uses for the different species are found.

In addition, there will also be increased use of the greenhouse container system for producing the main crops of loblolly, slash, and shortleaf pine, for three principal reasons (Tinus 1975). First, it extends the planting season. Bare root stock can be used only for a small portion of the year (Xydias 1981). The 3-month bare root planting season is too short to satisfy the growing reforestation job in the South. The container system offers the potential to plant throughout the year in many parts of the South. Second, the handling of nursery stock in the nursery, in transit and storage, and particularly in planting needs to be more completely mechanized. Because the container seedling is a standard package, it is probably easier to mechanize than the handling of bare root seedlings. Third, increasing numbers of seedlings in the South are grown from genetically improved seed. At $1,100 per kilogram value, it is important to produce maximum number of seedlings. In the greenhouse, expensive seed will not be washed out of the ground by torrential rains or devoured by blackbirds.

SOURCES OF INFORMATION

Although certain aspects of production problems in the South are different from those in other parts of the continent, there is still a great deal of commonality among container nursery problems. Southern container nurserymen can learn much valuable information from their counterparts elsewhere. Today there is enough information available so that anyone who studies the subject and plans well should not make any catastrophic errors (Tinus and McDonald 1979). Ten years ago that was not the case.

IMPORTANCE OF ESTABLISHING OBJECTIVES

To properly realize the benefits of the greenhouse container nursery system, it is necessary to have objectives clearly in mind. For example, in the Southwest there are two planting seasons: one in February and March, and one in August. Tree planting success in the early spring season has generally been low, because the planting season is invariably followed by a drought. The rains come in late summer. Seedlings have a good chance to get established, but bare root stock is not available then.

Here is how two organizations responded to the opportunity. Organization A began building a new nursery complex that was to include both a bare root and a container nursery. The design of the greenhouse system was contracted to an architectural firm with instructions that it be solar

1/Paper presented at Southern Containerized Forest Tree Seedling Conference, Savannah, Georgia, August 25-27, 1981.

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heated, highly mechanized, and quite permanent. After spending $250,000 on the design, it became obvious it would not be able to afford seedlings produced in such a facility, so the entire container nursery was scrapped. Development of the bare root nursery went ahead on schedule, but the organization was again locked into an early spring planting season. Just as every bare root nursery has problems unique to it which require research effort to make the operation a success, the Organization A nursery has a host of cultural problems yet to be solved before it will be able to grow high quality stock reliably. In contrast, the technology for growing container seedlings in greenhouses is much more easily transferred. With properly informed, competent help it is quite possible to do things right the first time.

At the same time, Organization B built a single, medium-sized, inexpensive greenhouse. It began growing pine in large containers and planted it in August with very high survival. The nursery and planting effort has grown tremendously since then, and the seedlings' initial survival and growth rates have been very high.

There are several lessons to be learned here. First of all, if someone nearby is doing something that works, don't be afraid to copy it, even if your own organization has the reputation for being the leading expert. Second, don't overdesign or overbuild. It is not necessary to have an expensive installation to grow fine container seedlings. Third, have your objectives clearly in mind. Organization A didn't know what it wanted from the container system, but Organization B did.

TAKE A SYSTEMS APPROACH

Whether you have a bare root or container system, believe in it. Take a systems approach, and do everything right, not just part of it, because attitude creates a self-fulfilling prophecy. To illustrate, Organization C had a successful bare root operation. Its nursery produced high quality stock. It was very careful about maintaining stock in good condition during transportation to the planting site. Its planters were well trained and highly motivated, and as a result establishment success was high. It also had a container operation, sort of an adjunct to the nursery stuck in a corner. The container stock produced was mediocre. It was shipped to the planting site with little allowance for the fact that it had to be treated differently than bare root stock. The planters grumbled about having to carry the extra bulk and weight, and the seedlings were so small they didn't look important. Sure enough, the bare root stock outperformed the container stock every time.

CONTAINERS AND STRUCTURES

Start with a large enough container. It is better to start with one that is big enough, even if it looks too expensive. If there is time, run some small scale field trials. After you succeed, then see if a smaller one will do. Frequently, a variety of sizes will be needed to handle different species and different planting sites.

Don't overbuild (Guldin 1981). Plan with the expectation that any facility built now will be obsolete in 10-15 years. Too many facilities are built of steel, concrete, and glass designed to last forever. Although greenhouse container technology is maturing to the point where there is enough information to do a good job reliably, some major changes are coming. Greenhouse production of seedlings is an energy intensive process, especially for winter crops, and a great deal of research is in progress to find ways to insulate greenhouses, make maximum use of solar heat, and modify growing regimes to conserve fuel. Make sure that any system built now has the flexibility to retrofit to a more energy efficient system later, or be prepared to scrap the whole thing and build a new one.

In addition, there is the prospect of entirely new growing systems. In nursery systems now in widespread use, container shape and air pruning control the root system configuration. Air pruning requires that the bottoms of the containers be exposed to circulating air. Therefore, the seedlings are grown on benches or tables. The greenhouse is heated most conveniently by a forced air system which makes air temperatures fairly uniform throughout the house. Dr. Carl Whitcomb, Oklahoma State University, has described experiments in which the greenhouse is floor heated, but the air is not. The seedlings are grown directly on the greenhouse floor. According to him, this results in a great saving in fuel costs, because the heat is applied to the seedlings and the air in the greenhouse is allowed to remain cold. The cold air loses far less heat to the outside than warm air. To use a floor heat system, you must get away from air pruning. Burdett (1978) and McDonald, Tinus, and Reid (1980) have described successful experiments in which root configuration is controlled by copper carbonate in latex paint on the container wall. With this technique, it may be possible to grow seedlings with a desirable root configuration without air pruning. Further, seedlings on the floor could be subirrigated, which would eliminate continual wetting of the foliage with nutrient solution and would greatly reduce the incidence of Botrytis, a foliage mold which is a serious pest in the Pacific Northwest and likely to be one in the Southeast. If this new system is found to be feasible and possibly superior to the current system, greenhouses and containers will be quite different from what they are today.

Another reason for not overbuilding is that reforestation is a long-term effort which should be kept at a fairly even level in the face of short term ups and downs in the economy. Administrators should concentrate on function and cost effectiveness and not become enamoured with structure. For example, Organization D built a very modest-appearing facility on the West Coast and took full advantage of the maritime climate to use minimum environmental control. It produced one crop per year. Much of the equipment was home-made and not fancy, but it worked well. The operation has grown, and the staff have become consultants to other companies up and down the West Coast.

In contrast, Organization E built a very expensive system, heated by electric boilers and with 7,000 lux of sodium arc lights. It produced two crops a year and tried to produce three. All of the equipment was the finest available, but several years ago, management decided it couldn't afford it any more. The capital cost per seedling produced was too much. The company still operates the facility, but produces seedlings on contract to other companies.

Finally, Organization F planned a greenhouse facility in the far North that was to produce three crops a year under fully controlled conditions, including sodium arc lights. The irrigation water was to be pumped from a river 3 km away. A natural gas pipeline would run a generating plant to produce electricity for the complex. When the price tag reached 20 million dollars, they asked me "Will it work?" I said, "Yes, it is biologically sound, but can you afford it?" After some soul searching, they decided they couldn't. Instead, they built a much more conventional greenhouse system for one crop per year, and the results, as far as I know, have been very satisfactory.

Be sure your architects and engineers have designed successful tree growing greenhouses before. Some years ago, Organization G built a greenhouse nursery system. It was a conventional fiberglass structure which the manufacturer had sold all over the country, but their structures apparently had not encountered the winds of the Great Plains. After losing pieces of roof several different times, they were convinced to eliminate the eaves and fasten the roof with lengths of electrical conduit rather than individual screws or nails. This same greenhouse was designed with an overhead polytube system. The upper echelon architects would not approve a structure so flimsy as polyethylene, so this became a $3,000 steel air duct which was good for shade, but not much else. During cold weather, the heating system did an excellent job of keeping the top of the greenhouse warm, but failed to maintain growing temperatures at plant level. Eventually, the heating system was rearranged and the air flow placed at floor level where it belonged.

Whatever you do, keep the design as simple as possible. There will be less to go wrong, and it will be cheaper and easier to fix if it does, especially when the equipment gets old. Make sure you have service for your equipment nearby, and spare parts for all essential pieces on hand.

MANAGING PEOPLE

Some of the most common problems in nursery operation are managerial, rather than technical. Several measures can be taken to avoid these "people problems."

Reforestation should be under a single unified management. Especially in organizations that do the whole job, one person should be in charge of the nursery, the transportation, the planting, and stand establishment. That way everyone is more likely to act as a team working together to solve problems rather than shifting the blame to someone else, or solving one's own problems at the expense of making someone else's more difficult.

There should be a clear line of authority. No one except the greenhouse operator should change the dials or apply treatments to the seedlings. If a higher level manager sees something wrong, the one directly in charge should be told to make the necessary changes; the manager should not make them himself.

Have the right kind of expertise where you need it. A horticulturist or equivalent should be in charge of the greenhouse, and should not be assigned purchasing, hiring and firing, and other paperwork which detract from greenhouse duties.

If the system works, don't change it. Any proposed change should be tested in a small way before it is applied to the entire nursery. Remember that a nursery's function is to guarantee on-time delivery of a specified number of high quality seedlings. Leave the research to researchers. Unfortunately, it is not uncommon that after two successful crops a nurseryman may think he is an expert and entitled to remold the growing regime at will. Frequently, when I am called upon to help, I find the nursery is no longer doing the things that originally made the operation successful.

Know when to seek advice. Do not let problems become disasters before asking for help. An expert consultant should be giving you a system, not just a patch. If the first expert doesn't tell you what you want to hear, by all means get a second opinion. The second expert may give you something different and perhaps equally good, but select one of the systems and don't mix the two. There are many right ways to do things, but not all of them are compatible with each other.

It is sometimes hard for administrators to recognize good advice and act on it. They frequently don't know when they need to buck their own organization to get things done right. Too often new container nurserymen or administrators will accept poor decisions without realizing the consequences until major problems develop.

If you do all of the things I have suggested, your success may not be guaranteed, but at least you can begin making original mistakes immediately.

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