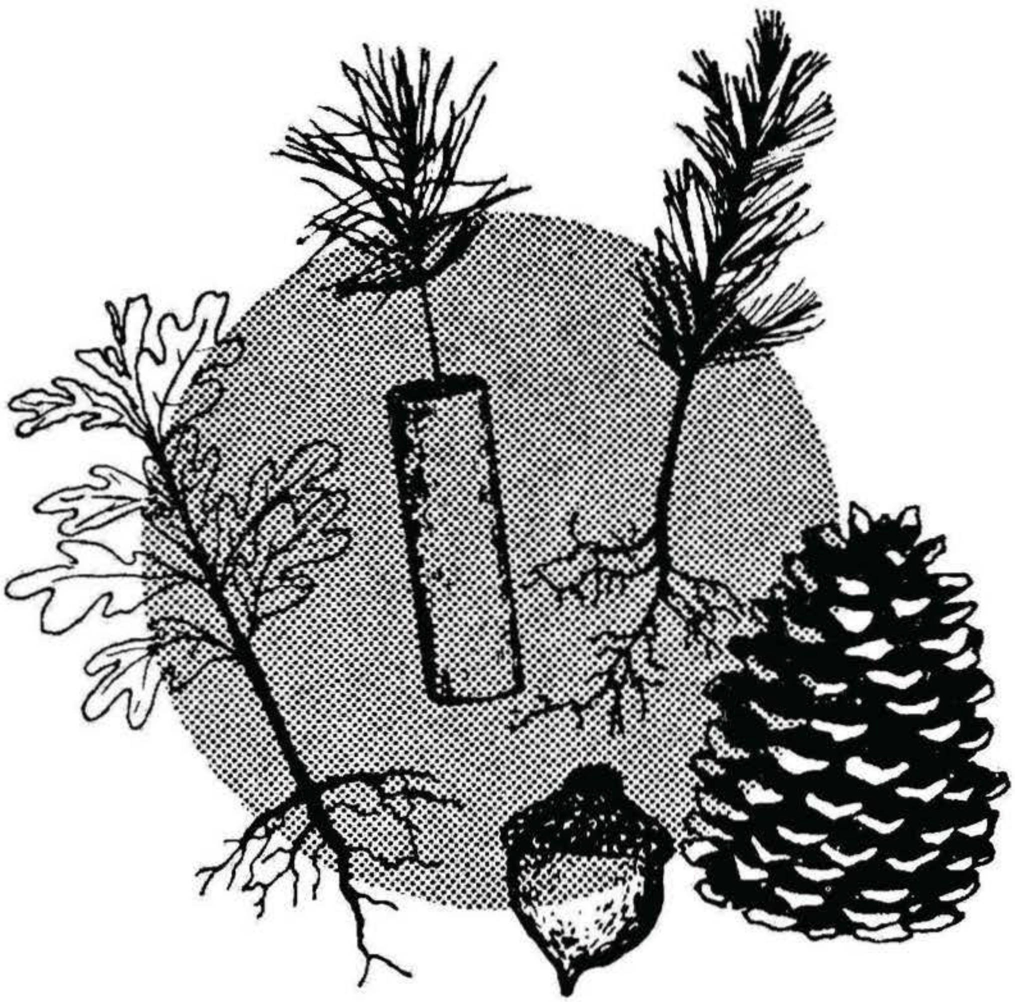
Technical Publication R8-TP 4

August 1983

PROCEEDINGS: 1982 Southern Nursery Conferences



WESTERN SESSION-Oklahoma City
August 9-12

EASTERN SESSION-Savannah
July 12-15

Cosponsors: Georgia Forestry Commission
Oklahoma Forestry Division
USDA Forest Service—Southern Region

TABLE OF CONTENTS

* This is a combined proceedings of the Eastern Session (Savannah, GA) and the Western Session (Oklahoma City, OK). Papers are listed (E) and (W).

Compilers' Note

The 1982 Southern Nursery Conference was successful due to the combined efforts of many individuals. Our sincere thanks to Terrell Brooks and Al Myatt for their outstanding work in organizing the sessions in Savannah and Oklahoma City, respectively.

This proceedings is dedicated to the following retiring nursery managers:

O. C. (Chris) Goodwin - North Carolina Forest Service
Neely D. Pearce - Alabama Forestry Commission

Our best wishes for many happy retirement years!

JOHN BRISSETTE
Nursery/Tree Improvement Specialist
USDA Forest Service
Jackson, MS

CLARK LANTZ
Nursery/Tree Improvement Specialist
USDA Forest Service
Atlanta, GA

USDA Forest Service
1720 Peachtree Road, N.W.
Atlanta, Georgia 30367

WHAT THE NEXT DECADE HOLDS FOR U. S. TREE NURSERIES: A PROGNOSIS

Stephen E. McDonald[1/]

Abstract.--Changes in the U. S. Forest tree nursery industry are predicted for the period 1982-92, based on trends and speculation. Economic, biological, engineering, and resource management developments are integrated in the predictions. Resultant professional impacts on nurserymen are deduced.

Introduction

More than speakers from anywhere else, those from Washington, D.C. can truly say "I'm very glad to be here." Today I want to spend a few minutes talking about where we are and where we are going in the forest tree nursery business in the United States. In doing this I have the singular opportunity to provide you with this perspective from the vantage point of your Nation's Capitol. As you know the folks in Washington know what is going on in the Country and exactly what our direction should be for the good of all Americans. Working there, I share this knowledge, so bear in mind that my observations will have a degree of accuracy and relevance you are usually not exposed to in professional meetings of this sort. Certainly my assessment of the present nursery situation will be as precise as, say, the assessment King Louis XVI made of the mood of the French people in 1792. I believe he was guillotined in 1793.

Production Trends

My fellow professionals, we should be proud of ourselves. In 1981 we collectively produced over 1 1/2 billion tree seedlings for conservation planting. This is an enormous achievement. If we increase outputs of trees in the United States by 100 billion seedlings per year for a couple of more years we will be up to the production level of 1960! That was the high-water-mark of the Soil Bank Program of the Eisenhower era. For the sake of perspective, however, let's look at a few numbers covering the last ten years. The figures come from the 1971, 1976, and 1981 Forest Tree Nursery Directories of the United States. The data comes from many sources and varies in quality, but they're the best overall figures we have.

Production-wise the trends look good (Figure 1). You can see that the trend line is up and that it is steeper for the last 5 years than it was for the preceding 5 year period (1971-1976). Over

---

1/ Forestation and Tree Improvement Specialist, Cooperative Forestry, USDA Forest Service Washington, D.C. Presented to Southern Nurserymen's Meeting, Oklahoma City, Oklahoma. August 10-12, 1982.

Well, what does this all mean to us? What kind of crystal-ball projections can we make on the basis of these generalized data?

First let's assume the figures we have just seen represent true trends and that the economic forces driving them will remain rather constant. If this happens it is obvious the forest tree nursery business will continue to be a "growth industry." By 1986, when the next Nursery Directory is put together, there would be nearly 100 more nurseries and we would be producing over 2 billion trees a year (Figure 11). By 1991 there would be 500 tree nurseries in the U. S. producing 2.5 billion trees. In other words, by 1986, we may need nurserymen to operate 60-70 additional nurseries of an overall average size of 7.2 million seedling output. That's pretty simplistic. Much of the recent growth in nurseries has been in the south by forest industry. Right now about 70 percent of the national production of tree seedlings is in the south and the percentage has been increasing. If we assume it will increase to 80 percent by 1991, that means over 2 billion trees will be grown in the south, alone, at that time.

The average forest industry tree nursery output in 1981 was 12.5 million trees. I think you would agree that is small for the south. If we assume a 20 million tree average southern nursery size in 1991 and an increase of 900 million of trees output over the 10 years, that translates to 45 new southern nurseries of significant size!

While such speculation is interesting, it is still speculation. Forest nursery production has been subject to many ups and downs over the years. One need only remember the Soil Bank Program of the late 1950's and early 1960's and the CCC Program of the 1930's and 1940's to know this. In addition, recessions, like the present one, result in depressed wood markets, less logging, and finally, less tree planting. Over the last year there has been a great deal of surplus stock in the Pacific Northwest. These trees were "in the pipeline" when the logging slowed down out there. I assume sowing is greatly curtailed now.

In addition to the effects of the recession, which I think are transitory, there is presently a debate between the USDA Forest Service and the National Forest Products Association (NFPA) about the projected wood needs of the Nation. NFPA estimates are much lower than USFS estimates. Their figures are based on (1) projections of smaller houses with less wood in them, (2) more plastic packaging and less paper packaging, and (3) less use of newsprint and other paper because of advances in electronic mail, newscasting, etc. If these assumptions come true they may have a dampening effect on nursery expansion.

the last two five year periods the increase has averaged over 9 percent per year. If we break the growth down into private, Federal, State, and forest industry portions some interesting things emerge (Figure 2). Both the forest industry and private sectors have grown at a rate exceeding State and Federal outputs over the last five years. Forest industry puts out more trees than any other segment. Private, nonindustrial output exceeds Federal nursery production. If we compare State and industry outputs to the total (Figure 3) you can see they produce the lion's share of the tree seedlings.

Now, if you look at the number of nurseries, there has been a huge jump over the last decade (Figure 4). There has been a 61 percent increase just since 1976. If we break these numbers down into private, Federal, State and forest industry segments, a startling increase in the number of private, nonindustrial nurseries becomes apparent (Figure 5). I am not sure how valid this increase in numbers is. In 1971 and 1976 no aggressive effort was made to include them in the U. S. Forest Tree Nursery Directory. In 1981 there was. Also, in 1981, I am sure some private nurseries were included in the Directory which produced nearly all ornamental stock. Presented in bar graph form (Figure 6) the same trends are apparent, with Federal and State nurseries growing much more slowly in number than private or forest industry ones.

The average nursery output has increased from about 5.2 million trees per year to about 7.2 million trees per year (Figure 7). The rate of increase in size of output has decreased since 1976, but, again, I think this has been skewed by the increased numbers of private nurseries now included in the Directory. Breaking nursery annual output into private, Federal, State, and forest industry segments we find that forest industry average nursery output has doubled from 6.1 to 12.2 million trees per year since 1971 (Figure 8). The average Federal nursery output has decreased because of construction of a number of small container facilities, primarily by the Bureau of Indian Affairs. Comparing State and industry nursery average output for 1971, 1976, and 1981 in a bar graph (Figure 9) shows how State average production has changed little relative to the forest industry nurseries.

If we compare total nursery production trends and numbers of nurseries (Figure 10) we can see the number of nurseries is increasing at a faster rate than production. I think the lines are probably really about parallel. All the small private units recently included steepens the "number of nurseries" line for 1976-1981.

There is a lot of attention now to reduction of the role of the Federal Government in people's everyday lives: fewer social programs, smaller Government, etc. Many of the programs targeted for reduction are those where Federal money is granted to local government or individuals for various purposes. This means State and Private Forestry grants to State Forestry are vulnerable. The President has requested $1,145,000 for cooperative tree nursery improvement and expansion in fiscal year 1983, a 34 percent reduction from 1981. The Forestry Incentives Program (FIP) will not be funded in FY 1983 unless Congress inserts it in the budget. All these sorts of decisions can affect nursery production. On the other hand the pendulum can swing the other way just as fast. In FY 1982 six billion dollars were budgeted for crop price support subsidies. After seven months 10 billion dollars had been spent! Consequently there is some renewed interest in a Soil Bank-like program to get agricultural land out of production. Such a program could save billions in subsidies, get a lot of trees planted, and reduce crop surpluses.

Who knows what will happen? I don't. If we believe the past is prologue we can make some general guesses. Tight money and recessions suppress forest industry reforestation activity. These conditions sometimes increase government reforestation to create jobs in rural areas or to help landowners. Easy credit and a booming economy stimulate forest industry reforestation and National Forest reforestation following logging. Most economists foresee a period of tight money and sluggish economic activity to the mid-1980's followed by a sustained, controlled improvement with modest inflation. This tells me we should not expect growth in the tree nursery field as in the last 10 years, but it won't be real bad either. If something unexpected happens, like a new Soil Bank Program, all bets are off! We could be a pretty valuable bunch of people all of a sudden if that happened.

Regional Perspective

In general terms what is the status of tree nurseries and nursery practices regionally? Here are my observations as an individual:

South - Forest industry nurseries are becoming increasingly important. Nursery production is nearly all bare-root. There are some indications containers will be used for special purposes. There is a big shortfall in pine planting; much more pine needs to be planted to keep up with harvesting. More expensive improved seed is becoming available. This fact, along with escalating labor costs, is increasing nursery production costs and driving moves to greater sophistication of operation. A region-wide nursery cooperative, for technical assistance and special studies, has been formed. There is much planting to do and a good outlook for tree nurseries.

North - Compared to the west and south, not all that much planting going-on. The Region is dominated by underutilized hardwoods. Some new forest industry is moving into the Lake States and Maine to purchase land. Some container use has developed in Lake States and Maine also. However, it will not be a dynamic tree nursery situation until hardwood use and technology are more economically-feasible.

West - About 25 percent of the total nursery production is in the west and 85 percent of container planting. Federal nurseries are concentrated in the west. Nursery technology and management are advanced because a high land and labor costs and species diversity. Nursery production should stay at about current levels or increase slightly in the near future.

The Professional Nurserymen

More and more tree nurserymen are college graduates. They are usually foresters that have learned the nursery trade on the job. Large Federal, State, and industrial nurseries in the west and south are beginning to hire staff specialists at nurseries. Horticulturists are becoming more numerous. Increased nursery size and value of the crops support the development of staffs capable of dealing expertly and quickly with biological and operational problems and providing operational continuity even if a key member is gone. The specialty is becoming more complex. Graduate programs in tree nursery management now exist at Auburn University and the University of Idaho.

I think the future for forest tree nurserymen is bright. As forest resources are more intensively utilized in this country and forest product prices rise, there will be more application of intensive silviculture coupled to shorter rotations. There will be a need to return valuable forest land to production promptly. Genetically-improved planting stock will increasingly dominate forest regeneration thinking of silviculturists. These driving forces will create demand for more and better tree seedlings, produced in a reliable and scientific manner. This is where nurserymen come in. It will be up to us to cope with these demands and to implememt and incorporate the changes necessary to meet these demands. From slide rule to microcomputer, from green-thumbing to horticultural prescription, from horse manure to hydroponic fertilization, we can either go positively and grow to the job or loiter in the name of tradition and be dragged forward by inevitable progress.

There are two things, I think, we collectively must learn to do to keep up. The first is ask for help to solve problems. In my ten years on a nursery in Idaho I hated to ask for help. After all I was the specialist. But in fifteen years, two graduate degrees, and forty publications relating to tree nurseries, I admit fully, and with wound-licking wisdom, that no one knows it all in the tree nursery game. I know I am not telling the veterans here anything new. So ask for technical help. The specialists may not tell you all you need to know or what you want to hear, but its better than blaming failures on acts of God. That only works so many times and then the boss wises-up!

Secondly, as your nursery grows in size and/or the job becomes more complex and technical, hire a competent staff and use all their talents. If you have to spend more and more time on management, hire a horticulturist to help out on the growing. It's so easy to forget how valuable, in dollars and cents, that crop in the field is. At every opportunity remind your boss of that fact. Less and less will we be able to run tree nurseries "on the cheap." Hire, and wisely use, an adequate staff.

Always remember you are one of an elite group. All the tree nurserymen in this Country could fit on one jet airplane. We have an admirable profession. Let's all continually upgrade its standards and add to its luster.

REFERENCES

Forest tree nurseries in the United States--1971 Report. USDA-Forest Service. Unnumbered Report, Washington, D.C. 18p.

A Directory of Forest Tree Nurseries in the United States. 1976. USDA-Forest Service. Unnumbered Report. July. Washington, D.C. 23p.

1981 Directory of Forest Tree Nurseries in the United States. American Association of Nurserymen, Inc. 230 Southern Bldg., 15th and H St. N.W., Washington, D.C. 40p. ($2.25 each).

FIGURE 1.TOTAL NURSERY PRODUCTION

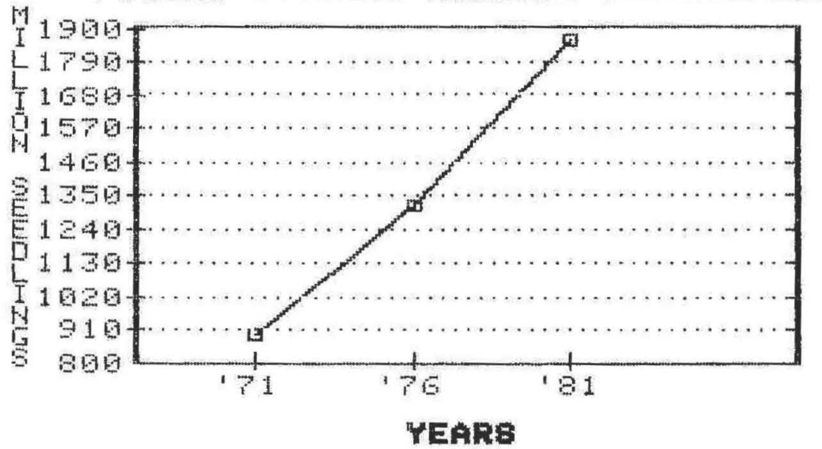


FIGURE 2.NURSERY PRODUCTION

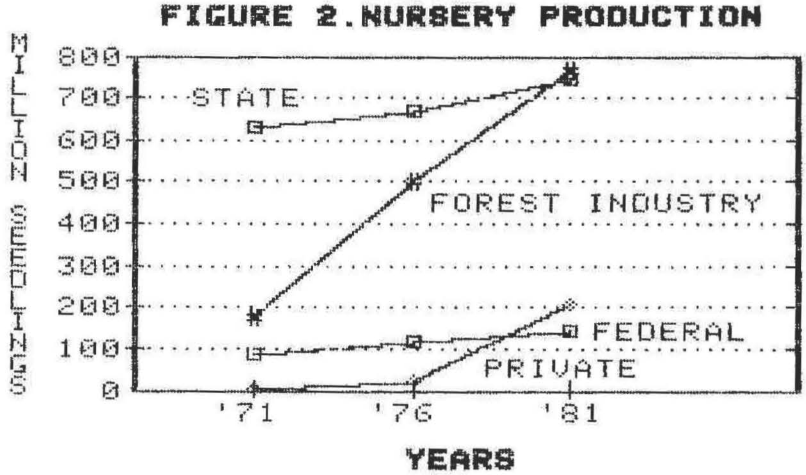


FIGURE 3.NURSERY PRODUCTION

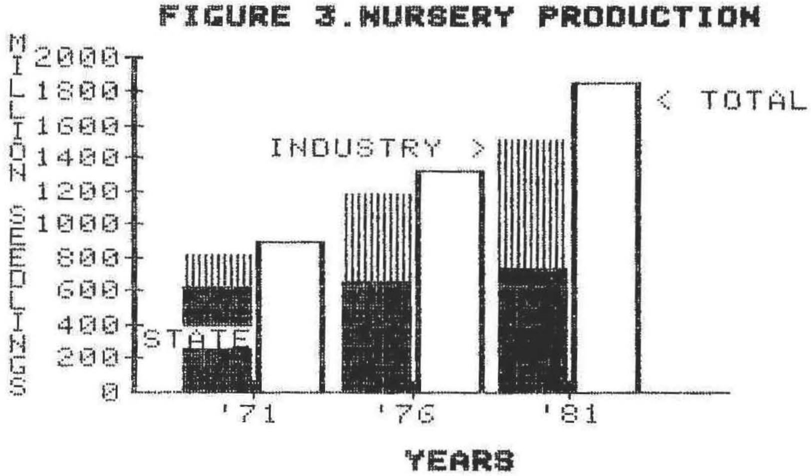


FIGURE 4.NUMBER OF NURSERIES

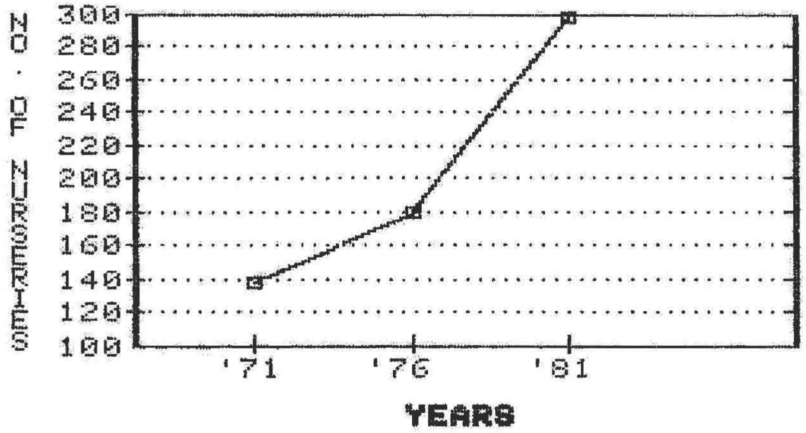


FIGURE 5.NUMBER OF NURSERIES

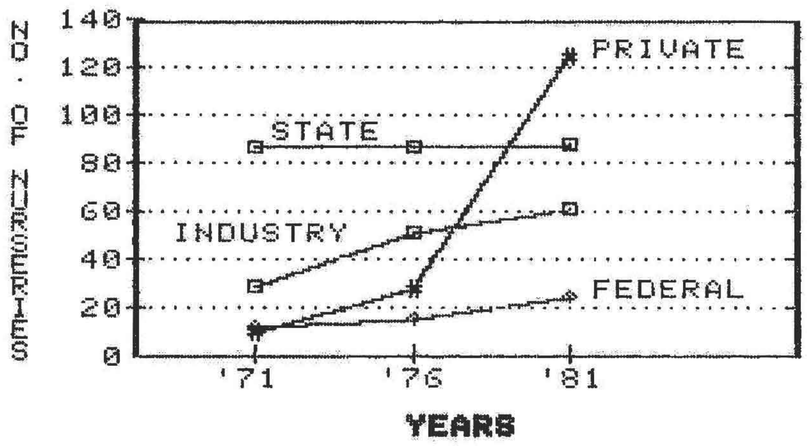


FIGURE 6.NUMBER OF NURSERIES

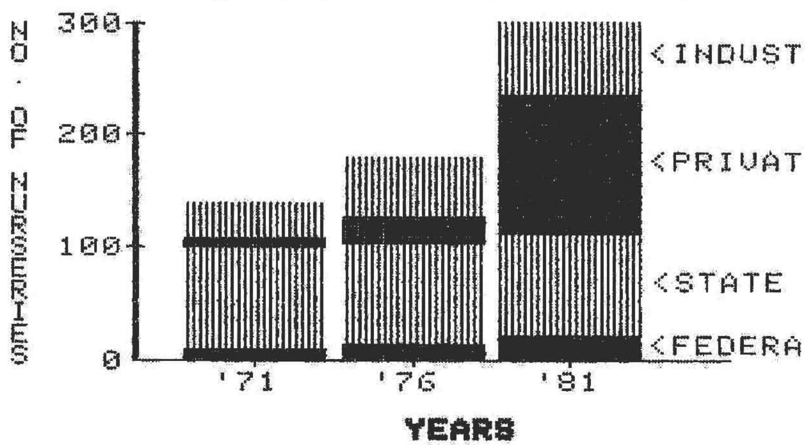


FIGURE 7. AVERAGE NURSERY OUTPUT

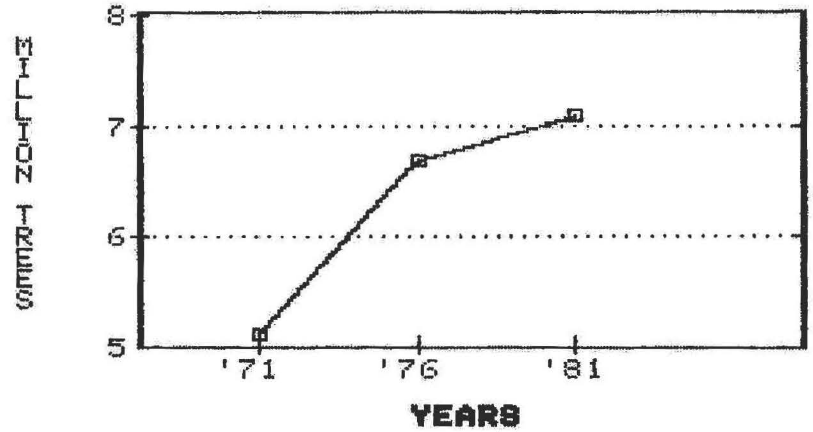


FIGURE 8. AVERAGE NURSERY OUTPUT

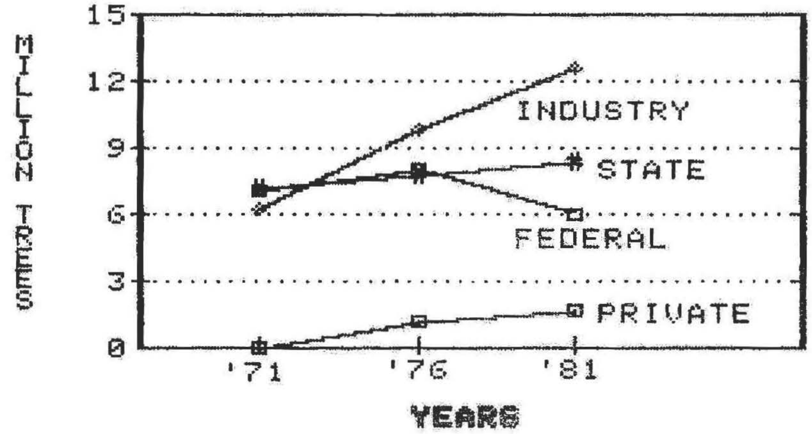


FIGURE 9. AVERAGE NURSERY SIZE

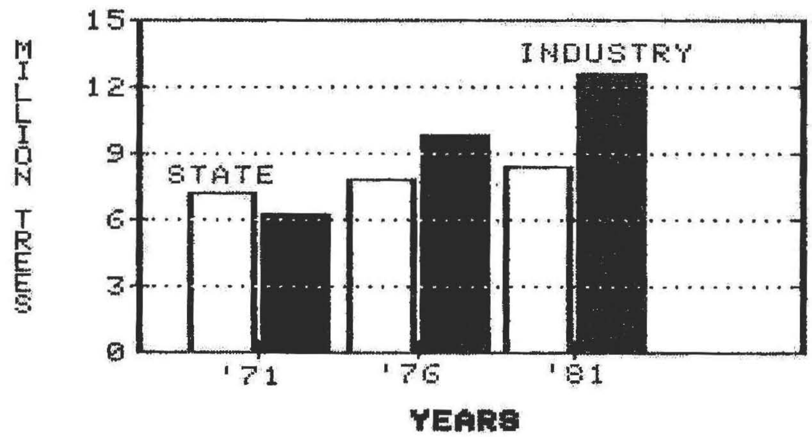


FIGURE 10. NURSERY PRODUCTION/NUMBERS

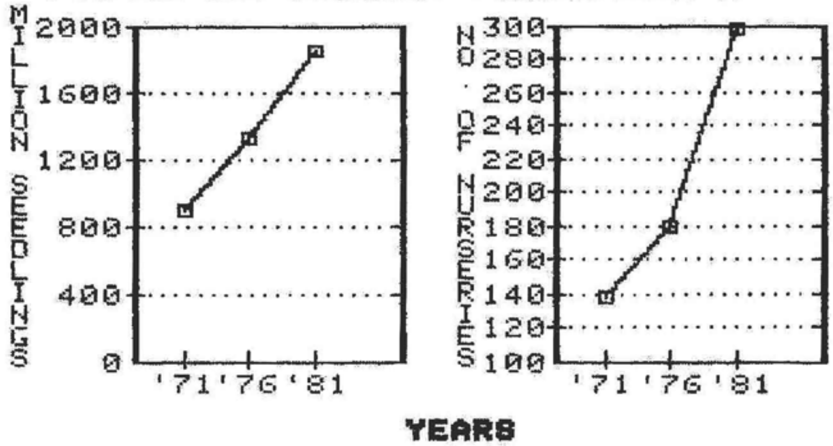
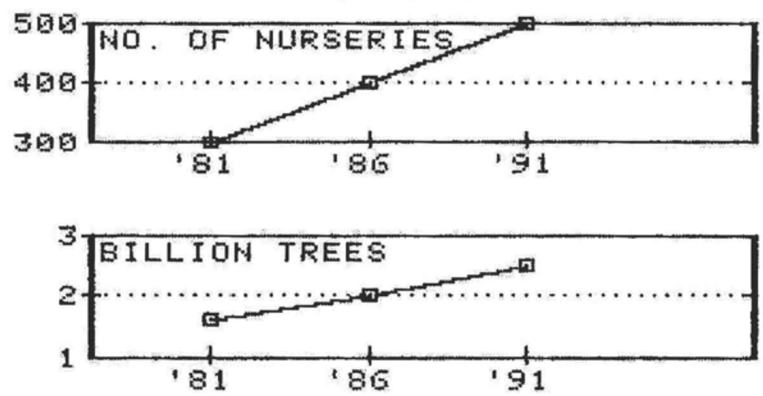


FIGURE 11. TRENDS: NURSERIES/TREES



UNION CAMP REFORESTATION PROGRAM

John G. Hamner[1/]

Introduction

This is about like old home week for me. I participated in and benefited from the Nurserymen's conferences for a number of years and then got involved in some other things and lost touch. I think the last conference I went to was in Wilmington and some of you know that's been a few years ago. It's good to be able to look around and see old classmates, such as Jim Barnett, Clark Lantz, Frank Bonner, and people like Terrell Brooks, Jim Wynens, Tom Dierauf, Carl Muller, and others that I've worked with in the past but haven't had much contact with in recent years. I appreciate being asked to be on the program this morning.

Clark asked me to talk to you about Union Camp's regeneration program. I am not sure how interesting this might be to you; I can assure you I will be brief. Clark sent a memo to the speakers and panel members on the program, instructing us to stay on schedule about five times in that memo and three of those instructions were underlined, so I will stay on schedule.

Organization

I think, before I get into our regeneration program, it might be well to put things somewhat in perspective about Union Camp Corporation.

We're not the biggest paper company in the country; the last I heard we ranked somewhere near tenth in the industry. We are fairly well known in this part of the country, and I guess I could say we are the biggest in Savannah, with apologies to Continental.

Actually, the Savannah Mill, about a mile up the river from where we are now, is purported to be largest in the world, with a daily production of 3,000 tons of pulp. In addition to this unbleached mill, we have another unbleached mill at Montgomery, Alabama, an unbleached mill in Monroe, Michigan, a bleached mill in Franklin, Virginia, and have recently broken ground for a new bleached mill at Eastover, South Carolina. Obviously, a major part of our Woodlands responsibility is to keep these mills supplied with wood.

Woodlands is also very closely associated with our Building Products Division. We've got about 13 company-owned saw mills or plywood mills of one kind or another in Virginia, North Carolina, Alabama, and Georgia, and Woodlands is charged with keeping them going as well.

We are into a number of other things, most of which are associated with land and wood products, such as chemicals, bags, boxes, real estate development, and so on.

1/ Operations Superintendent, Savannah Land Dept., Union Camp Corp., Savannah, Ga.

Well, enough of that. I better spend what time I have talking about our Woodlands operations.

Our Woodlands Division is headquartered here in Savannah. Greely McGowin, our Woodlands Vice-President, and Dick Mordecai, and General Manager of Woodlands, have their offices and staff at the Savannah Mill complex. The Woodlands Division is organized in four operating regions: the Alabama Region at Montgomery, the Franklin Region at Franklin, Virginia, the Savannah Region, headquartered here in Savannah, and the new Eastover Region at Eastover, South Carolina.

The Savannah Region includes our Woodlands operations in Georgia, Florida, and South Carolina, and is the largest of the four; of the 1.7 million acres of Company land in the Woodlands Division, about 1.1 million are in the Savannah Region. Most of what I tell you this morning about our regeneration work will refer to Savannah Region operations because that is what I am associated with and know a little about.

Site Preparation

We are regenerating 30,000 to 35,000 acres to pine land annually in the Savannah Region. Virtually all of this is artificial regeneration following clearcutting. We feel we have an intensive program, and a good program. Our Woodlands Division mission is to "provide an adequate supply of wood at a competitive cost to our user mills and to optimize the financial return of our Company land." We try to practice what we call "site-specific" forestry, i.e. we try to maximize wood production and do this as economically and efficiently as we can.

Every acre we regenerate receives at least one mechanical site preparation treatment and usually two. We shear the rougher sites with V-blades or KG blades and follow this with raking the material into windrows. This work is done with D-7 and D-6 size tractors. We call the combination of these two treatments "Land Clearing" and we do this on about half the acres we plant. This is expensive work and we don't do any more than we feel we have to. Our regeneration budget for 1982 is about 32,000 acres; our land clearing budget is about 14,800 acres.

The alternative treatment to land clearing is chopping, usually done by pulling 10-foot single-drum choppers with heavy rubber-tired skidders, either Franklin 195s or Cat 528s. Chopping is considerably less expensive than land clearing and we think it is a good first treatment on the lighter soils where the debris and brush is less of a problem. Our chopping budget for 1982 is about 15,000 acres.

The first treatment, land clearing or chopping, is usually followed by flat harrowing with off-set harrows or bedding with bedding harrows, pulled either by D-6 size tractors or skidders. I should tell you that our site preparation work is designed to accommodate mechanical tree planting. We machine plant every acre we can.

Burning is also an important part of our site preparation work. We burn the windrows following the land clearing operations and we broadcast burn the residual debris following chopping. This is done before we do the subsequent flat harrowing or bedding.

Tree Planting

All of our tree planting is contract work and practically all of it is machine planting. Of the 32,000 acres for 1982, we budgeted about 31,200 acres of machine planting and less than 1,000 acres of hand planting. The only hand planting we do is where it is too wet or too rough to plant with machines. The machine planting is done with drag type or three-point-hitch planters pulled with farm tractors.

We try to be as smart as possible with species selection and prescribe species based on the best knowledge we have on soils, drainage, and other species site relationships. At present we probably average about 65% loblolly, 30% slash, and 5% longleaf and sand pine in the Savannah Region.

We also try to prescribe spacing as best we can considering site, species, and disease incidence. Our spacing ranges from a low of about 600 stems per acre to a high of something over 900 stems per acre.

Soils Mapping

The newest part of our regeneration work is our soils mapping program. We undertook, a couple of years ago, an objective of soils mapping all of the land under our control, both fee and long term lease land. We have a Soils Supervisor and he has a staff of two soils technicians. The program is moving along pretty well. We are giving the highest priority to lands which will be regenerated within the next year or two; our objective is to map all of our land within the next five to ten years. We think the information from the soils mapping work will be very useful in all phases of our forest management work, including species selection, site preparation treatments, water control, and road construction work.

Nursery and Seed Orchard Operations

Our Tree Nursery is located at Bellville, Georgia, about 60 miles west of Savannah. You are going to have a chance to visit Bellville this afternoon so I am not going to say much about it at this point except to tell you we feel it is an efficiently-run operation and that Paul Riggs and Bill Pryor are doing a good job growing high quality pine seedlings at favorable costs. We have expanded the Bellville operation through the years and are presently growing about 50 million pine seedlings annually.

Our tree improvement work got started back in the mid-50's and we are self-sufficient now for all of our seed requirements for our regeneration programs.

We have almost 400 acres of established seed orchards, most of which are located in the vicinity of Bellville. Eventually, all of our orchard production for the Division will be located there. We collected something in excess of 13,000 pounds of seed from the orchards last fall including a considerable amount of 1-1/2 generation rust-resistant seed and some second generation seed.

Cultural Treatments

Time is getting on; there are two or three things I want to mention briefly.

We believe very strongly in prescribed burning and burn every acre we can; averaging about 100,000 acres a year in the Savannah Region. Most of this burning is by conventional means but we are becoming more and more involved in "mass-ignition burning." We burned about 15,000 acres like this last year and our plans are to double this next winter. It is an effective method of getting a lot of acres burned at a reasonable cost.

Fertilization is also becoming a more and more significant part of our pine management work. It is generally in two phases, the application of ground rock phosphate on young plantations or the application of high nitrogen analysis fertilizers on established stands. We are presently fertilizing about 15,000 to 20,000 acres of pine plantations annually.

About everything I have said so far refers to pine management. I should tell you that our folks in Franklin are just as intensive in hardwood management or more so. I won't get into the hardwood management program in Franklin because of time limitations and also because it is more in Jake Stone's domain than in mine. I will tell you that our hardwood nursery in Virginia is presently growing about 1,800,000 hardwood seedlings annually and planting about 3,000 acres a year in their hardwood regeneration work. Here in Savannah we are just beginning to get into some meaningful hardwood management work. At this point, it is all natural regeneration following clearcutting. We regenerated about 1,000 acres last year and will probably do about that for the next several years.

Conclusion

I've skimmed over this pretty quickly and didn't take time to go into a lot of detail about much of it. I expect that most of you are doing many or most of the same kind of things we are doing. We sure don't claim to know all the answers. We are trying to do whatever we can to maximize timber growth and to control costs. It's a real challenge to keep these in balance but we feel we are doing as good a job as we know how. We also realize that what we know is not enough. If we are to produce the wood Union Camp expects from us in the future, we not only have to do a good management job but we have to continue to develop and refine the technology. We are working at it.

THE OKLAHOMA LOBLOLLY AND SHORTLEAF PINE TREE IMPROVEMENT PROGRAM[1]

Ben Smith and C. G. Tauer[2]

ABSTRACT. The history and objectives of the Oklahoma forest tree improvement program are discussed from inception in 1965 to present.

Additional Keywords: *Pinus taeda*, *Pinus echinata*.

Dr. Clayton E. Posey, while at Oklahoma State University, initiated a program in late 1965 to improve the commercial forest trees in Oklahoma. His objectives were to improve the two native species of pine, shortleaf (*Pinus echinata* Mill.) and loblolly (*P. taeda* L.), for use in Oklahoma, and to provide trees of known parentage and geographic source for further research in genetics, physiology, pathology, and soils.

The program was based on the selection of superior trees from natural populations. Selections were made from twenty to sixty year old stands on the basis of phenotypic and physiologic characteristics. Forestry personnel from several agencies were trained in the identification of superior candidates from natural populations. The select candidate trees were evaluated by the comparison tree method. The best five neighboring trees growing in similar environmental conditions were compared with the candidate, which had to be a certain percent better than their average. Where possible, trees were selected from only even-aged stands that had not been high-graded.

The selected candidate trees were evaluated using a standardized rating system. The following characteristics were considered:

A. Total Height - The ratio of the height of the select tree to the height of the average of the five best check trees was expressed as a percentage. Select trees with less than a ten percent advantage received no points for height.

B. Volume - The select tree was given one point for each 10% excess in volume over the average of the check trees.

C. Crown - Crown was judged subjectively from the stand-point of the individual select tree as compared to the five check trees.

D. Form Class - Form class was determined by the Girard Form Class Method. The select tree was given one point for each form class greater than the average of the five check trees, less one point.

E. Straightness - Straightness was judged subjectively for the individual select tree and not compared to the check trees.

F. Pruning ability - The ability of the select tree to shed its lower limbs was scored by comparison to the five check trees.

1/ Professional Paper No. P-1257 of the Agriculture Experiment Station, Oklahoma State University

2/ Superintendent, Kiamichi Forestry Research Station and Associate Professor, Oklahoma State University, respectively

G. Branch Diameter - Branch diameter was judged subjectively from the stand-point of branch diameter of the select tree to the five check trees. A small branch diameter was preferred.

H. Branch Angle - Branch angle was judged subjectively for the select tree compared to the five checks. A flat branch angle was more desirable.

If the select tree was poorer than the check trees in any of these catagories, except straightness, points were deducted by the same scale as they were added when the select tree was superior to the check trees. A tree with a minus score in more than one characteristic was not accepted.

I. Age - A tree which was apparently more than three years older than the check trees was not accepted. Select trees which were apparently younger than the check trees were given bonus points.

J. Specific Gravity - Points were not awarded a select tree for specific gravity. The value of a tree for specific gravity was judged by two criteria:

1. The select tree's specific gravity was compared with that of its five check trees. This gives an indication of the tree's specific gravity relative to trees growing under the same environmental conditions.

2. The select tree's specific gravity was compared to the regional average. The specific gravity of the select tree had to be at or above the regional average.

Breeding orchards were established by grafting scions from the selected trees. In the spring of 1966, vigorous 1-0 seedling rootstock was planted to facilitate grafting of the select scion material. Later, in the spring, scion material from the previously selected trees was collected and grafted to this rootstock. Both field grafting and bed grafting was used. One breeding orchard for coastal plain loblolly pine and two shortleaf pine breeding orchards were established. Select shortleaf trees below one thousand feet elevation were established as one breeding orchard and were designated lower elevation shortleaf. The trees above this elevation were designated mountain shortleaf and were established in a separate breeding orchard.

A shifting clone orchard design was used. The objective was to position the ramets to insure that each clone had an equal chance of crossing with all other clones an equal number of times with a minimum chance of selfing. A twenty clone loblolly, a thirty clone lower elevation shortleaf and a twenty-four clone mountain shortleaf orchard were established in this manner.

In the spring of 1967 a cooperative working agreement between the Forestry Division, Oklahoma Department of Agriculture, and the Department of Forestry, Oklahoma State University, was consummated to provide for the development of improved varieties of pine trees for Oklahoma and to establish and maintain seed orchards in order to provide a reliable source of large quantities of improved seeds. This agreement dictated specific responsibilities of each cooperator as follows:

A. Oklahoma State University, Forestry Department, Agreed to:

1. Provide general technical advice and assistance for the entire program.

2. Give technical instruction, initially and at other times, to Department of Agriculture personnel on the performance of tasks connected with the program.

3. Devise suitable grading rules for all species and grade all trees selected for the seed orchards.

4. Provide laboratory and greenhouse facilities for the entire program. This will include facilities for the measurement of wood characteristics and the analysis of soils.

5. Maintain records for the entire program.

6. Initiate and perform studies to solve practical problems encountered.

B. Department of Agriculture, Forestry Division, Agreed to:

1. Locate and make selections of candidates to be considered for inclusion in seed orchards.

2. Collect scion or cutting materials and vegetatively propagate or assist in the propagation of acceptable candidate trees.

3. Cooperatively establish and maintain the seed orchards.

4. Develop and utilize interim methods to collect tree and shrub seed including material for vegetative propagation, from the best adapted sources.

5. Assist in the construction and modification of equipment and buildings.

C. It is Further Agreed by Both Parties:

1. All equipment, materials, and property of any kind purchased by either cooperator and not consumed in the program shall remain the property of the purchaser.

2. That nothing herein shall be construed as obligating either cooperator to make expenditures of money

present or future, in excess of appropriations authorized by law, and administratively made available.

3. Industrial organizations and individuals may cooperate in this program to the full extent of their interest but this will in no way change the responsibilities of the cooperators.

4. This Agreement shall become effective when completely executed and shall continue indefinitely but may be modified by mutual agreement between the parties in writing, and may be discontinued at the request of either party. Request for termination or any major change shall be submitted to the other party not less than 60 days in advance of the effective date desired.

The first improved seed produced as a result of this cooperative was collected from the pine seed orchards during October, 1972. The following listing depicts the annual yield from the 1972 through the 1981 seed harvests. The demand for loblolly seed in Oklahoma has increased due to regeneration of loblolly pine on what was once thought to be shortleaf sites. Consequently, demand for shortleaf seed has declined greatly and management of the shortleaf seed orchards was terminated indefinitely in 1981.

	Loblolly		Lower Shortleaf		Mountain Shortleaf	
	bushel cones	pounds seed	bushel cones	pounds seed	bushel cones	pounds seed
1972	--	5.5	--	5.8	--	1.7
1973	28.0	28.4	14.0	15.1	7.5	10.5
1974	19.5	23.8	14.0	5.5	3.0	3.7
1975	66.0	85.8	33.0	26.6	11.5	9.3
1976	95.0	123.2	34.5	13.6	14.5	3.7
1977	--	100.6	--	32.7	--	6.6
1978	--	53.6	--	64.8	--	22.7
1979	237.0	375.0	100.0	100.0	60.0	60.0
1980	425.0	500.0	22.7	22.0	85.0	80.0
			Management terminated			
1981	620.0	601.0	52.0	44.0	152.0	132.0

By 1973 sufficient open pollinated seed was generated in the orchards to allow the initiation of open pollinated progeny tests. The first test was field planted in February, 1975. The planting consisted of four replicates, each contained twelve 10-tree row plots of loblolly pine seedlings. Subsequent tests were established and have contributed information to the thinning/roguing of the loblolly orchard in 1982.

As a result of control pollination efforts, the first controlled cross progeny tests were outplanted in the spring of 1979. A randomized complete block design consisting of 4-tree plots with eight replications, representing sixty families, were planted in two locations. First year survival at both locations was sufficient to warrant retention of these tests. The tests will be measured in 1984 to evaluate five year performance. Progeny from the three different orchards are now in test at many sites representative of the area where the improved stock will be grown commercially. These full-sib progeny will also be used for second generation selection work.

In 1980, the Oklahoma Division of Forestry became a member in the Western Gulf Forest Tree Improvement Program (WGFTIP). Membership was deemed prudent due to the program's need for a broader genetic base as second generation work began. The broader genetic base will allow for continuation into second and third generation material without inbreeding in the orchards. Other benefits enjoyed by the membership are sharing of information and genetic material among the cooperators. Since becoming a member, seventy-two additional select loblolly trees have been located, graded and established in a scion bank to be used by the membership to support the overall plan of the cooperative improvement program.

In 1982, a six and one-half acre advanced generation loblolly seed orchard was established to provide more seed and higher quality seed for the tree farmers in Oklahoma. Scion material for this orchard was furnished through WGFTIP, and has been tested in first generation progeny tests.

First generation controlled-cross pollinations and progeny testing will continue for the next several years. Outplanting and measurement of these tests will follow the WGFTIP guidelines to insure future comparability of the Oklahoma program's data with related data generated by other WGFTIP cooperators. Continuation of advanced generation breeding work and orchards is planned.

Oklahoma Forestry Division, State Nursery

The Oklahoma Forestry Division Nursery, in Washington, Oklahoma has been located at the present site since 1946. It is the only state owned nursery in Oklahoma.

The Nursery has 65 acres under production. It grows 23-28 species per year; 6-8 conifer species, 4 shrub species, and the rest hardwood. All of the seedlings are 1-0 stock except for five species of 2-0 conifers. The Oklahoma Forestry Division Nursery produces 2-2½ million seedlings per year. The Nursery contracts with the Weyerhaeuser Co., Ft. Towson Nursery to grow 4-4½ million Loblolly Pine per year.

Most of the seedlings grown at the Oklahoma Forestry Division Nursery are produced for windbreaks, erosion control, wildlife habitat, firewood, Christmas trees, and timber. The Nursery sells the seedlings in multiples of 50, with a minimum of 200.

All planting is done with an Oyjord planter, then the seed beds are covered with hardwood sawdust and a light layer of hydromulch. Before planting, the seed is cleaned with a Clipper Shaker, an Oliver Gravity Seperator, and other seed cleaning equipment. Most of the hardwoods, and shrubs are topcut to 12-13 inches prior to lifting. All of the conifer species and a few shrub species are lifted with a Grayco Lifter. The hardwoods are hand harvested. The seedlings are hand counted and tied with Saxmayer Bundle Tyers before being packaged in paper bags with sphagnum moss.

Michael P. Vorwerk
Nursery Superintendent
Oklahoma Forestry Division

Pine Plantation Survival: A Corporate Look at the Problem

J.F. Godbee, Jr., J.L. Rakestraw and F.S. Broerman [1/]

Abstract.--The economic impact of poor initial stocking in terms of reduced wood yield and higher per unit production costs led the Union Camp Corporation to investigate causes of low stocking in young slash and loblolly pine plantations. Low seedling quality, poor planting technique, and adverse microenvironment, each caused from 3 to 6% mortality during the first year. Loss of seedlings to insects or diseases was negligible. Missed planting spaces lowered initial stocking by almost as much as first year mortality, indicating that increased supervision may be the single most important means of approaching satisfactory stocking. The tendency for early stabilization of first year mortality in slash pine suggests that stocking may be evaluated much earlier than previously thought, but this relationship was absent in loblolly.

Keywords: Seedling mortality, Union Camp Corporation, *Pinus taeda*, *Pinus elliottii*, reforestation, plantation establishment.

Forest land managers across the southeastern United States are becoming increasingly concerned over decreasing survival rates in pine plantations. Results of a recent APA survey (Weaver, et al. 1980) found that while total planted acreage has nearly doubled (1960-64 to 1975-79) average survival rates have dropped from 83 to 73 percent. Rowan (1980) listed poor handling and planting techniques as the major causes of this mortality. Other probable causes include weather, quality control at the nursery and changing plantation establishment practices.

Concern is well justified, especially in light of the fact that many foresters, land managers and nurserymen do not fully appreciate the consequences of low initial stocking. Consider the effect on absolute yield at rotation age (Fig. 1). Assuming initial planting of 720 stems per acre, a yield difference of nearly 7 cords/acre may be realized when initial survival is increased from 60 to 80%. Production cost decreases from $7-$10/cord since regeneration cost remains fixed while volume increases (Table 1). Moreover, poor stocking will not enable us to capitalize on technological inovations. Future productivity gains from genetics, competition control,

---

1/ Respectively, Pest Management Specialist, Research Forester and Manager, Woodlands Research. Union Camp Corporation, P.O. Box 216, Rincon, Georgia, 31326.

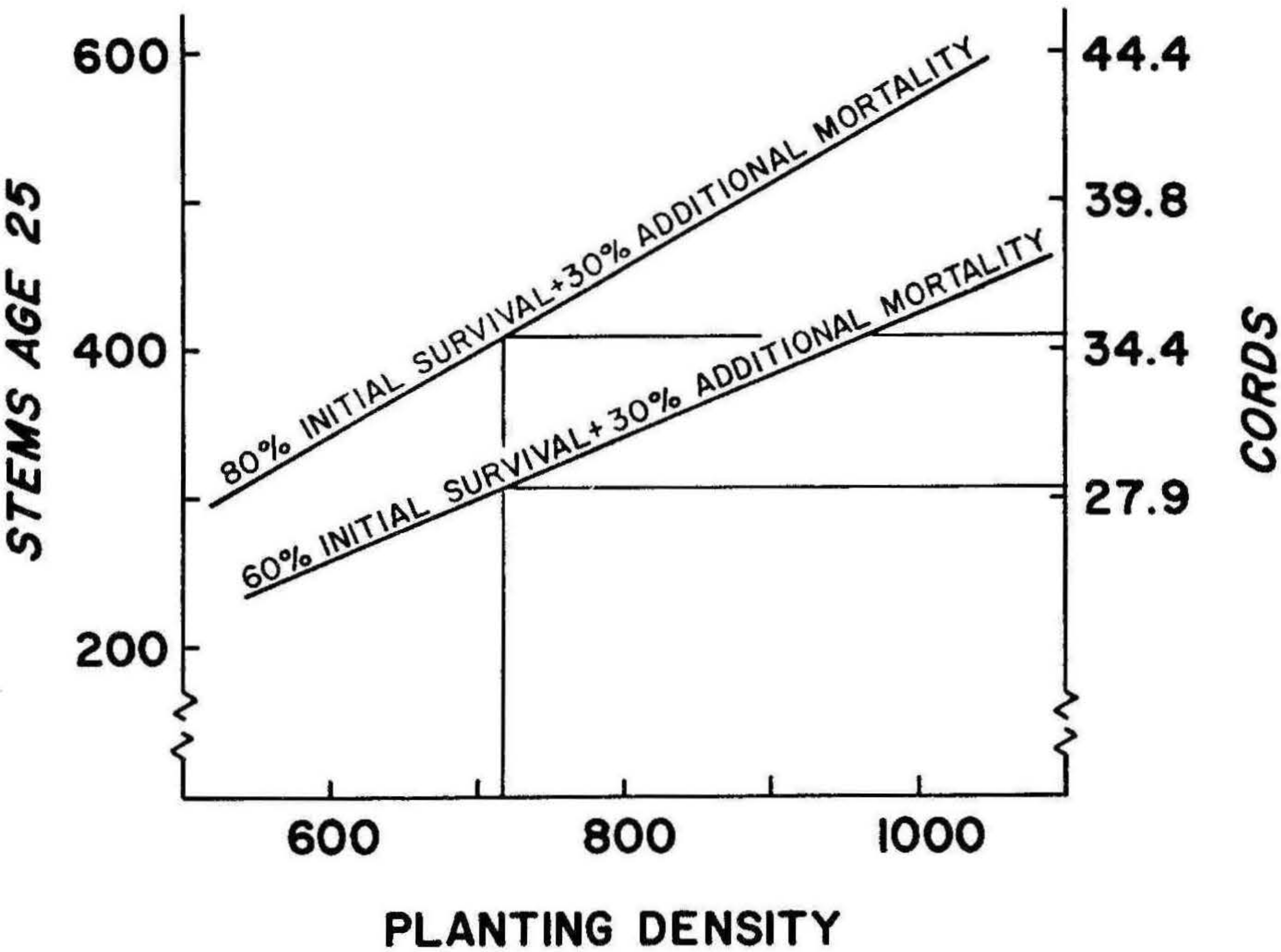


Figure 1. Effect of planting density and survival on expected volume per acre 1/

1) Loblolly pine SQ 60. University of Georgia 1982.1 Yield model.

fertilization, site preparation, drainage, etc., cannot be fully realized in understocked stands. In this paper, we report the findings of a study by Union Camp to determine the extent of decreasing initial survival on company lands.

Table 1. Effect of regeneration cost on cost per cord.

Av. Regeneration Cost/acre	SPA Age 25	Vol. Age 25 [2/]	Future cost/CD 10% interest
$90.00	300	27.9	$34.95
90.00	400	34.4	28.35
90.00	500	39.8	24.50

METHODS

Establishment of seedling monitoring plots was begun in Union Camp's Savannah operating region during the 1978-79 planting season. During the 1979-80 and 1980-81 seasons plots were also located in the Alabama and Franklin, Virginia regions. In all, 106 plantations, each containing two replicate plots were sampled. Each plot contained 72 planting spaces.

In order to give those directly responsible for planting the opportunity to closely observe potential plantation establishment problems, working circle foresters assisted the research department in the collection of data. Plots were observed monthly for one year to determine if causes of mortality could be precisely defined. Sites were classified by drainage class, land form, soil type, and site preparation treatments. Stand data on fertilization, planting method, seedling lifting and planting dates were recorded.

RESULTS AND DISCUSSION

Causes of poor stocking -- Thirty-five plots were established in the 1978-79 planting season. First year mortality averaged 17%. In addition, 13% of the potential planting spaces were not planted, resulting in a stocking figure of 73% at the end of the first growing season.

Results for the 1979-80 and 1980-81 planting seasons were similar. Mortality averaged 20%, spaces left unplanted 10%, and final stocking 72%.

[2/] Loblolly pine SQ 60 - University of Georgia 1982.1 loblolly yield model.

Only 2% of the potential planting spaces were left unplanted in the Franklin region, resulting from more extensive use of hand planting methods.

Causes of mortality -- Throughout the study, little variation was seen in the extent to which poor planting stock, inadequate planting techniques, and adverse environmental conditions contributed to mortality (Table 2). Three percent of total mortality involved seedlings judged to be of poor quality. However, an equal percentage of survivors was also composed of poor planting stock, suggesting that while seedlings of poor quality may survive at a lesser rate, the potential of a given seedling to survive cannot always be gauged by appearance (c.f. Wakeley 1954:105-108). Moreover, the same subjectivity in identifying poor risk seedlings apparently extends to diagnosing other causes of mortality. Approximately half of those seedlings judged to be poorly planted, or to be under environmental stress due to unfavorable microsite conditions, survived. While insects and diseases affected a rather large percentage of surviving seedlings (14-17%), most suffered mainly from tip moth (Rhyacionia spp.) damage, and mortality from such causes was negligible. Of surviving seedlings, 66-71% were classified as healthy at the end of the first growing season.

Table 2. Fate of loblolly and slash pine seedlings in various risk categories.

	1978-79		1979-80	
Risk Category	Mortality(%)	Survival(%)	Mortality(%)	Survival(%)
Poor planting stock	3	3	3	3
Poor planting technique	5	3	6	4
Adverse microenvironment	5	3	2	2
Insect &/or disease affected	0	14	0	17
Other [a]	4	6	6	8
Healthy	0	71	0	66

[a] Seedlings that were dead or unhealthy due to unknown causes.

Seasonal distribution of mortality -- Though some plots were established in plantations planted as early as late October, we were unable to detect any significant relationship between survival and month of planting ($P \leq 0.05$), suggesting that early planting may occasionally be successful (c.f. Dierauf 1876). However, we caution against broad application of this practice since the risk of early planting is high (e.g. Ursic et al. 1966, Cox 1969, Hill 1976). In addition, our finding is based on only three years' data in which early plantings were probably under-represented. We were similarly unable to detect any relationships between survival and seasonal rainfall or between survival and soil drainage class.

Monthly survival counts enabled us to examine the pattern of mortality within the first post-planting year. For convenience, we combined monthly data into spring (March through May), summer (June through August), and fall (September through December) categories. The mean percentage of surviving slash seedlings decreased from spring (91.1%) to summer (84.8%) but then remained constant through fall (84.7%). Spring survival rates for individual plots were also closely correlated with summer (r = 0.82, P = 0.0001, df = 26), and fall rates (r = 0.85, P $\leq$ 0.0001, df = 31), implying that fairly accurate prediction of first-year survival may be possible relatively early in the growing season.

The same trend did not hold for loblolly. Mean survival for this species declined steadily throughout the first year (spring 91.2%, summer 84.1%, fall 78.1%). Moreover, the correlations of spring survival with summer (r = 0.63, P $\leq$ 0.0001, df = 64) and fall rates (r = 0.46, P = 0.0001, df = 65) were poorer than for slash. Initially, this difference was attributed to the fact that most slash plantations were in Florida where summer rains are common, while most loblolly sites were further north where summers are drier. However, when slash and loblolly plantations on the same forest were compared, the trend was still evident.

RECOMMENDATIONS

The results of this survey are preliminary. However, there is sufficient evidence to justify several recommendations. First, our finding that missed planting spaces lowered initial stocking nearly as much as first year mortality indicates that careful supervision of planting operations is the closest expedient to satisfactory stocking, at least for Union Camp. More careful site preparation may also help in this regard, since several participating foresters commented that a fair number of planting spaces were missed because they were just too rough to plant. No single mortality factor assumed over-riding importance. All causes of mortality were individually low. Mortality of trees that were considered high risk due to poor seedling quality, adverse microsite, or poor planting technique could not be easily produced; the percentages of such trees dying were nearly the same as those surviving in each of these categories. Field personnel thus would have difficulty gauging survival potential based on seedling morphology or early plantation inspection. The subjectivity involved in such judgments argues against field-grading of seedlings.

The tendency for mortality of slash pine to stabilize during summer suggests that survival checks to determine stocking adequacy may be done relatively early in the summer with little loss of accuracy. Continued mortality of loblolly through the first year and low correlations of survival rates among seasons make early checking for this species unwise.

Again, we admonish that these conclusions are based on relatively small samples and reflect the experience of just one company. However, there does appear adequate reason for concern over inadequate survival in the Southeast. The economic importance of making even small gains in productivity is obvious, and we hope this paper will stimulate continued work in this direction.

LITERATURE CITED

Cox, R.G. 1969. Summer pine planting unsuccessful in North Mississippi. Tree Planters' Notes 20(1):4-5.

Dierauf, T.A. 1976. Fall planting and storage using non-dormant seedlings. Pages 30-36 *in* C.W. Lantz, ed. Proc. 1976. Southeastern Nurserymen's Conf., 168p.

Hill, H.L. 1976. Early lifting and early planting can contribute to plantation failures. Pages 162-165 *in* C.W. Lantz, ed. Proc. 1976. Southeastern Area Nurserymen's Conf., 168p.

Rowan, S.J. 1980. A progress report: plantation survival of nursery grown seedlings in Georgia. Pages 31-33 *in* C.W. Lantz, ed. Proc. 1980 Southern Nurserymen's Conf., 123p.

Ursic, S.J., H.L. Williston, and R.M. Burns. 1966. Late planting improves loblolly survival. U.S. For. Serv. Res. Pap. SO-24, 12p.

Wakeley, P.C. 1954. Planting the southern pine. U.S. Dept. Agric. For. Serv., Agric. Monogr. 18, 233p.

Weaver, G.H., R. Izlar, F.S. Broerman, and K. Xydias. 1980. Preliminary report on the 1979 A.P.A. pine plantation survival and nursery practices survey. Pages 24-30 *in* C.W. Lantz, ed. Proc. 1980 Southern Nurserymen's Conf., 123p.

LOBLOLLY PINE SEEDLING SURVIVAL STUDY,

1979-80 AND 1980-81 PLANTING SEASONS

Carl A. Muller[1]

Abstract.-- For two consecutive, survival-study test years, loblolly pine seedlings that were conventionally lifted, graded, and packed attained an average survival rate of 86 percent when planted operationally by field crews. Similar seedlings that were hand planted with maximum care had a 91-percent survival rate at the same, site-prepared locations. At a second location where site conditions for planting were nearly optimum, the seedlings achieved 96 percent survival. In an auxiliary study, seedlings were taken directly from the nursery beds by hand and immediately planted with maximum care at an old-field site; their survival was increased to 99 percent.

[1] Reforestation Forester, Hammermill Paper Company, Southern Timberlands Division.

INTRODUCTION

Securing acceptable seedling survival in forest plantations should be of the utmost importance to all industrial reforestation programs for many obvious economic reasons. The concern for the successful establishment of loblolly pine plantations influenced Hammermill Paper Company to initiate an operational survival study in the fall of 1979. Periodic inspections were made during the first and second outplanting years. The test was replicated in 1980. The final inspections of the second year installations will be completed in November 1982. The overall objective of these studies is to critically appraise the various factors affecting seedling survival, and identify those most relevent to the Company's planting program. Future efforts to increase seedling survival and reduce the risk for re-planting will be directed toward those factors which are determined to be controllable. Records of the complete procedures, results, and miscellaneous observations are on file at the Southern Timberlands Division office in Selma, Alabama and are available to all interested Foresters.

The tests and procedures used for installing this study will be covered in the following segments of this report.

TEST I METHODS

The first test method consisted of controlled operational type outplantings of randomly selected seedling bales. For each 150,000 loblolly pine seedlings processed for the Company's planting program, paired samples were drawn. The pairs consisted of a lot of "1,000" seedlings and a lot of "250" seedlings taken simultaneously from the nursery packing station conveyor. These seedlings had been previously lifted, graded, counted, and treated with kaolin clay slurry in the standard nursery manner. The lots of 1,000 seedlings each were packed in standard open-end paper bales. The smaller "250" count samples, were completely enclosed in plastic bags and tied with twine. The bales were marked for identification and were shipped either immediately with other seedlings consigned to a forest district, or they were moved into cold storage and held as dictated by distribution schedules. Every movement of the study bales was recorded until the field planting sites were reached and the sample trees were planted. These bales were planted by district crews, using the techniques best suited to the tract.

The "250" seedling groups were handled with maximum care throughout the duration of the cold storage period. They were transported to the operational sites and hand planted with maximum care by the study manager. The sample was planted adjacent to the districts paired operational planting from the marked bale. The planting site conditions were observed and recorded. Individual sample seedlings from each of the paired plots were flagged and numbered to facilitate later observations. These plots were staked and mapped and inspections were made in April, July, and November during the first growing season. Second year observations were conducted in November. The second phase of Test I was to compare the performance of the plantings previously described with tests established on an optimum old field planting chance. To accomplish this, sample seedlings from the maximum care "250" bag were carefully hand planted in a favorable field site characterized by a fertile loamy sand soil of excellent tilth.

TEST I RESULTS

As indicated in Table 1 the average survival rate for the paired plots installed at the site prepared tracts was 86% for the operational planting methods and 91% for the seedlings handled and planted with maximum care procedures by the study manager. Survival was increased by another 5% increment to 96%, when sample maximum care seedlings were hand planted at the more favorable old field site. The record of causes of mortality observed at the operationally planted plots, as summarized in Table 2 provides a basis for future improvements in planting efficiency. The implementation of selected corrective measures as disclosed by this study should increase initial survival and growth on operational forest plantings. The survival figure of 91% is suggested as a goal for future Company reforestation efforts. The 96% survival attained with operationally lifted and normally stressed nursery stock, indicates the degree to which a favorably textured soil free of clods and debris assisted root regeneration and seedling survival.

The predominant factors contributing to 82% of the observed causes of mortality were as follows:

1. Planting efficiency was hindered by variances in seedling top dimensions and the configuration, volume, and spread of the root systems.
2. Survival was hindered by the use of nursery stock

Table 1

TEST I RESULTS

Summary: Loblolly Pine Seedling Survival Percentages

Combined Results for Two Survival Test Years (1979-80 & 1980-81)

Basis: Trees Surviving at End of First Growing Season

	No. of Plots	Operational Planting At Tract	Maximum Care Handling & Hand Plant At Tract	Maximum Care Handling & Hand Plant At Old Field Site
Company Hand Crews:	29	87%	92%	95%
Contract Hand Crews:	11	81%	93%	98%
Sub-Total:	40	85%	92%	96%
Company Machines:	35	88%	90%	96%
Totals:	75	86%	91%	96%

Table 2

TEST I RESULTS

1980-81 Study Year-First Year Mortality Causes

Operational Planting Techniques

Controllable Causes:	25%	
Unacceptable Planting Depth Roots not Packed Firmly Insufficient Lateral Roots Roots injured with Packing Wheels & Dibbles Seedling Top Injury		
Partly Controllable:	57%	
Low Vigor: Physiological Stresses Vegetative Competition Soil Erosion		
Sub-Total:		82%
Uncontrollable:	13%	
Drought Rabbit & Rat Deer		
Undeterminable:	5%	
Total:		100%

Basis: 1750 Seedlings

Techniques: Machine, Dibble & Planting Hoe.

under phyliological stress. These stresses were caused by shocks accumulated between lifting and planting.

3. Difficulties encountered with backfilling and packing soil for adequate root contact adversely impacted survival.

4. Adverse affects on planting in rough terrain with residual debris also was a major problem.

5. Improper selection of the most favorable spot in which to locate the transplant was also a major problem, especially with minimum site treatments.

The inferred consequences of these five factors were (1) reduced root regeneration and (2) impaired moisture absorption and therefore nutrient uptake. The combination of these two factors probably was the major cause of mortality for this study.

TEST II METHODS

Th second major test method used in the study was to appraise the physiological condition of the Company's nursery stock throughout the two installation years, and thereby establish a bench mark for potential seedling survival. All of the normal nursery handling methods were intentionally by-passed. At bi-weekly intervals from mid-November to mid-March, sample seedlings were carefully hand-dug, lifted, graded, and immediately planted on the old field site where planting conditions were nearly optimum.

Survival observations were made at this site simultaneously with those made on the district study plots.

TEST II RESULTS

Test II achieved an overall survival rate of 99% as shown in Table 3. It is suggested that this high survival rate can be attributed to the following factors.

1. The excellent physiological condition of the nursery stock when planted.

2. The favorable soil texture at the optimum field site.

3. The conservation of ample fibrous root masses.

4. The placement of root systems to achieve firm physical contact with the soil.

The seedling survival of early lifted and planted seedlings (November 19), and the survival of late lifted and planted seedlings (March 10), were both nearly 100%. However, all the bi-weekly plantings made prior to December 20 experienced severe needle burn following the first freeze. Later growth and shoot elongation were not adversely affected. Subsequent plantings had noticeably less foliage burn and retained a thrifty color throughout the transplanting season. The excellent performance of bi-weekly plantings which were hand-dug and set, illustrates the maximum survival potential.

Table 3

TEST II RESULTS

Summary of Loblolly Pine Seedling Survival Percentages-At Optimum Field Site

Combined Results For The Two Test Year Installations: 1979-80 & 1980-81

Basis: Trees Surviving At End Of First Growing Season

Seedlings Hand Dug & Immediately Hand Planted With Maximum Care At Bi-Weekly Intervals

From: November 19 to March 10

Total Number of Seedlings: 2829

Survival Percentage: 99%

CONCLUSION

Based on the results of this survival study and related observations made during two transplanting seasons, it is reasonable to assume that the greatest opportunities to lower seedling mortality originate in the tree nursery. It is here that an optimum prescribed type seedling may be cultured, a useable one that matches the planting site and requires no alteration by field workers. Seedling size and shoot to root ratio should be controlled at the nursery and not at the planting site. The morphological and physiological attributes of a seedling crop can be enhanced by the proper timing of the effective cultural activities. The configuration of the root system must accomodate site conditions and planting methods.

The controllable mortality factors are widespread and overlapping. The selection of the proper site preparation treatments and its consequences upon debris removal, vegetative competition, and soil erosion, and soil moisture have a direct bearing on survival. Tree planting equipment must be selected according to the planting opportunity and maintained in suitable condition. The manner in which seedling bales are transported, stored, and handled after leaving the nursery must preserve the good physiological condition of the seedlings.

Dedicated supervision of all hand and machine planting crews is essential. The many administrative and supervisory details that benefit seedling survival, should be the primary objective of an annual pre-planting training session for reforestation personnel. It is at these meetings that participating nurserymen can emphasize the importance of proper handling of bare-root seedlings to conserve physiological vigor. Tree planters must often be reminded that seedling vigor varies throughout the season and that nursery workers can not altogether refrain from occasionally stressing lots of seedlings by lifting them under adverse conditions. Shipping committments at times dominate the best nursery practice. Since these pre-stressed lots are not recognizable, it is essential that all seedlings be given maximum affordable care.

The goal of acceptable loblolly pine seedling survival in plantations is highly dependent upon the dedicated joint efforts of all nursery and reforestation personnel to follow the best known practices as provided by cooperating research workers.

Plantation Survival of Nursery Grown Seedlings in Georgia - Second Year Progress

by

S. J. Rowan

Abstract.--Second year data from a study of tree survival in plantations in Georgia indicate that poor handling after seedlings are shipped from nurseries and poor planting techniques are the primary causes of excessive seedling mortality.

In continuation of a study first reported at the Kentucky Nursery Conference in 1980, first and second year data are presented. The third year's plantings are established, and growth and survival data will be collected in the fall and winter of 1982. These data will be published soon as a Georgia Forestry Research Council Report and, consequently, data presented in Savannah will not be published in these proceedings.

Methods used in this study were previously explained, (Proceedings 1980 Southern Nursery Conference Tech. Pub. SA-TP 17, Nov. 1981:31-33). Results indicate that poor handling after seedlings are shipped from nurseries and poor planting techniques are the primary causes of excessive seedling mortality. Survival among properly planted trees, however, is significantly affected by top/root ratio, root/tree ratio, weight of roots $\gtrsim$4mm long, and weight of roots $\gtrsim$5.6 mm long. Thus, root biomass is a most significant attribute of seedlings and one that deserves more attention and care than nurserymen or forest managers traditionally give. It should be noted, however, that the smaller feeder roots (2 mm and less) or those roots that usually are mycorrhizal were not significantly correlated with first year survival.

EFFECTS OF PROPAGATION CONTAINER SIZE AND TRANSPLANTING DATE ON THE GROWTH OF TREE SEEDLINGS

Bonnie Lee Appleton and Carl E. Whitcomb[1]

Abstract. -- Superior growth was made by deciduous and coniferous trees started in the largest volume container (41 cu.in.). This effect remained evident through the second growing season for all species. Earlier transplant dates were in some cases better, but planting date was much less important than container size.

Additional keywords: Cedrus deodara, Pinus taeda, P. thunbergi, P. resinosa, P. sylvestris, P. eldarica, Pistacia chinesis, Quercus shumardi, tree seedlings, container volume.

Previous studies of container grown tree seedlings have shown that the size of the propagation container can significantly influence subsequent tree growth and development. Davis and Whitcomb (1975) showed that greater root growth could be obtained in 2 1/2 inch square bottomless milk cartons as opposed to 1 1/2 and 2 inch square containers. Hathaway and Whitcomb (1977) showed that size and volume are important, with half pint milk cartons (2 3/4 inch square) producing seedlings equal to larger containers. Similar effects of volume upon tree seedling growth have been shown by Tinus and McDonald (1979), and by Wall and Whitcomb (1980) and are cited by Carlson (1979).

Whitcomb, Storjohann and Gibson (1977) reported that early summer transplant dates were preferrable for container grown deciduous tree seedlings, but that for slow growing conifers transplant date had little effect on subsequent growth. The various components of an integrated tree seedling production system, including container design and the use of bottomless containers, are discussed by Whitcomb (1981).

The following study was designed to further evaluate the effects of propagation container size and transplant date on subsequent tree growth and to determine whether or not a container size-transplant date interaction might exist.

METHODS

1981 - Year one.

Seeds of six conifers, deodar cedar, Cedrus deodara; loblolly pine, Pinus taeda; Japanese black pine, P. thunbergi; red pine, P. resinosa; Scotch pine, P. sylvestris; and Afghan pine, P. eldarica, and one deciduous tree, Chinese pistache, Pistacia chinesis, were direct seeded into four different container sizes on March 12, 1981. Seeds of a second deciduous tree, Shumard oak, Quercus shumardi, were first pregerminated in moist peat moss and subsequently transplanted to the containers on March 24.

The four containers consisted of a) half pint milk cartons measuring 2 3/4" x 2 3/4" x 5 1/2" deep holding 41 cu.in., b) 3" square nu-pots holding 22 cu.in., c) 2 1/4" square nu-pots holding 12 cu.in. and d) paper pots holding

[1] Graduate Research Assistant and Professor, Department of Horticulture and Landscape Architecture, Oklahoma State University, Stillwater, OK 74078.

9 cu.in. All containers were bottomless. A propagating medium of peat and perlite (1:1 by volume) containing 6 lbs./cu.yd. 18-6-12 Osmocote and 1 lb./cu.yd. Micromax was used. Seedlings were produced in an unheated greenhouse designed to provide good air circulation and air root pruning.

The two deciduous trees were transplanted into larger containers on May 12, May 26, June 9 and June 23, and the six conifers were transplanted on the three later dates. The deciduous trees were transplanted into three gallon white poly bags, the conifers into one gallon white poly bags using a medium of bark, peat and sand (3:1:1 by volume) containing 14 lbs./cu.yd. 17-7-12 Osmocote, 8 lbs./cu.yd. dolomite and 1 1/2 lbs./cu.yd. Micromax. The plants were placed on a container bed in full sun in a completely randomized block design by species with six uniform seedlings per container design as replications for each transplant date.

The trees were evaluated in mid-August with height and caliper taken for the deciduous trees and height and number of branches for the conifers. Height and caliper were taken again for the deciduous trees in mid-November.

Plants from one transplanting date of Shumard oak, Chinese pistache, deodar cedar and Afghan pine were transplanted to the field on December 4. Plants from the remaining two transplant dates for the deodar cedar and the Afghan pine along with all of the plants of the five remaining pines were overwintered in an unheated single poly greenhouse.

1982 - Year two.

All plants overwintered in the poly greenhouse were kept on the container bed for a second growing season. The Scotch and red pines remained in the one gallon bags while the Japanese black pines were transplanted into two gallon plastic pots and the loblolly and Afghan pines and deodar cedar into three gallon poly bags. A growing medium of bark, peat and sand (3:1:1 by volume) containing 14 lbs./cu.yd. of an 18-6-12/17-6-12 Osmocote blend, 6 lbs./cu.yd. dolomite and 1 1/2 lbs. Micromax micronutrients was used.

In early August height, caliper and number of branches was taken for the deodar cedar and loblolly and Japanese black pines and height and number of branches for the Scotch pine. The red and Afghan pines will be evaluated in the fall of 1982.

RESULTS

1981 - Year one.

All tree species produced superior seedlings when grown in the milk cartons as compared to the three smaller containers. Seedlings were taller, had thicker stems, and the conifers exhibited increased branching (Table 1).

A much less dramatic result was noted with regard to transplant date although earlier transplanting was generally preferred (Table 2).

Very little container size-transplanting date interaction was observed.

Considerable winter kill occurred in the field transplanted trees so no further evaluations were made of their growth.

Table 1. Effect of container size on plant height and caliper or height and number of branches[z]

Species	Container: Milk Carton	3" nu-pot	2¼" nu-pot	Paper pot
Chinese pistache				
height[y]	87.7b[x]	67.9a	68.3a	59.0a
caliper	1.10b	0.71a	0.68a	0.60a
Shumard oak				
height	71.8b	61.2a	49.0a	55.8a
caliper	1.00b	0.70a	0.59a	0.65a
Deodar cedar				
height	20.3b	15.7a	16.1a	16.1a
#branches	21.1b	6.9a	6.8a	6.8a
Loblolly pine				
height	36.2b	24.4a	25.4a	22.2a
#branches	8.1b	5.3a	6.3a	4.6a
Japanese black pine				
height	16.2b	11.2a	10.9a	11.9a
#branches	3.3b	1.4a	2.3a	2.2a
Red pine				
height	7.9b	5.7a	5.1a	5.4a
#branches	2.8b	1.7a	1.1a	1.6a
Scotch pine				
height	10.3b	9.3a	8.3a	9.8a
#branches	3.9b	3.2a	2.9a	3.3a
Afghan pine				
height	22.0b	17.1a	16.6a	19.6a
#branches	22.1b	8.9a	10.1a	11.4a

[z]means of six plants for each of the 3 or 4 planting dates
[y]all heights and calipers in centimeters (cm)
[x]all milk carton means significantly better than the other 3 containers at the 0.01 level or higher (protected LSD test)

Table 2. Effect of transplanting date on plant height and caliper or height and number of branches[z]

Species	Date: May 12	May 26	June 9	June 23
Chinese pistache				
height[y]	73.4_a[x]	68.5_a	77.8_b	63.1_a
caliper	0.80_a	0.75_a	0.85_a	0.69_a
Shumard oak				
height	71.8_b	64.3_a	56.6_a	45.1_a
caliper	0.81_b	0.78_a	0.72_a	0.62_a
Deodar cedar				
height	-	19.6_b	16.4_a	15.1_a
#branches	-	10.9_a	10.5_a	9.8_a
Loblolly pine				
height	-	28.0_a	28.1_a	25.1_a
#branches	-	5.6_a	6.7_a	6.0_a
Japanese black pine				
height	-	14.3_a	10.6_a	12.8_a
#branches	-	2.6_a	2.1_a	2.2_a
Red pine				
height	-	5.6_a	6.4_a	6.1_a
#branches	-	1.7_a	2.1_a	1.6_a
Scotch pine				
height	-	9.8_a	9.8_a	8.7_a
#branches	-	4.0_a	3.3_a	2.8_a
Afghan pine				
height	-	18.6_a	20.9_a	16.9_a
#branches	-	14.6_a	13.5_a	11.3_a

[z] mean of six plants for each of the four containers
[y] all heights and calipers in centimeters (cm)
[x] dates significant at the 0.05 level or higher (protected LSD test)

1982 - Year two.

With one exception (height of Scotch pine) the trees grown from the milk carton seedlings were still superior after the second growing season (Table 3).

Table 3. Effect of tree seedling container size on subsequent (second year) tree growth[z]

	Container			
Species	Milk carton	3" nu-pot	2¼" nu-pot	Paper pot
Deodar cedar[y]				
height	72.0b[x]	62.8a	61.7a	61.8a
caliper	1.50b	1.26a	1.26a	1.20a
#branches[s]	266.6b	171.3a	169.2a	166.0a
Loblolly pine				
height	128.7b	114.7a	115.7a	115.7a
caliper	2.5b	1.8a	2.0a	1.8a
#branches[s]	47.7b	33.2a	36.3a	29.1a
Japanese black pine				
height	70.8b	59.8a	62.8a	58.6a
caliper	1.6b	1.2a	1.3a	1.3a
#branches[s]	23.0b	12.8a	13.0a	15.6a
Scotch pine				
height	37.0a	36.0a	33.0a	37.1a
#branches[q]	47.5b	35.8ab	30.3a	38.5ab

[x] all milk carton means significantly better than the other 3 containers at the 0.01 level (with noted exception) (protected LSD test)
[z] means of six plants for each container size for two or three planting dates (excludes field planted trees)
[y] all heights and calipers in centimeters (cm)
[q] buds or branches 1/2" or longer
[s] branches 1" or longer

As with the previous year's data, transplanting date had a minor effect on tree growth and no appreciable container size-transplanting date interaction was observed.

Frequently the improved growth that is obtained from various experimental factors during the first year of plant growth is diminished in subsequent years. That was not the case to date in this study although whether this benefit will continue in the future has yet to be determined.

The fact that earlier transplant dates had little effect on plant growth during either the first or second year suggests that, given an adequate volume of medium and nutrients during propagation, a healthy and vigorous tree seedling will transplant relatively well even under less than optimum temperature conditions.

Since no significant container size-transplant date interaction occurred it appears that the restricted growth incurred by tree seedlings propagated in small containers cannot be overcome even by early transplanting.

Based on these and the previous studies that have been cited, tree seedling growth can be expected to increase as container volume increases up to a volume of approximately 41 cu.in.

LITERATURE CITED

Carlson, L.W. 1979. Guidelines for rearing containerized conifer seedlings in the Prairie Provinces. Information Report NOR-X-214, p.5. Northern Forest Research Center, Edmonton, Alberta, Canada.

Davis, R.E. and Whitcomb, C.E. 1975. Effects of propagation container size on development of high quality seedlings. Proc. Int. Plant Prop. Soc. 25:251-257.

Gibson, J.D. and Whitcomb, C.E. 1980. Producing tree seedlings in square bottomless containers. Orn. South 2(5):12-15.

Hathaway, R.D. and Whitcomb, C.E. 1977. Propagation of Quercus seedlings in bottomless containers with Osmocote. J. Arboric. 3(11):208-212.

Owston, P.W. and Stein, W.I. 1977. Production and use of container seedlings in the west. In Proceedings of Meetings, Intermountain Nurserymen's Association, p. 117-125.

Tinus, R.W. and McDonald, S.E. 1979. How to grow tree seedlings in containers in greenhouses. General Technical Report RM-60, 256 p. Rocky Mtn. Forest and Range Exp. Stn., Bottineaus, ND.

Wall, S. and Whitcomb C.E. 1980. A comparison of commercial containers for growing tree seedlings. In Okla. Agri. Exp. Stn. Research Report P-803, p. 72-75.

Whitcomb, C.E., Storjohann, A., and Gibson, J. 1977. Effects of time of transplanting container grown tree seedlings on subsequent growth and development. In Okla. Agri. Exp. Stn. Research Report P-777, p. 37-39.

Whitcomb, C.E. 1981. Growing tree seedlings in containers. Okla. Agri. Exp. Stn. Bulletin #755, 18p.

FLORIDA DIVISION OF FORESTRY
PINE NURSERY SEEDLING IMPROVEMENT STUDIES

An Outline of Highlights & Current Status

E. L. Barnard, Forest Pathologist
Divisions of Forestry & Plant Industry
P. O. Box 1269
Gainesville, FL 32602

Several studies have been initiated in Florida over the past four years to identify and correct problems contributing to unsatisfactory field performance of commercially grown bare-root pine seedlings. This brief report is intended only to provide interested parties with a synopsis of the type of studies being conducted and some key findings to date. Elaborate summaries of detailed data, etc., are omitted here for simplicity and, quite honestly, the lack of sufficient time to organize same into a meaningful and coherent package. Also, some of our studies are still in progress, making data summaries at this time premature. Readers with particular interest in or questions regarding specific aspects of these studies are invited to contact the author.

Comprehensive "Seedling Quality" Studies

Two years of seedling quality studies involving comparative analysis of seedling (slash pine) morphological and biochemical attributes in relation to field performance (survival & growth) on seedlings from five commercial forest nurseries have been conducted. All possible statistical analyses are not yet complete and field measurements are still being taken (through 3'rd year). Interesting results to date include:

1) higher root starch concentrations (mg/g root dry weight) in "late season" (i.e., February) as opposed to "early season" (i.e., December) seedlings,

2) better field survival for seedlings lifted and outplanted in December as opposed to February (suspect weather related),

3) generally poor survival (1'st year) of seedlings with "low" root starch as compared to companion seedlings (i.e., lifted on same date from different nursery and/or different seedbed within same nursery) with "high" root starch levels,

4) a possible association between low root starch reserves and a) excessive seedbed density and b) excessively high seedbed pH due to high levels of calcium in irrigation water,

5) a general increase in root mass and a concomitant decrease in shoot/root ratio in February-lifted seedlings as opposed to December-lifted seedlings.

Comparative Fumigation Trials

Early circumstantial evidence suggested possible adverse side effects on seedlings of seedbed fumigation with methyl bromide containing high levels of chloropicrin. Two years of seedling comparisons (morphology and field performance), however, have demonstrated no differences between seedlings grown in soils fumigated with methyl bromide formulations containing 2% or 33% chloropicrin.

Current efforts are being aimed at comparing (on the basis of pre- and post-fumigation sclerotial populations and/or viability) the relative efficacies of methyl bromide formulations containing 2 or 33% chloropicrin in controlling *Macrophomina phaseolina*, the cause of charcoal root rot.

Seedling Packaging - Comparisons of Selected Media

Survival of seedlings stored for varying lengths of time in peat moss was notably better than that for seedlings stored similarly in either Hydromulch® or Terra-Sorb®. Results of this study are not to be taken as a bottom line reality for all seedlings under all storage and/or handling conditions, but rather as an indicator of the potentials for microbial and/or aeration problems under certain conditions.

Current Efforts

Other investigations are under way in cooperation with various graduate students from the University of Florida. These studies are centering on a) root pruning, b) seedling life tables, c) solar pasteurization of seedbed soils, and d) cultural practices in relation *Rhizoctonia* needle blight(s) of longleaf pine. We are also in the second year of a U. S. Forest Service - funded statewide survey of sand pine seedbeds for *Phytophthora cinnamoni* in cooperation with Dr. R. S. Webb of the University of Florida's School of Forest Resourses and Conservation.

Note: These studies to date have been successful and show promise for considerably more positive accomplishments due primarily to the positive cooperation among Florida's Forest Industries and Dept. of Agriculture & Consumer Services, as well as the U. S. Forest Service, and the University of Florida.

Note: This paper was presented in two panel discussions in the 1982 Southern Nursery Conference--Savannah, Georgia.

ECONOMIES-OF-SCALE FOR NEWLY CONSTRUCTED SOUTHERN PINE NURSERIES

Richard W. Guldin[1]

Abstract.--Cost is an important consideration in constructing and operating new nurseries to grow bare-root and containerized southern pine seedlings for reforestation. Each type of nursery has different capital requirements. The cost of erecting a container seedling nursery is competitive with the cost of building a new bare-root nursery. By analysis it is shown that containerized seedlings can be grown economically and deserve a place in pine reforestation programs.

Additional keywords: Reforestation, regeneration.

The South's Third Forest report by the Southern Forest Resource Analysis Committee (1969) called for regenerating 30 million unproductive acres to pine by 1985. This need was seen as an addition to the reforestation of currently productive land from which the timber will be harvested. The report also called for an additional 60 million acres forested with genetically improved stock by the year 2000. However, the annual rate of regeneration by both direct seeding and planting in the entire South--including idle farmland, forest land understocked with pine, unproductive upland sites converted to pine, and recently harvested acreage promptly regenerated--has not exceeded 1.6 million acres since this report was issued 13 years ago. Present reforestation rates are barely achieving half the goal. A major constraint precluding attainment of the reforestation goal is the lack of seedlings. Twice as many are needed as are available; preferably these would all be from genetically improved seed.

An inadequate amount of seedling production capacity is the major bottleneck to growing sufficient seedlings. Finding suitable nursery sites is difficult, and building new nurseries is expensive. Just the construction costs for two new forest industry bare-root nurseries that began in 1980 were $1 million and $2 million for annual outputs of 18 and 35 million seedlings respectively. A third nursery that is under construction at a cost of $2 million will produce 25-30 million seedlings annually beginning in 1983 or 1984. These costs equate to between $56 and $67 per 1000 seedlings annual production capacity, excluding land cost. Yet these three nurseries add only 7 percent to the total southern pine nursery capacity. Applying these costs, it would require an additional $72 million to double existing pine seedling output, assuming that suitable nursery sites are already owned.

Building new container seedling nurseries could help meet the seedling need. But are they economical? This paper updates the estimated costs of building four types of new container seedling nurseries reported in Guldin (1982a, 1982b) and compares them to the cost of building new bare-root nurseries.

---

[1] Economist, Southern Forest Experiment Station, USDA Forest Service, New Orleans, LA.

NURSERY ALTERNATIVES

Bare-root nurseries have been the principal supplier of pine seedlings for artificial regeneration in the South since F.O. Bateman pioneered successful planting practices in the 1920s. Because of the bare-root capacity presently available, amounting to 1.2 billion seedlings last year, bare-root seedlings will remain dominant. They will continue as the benchmark against which the costs of new technologies, such as growing seedlings in containers, are compared.

The costs determined for each type of nursery are influenced by a number of assumptions. Biological assumptions vary among the five alternatives and will be addressed separately for each. Several cost assumptions, however, are common to all five. These are capital, labor, and overhead costs as well as costs of goods and services.

Capital costs were based entirely on price quotations from nursery equipment manufacturers and wholesalers or on actual bids for recently constructed facilities across the South.[2] Locally available construction materials were priced at retail outlets in the New Orleans, Louisiana area. A factor equal to 10 percent of total costs was added to cover miscellaneous items and contingencies. All costs are on a July 1, 1982, 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 perfrom 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 cost to the employer of social security tax, workmen's compensation insurance and unemployment insurance. The last two were 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 on prices quoted by their suppliers.

Direct overhead costs of the nursery operation itself were included in the total cost estimates. However, nothing was added for general administrative expenses related to higher echelons of the firm or agency.

BARE-ROOT NURSERY

Bare-root seedling total costs have both a capital component and a production component.

2/ The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such does not constitute an official endorsement or approval of the product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

Capital Costs

Capital costs for a new bare-root nursery fall into three 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 soils are often also the best agricultural sites. A high price is required to bid such acreage from crop production. Land acquisition expenditures include not only the purchase price paid, but also search and closing costs. If a nursery site is already owned by the firm or agency, its cost comprises the net benefits foregone from the prior land use. In addition, if the location selected is not optimal, but is the best owned by the firm or agency, there is an opportunity cost involved in settling for a sub-optimal site. Using Wakeley's guidelines, it has been assumed that 3.5 acres are needed for beds, paths, roads, and administrative areas for each 1 million seedlings grown annually.

Once acquired, acreage must be cleared and leveled, beds laid out, and an irrigation system installed. Organic amendents, or other soil management practices, may be needed to build up the soil prior to producing the first crop of seedlings.

While all site improvements, such as the irrigation system, have an assumed 20 year lifetime, the inherent land value is presumed constant in perpetuity. Therefore, land acquisition costs must be converted to an annual value using the formula for a perpetual annual series rather than for a terminable annual series. Costs for land acquisition and site improvements were thus converted to an average annual cost basis per one million seedlings annual capacity. When this figure ($3,614 per million seedlings) is multiplied by nursery output the result is the annual land capital cost.

The required buildings are a nursery office, equipment storage and repair garage, a packing building, and a refrigerated seedling storage warehouse. The sizes of the first two do not vary with seedling production, but the sizes of the other two will. All buildings are assumed to have a 20-year life.

Equipment needs include pickup trucks, tractors, seed sowers, sprayers, seedling lifters, forklift trucks, and wagons. Nurseries that produce less than 6 million seedlings annually have at least one of each type of equipment. As nursery output exceeds 6 million seedlings, equipment needs rise rapidly, because seedling production becomes more heavily mechanized. In addition to more pieces of equipment, equipment size and horsepower also increase. Both factors contribute to higher costs. Equipment purchase prices were depreciated over assumed lifetimes, generally five years. Annual operating costs were then added and the sum divided by annual output to obtain the annual equipment cost per million seedlings.

The combined capital costs associated with land acquisition and development, construction of all needed buildings, and purchase and operation of equipment were converted to an annual cost per 1,000 seedlings for nurseries ranging in size from 5 to 30 million seedlings annually (fig. 1). The capital cost per 1,000 seedlings declines rapidly as nursery size increases to 12 million seedlings. Beyond 15 million seedlings, capital costs continue to decline as output increases, but at a much lower rate. The minimum output of a new bare-root nursery should be 15 million seedlings to obtain the most benefit from economies of scale.

Seedling Production Costs

Records for several public and private nurseries were examined, principally to determine staffing requirements and other costs by broad production categories. A composite budget was estimated, based on these costs, for a nursery producing 30 million seedlings annually (table 1). The total production cost of $27.16 per 1,000 seedlings includes all salaries, wages, employer-paid fringes (except pension plans), office expenses, seed, fertilizer, pesticides, packing supplies, and other miscellaneous items and materials essential for nursery operations. This cost is unaffected by nursery size, provided production rate remains constant.

The estimated cost is heavily dependent upon the amount of temporary labor used and the temporary employee wage rate. The assumed wage of $6.00 per hour, plus 15% in employer-paid fringe benefits, is higher than the minimum wage ($3.35 per hour plus 15%) typically paid by state nurseries. The daily rate for temporary employees at the Forest Service's W.W. Ashe Nursery in Brooklyn, MS, is currently $60.90. In a 1980 check of nursery hand-weeding costs, 7 of 22 industrial nurseries paid higher hourly rates than Ashe (Guldin 1982a). For temporary daily labor rates above or below the $55.20 used for our comparisons, production costs should be adjusted accordingly.

CONTAINER NURSERY ALTERNATIVES

Three major factors must be determined before cost estimates can be developed for a container seedling nursery: location of the nursery, type of germination house, and type of container. Location and type of germination house jointly determine the number of seedling rotations that can be germinated annually in each house. Type of container and size of germination house jointly determine the number of seedlings grown per rotation. Thus, all three elements together not only determine annual seedling output, but also influence costs.

Nursery Location

Contrary to the bare-root 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. Both the number of rotations grown annually and output increase as the length of the growing season increases. Higher outputs spread annual capital costs over a larger number of seedlings.

Table 1.--Production costs for sowing, growing, lifting, and packing 30 million bare-root seedlings.

Seedling Production		Cost
Labor		
Permanent Employees	900 man-days @ $73.60	$ 66,240
Temporary Employees		
Seeding	1200 man-days @ $55.20	66,240
Hand Weeding	1200 man-days @ $55.20	66,240
Supplies and Materials		
Fertilizers		20,000
Pesticides		70,000
Miscellaneous		10,000
Seed	4100 lbs. @ $15.00/lb.	61,500
Maintenance	67% of annual equipment cost	41,930
Subtotal		$402,150
Lifting and Packing		
Labor		
Permanent Employees	400 man-days @ $73.60	$ 29,440
Temporary Employees	3700 man-days @ $55.20	204,240
Supplies and Materials		55,000
Maintenance	33% of annual equipment cost plus 10% of annual building cost	26,810
Subtotal		$315,490
Local Overhead		
Labor		
Supervisors	520 man-days @ $92.00	$ 47,840
Secretary	260 man-days @ $55.20	14,352
Supplies, Materials, and Utilities		35,000
Subtotal		$ 97,192
	Total Production Cost	$814,832
Total Production Cost per 1,000 Seedlings		$ 27.16

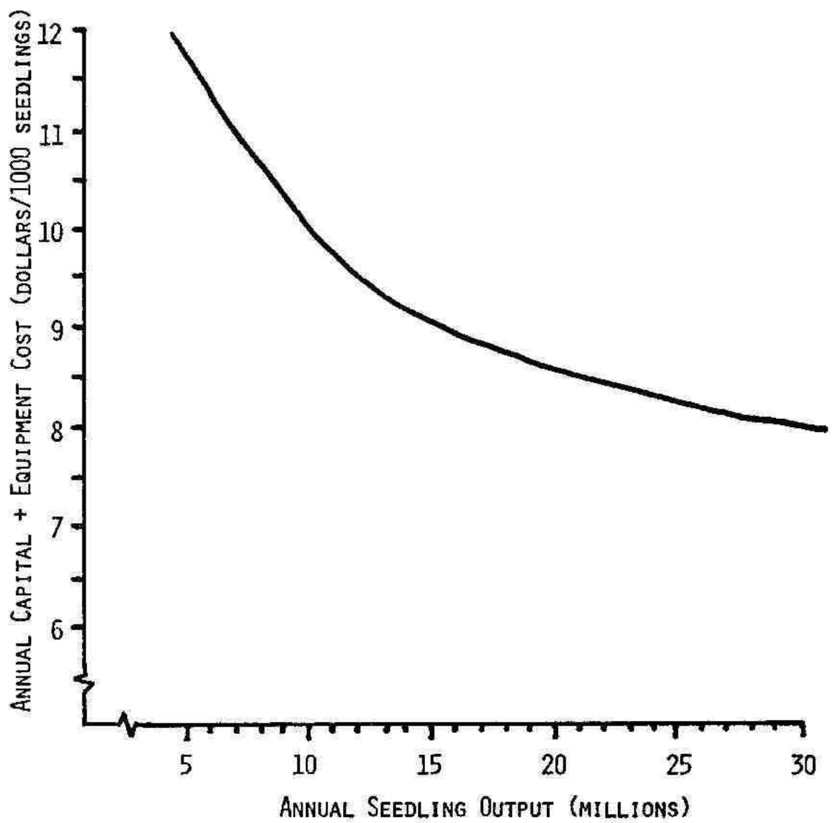


Figure 1.--Annual capital and equipment costs per 1,000 bare-root seedlings.

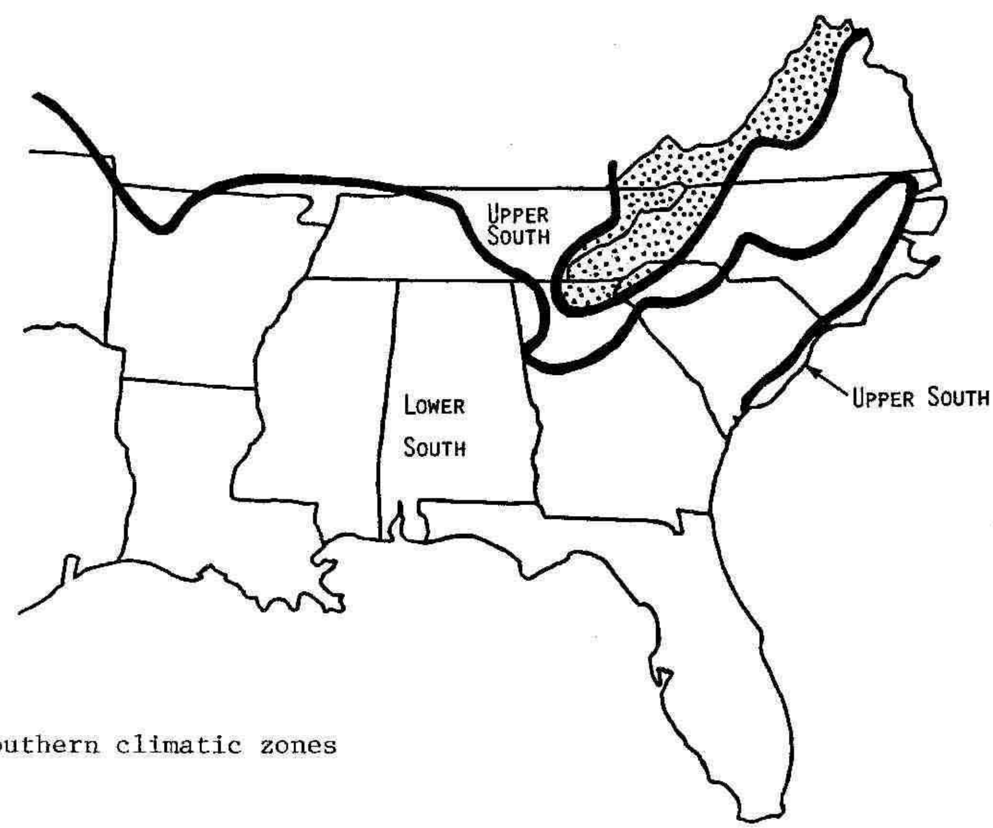


Figure 2.--Southern climatic zones

The South was divided into two climatic zones based on the length of the frost-free growing season and incidence of daily air temperatures exceeding 90°F (fig. 2). 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 one 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°F
	(No. of days)	(No. of days)
Upper South	185-215	30-60
Lower South	215-310	60-120

Mircroclimatic conditions may alter actual production schedules and potential seedling outputs in either zone.

Germination Houses

A container seedling nursery requires buildings for three 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 three functions, production efficiency increases if separate buildings are available that specialize in each activity. 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 will identify the type of nursery.

The four types of container seedling nurseries (and germination houses) share several common features. Some of these relate to biological conditions, whereas others induce commonality for cost comparison purposes. The common features are:

--Each nursery "replicate" (smallest efficient production unit) has one headhouse, five greenhouses for germination, and five shadehouses for hardening off. An exception is the pole shadehouse nursery, which has one headhouse, no greenhouses, and six pole shadehouses for both germination and hardening off.

--A sufficient number of CCA type C treated southern pine pallets to fill each greenhouse and shadehouse, included in building construction costs.

--Loblolly (*Pinus taeda* L.) or slash pine (*P. elliottii* Engelm. var. *elliottii*) seedlings grown in 12 to 16 week rotations.

--One "greenhouse rotation" is equivalent to 3,420 square feet, ± 2 percent, of usable growing space. Greenhouse sizes were selected to provide this much net 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 needed space. Multiplying container cell densities per square foot by the net growing space per rotation yields the total number of cells per rotation.

--Ninety-five percent of the cells produce plantable seedlings. Sowing two seeds per cell, plus thinning and transplanting excess seedlings to vacant cells, has attained this percentage of plantable seedlings in existing southern container seedlings 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 an adequate water supply should cost no more than $500 per acre.

Glass Greenhouse Nursery.--A glass greenhouse nursery has a wood-frame headhouse measuring 40 x 60 feet, which contains 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 five gable-roofed, aluminum-framed, glass-glazed greenhouses measures 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; and all utilities and connections, including a telephone alarm system. Each of the five pole shadehouses is 44 x 240 feet. They are constructed of shadecloth stretched over a nylon rope grid supported by three rows of CCA type C treated poles. Irrigation is the environmental control provided in the shadehouses. Each shadehouse provides sufficient space for two greenhouse rotations while hardening off seedlings prior to outplanting.

Shadehouses function as a "surge bin" between greenhouse production and field planting. The total construction cost of this nursery replicate is $713,135, which is equivalent to an annual fixed cost of $94,993 (table 2).

Fiberglass Greenhouse Nursery.--The same type of headhouse is used as for the glass greenhouse. Each of the five fiberglass-sided greenhouses has a double bowed and trussed roof covered with two layers of ultraviolet resistant polyethylene sheeting, held apart by air pressure form a small blower. The structures measure 34 x 150 feet. They contain the same climate control equipment as the glass greenhouse, except for the irrigation system. The fiberglass-sided 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 five pole shadehouses used for hardening off are of the same construction as those used in the glass greenhouse nursery, but each measures 36 x 300 feet. The total construction cost of this facility is $350,116, which is equivalent to an annual fixed cost of $51,144.

Table 2.--Capital costs of nursery construction, including land acquisition.

Number of Germination Houses	Type of Cost	Type of Germination House: Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
One					
	Total	$208,751	$142,921	$85,644	$71,103
	Annual	28,653	20,904	13,911	10,695
Two					
	Total	334,847	203,187	115,091	86,009
	Annual	45,223	29,725	20,045	13,613
Three					
	Total	460,943	263,453	144,538	100,915
	Annual	61,793	38,546	26,179	16,531
Four					
	Total	587,039	296,624	169,378	115,821
	Annual	78,363	43,331	31,050	19,449
Five					
	Total	713,135	350,116	197,671	130,727
	Annual	94,993	51,144	36,868	22,367
Six					
	Total				145,633
	Annual				25,285

Timber Truss Greenhouse Nursery.--Annual seedling production levels are lower for this type of greenhouse than for the glass and fiberglass structures. Thus less expensive partially-mechanized media-mixing, container-filling, and seed-sowing equipment is used in the headhouse. A forlkift truck is still included. Timber truss greenhouses measure 34 x 150 feet. They are built 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 are 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 used for the fiberglass greenhouse nursery. The total construction cost of a timber truss greenhouse nursery is $197,671 and the annual fixed cost is $36,868.

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 is $145,633, or an annual fixed cost of $25,285.

Types of Containers

Four types of containers, each in two sizes, were considered in the study: Styroblocks, Multipots, Rootrainers, and Todd Planter Flats (table 3). The purchase price of the containers, container reusability, container cell density per square foot, and labor requirements for container assembly, filling, and sowing are the 4 factors that affect the cost of growing seedlings.

Styroblocks, Multipots, and the Rootrainer trays can be used for six rotations. The Rootrainer cells, however, last only two rotations. Todd Planter Flats can be used for three rotations. These lifetimes, based on actual use in southern nurseries, were used to adjust the prices of the containers to a container purchase cost per 1,000 seedlings produced.

The 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. None of the other containers need assembly.

Analysis of the cost and operations records of existing container seedling nurseries in the South reveals that labor and material costs are determined primarily by the type of container selected. The labor cost for tending a single rotation once seed is sown is fixed, independent of the type of germination house. However, the labor cost per 1,000 seedlings is greatly influenced by container cell density.

Table 3.--Production costs for growing loblolly pine seedlings in containers of various cell densities and volume.

	Styroblocks		Multipots		Rootrainers		Todd Planter Flat	
	Quarter blocks Number 2	Quarter blocks Number 4	V-50	V-93	Ferdinand	Fives	100A	150-5
1. Container Purchase 1/	$ 5.20	$ 6.88	$ 5.27	$ 8.83	$10.56	$15.62	$ 4.18	$12.19
2. Media @ $27/20 cubic feet	2.10	3.36	2.85	4.70	2.10	2.94	1.26	3.15
3. Seed @ $15/pound	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
4. Seed Treatment	.08	.08	.08	.08	.08	.08	.08	.08
5. Fertilizer & Pesticides	.15	.15	.15	.15	.15	.15	.15	.15
6. Utilities 2/	1.51	1.93	1.88	3.14	1.31	1.89	1.92	3.06
7. Labor								
a. Filling and Seeding	1.77	1.77	1.27	1.40	3.73	3.73	2.71	2.71
b. Daily Greenhouse Management 3/	7.10	8.52	8.31	13.88	5.78	8.33	8.07	13.53
c. Supervision 4/	3.55	5.96	5.82	9.90	3.55	4.17	5.76	9.65
Total Cost per 1000 cells	$23.09	$30.28	$27.26	$43.17	$28.89	$38.54	$25.76	$46.15
Total Cost per 1000 seedlings 5/	$24.31	$31.87	$28.69	$46.01	$30.41	$40.57	$27.11	$48.58
Container Cell Density Per Square Foot	96	75	82	49	118	82	80	50
Container Cell Volume in Cubic Inches	2.5	4.0	3.4	5.7	2.5	3.5	1.5	3.8

1/ Assembly costs are included, if needed. All costs include freight from the distributor to the mid-South (Monroe, LA; Vicksburg, MS; Natchez, MS).

2/ No active winter time growth in greenhouses is assumed, only extended hardening off (temperatures 35°-40° F overnight).

3/ Fixed cost of $2208 per greenhouse rotation (3420 square feet of growing space).

4/ Fixed cost of $1575 per greenhouse rotation.

5/ Assumes 95 percent of cells contain plantable seedlings.

CALCULATING CONTAINER SEEDLING TOTAL COSTS

Determining the total cost per 1,000 containerized seedlings involves several choices. Two facts must be known before cost calculations begin: the desired annual nursery output and the probable location of the nursery, whether in the upper or lower South (fig. 1).

The initial choice is the type of container to be used. The container establishes the cell density per square foot, which, with the assumed stocking level (95 percent plantable seedlings in this study), determines the number of germination houses needed to produce a given annual output. The three major variables affecting the choice of container are the container's cost contribution to seedling production, cell density, and cell volume. Low cost is generally traded off against low density or large volume. Barnett and McGilvray (1982) concluded that 100 cells per square foot is the optimal cell density for loblolly and slash pine. Lower densities are preferred for longleaf pine (P. palustris Mill). Containers with lower densities and larger volumes require a growing period longer than 12 to 16 weeks for the seedling roots to fully develop and bind the media together for easy extraction from the container. To illustrate the cost calculation method, Number 2 Styroblocks were selected because they have the lowest production cost per 1,000 seedlings and are the closest to the optimal cell density for loblolly pine.

The second choice is the type of germination house to be used. The timber truss greenhouse has the lowest capital cost per 1,000 seedlings in the lower South, while the pole shadehouse results in the lowest capital cost per 1,000 seedlings in the upper South (table 4). The fiberglass and glass greenhouse options offer greater control of seedling growth environment. However, the annual production per germination house from these two options is not sufficiently greater to reduce average capital cost per 1,000 seedlings to the timber truss greenhouse or pole shadehouse levels. If a controlled environment is required, the fiberglass greenhouse is clearly less expensive. However, the cost disparity between it and the two lower capital cost options suggests that multipurpose nurseries (combining progeny testing or other research with mass production of seedlings for reforestation) are cost efficient. If a highly-controlled 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 to produce quality reforestation seedlings in the South. To illustrate the cost calculation method, suppose that a nursery in the lower South is planned, using timber truss greenhouses for germination. Cost calculation proceeds as follows. From Table 4, find the annual output per timber truss greenhouse in the lower South when using Number 2 Styroblocks, 1,252 thousand seedlings. Then, divide the desired output of 25 million seedlings by the output per germination house. The quotient of 19.97, rounded to the next higher whole number, is the number of germination houses needed. Divide the rounded result by five, the number of germination houses per timber truss greenhouses replicate, to obtain the number of replicates needed. In the case of our example, 4.0 replicates are needed.

Table 4.--Annual Output Per Germination House

	Type of Germination House			
	Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
	--Thousand Seedlings--			
Lower South				
#2 Styroblock	1246	1252	1252	633
#4 Styroblock	973	978	978	495
V-50 Multipot	1064	1036	1036	802
V-93 Multipot	636	639	639	323
Ferdinand	1531	1539	1539	778
Fives	1064	1036	1036	802
Todd 100A	1038	1044	1044	528
Todd 150-5	649	652	652	330
Upper South				
#2 Styroblock	934	939	939	633
#4 Styroblock	730	734	734	495
V-50 Multipot	798	802	802	802
V-93 Multipot	477	479	479	323
Ferdinand	1148	1155	1155	778
Fives	798	802	802	802
Todd 100A	779	783	783	528
Todd 150-5	487	489	489	330

Because the replicate quotient is a whole number, use the lowest capital cost of the range presented (table 5). In the example, the capital cost per 1,000 seedlings grown in Number 2 Styroblocks in timber truss greenhouses in the lower South is $5.89. The total cost for these container grown seedlings is the sum of the capital cost per 1,000 seedlings and the production cost per 1,000 seedlings (table 3), $5.89 + $24.31 = $30.20 per 1,000 seedlings.

If the replicate quotient ends in a decimal and not a whole number, some interpolation is needed. Suppose that only 20 million seedlings are needed. This translates into 16 timber truss germination houses and 3.2 replicates. For the three complete replicates, the lowest average capital cost can be used, $5.89. However, the 0.2 replicate left is comprised of a headhouse and all its equipment, one germination house and one shadehouse. This last partial replicate has a much higher capital cost per 1,000 seedlings produced because 80 percent of the headhouse capacity is unused (four more germination houses could be served). A decimal replicate remainder of 0.2 requires using the highest capital cost of the range presented (table 5), $11.11 per 1,000 seedlings. The average capital cost for all the seedlings produced is the arithmetic average:

$$\frac{(3.0 \times \$5.89) + (0.2 \times \$11.11)}{3.2} = \$6.22 \text{ per 1,000 seedlings}$$

Where decimal remainders are 0.4, 0.6, or 0.8, the capital cost range must be interpolated to find the upper quartile of the range, the midpoint of the range, or the lower quartile of the range respectively. As the decimal increases, the amount of unused headhouse capacity decreases, and the capital cost approaches the lower end of the range presented (table 5).

Most container seedlings nurseries presently operating in the South produce between 400,000 and 1.5 million seedlings annually. This is less than the full first replicate for all containers and germination houses investigated. These existing nurseries will find their marginal cost per 1,000 seedlings drop, due to increasing returns-to-scale, as outputs are increased to the point where the headhouse investment is heavily utilized in the 3 to 4 million seedlings annual output range. New container seedling nurseries should have annual outputs greater than 3 million seedlings and strive to size their operations in full replicates to benefit from economies-of-scale and efficient capital investment.

BARE-ROOT AND CONTAINER NURSERY COST COMPARISONS

A comparison of seedling production costs between the two types of nurseries reveals that three types of containers are competitive (within ± 10 percent) with bare-root seedlings ($22.16): Number 2 Styroblocks ($24.31), Todd 100A Planter Flats ($27.11) and V-50 Multipots ($28.69). Labor comprises 60 to 65 percent of bare-root seedling production cost, but only 50 to 60 of container production costs. Thus, bare-root costs would drop faster if a lower temporary wage rate than the assumed $6.00 per hour were paid. But even at the minimum wage, use of the three competitive containers would still range from 2 percent cheaper to only 12 percent higher than bare-root seedlings ($22.00).

Table 5.--Capital Cost per 1,000 Seedlings

	Type of Germination House			
	Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
Lower South				
#2 Styroblock	$23.00-15.25	$16.69-8.17	$11.11-5.89	$16.89-6.65
#4 Styroblock	29.44-19.52	21.37-10.45	14.22-7.54	21.62-8.52
V-50 Multipot	26.93-17.85	19.54-9.56	13.00-6.89	19.77-7.79
V-93 Multipot	45.06-29.88	32.70-16.00	21.76-11.54	33.09-13.04
Ferdinand	16.89-11.20	12.26-6.00	8.16-4.32	12.40-4.89
Fives	26.93-17.85	19.54-9.56	13.00-6.89	19.77-7.79
Todd 100A	27.60-18.30	20.03-9.80	13.33-7.07	20.27-7.99
Todd 150-5	44.16-29.28	32.05-15.68	21.32-11.31	32.43-12.78
Upper South				
#2 Styroblock	$30.67-20.33	$22.26-18.15	$14.81-13.08	$16.89-6.65
#4 Styroblock	39.25-26.03	28.49-23.23	18.96-16.75	21.62-8.52
V-50 Multipot	35.90-23.80	26.06-21.25	17.34-15.32	19.77-7.79
V-93 Multipot	60.08-39.84	43.60-35.56	29.02-25.63	33.09-13.04
Ferdinand	22.52-14.93	16.34-13.33	10.87-9.61	12.40-4.89
Fives	35.90-23.80	26.06-21.25	17.34-15.32	19.77-7.79
Todd 100A	36.80-24.40	26.71-21.78	17.77-15.70	20.27-7.99
Todd 150-5	58.88-39.04	42.73-34.85	28.44-25.12	32.43-12.78

Consequently, changes in temporary wage rates will affect absolute production costs levels, but not the relative ranking of container versus bare-root technologies.

Production costs are essentially equivalent once a new nursery is constructed. Therefore, the key discriminator between container and bare-root seedling technology is relative capital cost. Past comparisons have been between bare-root seedling nurseries in their most efficient output range (15 to 30 million seedlings annually) and container nurseries one-tenth the size. Equitable comparison requires that both types of nursery have equivalent outputs.

A comparison of bare-root nursery capital costs per 1,000 seedlings (fig. 1) and the cost ranges for the four types of container nurseries (table 5) reveals that certain combinations of container and germination houses are quite competitive when headhouse capacity is fully utilized. The only two containers not competitive in either a timber truss greenhouse or pole shadehouse nursery are the V-93 Multipots and Todd 150-5 Planter Flats. The low capital cost of Ferdinand Rootrainers, by virtue of their high cell density, is sufficient to offset the production cost differential that favors bare-root seedlings. This makes the Ferdinand Rootrainer a fourth competitive container on a total cost basis.

The final comparison to be made concerns the initial capital investment required for a new nursery. In an era of high interest rates for private firms and of tightening public agency budgets, the level of initial construction costs could be a important consideration.

Construction expenditures for a 25 million seedling container nursery using Number 2 Styroblocks in the lower South are:

4 headhouses @ $55,697	$222,788
20 timber truss germination houses @ $13,271	265,420
20 pole shadehouses @ $14,096	281,920
22 acres of land @ $500	11,000
	$781,128

The total construction cost (including land costs) per 1,000 seedlings annual capacity is $31.25 -- half the $56 to $67 range (excluding land costs) of the three recently constructed bare-root nurseries. A public agency forced to purchase land for a new bare-root nursery could add another $10 to $15 per 1,000 seedlings annual capacity in cost.

If all the Number 2 Styroblocks needed to simultaneously fill all the germination and hardening houses are purchased as an initial construction expenditure ($617,760), their cost raises the construction expense to $55.95 per 1,000 seedlings annual capacity. Buying the blocks up front would lower production costs for the first 2 years to $18.84 per 1,000 seedlings -- 30 percent less ($208,000 annually) than at the bare-root level. After 2 years, when block replacement begins, the costs would rise from 30 percent less to 10 percent less than bare-root production.

CONCLUSIONS

Seedlings for reforestation can be produced as inexpensively in containers as in a new bare-root nursery. Four containers -- Number 2 Styroblocks, V-50 Multipots, Todd 100A Planter Flats, and Ferdinand Rootrainers -- all are cost competitive with bare-root seedlings grown in a new nursery.

The most cost-efficient procedures in the South is to grow seedlings in low-capital germination houses. High-capital germination houses do not boost output enough to pay for themselves.

Container seedling nurseries become cost-efficient at much lower output levels than do bare-root nurseries. The minimum container nursery capacity that captures the majority of economies-of-scale is a 3 to 4 million seedling annual output. Anything below this level results in under utilization of the headhouse investments. Full employment of headhouse machinery dictates the efficient production range of the nursery. Consequently, container seedling nurseries provide much greater flexibility in sizing the nursery to fit output needs and in locating the nursery to better serve planting areas.

LITERATURE CITED

Barnett, James P. and John M. McGilvray. 1981. Container planting systems for the South. U.S. Dept. Agri., For. Serv. Res. Pap SO-167, 18 p. South. For. Exp. Stn. New Orleans, LA.

Guldin, Richard W. 1982a. Nursery costs and benefits of container-grown southern pine seedlings. South. J. of App. For. 6(2):93-99.

1982b. "Capital intensity and economies-of-scale for different types of nurreries" in Guldin, R.W. and Barnett, J.P. (eds.), Proc. of the Southern Containerized Forest Tree Seedling Conf., USDA Forest Service Gen. Tech. Rept. SO-37. South. For. Exp. Stn., New Orleans, LA. pp. 87-96.

Southern Forest Resource Analysis Committee. 1969. The South's Third Forest: How it can meet future demands. South. For. Res. Analysis Comm. New Orleans, LA. 53 p.

Wakeley, Philip C. 1954. Planting the southern pines. Agriculture Monograph No. 18. U.S. Dept. Agri. For. Serv. 233 p.

COMPUTER USE AT LUCKY PEAK NURSERY[1/]

Richard H. Thatcher[2/]

Abstract.--After almost a years operational use of the Nursery Management Information System, Lucky Peak Nursery has found the computer system a valuable tool. NMIS is designed for use by the nursery personnel with little or no background in computer operations. Use of the available programs has significantly reduced work hours involved in data storage and computation.

Prior to the Nursery Management Information System (NMIS), all records for our 600+ seed sources and 300+ seedling lots were kept by hand on various cards records, and forms located in at least 4 different places in the nursery office Seedling shipping volume at Lucky Peak is between 5mm and 6mm a year. Every major activity on seed and seedlings was recorded, from the yearly inventory of seed to the shipping of seedlings. A lot of time was spent recording the data to the various cards, etc.

As a nursery manager, I was looking for help in being more efficient in data storage and retrieval. Help was also needed to answer some of those strange questions that come down the chain-of-command--how much Douglas-fir seed was collected in 1974 at 5000' elevation on the Payette National Forest, how much Jeffrey pine was sown at the nursery in 1979, what did you send me in 1974. The list goes on and on--you know what I'm talking about. Requests like these would cause a great deal of teeth-gritting, thinking about all the time and running to get the data.

Thats where we were, now where are we?

On a cold gray morning in January 1981, the last box containing the computer hardware was opened. That was the day we started as a pilot nursery for the Forest Service's Nursery Management Information System program. Our job was to locate "bugs" in the programs, make recommendations for changes and modifications, and see if we could service and be compatible with the computer. By August, the sun was shinning and we could talk about NMIS without using a lot of expletive adjectives!

Since last August, all data for all seed lots has been put on the seed program. All data for last years 2-0 and this years 1-0 and 2-0 has been put on the seedling program. A seed and seedling history report located in the exhibits shows the data we are recording and how the format looks. These history reports contain all the data we are recording; the beauty of the program is the flexibility and speed which data can be applied and retrieved.

As a manager, the bottom line is "how cost effective is it?" Our system is composed of a Texas Instruments 990 CTR, two Texas Instruments FD1000 disc drive units, and a Texas Instruments OMNI printer - total cost about $14,000.00. All hardware is the same at the ten Forest Service Nurseries using NMIS. We did not hire a computer technician to operate the programs--the programs are clear enough that we utilize nursery workers as operators. Cost effectiveness is both tangible and intangible. (see Table 1)

1/ Presented to the meeting of the Southern Nursery Conference (Eastern Session), Savannah, Georgia, July 12-15, 1982

2/ Nurseryman, USDA Forest Service, Region 4, Boise National Forest, Lucky Peak Nursery, Boise, Idaho 83706

TABLE 1

Activity	Recording Time NMIS	Card File
Apply one cultural activity to 40 sources in one field	2 minutes	25 minutes
Apply daily pack by source	30 sec./source	15 sec./source
Apply 5 cultural activities to 40 sources in one field all one level	3 minutes	60 minutes
Apply seed test data for one seed source	30 seconds	30 seconds
Report of seed not tested within last three years	8 minutes	80 minutes
Report of seedlings delivered in order by date and customer	14 minutes	120 minutes
	printed	Legibility?

We had three programs developed for us by the computer section in our Supervisor's Office. These programs were: 1. Inventory computation, 2. Shoot and caliper means and Standard Deviation, and 3. Sowing calculations. (see Exhibits)

The sowing program enabled us to compute the sowing schedule in 1½ days; by hand it would have taken 4 days. At this time there is no cross-over from NMIS to the sowing program.

The inventory and size calculation determination in the past was done by the inventory crews, a fistful of calculators, and about 5 weeks time. Each crew would do the calculations for their field work each day. This would be about 30% of their time each day on calculations. Last summer, with the computer program, one crew could input all the data from one days field work in about 3 hours. Total inventory work last year took 3 weeks for about the same volume of trees as the year before. We felt we cut inventory cost by 380 work hours.

The more seed and seedling lots you have, the more cost efficient the computer becomes.

One of the main disadvantages of the computer is the feeling of panic when a breakdown in the equipment occurs. We experienced head adjustment problems on one of the disk drive units 3 times in five months. Repair required sending the faulty unit to California for 3 to 5 weeks. The last breakdown was handled by our forest computer specialist in two days. Even though good procedures include making a "back-up" data disk after each input session (so you don't lose data if your main data disk is damaged), the mere fact of machine malfunction prohibiting you from seeing your data when you want is a chilling feeling.

There is interest in developing at least two more programs for NMIS. We need a program to apply all soil maintenance activities, and a program to record all cone and seed processing activities. Hopefully our Forest Service programmers in Ft. Collins, Colorado will work on these programs.

In closing I would say that the computer-age has come to Lucky Peak Nursery. When all the frustrations, malfunctions, and costs are compared to increased efficiency, rapid report generation, and unlimited programming potential, a nursery computer system is a valuable tool for the nursery manager.

LUCKY PEAK NURSERY

SEED HISTORY REPORT
RUN DATE
07/01/82

SEED LOT ID	ORIG DATE	SPECIE	REG	FOR	DIST	BREED ZONE	GEN BASE	HABIT CODE	SEED ZONE	ELEV	COLLECTION YEAR	COLLECTION MTH	COLLECTION TYPE	SOIL TYPE	CERT CODE	SUB LOT	STORED FOR	INITIAL AMOUNT STORED	EXTRACT CODE	STORE LOC	TOWN SECTION
PP02 71003	120271	PIPO	04	02	X	0				5.5	71			100			02	508.0		3	LOGGING GULCH

********** SEED TEST **********

TYPE OF TEST	241	241
TEST NUMBER	006486	041093
TEST DATE	0877	0680
UNIT OF WT	P	P
GROSS SEED/UNIT WT.		9700
PERCENT PURITY		99
PERCENT FILLED		0
VIABLE SEED/UNIT WT.		8546
PCT MOIST CONTENT		6.
NUMBER DAYS STRATIFIED		28
DAYS UNSTRAT (CATAGORY)	7	7
PCT	0	0
DAYS STRAT	7	7
STRAT PCT	27	58
DAYS UNSTRAT (CATAGORY)	14	14
PCT	13	9
DAYS STRAT	14	14
STRAT PCT	80	80
DAYS UNSTRAT (CATAGORY)	21	21
PCT	24	21
DAYS STRAT	21	21
STRAT PCT	83	88
DAYS UNSTRAT (CATAGORY)	28	28
PCT	46	50
DAYS STRAT	28	28
STRAT PCT	86	89
DAYS UNSTRAT (CATAGORY)	35	35
PCT	63	53
DAYS STRAT	35	0
STRAT PCT	88	0
SURVIVAL FACTOR		85
NURSERY FACTOR		15
SEEDLING/UNIT BARE ROOT		7264
SEEDLING/UNIT CONTAINER		0

LUCKY PEAK NURSERY

SEED HISTORY REPORT

RUN DATE 07/01/82 PAGE 1 B

SEED LOT ID	DATE MMDDYY	ACT CODE	ACTIVITY NAME	UNIT WT.	BEGINNING AMOUNT	AMOUNT INVOLVED	ENDING AMOUNT	BILLING NUMBER	PURCHASE ORDER NO	COST/WT
PP02 71003	012182	236	NURSERY SOWING	P	411.3	30.0	381.3			
PP02 71003	012082	243	INVENTORY	P	410.8	411.3	411.30			
PP02 71003	042281	241	TEST	P	410.8	.05	410.8		UTAH STATE NURS.	
PP02 71003	031181	236	NURSERY SOWING	P	445.8	35.0	410.8			
PP02 71003	031980	243	INVENTORY	P	442.8	445.8	445.8			
PP02 71003	031080	236	NURSERY SOWING	P	501.8	59.0	442.8			
PP02 71003	030979	236	NURSERY SOWING	P	618.3	116.5	501.8			
PP02 71003	030279	236	NURSERY SOWING	P	642.0	23.7	618.3		HERBICIDE STUDY	
PP02 71003	013079	230	SEED TRANSACTIONS	P	643.0	1.0	642.0		P.T. TEST	
PP02 71003	021478	236	NURSERY SOWING	P	648.5	5.5	643.0		HERBICIDE STUDY	
PP02 71003	011678	236	NURSERY SOWING	5	971.5	323.5	648.5			
PP02 71003	050977	243	INVENTORY	P	971.5	971.5	971.5			
PP02 71003	032977	236	NURSERY SOWING	P	977.0	5.5	971.5		HERBICIDE STUDY	
PP02 71003	032777	236	NURSERY SOWING	P	1028.0	51.0	977.0			
PP02 71003	021577	236	NURSERY SOWING	P	1210.0	182.0	1028.0			
PP02 71003	101376	232	DONATE	P	1225.0	15.0	1210.0		I.F.&RES.	
PP02 71003	040676	232	DONATE	P	1225.0	.22	1225.0		U. I.	
PP02 71003	040576	236	NURSERY SOWING	P	1258.0	33.5	1225.0			
PP02 71003	111274	236	NURSERY SOWING	P	1265.0	6.5	1258.0			
PP02 71003	040874	243	INVENTORY	0	1266.0	1265.0	1265.0			
PP02 71003	032674	236	NURSERY SOWING	P	1577.0	311.0	1266.0			
PP02 71003	071333	238	MIXED SOURCES	P	374.0	1203.0	1577.0		COMBINE 7 LOTS	
PP02 71003	091972	237	DIRECT SOWING	P	375.0	1.0	374.0		DIRECT SOW 0206	
PP02 71003	031072	236	NURSERY SOWING	P	508.0	133.0	375.0			
PP02 71003	110971	240	SEED STORAGE	P		508.0	508.0			

SEEDLING HISTORY REPORT

RUN DATE 07/01/82 PAGE 1 A

SEED IDENTIFICATION				ORDERING INFORMATION		SEED TEST		GERMINATION	SOWING INFORMATION	
SEEDLING				GROWN FOR	04-02	TEST TYPE	241	STRATIFIED TEST		
LOT ID	8202 71003	REGION	04	YEAR DESIRED	82	TEST		DAYS/PCT 7 /58	EST SURVIVAL	
ORIGINATION		FOREST	02	TREES		NUMBER	041093	DAYS/PCT 14 /80	PER CENT	85
DATE	120079	DISTRICT		ORDERED	325	TEST DATE	0680	DAYS/PCT 21 /88	NURSERY FACTOR	15
				STOCK TYPE	B	UNIT OF		DAYS/PCT 28 /89	UNIT OF WEIGHT	P
SPECIES	PIPO	YEAR		AGE CLASS		WEIGHT	P	DAYS/PCT 0 /0	UNIT OF LENGTH	F
BREEDING		COLLECTED	71	DESIRED	2.0	GROSS SEED			AMOUNT TO SOW	59
ZONE		METHOD				UNIT WT	9700	UNSTRATIFIED TEST	DENSITY DESIRED	25
GENETIC		COLLECTION		MINIMUM STOCK		PER CENT		OR (CATAGORY)	SEED TO DROP	
BASE		TYPE		HEIGHT	0	PURITY	99	DAYS(CAT)/PCT 7 /0	PER SQ. UNIT	38
HABITAT		COLLECTION		MINIMUM STOCK		PER CENT		DAYS(CAT)/PCT 14 /9	SEED DRILL	LOVE
CODE				CALIPER	0	FILLED SEED	0	DAYS(CAT)/PCT 21 /21	DRILL SETTING	3-2
SEED ZONE				MINIMUM SHOOT		VIABLE SEED		DAYS(CAT)/PCT 28 /50	TURNS PAST MARK	10
ELEVATION	5.5			ROOT RATIO	0	UNIT WT.	7682	DAYS(CAT)/PCT 35 /53	INPUT GEAR	
						PER CENT			OUTPUT GEAR	
SOIL TYPE	100			MAXIMUM STOCK		MOISTURE			CALCULATED	
CERT CODE				HEIGHT	0	NUMBER DAYS			LENGTH	4402
SUBLOT				MAXIMUM STOCK		STRATIFIED	28		ACTUAL LENGTH	5203
NUMBER				CALIPER	0				AMOUNT SOWN	59.0
NURSERY ID	88			MAXIMUM SHOOT					NUMBER DAYS	
RANGE/TOWN/SECTION	RED CANYON			ROOT RATIO	0				STRATIFIED	31

INVENTORY

SEEDLING LOT ID	DATE MMDDYY	INVENTORY CODE	NAME	TREE AGE	GROSS TREES	NET TREES	AVG HT	AVG CAL	CUL PCT	LENGTH UNIT	DENSITY SQ UNIT	STD DEV	LOT LENGTH
8202 71003	070081	422	SEED LOT INVENTORY	2.0	311	260	11.	4.5	17	F	17	5.1	5203
8202 71003	080080	412	SEED LOT INVENTORY	1.0	297	218			27	F	16	0	5203

LUCKY PEAK NURSERY

SEEDLING HISTORY REPORT

RUN DATE 07/01/82 PAGE 1 B

STOCK TRANSACTIONS

SEEDLING LOT ID	DATE MMDDYY	*ACTIVITY* CODE	*ACTIVITY* NAME	TREE AGE	NUMBER TREES (M)	TEMP (C)	P-M STRESS	BILLING NUMBER	PURCHASE ORDER NO
8202 71003	041982	551	PICK UP	2-0	103.75				LOWMAN
8202 71003	040882	551	PICK UP	2.0	51.2				IDAHO CITY
8202 71003	040182	551	PICK UP	2.0	89.27				LOWMAN
8202 71003	033082	551	PICK UP	2.0	8.9				CASCADE
8202 71003	031782	520	PACKING	2.0	33.73				
8202 71003	031782	510	LIFTING	2.0					ALL
8202 71003	031682	510	LIFTING	2.0					4-3 4-5-1-2
8202 71003	031682	520	PACKING	2.0	224.57				

LUCKY PEAK NURSERY

SEEDLING HISTORY REPORT
RUN DATE 07/01/82
PAGE 1 C

SOWING LOCATIONS

SEEDLING LOT ID	FIELD	UNIT	BED	SOWING LOCATION	LENGTH UNIT	LENGTH SOWN
8202 71003	4	5	4	N230	F	230
8202 71003	4	5	3		F	413
8202 71003	4	5	2		F	413
8202 71003	4	5	1		F	413
8202 71003	4	4	5		F	413
8202 71003	4	4	4		F	413
8202 71003	4	4	3		F	413
8202 71003	4	4	2		F	413
8202 71003	4	4	1		F	413
8202 71003	4	3	5		F	414
8202 71003	4	3	4		F	414
8202 71003	4	3	3		F	414
8202 71003	4	3	2		F	414
8202 71003	4	3	1	N-13	F	13

CULTURAL TREATMENTS

SEEDLING LOT ID	FIELD	UNIT	BED	DATE MMDDYY	*ACTIVITY* CODE	NAME	ACTIVITY METHOD	ACTIVITY RATE
8202 71003	4			091581	342	SOIL	21-0-0	100#/AC
8202 71003	4			052681	352	ROOT HORIZONTAL		9"
8202 71003	4			051281	353	ROOT VERTICAL		6"
8202 71003	4			043081	392	PESTICIDE APPLIED	BIFENOX #229	3#AI/AC
8202 71003	4			100880	342	SOIL	6-2-0	1000#/AC
8202 71003	4			090280	342	SOIL	6-2-0	500#/AC
8202 71003	4			061080	392	PESTICIDE APPLIED	DACTHOL #230	10.5#AI/AC
8202 71003	4			041780	392	PESTICIDE APPLIED	DYMID #231	6#AI/AC
8202 71003	4			041780	270	SOWING	SOWING	
8202 71003	4			090079	121	PLASTIC SEAL	#113	350#/AC
8202 71003	4			080079	154	RIPPING	N-S E-W DEEP RIP	36"
8202 71003	4			050079	141	COVER CROP	SAWDUST	2"
8202 71003	4	5	4	060380	342	SOIL	6-2-0	400#/AC

```
NMIS   Seed Subsystem  Version 2.3.0   Dist. date 06/01/82

MASTER MENU

ENTER FUNCTION YOU WISH TO PERFORM

1. DATA RETRIEVAL/MODIFICATION/DELETION
2. DATA ENTRY (ADD NEW ENTRIES FOR ALL DATA SUBSETS)
3. DATA ENTRY (ADD NEW ENTRIES FOR A DATA SUBSET)
4. FILE STATISTICS
5. REPORT GENERATION
6. COMPRESSION OF DATA SET
7. BACK-UP OF DATA SET OR SYSTEM DISKETTE
8. NMIS SYSTEM UTILITIES
9. T.I SYSTEM UTILITIES

ENTER THE NUMBER CORRESPONDING TO YOUR CHOICE 5
```

```
REPORT SELECTION MENU

0. INFORMATION ON SELECTING AND SORTING REPORTS
1. SEED ACTIVITY SUMMARY
2. SEED HISTORY REPORT
3. SEED HISTORY REPORT - SEED TEST ONLY
4. SEED HISTORY REPORT - SEED ACTIVITY ONLY
5. SEED CODE INFO LISTING
6. SEED CODE REPORT
7. SEED ACTIVITY REPORT
8. SEED BOOK INVENTORY
9. SEED BOOK INVENTORY (LOT)
10. SEED BOOK INVENTORY (SEED CODE)

ENTER NUMBER CORRESPONDING TO REPORT YOU WISH TO RUN
AND 'RETURN' OR 'ESC' AND 'RETURN' TO RETURN TO -MAIN MENU-:
```

```
************************************************************************
*                       NURSERY MANAGEMENT                             *
*                         SEED CODE INFO                               *
*                      REPORT DATA SELECTION                           *
************************************************************************
*         SEED LOT ID # _ _        ORIGINATION DATE _ _                *
*              SPECIES _ _                   REGION _ _                *
*               FOREST _ _                 DISTRICT _ _                *
*        BREEDING ZONE _ _             GENETIC BASE _ _                *
*         HABITAT CODE _ _                SEED ZONE _ _                *
*            ELEVATION _ _           YEAR COLLECTED _ _                *
*     METHOD COLLECTED _ _       TYPE OF COLLECTION _ _                *
*            SOIL TYPE _ _                CERT. CODE _ _               *
*        SUBLOT NUMBER _ _               STORED FOR _ _                *
*           UNIT OF WT _ _               AMT. STORED _ _               *
*      EXTRACTORY CODE _ _         STORAGE LOCATION _ _                *
* TOWNSHIP/RANGE/SECTION _ _                                           *
*                                                                      *
*                                                                      *
*                                                                      *
*                                                                      *
************************************************************************
1st '_' IS FOR SORT KEY. 2nd '_' IS SELECTION KEY
```

```
NMIS  Seedling Subsystem  Version 2.2.2  Dist. date 02/01/82

MASTER MENU

ENTER FUNCTION YOU WISH TO PERFORM

1. DATA RETRIEVAL/MODIFICATION/DELETION
2. DATA ENTRY (ADD NEW ENTRIES FOR ALL DATA SUBSETS)
3. DATA ENTRY (ADD NEW ENTRIES FOR A DATA SUBSET)
4. FILE STATISTICS
5. REPORT GENERATION
6. COMPRESSION OF DATA SET
7. BACK-UP OF DATA SET OR SYSTEM DISKETTE
8. NMIS SYSTEM UTILITIES
9. T.I SYSTEM UTILITIES

ENTER THE NUMBER CORRESPONDING TO YOUR CHOICE 5
```

```
REPORT SELECTION MENU

0. INFORMATION ON SELECTING AND SORTING REPORTS
1. SEEDLING HISTORY REPORT
2. SEEDLING HISTORY REPORT-PAGE A ONLY
3. SEEDLING HISTORY REPORT - STOCK TRANSACTIONS ONLY
4. SEEDLING HISTORY REPORT - CULTURAL TREATMENTS ONLY
5. INVENTORY ACTIVITY REPORT
6. STOCK TRANSACTIONS ACTIVITY REPORT
7. CULTURAL TREATMENTS ACTIVITY REPORT
8. ORDERING INFO LISTING

ENTER NUMBER CORRESPONDING TO REPORT YOU WISH TO RUN
AND 'RETURN' OR 'ESC' AND 'RETURN' TO RETURN TO -MAIN MENU-:
```

```
*****************************************************************************
*                         NURSERY MANAGEMENT                                *
*                         SEEDLING LOT INFO                                 *
*                       REPORT DATA SELECTION                               *
*****************************************************************************
*     SEEDLING LOT ID # _ _        ORIGINATION DATE _ _                     *
*               SPECIES _ _                  REGION _ _                     *
*                FOREST _ _                DISTRICT _ _                     *
*         BREEDING ZONE _ _            GENETIC BASE _ _                     *
*          HABITAT CODE _ _               SEED ZONE _ _                     *
*             ELEVATION _ _          YEAR COLLECTED _ _                     *
*  METHOD OF COLLECTION _ _      TYPE OF COLLECTION _ _                     *
*             SOIL TYPE _ _              CERT. CODE _ _                     *
*         SUBLOT NUMBER _ _              NURSERY ID _ _                     *
*           RANGE/TOWNSHIP/SECTION _ _                                      *
*             GROWN FOR _ _              STOCK TYPE _ _                     *
*          YEAR DESIRED _ _       AGE CLASS DESIRED _ _                     *
*         TREES ORDERED _ _        MIN STOCK HEIGHT _ _                     *
*     MIN STOCK CALIPER _ _     MIN SHOOT ROOT RATIO _ _                    *
*      MAX STOCK HEIGHT _ _       MAX STOCK CALIPER _ _                     *
*  MAX SHOOT ROOT RATIO _ _                                                 *
*****************************************************************************
1st '_' IS FOR SORT KEY. 2nd '_' IS SELECTION KEY
```

```
STOCK SIZE CALCULATION DATA FILE CREATION

THIS PROGRAM CREATES A DATA FILE FOR USE AS INPUT
TO THE STOCK SIZE CALCULATION PROGRAM.

PLEASE ENTER HEIGHT IN CENTIMETERS AND CALIPER
IN MILLIMETERS; FOR EXAMPLE, 25.4,4
ENTER 0,0 FOR LAST ENTRY.

INPUT HT.IN.CM, CAL.IN.MM:  1.5,3
INPUT HT.IN.CM, CAL.IN.MM:  4.5,2.5
INPUT HT.IN.CM, CAL.IN.MM:  5.7,3.5
INPUT HT.IN.CM, CAL.IN.MM:  10.8,2.8
INPUT HT.IN.CM, CAL.IN.MM:  12.2,4.5
INPUT HT.IN.CM, CAL.IN.MM:  12,3.58
INPUT HT.IN.CM, CAL.IN.MM:  7.5,2.5
INPUT HT.IN.CM, CAL.IN.MM:  8.5,2.75
INPUT HT.IN.CM, CAL.IN.MM:  9.5,2.75
INPUT HT.IN.CM, CAL.IN.MM:  10.8,3.25
INPUT HT.IN.CM, CAL.IN.MM:  0,0


SEEDLING ID IS:  8402675004

MEAN IS:
    HT.IN.CM 8.3 CAL.IN.MM 3.13

STANDARD DEVIATION IS:
    SD.HT 3.51125 SD.CAL .61473

% OF ENTRIES WITHIN ONE STANDARD DEVIATION OF THE MEAN IS:
    HT.% 60 CAL.% 40
```

BED INVENTORY

```
SEEDLING ID IS:  8402675004
FIELD IS:        11
COMPARTMENT IS:  5
BED IS:          5
BED LENGTH IS:    402
CULL % IS:        .18
PLOT COUNT ( 1 ) IS:    109
PLOT COUNT ( 2 ) IS:    140
PLOT COUNT ( 3 ) IS:    135
PLOT COUNT ( 4 ) IS:    125
PLOT COUNT ( 5 ) IS:    128
PLOT COUNT ( 6 ) IS:    139
PLOT COUNT ( 7 ) IS:    136
PLOT COUNT ( 8 ) IS:    135

FOR THE ABOVE SET OF DATA:
     GROSS MEAN =         130.88
     GROSS BED COUNT =    52613.76
     NET BED VOLUME =     43143.28
     NET MEAN =           107.32
     DENSITY =            37.39
```

SOWING CALCULATIONS

```
ENTER SEEDLOT I.D.        84064750004
ENTER SEEDS PER POUND     15600
ENTER GERM (INCLUDE DECIMAL POINTS)    .87
ENTER PURITY              .98
ENTER SURVIVAL FACTOR     .85
ENTER AMOUNT REQUESTED    30000
ENTER CULL FACTOR      .25
ENTER SEEDLING DENSITY    25
VIABLE SEED PER LB.   11305
PLANNED PRODUCTION # 1   40000
SEED REQUIRED   3.538
10% OF SEED REQUIRED    .354
ENTER THE AMOUNT OF SEED YOU WISH TO SOW  3.6
PLANNED PRODUCTION # 2   40698
TOTAL SQ. FT.   1628
TOTAL BED LENGTH   465
SEED DROP PER ROW FT.   17
TOTAL SOWN   30524
                     PRINT THIS DATA ON THE PRINTER
ANOTHER LOT?  Y/N
```

WEST TEXAS NURSERY OPERATIONS

Denise L. Word and Robert J. Fewin [1/]

Abstract.--An overview of windbreak seedling production at the Texas Forest Service West Texas Nursery is presented. Included is a brief analysis of the climate and soils of West Texas and windbreak planting stock requirements which influence nursery production procedures and objectives. The production of 107,000 containerized conifers in a 1,500 square foot glass greenhouse and 467,000 bare-root hardwoods in a 5 acre field nursery are emphasized.

Additional keywords: Trickle irrigation, greenhouse cooling system, two crop rotation, bullet container, polystyrene container.

The specific need for windbreak plantings in the arid and semiarid regions of Texas are comparable to those throughout the Great Plains. Windbreaks are planted to protect homesteads and agricultural land from damaging winds, they provide protection for livestock and habitat for many species of wildlife.

The occurrence of windbreaks in West Texas is not as common as other portions of the Great Plains. The lack of windbreaks does not reflect landowner attitude toward tree plantings because from 1940 to 1978 the Texas Forest Service shipped over 12 million seedlings from its East Texas nursery to the western part of the state. The problem has been that bare-root seedlings produced in East Texas do not perform well under the extremes in growing conditions of West Texas.

Diversity of soils and climate of the region present innumerable challenges to the landowner establishing tree plantings. In general, the soils range in texture from sands to heavy clays from south to north with depths ranging from 2 to 48 inches of soil over caliche rock or zones of high calcium carbonate accumulation. Annual precipitation ranges from 10 to 20 inches from west to east. The most noted characteristics of the region, which contribute significantly to the success or failure of tree plantings, are the high winds and drought conditions during the late February and early March tree planting season. In order to overcome the adverse climatic and edaphic conditions and to insure reasonable planting success, the landowner must use planting stock specifically adapted to the region.

The Texas Forest Service took a major step toward providing landowners with adapted planting stock in April 1978 when the first greenhouse crop of containerized windbreak conifers was sown. The greenhouse is part of the Texas Forest Service West Texas Nursery complex (office-greenhouse-lath house) located at the Texas A&M University Agricultural Research and Extension Center, Lubbock, Texas. The following year field production of bare-root hardwoods

1/ Nursery Specialist and Silviculturist, West Texas Nursery, Texas Forest Service, Lubbock, Texas.

was initiated on a 5 acre site located at the High Plains Research Foundation Halfway, Texas, 35 miles north of Lubbock.

WINDBREAK PROGRAM AREA

The West Texas Nursery windbreak program is concentrated in a 69 county area (Figure 1). Historically, the greatest number of windbreak plantings have been made in this region because it is predominately farmland with soils that are highly susceptable to wind erosion. Sales and distribution of windbreak seedlings in the remaining portion of the state are handled by Indian Mound Nursery located in central East Texas.

GREENHOUSE PRODUCTION OF CONIFERS

The greenhouse is a 30 by 50 foot glass structure. The basic operating procedure and internal components are patterned after Dr. Richard Tinus' work at Bottineau, North Dakota on greenhouse production of containerized conifers. The environmental parameters manipulated to enhance rapid terminal growth of conifers are extended photoperiod, humidity, fertilization and temperature.

A unique feature of the greenhouse is the cooling system which employs lava rock rather than aspen pads or manufactured materials as the cooling element. Figure 2 illustrates the design of the cooling system.

The cooling system which is positioned at the south end of the greenhouse includes: (1) 24 inch motorized louvers across the end of the greenhouse at bench height; (2) one layer thick bed of 1 inch diameter lava rock spread on galvanized wire shelf attached to the outside of the greenhouse at eave height (7 foot); (3) a misting system over the lava rock; and (4) a concrete floor below the lava rock which slopes to a sump. Two 42 inch exhaust fans located at the north end of the greenhouse provides suction air flow. A saran shade cloth (55% shade) is stretched over the exterior of the greenhouse for added temperature control.

The galvanized wire shelf that supports the lava rock is 5 foot wide and extends the full width of the greenhouse. The area below the shelf down to the concrete floor is enclosed with fiberglass and sealed so air must pass through the wet lava rock before entering the greenhouse. The principle of the lava rock system is the same as aspen pads. The rock is porous with a high water retention capacity and large enough for air to be pulled through with little resistance.

The effectiveness of the system during summer months is dependent upon ambient humidity as is the case with evaporative type cooling systems. Greenhouse temperature can be maintained 12 to 15 degrees fahrenheit below outside temperature during summer months when ambient humidity is 30 percent and less.

General Production Procedures

Conifers produced in the greenhouse include: Arizona cypress (*Cupressus arizonica* L.); eastern redcedar (*Juniperus virginiana* L.); ponderosa pine

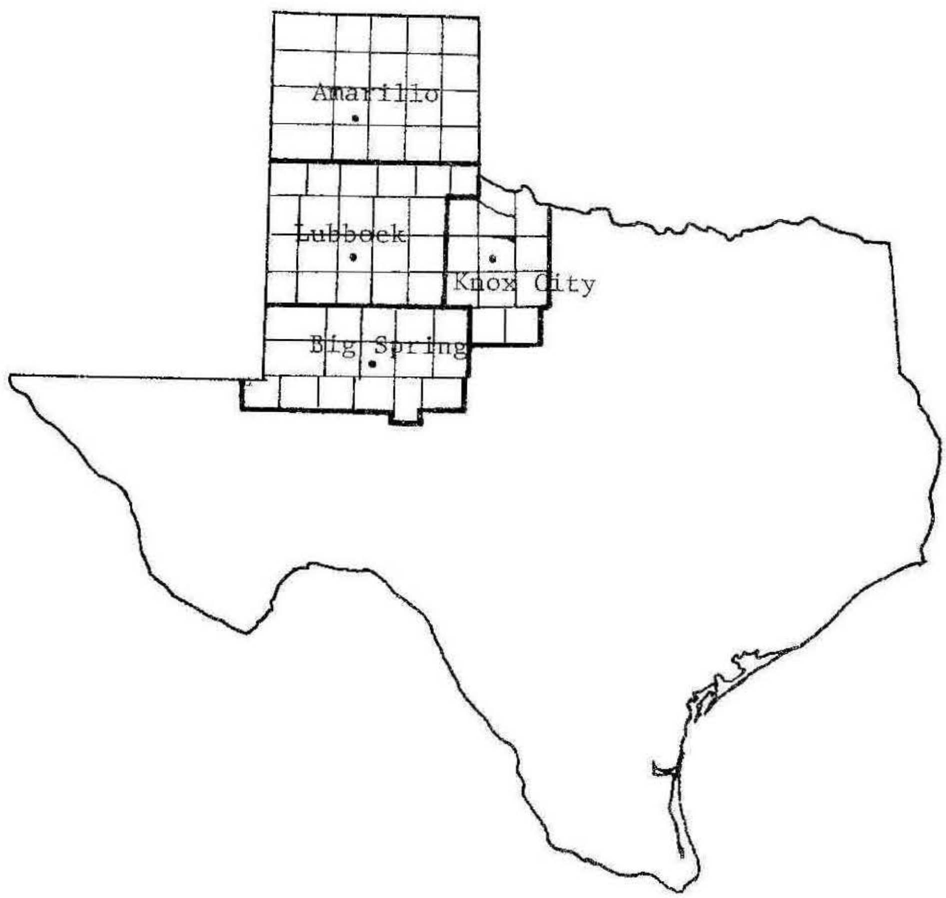


Figure 1.--The 69 counties in the arid and semiarid region of Texas included in the Texas Forest Service West Texas Nursery windbreak program.

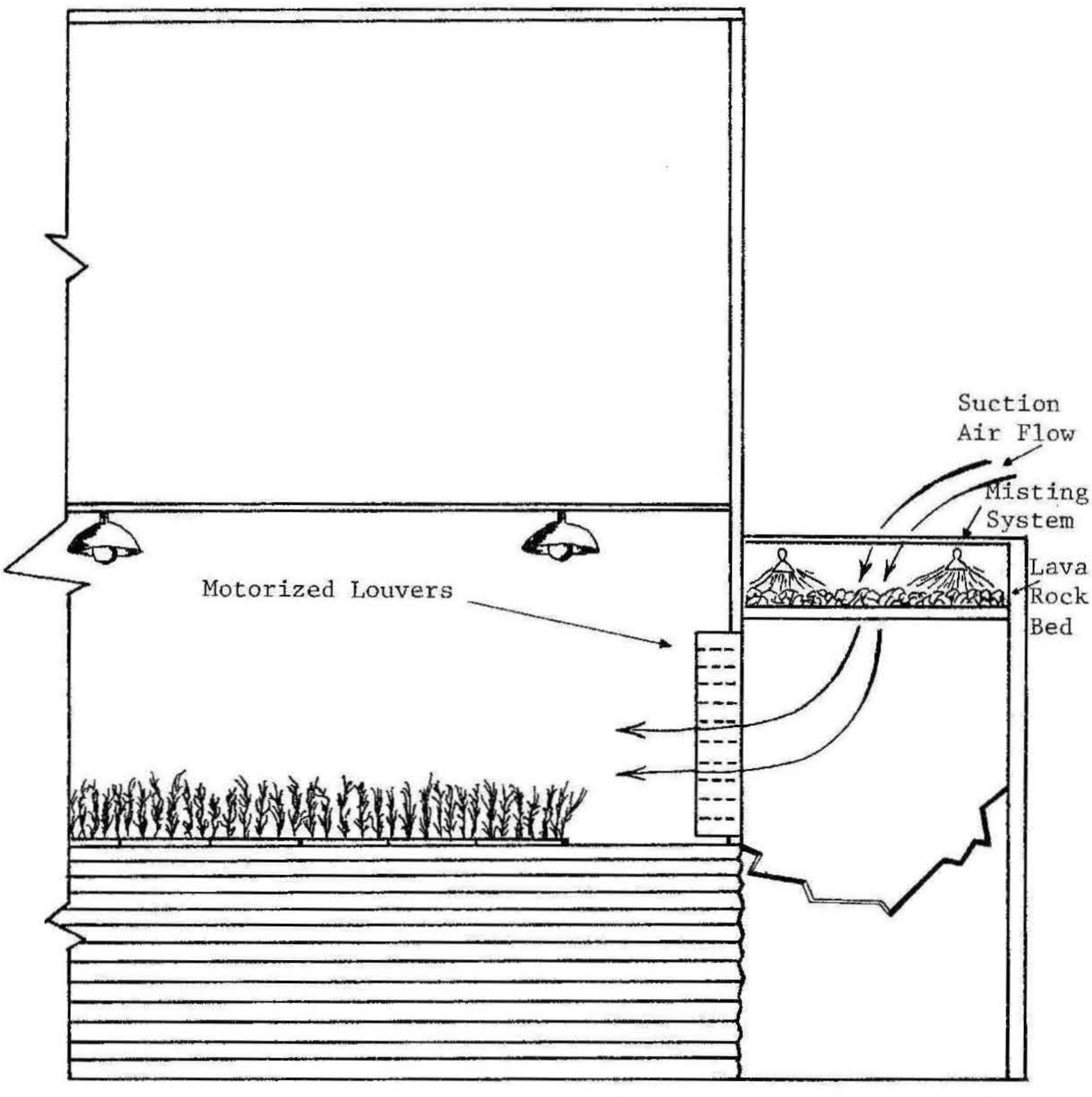


Figure 2.--A schematic side view of the greenhouse illustrating the basic design and function of the lava rock cooling system.

(*Pinus ponderosa* var. *ponderosa* Laws.) and Austrian pine (*Pinus nigra* Arnold). These introduced species perform well in West Texas once they are established.

Grading Standards--Stem caliper has proven to be the most reliable indicator of seedling quality because it generally reflects the degree of root development. The most desirable containerized conifer for planting in West Texas has a stem caliper of at least 3/16 inch at the root collar and a 6 inch top on the pines and an 8 inch top on cypress and redcedar.

Growing Media and Sowing Rates--The growing media used in all production phases is a 1:1 mixture of peat and vermiculite. Two seeds per cell are sown with a vacuum seeder. Containers are thinned to one seedling per cell when germination is complete.

Production Stages

In the four years that the greenhouse has been operational, annual production has not remained static. Demand for planting stock has forced production to rapidly progress from one crop per year in 1978 when 23,000 seedlings were produced to the present two crop rotation with 107,000 seedlings being produced annually.

The four fold increase in annual production was not achieved strictly by converting to a two crop system. Additional bench space was added in the isles and eventually a smaller container used during a specific phase of greenhouse production that significantly increased capacity.

One Crop Rotation--The first greenhouse crop of seedlings, Austrian and ponderosa pine, were carried through a 10 month production cycle. The seed was sown on April 20, 1978 in polystyrene box containers that measured 12 x 14 x 8 inches and has 30 cells with a volume of approximately 30 cubic inches per cell. This container has subsequently proven to be ideal for the development of seedlings with the root mass, stem caliper and top height needed for good survival in West Texas. The greenhouse was constructed with 905 square feet of bench space which held 776 polystyrene containers for a total of 23,280 seedling capacity.

During the first stage of production, the seedlings received a high nitrogen fertilizer, extended photoperiod and temperatures maintained near 70^{o} F until November 1, at which time the desired top height had been attained. The seedlings were then subjected to stress to induce bud set. Irrigation and extended photoperiod was terminated and the temperature regime changed to a 78^{o} F day and 68^{o} F night diurnal pattern. Once bud set was evident, irrigation was resumed with a high phosphorus and potassium and low nitrogen fertizer for two months to promote stem caliper and root and bud development. The hardening-off process began on Jaunary 1 when temperature in the greenhouse was reduced 5^{o} every 5 days until it reached ambient temperature. The seedlings were then moved to the lath house in February and subsequently distributed to the landowners in March 1979. The greenhouse crop that followed was the first phase of the two crop rotation.

Two Crop Rotation--The principle of the two crop rotation is that the greenhouse is used exclusively to promote rapid terminal growth. Each crop remains in the greenhouse for 6 months receiving high nitrogen fertilizer, extended photoperiod and 70^{o} F temperatures. Bud set, increase in stem caliper and root volume and hardening-off is accomplished in the lath house. The lath house has 10,000 square feet of growing space and is equipped with an overhead irrigation system.

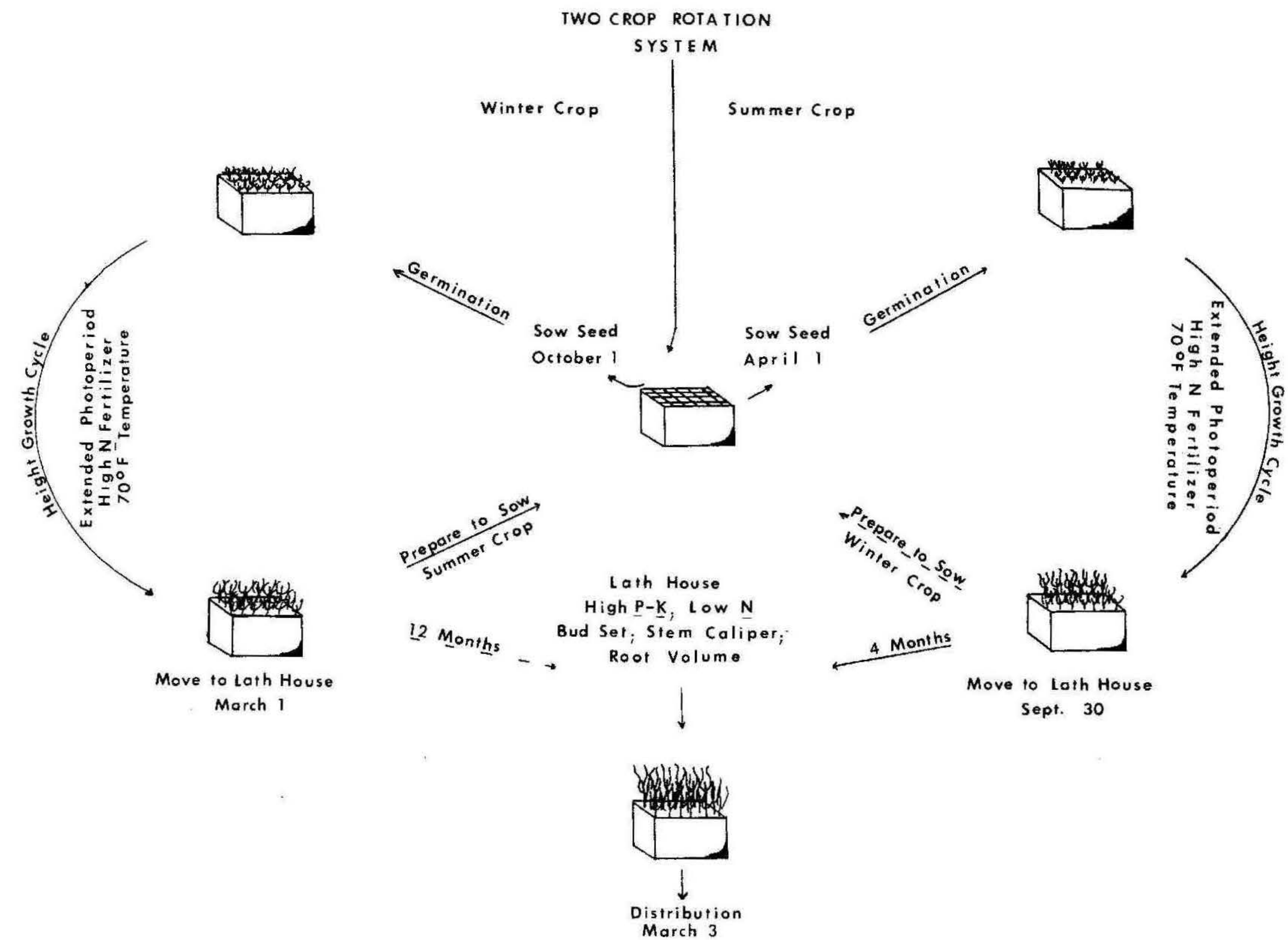
The winter crop is considered the first half of the annual two crop rotation. A simplified production flow diagram of the two crop rotation system is illustrated in Figure 3. Seed is sown on October 1. When germination is complete at three weeks, high nitrogen fertilization and extended photoperiod is initiated with temperatures maintained at 70^{o} F. The seedlings are then moved to the lath house on March 31. The last killing frost occurs around April 1, therefore, the seedlings are covered with plastic at night until buds and woody stem tissue develop. These seedlings remain in the lath house through the summer and winter months, receiving high P-K and low N fertilizer, then distributed to the landowners the following March. Consequently, the winter crop is 18 months from seed when the landowner plants them in the field.

The summer crop is sown on April 1 and the seedlings moved to the lath house on September 30. The first killing frost generally occurs around November 15, which leaves ample time (6 weeks) for the seedlings to set bud and develop woody stem tissue for winter hardiness. Seedlings produced in the summer crop are 11 months old when they are distributed to the landowners in March.

A total of 46,560 seedlings are produced when the polystyrene container is used in the two crop rotation.

The polystyrene container was used in the greenhouse from 1978 to the fall of 1981 when a bullet container was substituted. A tray, which holds 98 bullets, measures 12 x 14 x 7 inches. The volume of a bullet is 10 cubic inches which is one-third the volume of the polystyrene cell. Preliminary testing showed all four conifers could be grown in the bullet to the desired height in six months without root binding. Consequently, the bullet container was used to recharge the greenhouse for the winter crop in October, 1981. There was bench space for 462 trays @ 98 bullets/tray which equals 45,276 seedlings. By converting to the bullet container, seedling production per square foot of bench space was almost doubled. In addition, 12 inch wide side benches were added to each of the 4 isles which further increased the greenhouse capacity by 89 trays or 8,722 seedlings. The current greenhouse capacity is 53,998 seedlings per crop or 107,996 seedlings on a two crop rotation system.

A disadvantage to the bullet container is that seedlings must be transplanted to the polystyrene container at the end of the six month greenhouse cycle in order to obtain the desired root system. Approximately 690 man hours are required to transplant 53,998 seedlings at a cost of about \$3,600.00. However, when considering windbreak conifers are sold for \$1.00 per seedling and greenhouse capacity is increased by 30,718 seedlings, there is ample justification for the added cost of transplanting.



TWO CROP ROTATION SYSTEM
Winter Crop
Summer Crop
Germination
Sow Seed October 1
Sow Seed April 1
Germination
Height Growth Cycle
Extended Photoperiod
High N Fertilizer
70°F Temperature
Height Growth Cycle
Extended Photoperiod
High N Fertilizer
70°F Temperature
Prepare to Sow Summer Crop
Prepare to Sow Winter Crop
12 Months
Lath House
High P-K, Low N
Bud Set; Stem Caliper; Root Volume
4 Months
Move to Lath House March 1
Move to Lath House Sept. 30
Distribution March 3

Production Efficiency

All containers are graded to 30 plantable seedlings one week prior to being distributed to the landowners. Height, bud set (pines) and stem caliper of each seedling is measured. Thus far, only 70 percent of the seedlings produced under a two crop rotation system reaches plantable grade within a production year. Five percent are culls and 25 percent are classified as sub-standard and held in the lath house an additional year. Seedlings that fall in sub-standard category are primarily Austrian and ponderosa pine which have less than the minimum 6 inch top height.

Greenhouse sowing shcedules have been altered so that the pines and red-cedar are being produced strictly during the winter crop. This will give them an opportunity to put on a second flush of growth while being held in the lath house during the summer months. This change should improve production efficiency significantly.

The summer crop is devoted almost entirely to Arizona cypress which easily attains the minimum 8 inch height by the end of the greenhouse growing cycle.

FIELD PRODUCTION OF BARE-ROOT HARDWOODS

The field nursery site measures 360 x 600 feet. It contains 4.95 acres. Approximately 4.5 acres are tillable with a net seedbed area of 2.06 acres. The non-tillable area is a 15 foot border on the east and west boundaries.

The nursery is divided into 8 compartments. Each compartment contains 10 production seedbeds. A seedbed is 2.5 x 345 feet for a total of 8,625 square feet of growing space per compartment.

Annual production targets have increased from 250,000 seedlings in 1979 to the current 467,000 seedlings. The species produced each year include: Russian olive (*Elaeagnus angustifolia* L.); green ash (*Fraxinus pennsylvanica* Marsh.); thornless honeylocust (*Gleditsia triacanthos* L.); mulberry (*Morus* spp.); native plum (*Prunus angustifolia* Marsh.)and bur oak (*Quercus macrocarpa* Michx.)

General Production Procedures

The nursery site is bordered by open fields which leaves the production beds exposed to the hot, dry west winds. Living barriers of sudax, a hybrid sorghum, are established on the first bed in each compartment. It will attain a mature height of 8 feet in 60 days. Two rows of sudax are sown on each bed at the rate of 15 seeds per linear foot which creates a dense barrier that is effective through the month of October.

Four compartments are used for the production of hardwoods each year while the remaining four compartments are sown to a cover crop. The sowing of seedbeds begins around April 15. Planet Jr. planters are used to sow Russian olive and mulberry while the remaining species are hand sown. Three rows of seedlings, spaced 9 inches apart, are produced on each bed.

Treflan EC herbicide applied at the rate of 3/4# active ingredient per acre gives excellent weed control through most of the growing season. It is applied to the beds and watered into the soil after the tree seed is sown.

The nursery soil is a clay loam that will crust over when it dries inhibiting tree seed germination. Burlap is used to prevent drying of seedbeds during germination.

Trickle Irrigation System--Before the first field crop could be sown, an irrigation system had to be installed on the nursery site that was efficient and required little maintenance. The source of water for the nursery site was extended from an underground lawn sprinkler system. A 4 inch PVC underground main distribution water line was extended 600 feet east-west (long axis) through the center of the site. The water well that feeds the system pumps sand, therefore, a sand separator and 200 mesh filter were installed in the main water line. A 2 inch underground distribution line "T's" off and lays parallel with the main water line at 4 locations (Figure 4). The 2 inch lines distribute water to each compartment.

Risers, 1 inch PVC pipe, extend upward from the 2 inch distribution line to a height of 4 inches above ground. The risers are spaced every 5½ feet, which mark the center of each seedbed. Two 1 inch PVC "T's" with ½ inch male adaptors are attached to the top of each riser. Bi-wall drip irrigation tubing is clamped to each male adaptor then laid out over the length of the seedbed. When installation is complete, there are two 170 foot rows of tubing laid out over the surface of a bed on the north and south side of the riser.

The 19 mil. irrigation tubing has laser cut holes spaced at 10 inch intervals. Approximately 3/4 inch of water can be applied to a bed in a two hour period with 8 p.s.i. pressure per riser.

The drip irrigation tubing is very efficient in terms of water utilization. It is re-usable and relative inexpensive costing 4.5 cents per linear foot.

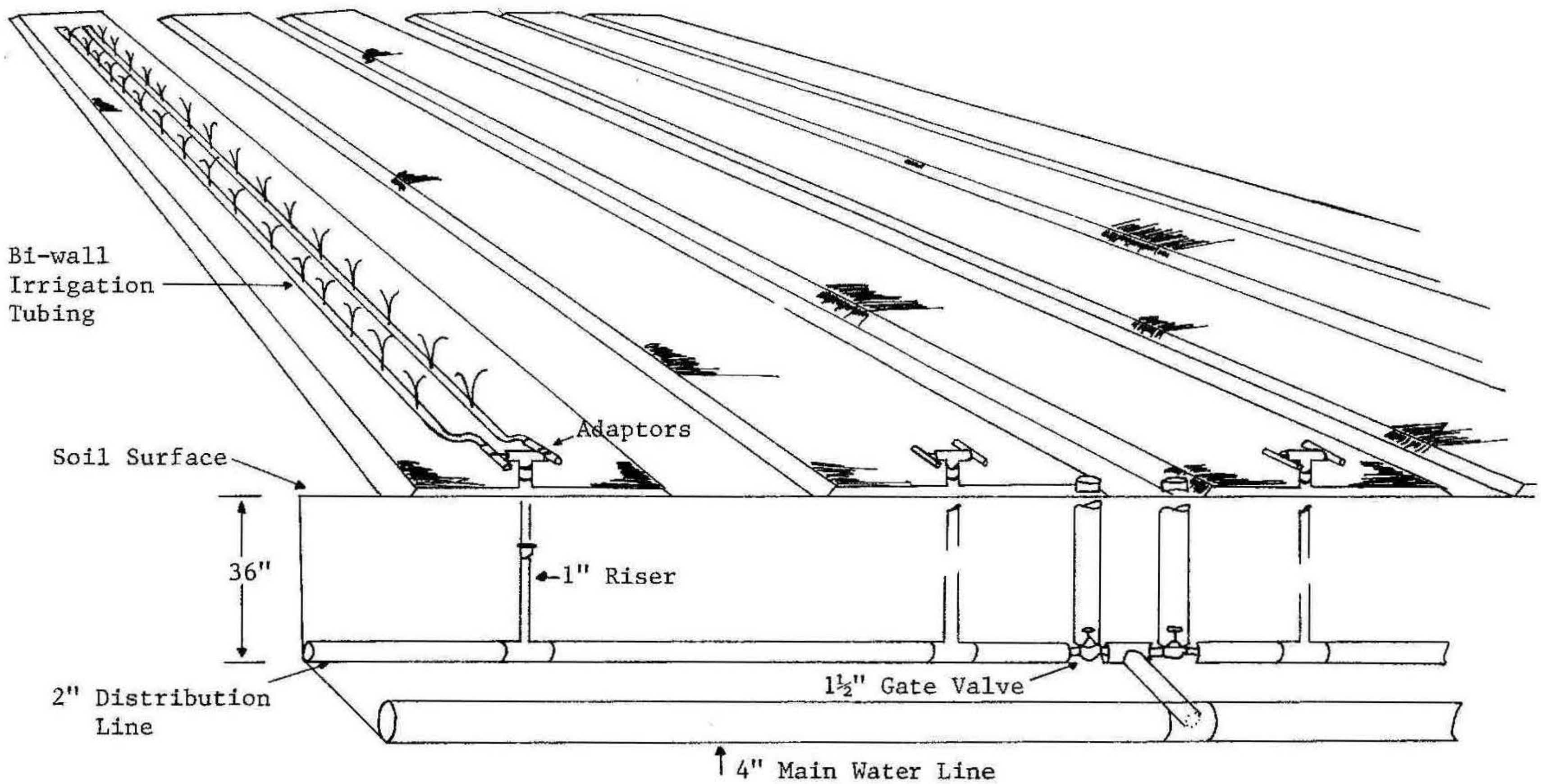
Production Efficiency

The grading standard for hardwood seedlings is a stem caliper of at least 3/16 inch at the root collar and a minimum of 12 inch top height. Normally, 80 percent of the seedlings produced will exceed the minimum growing standard. It is not uncommon to discard seedlings because they are to large. This is particularily true of Russian olive and mulberry.

SEEDLING DISTRIBUTION

The distribution of bare-root hardwoods and containerized conifers are two different operations, each requiring all available labor and working space to complete. Seldom are there more than five people involved in field nursery and greenhouse operations.

Figure 4.--Schematic of the underground irrigation system installed in the hardwood field nursery.



Bare-root Hardwoods

Field lifting of hardwoods begin the first week of February, weather permitting. Hardwoods are field graded and tied into bundles of 50 seedlings then packed with wet moss in an enclosed trailer and transported to Lubbock where orders are assembled and shipped.

There are two major problems with the lifting and shipping of hardwoods. First, there is considerable distance between the field nursery and headquarters where seedlings are bundled and shipped. Considerable time is devoted to transporting labor and seedlings to and from the field nursery. Second, the lifting season is relatively short...five weeks. Field lifting can be delayed because of snow or freezing conditions in February while bud break can occur in the field nursery the first week of March in species such as Russian olive.

Containerized Conifers

Containerized conifers are distributed to landowners from four locations. Figure 1 gives the location of each pickup station and the counties serviced. The specific distribution sites are state and federal facilities such as an experiment station or Soil Conservation Service office.

Pickup dates are determined before seedling sales begin in September. The landowner is made aware of his pickup date and location when seedlings are purchased and a written reminder is mailed two weeks in advance.

Containerized seedlings are trasnported to three pickup stations... Knox City, Big Spring, and Amarillo. Seedlings arrive at the pickup station the evening before and nursery personnel are on hand the following day to distribute seedlings to landowners and to answer questions. West Texas Nursery is the fourth pickup station where a large percentage of the seedlings are distributed.

The system of distributing containerized conifers has been very successful. A major advantage to the system is nursery personnel have direct contact with the landowner. It is felt that the one-to-one contact has played a major role in the success of the nursery program.

CONCLUSION

The Texas Forest Service West Texas Nursery has been operational four years. The demand for planting stock has increased dramatically each year. The production of 107,000 containerized seedlings will satisfy demand for a short period of time. Landowners are presently purchasing trees for one and two row homestead windbreaks which on the average require only 90 to 150 seedlings. However, with the growing interest in the planting of windbreaks around the agricultural fields, annual demand will approach 200,000 seedlings within the next 5 to 7 years. Field production of hardwoods will remain constant for the next five years because demand is for containierzed conifers.

OPTIMIZING NURSERY GERMINATION BY FLUID DRILLING AND OTHER TECHNIQUES

James P. Barnett [1/]

Abstract.--Fluid drilling techniques allow partial germination of seeds before sowing, separation of those that have failed to germinate, and then sowing viable seeds through a seed-gel mixture. Although research has been primarily with vegetable seeds, preliminary work indicates considerable potential in forestry. Other techniques are available to help optimize germination on nursery beds. Lengthening the period of stratification can greatly speed germination, make it more uniform, and reduce inter-seedling competition that will lessen the proportion of cull seedlings. Stratifying dormant seeds such as loblolly pine for 60 instead of 30 days will markedly improve the speed as well as total germination under the less than optimum conditions encountered on nursery beds. Individual seedlots vary in their response to stratification and comparative germination tests should be used to determine stratification requirements.

INTRODUCTION

It is well known, particularly among nurserymen, that seeds do not germinate and develop as well in the field as standard laboratory germination tests indicate. This is due partly to unfavorable climatic and soil conditions during and following sowing, as well as to the presence of soil pathogens. Numerous attempts have been made to develop vigor or stress tests that would allow nurserymen to be able to predict field performance more accurately. However, these efforts generally have been unsuccessful, and germination tests remain the best means of estimating nursery performance.

The problems of poorer than expected germination, inaccurate spacing, and staggered germination increase the percentage of cull or inferior seedlings and can significantly increase seedling costs. Ideally, (1) every seed sown should result in a seedling, (2) germination should be prompt and uniform, and (3) each seed should be accurately spaced within the nursery bed. Fluid drilling, a relatively new technique, offers the potential of meeting these objectives. It involves "pregermination", in which seeds have barely begun the germination process--radicle emergence is only 1 to 2 mm. This allows for removal of nonviable seeds from the lot.

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

Seed stratification is also being used to increase seed performance in the field. Varying the lengths of stratification gives the nurseryman another means of optimizing nursery germination.

FLUID DRILLING

Work done in England at the National Vegetable Research Station (Currah et al. 1974) has established the distinct advantages of using pregerminated seeds over ungerminated seeds. These advantages are obtained by a fluid drilling technique in which seeds are pregerminated under optimum conditions. Seeds that failed to germinate are then separated out and the pregerminated seeds are sown in a seed-gel mixture. Research to date with fluid drilling techniques has been primarily limited to vegetable seeds but is now in progress with southern pine seeds. Although the results to date are preliminary, they do indicate the potential for the techniques in forestry.

Pregermination.--Some of the causes for problems in nurseries are related to poor or slow germination. Fluid drilling offers the potential of sowing partially germinated seeds. No allowances have to be made for poor viability or inconsistencies between laboratory and nursery performance, since only seeds that have already begun the germination process will be sown. Seeds are pregerminated in aerated water with optimum temperature and light conditions.

Earlier work (Barnett 1971) with aerated water soaks as a means of stimulating germination has shown that germination of southern pine seeds in water is feasible. Even at low temperatures (about 40°F), germination will eventually occur, but it is more prompt at higher temperatures (70°F). The stratification and pregermination processes can both be done in aerated water. However, the most prompt and uniform pregermination is accomplished when stratification is done before and separately from pregermination. Our tests have shown that pregermination is more efficiently done when dormant seeds such as loblolly are already stratified. We do not have sufficient data at the present time to identify the optimum temperature and light regimes for this technqiue.

Pregermination can be done with equipment as simple as an aquarium tank and aerator; however, more sophisticiated and reliable equipment is now commercially available from Fluid Drilling Limited® 2/. A variety of pregermination units are available that aerate the water and maintain temperatures from near freezing to about 95°F. After germination, the development of the seeds must be arrested until it is convenient to sow them. This can be done by cooling them to near 32°F and maintaining this temperature during storage for up to 2 weeks (Currah 1978).

2/ Use of trade names does not imply endorsement by the U.S. Department of Agriculture. They are used solely to identify materials.

Sorting of pregerminated seeds.--An important part of the fluid drilling technique is separation of partially germinated from ungerminated seeds. Ungerminated seeds are removed from the seedlot with a solution of a proper specific gravity. The germinated seeds float, whereas the ungerminated ones sink. Taylor et al. (1978) developed a density sorting method using a sucrose solution of an appropriate specific gravity. Sorting of pregerminated from ungerminated seeds is particularly important in seedlots of low viability. In high quality lots, separation may not be necessary or desirable because the separation process is not completely accurate. In the example shown in figure 1, separation is only about 80 percent complete with a solution of 1.12 specific gravity. However, if the settled seeds are returned to the solution, the proportion of separation will increase.

Gel seed carrier for planting.--Pregerminated seeds should have an exposed radicle of only 2 to 3 mm in length, but even then the seeds are subject to damage. For protection, the pregerminated seeds are normally suspended in a viscous gel that is thick enough to protect them and provide a means of transporting and metering a given quantity of seeds. Fluid Drilling Limited® has a portable mixer that efficiently mixes a carrier powder and cold water to form a viscous gel. By mixing a known number of seeds into a quantity of gel, the seed density (number of seeds per planted area) can be determined by the rate of gel application.

The seed-gel mixture has generally been applied with a planter consisting of a single large holding tank and a number of peristaltic pumps, one pump per row. Each pump would extrude a quantity of gel determined by the travel speed of the planter. Using this type of apparatus, the seed density can be controlled with reasonable accuracy, but the resulting spacing of the seeds is random. Searcy and Roth (1981) have developed a prototype precision metering system that holds considerable promise for accurate spacing of pregerminated seeds.

Potential applications.--Although the use of pregerminated seeds in forest seedling production has not been reported, the application of this technique could result in cost reductions in both seedbed and containerized seedling operations. Reductions should occur in the number of cull plants and in the labor requirement for seedling production. Use of optimum germination conditions and the ability to eliminate nonviable seeds will allow maximum yield from the seedlot. Pregermination will result in earlier emergence of the seedlings and allow them to develop over a variety of temperatures, including those at which seeds may not normally germinate. This uniform seedling development should also reduce the number of cull plants due to less inter-plant competition. These benefits are being used in vegetable production and they should be further investigated for forest practices.

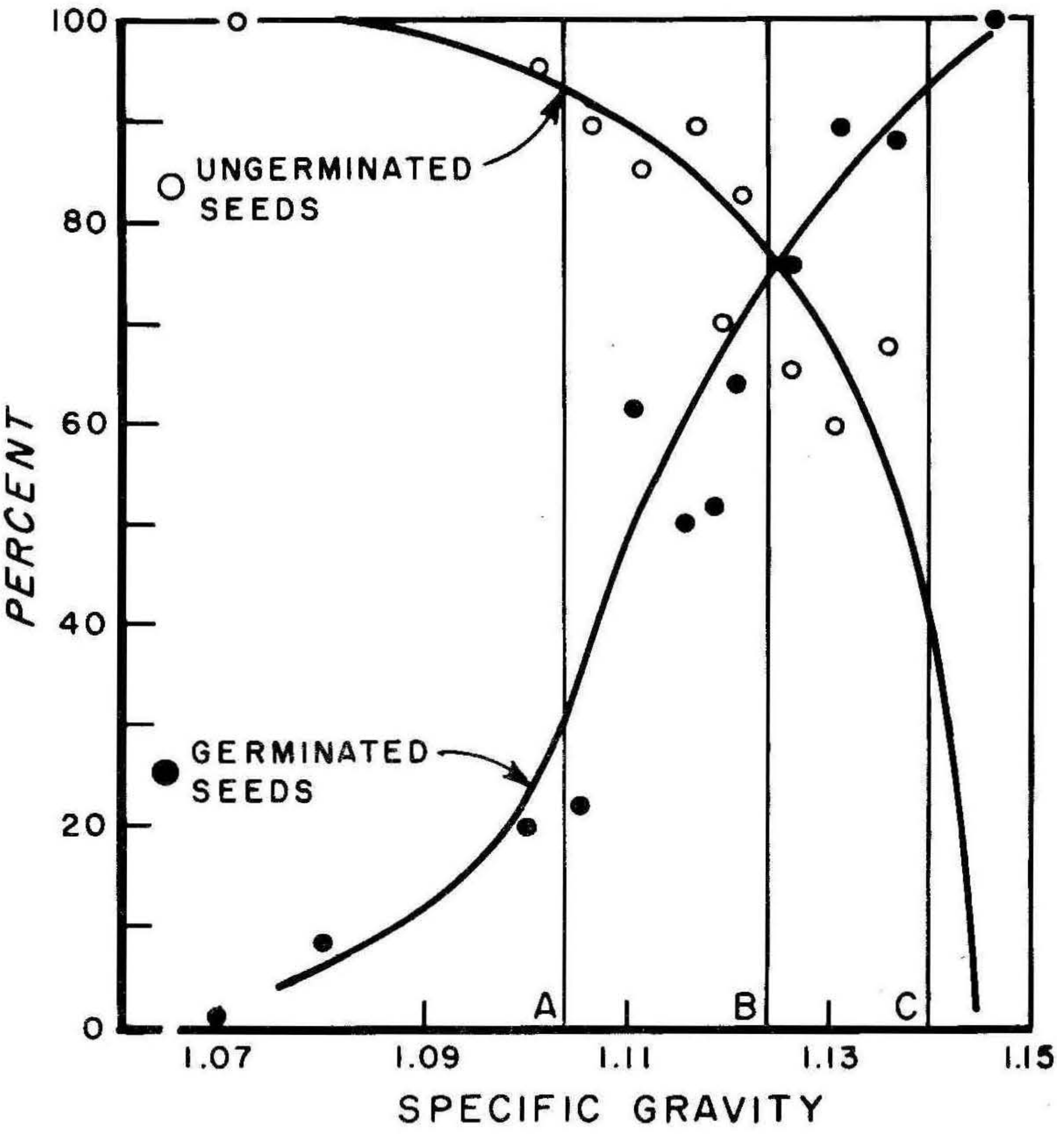


Figure 1.--Separation of germinated from ungerminated seeds by specific gravity solutions.

CURRENT WAYS TO OPTIMIZE GERMINATION

Although fluid drilling techniques offer considerable potential in maximizing seed germination and development under field conditions, some techniques are already available that merit special consideration. Lengthening the period of seed stratification can have a great influence on germination under adverse nursery conditions and can reduce the variability in seedling development that results in cull seedlings.

Stratification effects on germination.--Stratification of dormant-seeded species such as loblolly pine is necessary to obtain prompt and complete germination. The amount of stratification required by a seedlot varies by the dormancy of the species and the need for uniformity of germination. Loblolly pine is generally considered the most dormant of the southern pines and increasing lengths of stratification result in faster and more uniform germination. Normally only 30-day stratification is used with loblolly pine, but the positive response to stratification increases with 45 or 60 days of treatment (figure 2). It is also important to note that this response curve was developed under ideal laboratory conditions.

Overcoming adverse germination conditions.--Response to 30-day stratification can differ greatly when evaluation is under less than the optimum conditions of the testing laboratory. McLemore (1969) evaluated the effects of long periods of stratification under simulated field conditions and under standard laboratory conditions. Longer periods of stratification were required to obtain prompt and complete germination of loblolly pine seeds under less optimum conditions (table 1). Thirty days of stratification resulted in slow and incomplete germination under conditions of lower temperature and shorter photoperiods. Lengthening seed stratification periods will greatly improve the completeness and uniformity of germination in nursery beds during early spring and later at higher temperatures (Barnett 1979). Stratification becomes very important in environments where temperature and other stresses cannot be controlled. Recent research indicates that with stratification, pine seeds can withstand fluctuating exposures to temperature extremes (>85°F) without adverse effect (Dunlap and Barnett 1982a). It is also interesting to note that differences in germination and seedling development due to variations in size can be lessened by increasing the length of stratification (Dunlap and Barnett 1982b). The larger seeds of a lot are generally less dormant than those of the small and medium size classes.

Species requirements.--The need for stratification varies with species, primarily because of the different levels of dormancy among species (Barnett 1976). Shortleaf and slash pines are less dormant than loblolly but may also benefit from stratification for 30 days. Longleaf usually germinates well without treatment.

Not only does the need for stratification vary by species, but it also differs from one seedlot to another. To confuse matters even more, dormancy of a particular seedlot may increase in storage (Barnett and McGilvray 1971). However, there are tests to determine if and how much stratification is needed for a particular lot of seed.

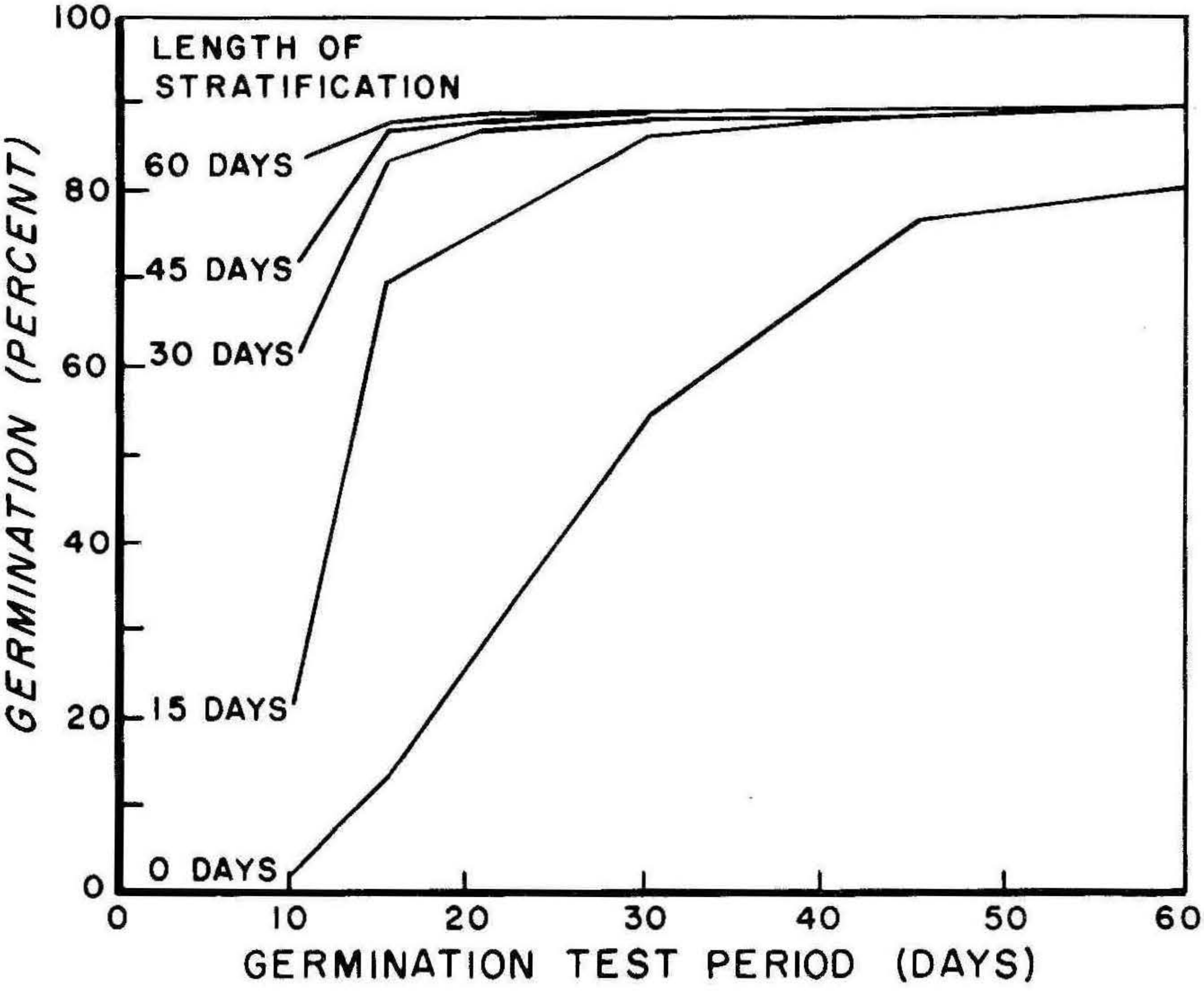


Figure 2.--Benefits of cold stratification for speeding germination of loblolly pine (*Pinus taeda*). Adapted from McLemore and Czabator (1961).

Table 1.--Effect of length and method of stratification in two testing environments a/

Days of stratification	Stratified in refrigerator at 34°F: Germination percent	Germination value	Stratified outdoors: Germination percent	Germination value
	Tested at 60°F with 11-hour photoperiod			
0	< 1	0.0	< 1	0.0
30	68	7.1	59	6.0
60	95	17.3	91	11.4
113	99	24.0	98	19.6
	Tested at 72°F with 16-hour photoperiod			
0	96	20.8	96	20.8
30	99	37.6	98	41.8
60	99	47.1	99	47.0
113	100	50.3	99	56.3

a/ Adapted from McLemore (1969). Germination values represent the speed as well as completeness of germination (Czabator 1962).

Comparative tests.--The easiest way to establish the response of a seedlot to stratification is by comparative germination tests. It is highly desirable to test seed, both before and after stratification, for different lengths of time. For example, loblolly and shortleaf seeds should be tested with and without stratification for both 30 and 60 days. Slash seeds should require testing only with and without 30-day stratification. Since the testing will be done under nearly optimal conditions, you may not note appreciable differences in response between 30 and 60 days of stratification. However, go with the longer period of stratification unless it is detrimental to viability; your nursery performance will improve greatly. Stratification may adversely affect germination of some lots, particularly weak ones; therefore the comparative tests are helpful for evaluation of treatment responses.

SUMMARY

Fluid drilling techniques, developed for vegetable crops, offer the potential for improving seed and seedling performance in nurseries. Seeds go through a pregermination step and ungerminated ones are removed. The germinated seeds can then be drilled on the nursery bed through a seed-gel mixture. These techniques are still under development for forest seeds.

Proven techniques to improve seed performance include stratification. Lengthening the period of stratification from 30 to 60 days can greatly speed germination, make it very uniform, and therefore reduce the inter-seedling competition that increases the proportion of cull seedlings. Nurserymen and others that use seed should establish the responses of individual seedlots to stratification by use of comparative germination tests. Test seeds both with and without stratification for different lengths of time. Use the longer periods of stratification unless they are detrimental to germination, and your performance in nurseries will greatly improve.

LITERATURE CITED

Barnett, J. P. 1971. Aerated water soaks stimulate germination of southern pine seeds. USDA Forest Serv. Res. Pap. SO-67, 9 p. Southern Forest Experiment Station, New Orleans, LA.

Barnett, J. P. 1976. Delayed germination of southern pine seeds related to seed coat constraint. Can. J. For. Res. 6: 504-510.

Barnett, J. P. 1979. Germination temperatures for container culture of southern pines. Southern J. Appl. For. 3: 13-14.

Barnett, J. P. and J. M. McGilvray. 1971. Stratification of shortleaf pine seeds. Tree Plant. Notes 22(3): 19-21.

Currah, Ian E. 1978. Fluid drilling. World Crops and Livestock 30(1): 22-24.

Currah, I. E., D. Gray, and T. H. Thomas. 1974. The sowing of germinated vegetable seeds using a fluid drill. Ann. Appl. Biol. 76: 311-318.

Czabator, F. J. 1962. Germination value: an index combining both speed and completeness of pine seed germination. For. Sci. 8: 386-396.

Dunlap, J. R. and J. P. Barnett. 1982a. Germination characteristics of southern pine as influenced by temperature. In: Guldin, Richard W. and James P. Barnett, eds. Proceedings of the Southern Containerized Forest Tree Seedling Conference; August 25-27, 1981; Savannah, GA., p. 33-36; USDA, Forest Serv., Southern Forest Experiment Station, New Orleans, LA.

Dunlap, J. R. and J. P. Barnett. 1982b. Influence of seed size on germination and early development of loblolly pine (Pinus taeda L.) germinants. Canadian J. Forest Research. (In press)

McLemore, B. F. 1969. Long stratification hastens germination of loblolly pine seed at low temperatures. J. Forestry 67: 419-420.

McLemore, B. F. and F. J. Czabator. 1961. Length of stratification and germination of loblolly pine seed. J. Forestry 59: 267-269.

Searcy, Stephen W. and Lawrence O. Roth. 1981. Precision metering and planting of pregerminated seeds for seedling production. In: Forest Regeneration, p. 46-52. Proceedings, American Society Agric. Eng. Symp. on Engineering Systems for Forest Regeneration, Raleigh, NC. March 2-6, 1981.

Taylor, A. G., J. E. Motes, and H. C. Price. 1978. Separating germinated from ungerminated seed by specific gravity. HortScience 13(4): 481-482.

MEASURING SOUTHERN PINE SEED QUALITY WITH A CONDUCTIVITY METER--DOES IT WORK?

F. T. Bonner and J. A. Vozzo[1]

Abstract.--Preliminary tests of an ASA-610 Automatic Seed Analyzer from Agro Sciences, Inc. with five species of southern pines indicate that valid estimates of seed quality are possible from leachate conductivity measurements. Several factors which influence the results are discussed. Studies still in progress are expected to bring measurement errors to within acceptable limits.

Additional keywords: Germination, seed tests, loblolly pine, slash pine

Of all the methods proposed to measure seed quality in recent years, one has become the basis for commercial development of equipment to do the job. The machine used in this process is the ASA-610 Automatic Seed Analyzer, developed and marketed by Agro Sciences, Inc. of Ann Arbor, Michigan.[2] This machine measures the electrical conductivity of water in which a seed has been soaked. The amount of current passing through the soak solution is influenced by the amount of solutes leaching from the seed, which, in turn, is theoretically related to the vigor of that seed as a function of membrane integrity. This is a non-destructive test, and the seeds can be subsequently germinated or dried for storage.

It is assumed that as a seed deteriorates, its membranes break down and allow the leaching of internal substances. Murphy and Noland (1982) found that heat-killed embryos of sugar pine had higher rates of solute leakage than did viable ones, and Pitel (1982) demonstrated that increasing periods of accelerated aging of jack pine seeds resulted in increased conductivity of the soak water. Hocking and Etter (1969) reported a close correlation between germination of white spruce and the sugar concentration in seed leachate. The relationship of leached solutes and field emergence was first demonstrated for peas in 1968 (Matthews and Whitbread 1968). Later research has supported the principle, and the International Seed Testing Association has included an electrical conductivity test in its Handbook of Vigor Test Methods (ISTA 1981).

The first machine marketed by Agro Sciences to measure seed quality used a forcep-type electrode system which measured current passing through a single seed. The ASA-610 now on the market has a multiple-electrode plate which fits onto a tray with 100 uniform compartments for soaking the seed sample (usually one seed per compartment). When the plate is placed on the tray, the

---

1/ Supervisory Plant Physiologist and Research Plant Physiologist, Southern Forest Experiment Station, Forestry Sciences Laboratory, Starkville, Miss.

2/ Mention of a trademark, proprietary product or vendor does not constitute a guarantee or warranty of the product by the U. S. Forest Service and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

electrode pairs are immersed in the soak solutions. The ASA-610 then measures the individual current levels in 100 seed compartments simultaneously.

This new model has shown great promise with agricultural seeds (McDonald and Wilson 1979). The potential value of such a method for quick estimates of the seed quality is enormous. An ASA-610 was acquired for the Forestry Sciences Laboratory in 1981, and tests were begun on southern pine seeds.

MATERIALS AND METHODS

The basic approach to evaluation of the ASA-610 was to draw samples from a wide variety of seed lots, take conductivity readings, and then germinate these same seeds in the laboratory. Seed lots over a wide range of ages (collected 1967 to 1981) from throughout much of the native range of the species were used. Tests were carried out on 25 lots of loblolly, 25 of slash, 6 of shortleaf, 7 of longleaf, and 4 of eastern white pine.

Several factors influence the current readings in the solutions: (1) amount of soaking time, (2) temperature of the solution, (3) water level in the measurement cells (seed:water ratio), and (4) initial seed moisture content. After extensive preliminary testing, the following conditions were selected for standardization of measurement technique:

(1) soaking time - 48 hours
(2) solution temperature - 25 ± 1°C (laboratory temperature)
(3) water level - cells uniformly full (4 ml deionized water)
(4) initial seed moisture content - 10 to 12% or lower (only dry seed lots from storage were used).

There were two approaches to evaluation:

(A) Individual Seed Response - Conductivity measurements for individual seeds were related to the number of days required for germination of those seeds. Conductivity measurements were taken on two samples per lot. These seeds were then germinated in cabinet germinators set for the standard 20°/30°C alternating regime (AOSA 1981). Leachate conductivities were recorded on tape, and seed identities were maintained during the germination tests. Simple correlation coefficients were calculated.

(B) Entire Sample Response - As in germination testing, response of a suitable sample is more likely to reflect the condition of the population as a whole than are measurements on individual seeds. One approach suggested by the manufacturer is to set a threshold value of cell conductivity. These values are called "partition values," and they theoretically separate live and dead seeds. Partition values usually vary among species and must be chosen empirically. By plotting the frequency distribution of individual seed conductivities and comparing these data to germination results, trial partition values were chosen. In subsequent tests, the meter was set on these partition values, and the readout gave the number of seeds whose conductivity was lower than the partition value.

In addition to partition value estimates, mean conductivity of the 100-seed samples and the standard deviation about the mean (a measure of uniformity) were related to the germination response of the samples from each lot by linear regression. Germination tests were done in accordance with the rules of the Association of Official Seed Analysts, which establishes standard seed testing procedures (AOSA 1981).

RESULTS

(A) Individual Seed Response - This approach proved fruitless. The scatter of a typical sample (figure 1) shows the poor relationship between leachate conductivity and speed of germination. All correlation coefficients were extremely low and non-significant at the 5 percent level.

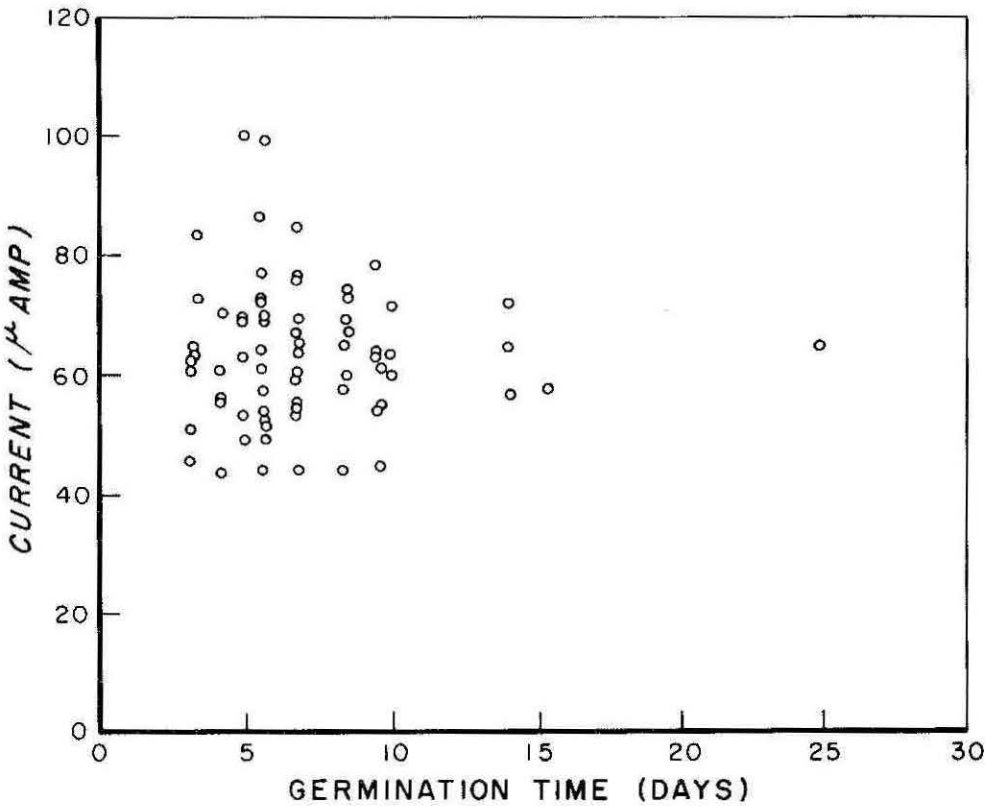


Figure 1.--Relationship of leachate conductivity and the number of days until germination for individual seeds of slash pine.

(B) Sample Response - For loblolly and slash pines, conductivity readings (mean of duplicate samples of 100) were significantly correlated with laboratory germination. The relationship was much stronger in slash, where an r value of -0.8939 was obtained for laboratory germination and mean conductivity (figure 2). This same comparison gave an r value of -0.6502 for loblolly (figure 3).

For shortleaf, longleaf, and eastern white pines, too few lots were available to make these analyses, but a summary of the data suggests that a similar relationship may exist (table 1).

Graphic analysis of the data was used to pick the most likely partition values for loblolly and slash pines. Rearrangement of the germination data in descending order facilitates this comparison (table 2). It can be quickly

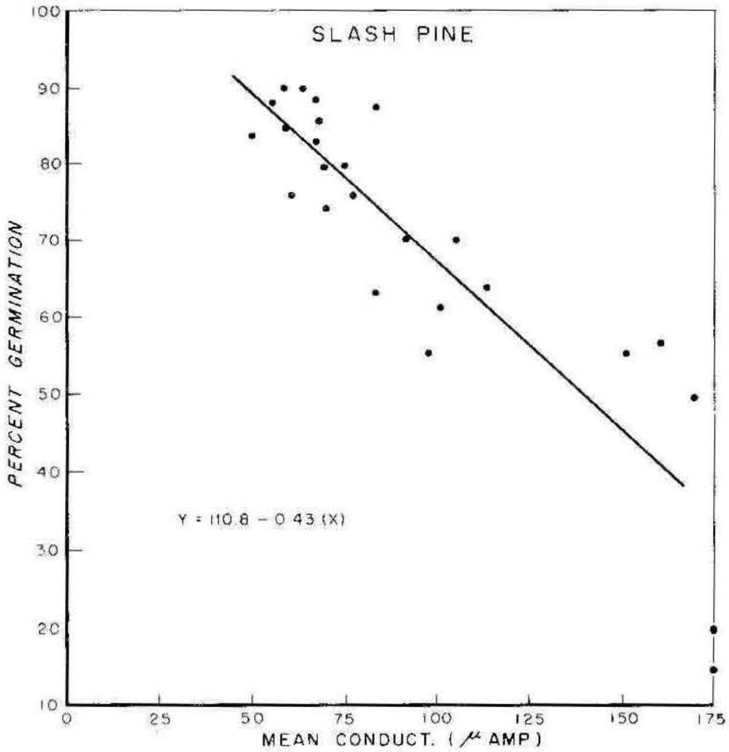


Figure 2.--Relationship of laboratory germination to mean leachate conductivity for 25 lots of slash pine. Each value is the mean of two replicates.

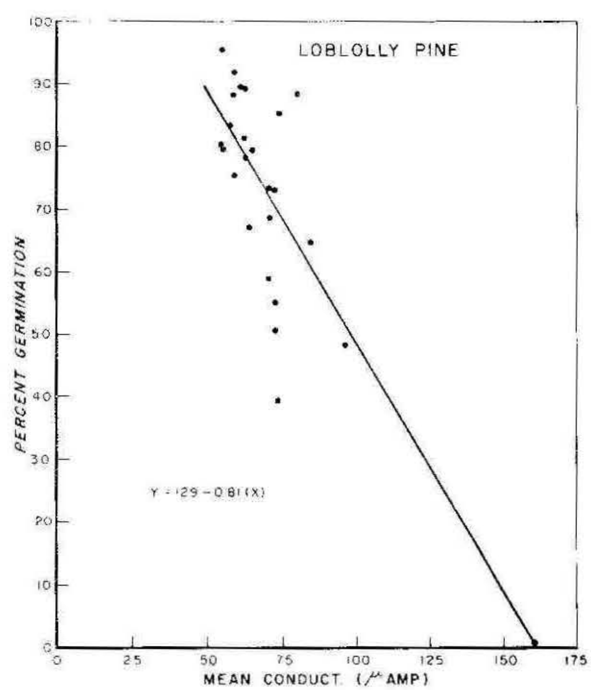


Figure 3.--Relationship of laboratory germination to mean leachate conductivity for 25 lots of loblolly pine. Each value is the mean of two replications.

Table 1. Relationship of laboratory germination to conductivity of seed leachate for three pine species. Each value is the mean of two replications

	Laboratory germination	Mean conductivity	Standard deviation of conductivity
	percent	microamp	microamp
Shortleaf	70	43.1	22.1
	68	44.4	18.4
	63	48.0	20.8
	44	43.2	13.3
	4	43.2	9.4
	2	43.2	7.8
Longleaf	84	101.4	95.6
	68	93.4	95.6
	68	103.5	99.3
	58	153.0	134.8
	38	156.5	127.6
	18	220.0	160.2
	10	355.0	203.6
Eastern white	44	59.6	45.5
	34	72.0	49.6
	18	56.6	34.0
	10	132.8	70.2

seen that the ASA-610 did a better job of predicting slash than loblolly germination. Loblolly germination was overestimated, particularly in the poorer lots. The loblolly seeds were not stratified prior to germination testing, however, and this fact may have contributed to the overestimation.

To test the choice of partition values for these two species, the measurements were reported on 25 lots of each. Of the 25, 13 lots of loblolly and 20 lots of slash were repeaters from the first test. This time the loblolly received 28 days of stratification at 3°C between conductivity measurements and germination. Four samples of 100 seeds each from 50 lots (loblolly and slash) were also planted in randomly-placed rows in the Forestry Sciences Laboratory experimental nursery in a vigor evaluation test which purposely creates stressful conditions. Emergence was counted weekly for 6 weeks.

Results of this second test supported those of the first, and this time loblolly performance was much better correlated with the conductivity measurements. As before, however, germination of the best loblolly lots was slightly underestimated, while that of the poorer lots was overestimated (table 3). The same condition existed with the slash lots, but to a lesser degree (table 4). Simple correlation coefficients between nursery emergence at 6 weeks and

Table 2. Laboratory germination and germination predicted by the ASA-610 for 25 lots each of loblolly and slash pines. Each value is the mean of two replications

Loblolly		Slash	
Laboratory germination	Predicted by ASA-610[a/]	Laboratory germination	Predicted by ASA-610[b/]
	percent		
89	96	91	90
86	97	90	92
75	94	88	92
74	78	88	98
72	61	87	71
68	84	86	90
68	68	85	94
66	73	84	97
59	81	83	86
56	74	80	74
56	58	79	88
54	73	76	88
54	69	76	74
51	58	74	89
48	92	71	82
44	77	70	61
41	82	64	74
38	66	64	49
32	84	62	66
18	77	57	24
16	96	56	72
16	67	56	38
2	18	50	52
1	12	20	22
0.5	2	14	21
Mean			
47	69	70	71

a/ Partition value = 70.
b/ Partition value = 80.

mean conductivity of seed leachates was -0.6390 for loblolly and -0.6576 for slash (both significant at the 5 percent level). Correlation coefficients between laboratory germination and mean conductivity were also significant: -0.8197 for loblolly and -0.8497 for slash. The higher coefficients for laboratory germination were not surprising, as additional environmental factors which can inhibit germination abound in nursery beds.

Table 3.--Laboratory germination, germination predicted by the ASA-610, and nursery emergence at 6 weeks for 25 lots of loblolly pine.

Loblolly		
Laboratory germination	Predicted by ASA-610[a/]	Nursery emergence @ 6 weeks
-------------------------------	percent	-------------------------------
96	86	57
92	85	60
88	68	60
88	84	56
88	78	57
88	40	49
85	62	46
84	86	43
80	88	59
80	88	38
79	64	48
78	82	47
75	87	56
74	73	28
74	62	45
68	76	42
67	72	46
66	42	45
63	44	32
58	68	32
56	52	13
52	73	27
49	46	22
39	55	18
1	12	1

a/ Partition value = 70.

At this stage of the work, the following conclusions seem reasonable:

(1) The principle of the method is biologically valid, and significant correlations between seed quality and leachate conductivity can be shown.

(2) With the methods of measurement used so far, variation is still large. Experiments are underway to solve this problem by studying such factors as:

(a) soaking time - less than 48 hours may be sufficient.

(b) amount of seed - with one seed per cell there seems to be better correlation as seed size increases (shortleaf < loblolly < white < slash < longleaf).

Table 4.--Laboratory germination, germination predicted by the ASA-610, and nursery emergence at 6 weeks for 25 lots of slash pine

Slash		
Laboratory germination	Predicted by ASA-610[a]	Nursery emergence @ 6 weeks
	----percent----	
90	94	41
89	82	52
86	94	39
85	98	44
85	89	38
84	96	34
79	80	46
78	86	41
78	82	43
74	91	41
70	84	32
70	93	35
69	84	57
69	84	29
66	84	37
65	74	28
65	80	39
64	84	30
63	88	34
62	58	30
61	90	38
57	38	29
48	68	27
42	36	26
36	42	16

a/ Partition value = 80.

(c) cleanliness of seed - dirty seed lots give more variation - a standard preliminary wash may help.
(d) agitation during leaching - this could easily be standardized and perhaps cut down on test time.
(e) temperature during leaching - higher temperatures might speed the measurement time.
(f) pretreatments - stratification or chemical treatments should be studied.

(3) Leachate conductivity measurements will probably never match the precision of germination tests, but there is a great deal of interest in a reliable measure of seed quality that can give results within 24 hours without the subjectivity of X-ray or tetrazolium tests.

LITERATURE CITED

Association of Official Seed Analysts. 1981. Rules for testing seeds. J. Seed Technol. 6(2): 1-126.

Hocking, D. and H. M. Etter. 1969. Rapid germinability test for white spruce. Can. J. Plant Sci. 49: 527-528.

International Seed Testing Association. 1981. Handbook of vigour test methods. D. A. Perry, ed. Int. Seed Test. Assoc. Zurich. 72 p.

McDonald, M. B., Jr. and D. O. Wilson. 1979. An assessment of the standardization and ability of the ASA-610 to rapidly predict potential soybean germination. J. Seed Technol. 4(2): 1-11.

Matthews, S. and R. Whitbread. 1968. Factors affecting pre-emergence mortality in peas. I. An association between seed exudates and the incidence of pre-emergence mortality in wrinkle-seeded peas. Plant Path. 17: 11-17.

Murphy, J. B. and T. L. Noland. 1982. Temperature effects on seed imbibition and leakage mediated by viscosity and membranes. Plant Physiol. 69: 428-431.

Pitel, J. A. 1982. Accelerated aging studies of seeds of jack pine (*Pinus barksiana* Lamb.) and red oak (*Quercus rubra* L.). p. 40-54. *In*: *Proc. Int. Symp.* on Forest Tree Seed Storage. Chalk River, Ontario, Canada, Sept. 23-27, 1980. IUFRO Working Party S201.06 and Canad. For. Serv.

EXPANDED LABORATORY FACILITIES

Robert P. Karrfalt and Oscar Hall[1]

Abstract

Changes that have occurred in the operation and physical facilities at the National Tree Seed Laboratory are presented.

Additional Key Words: Laboratory, Changes, Facilities

INTRODUCTION

Several major changes have recently occurred at the National Tree Seed Laboratory. Almost no area of the Laboratory is unaffected. Changes will lead to higher efficiency in the Laboratory services to the users.

PHYSICAL FACILITIES

Physical facilities have been modernized and expanded. The square footage increased 50 percent, which provides space for training and more efficient flow of work. With the doubling and tripling of the workload in recent years, the expanded work space is an asset to the Lab. Specific improvements include new lighting in all germination rooms; a new chilling unit for germination rooms; modernization of vacuum seed counting system; and construction of separate rooms for purity testing and quick tests. These improvements permit us to maintain the highest standards of testing accuracy, at the lowest possible cost.

---

[1] The authors are, respectively, Seed Processing Specialist and Seed Testing Specialist, USDA Forest Service, National Tree Seed Laboratory, Route 1, Box 182-B, Dry Branch, GA 31020.

Other important additions include a conference room where training sessions (coordinated through the Nursery and Tree Improvement Specialists) can be held for approximately 20 people, and a seed processing room where working demonstrations are set up for training. The seed processing room also aids us in quickly obtaining answers to questions on processing procedures or equipment. All physical plant improvements were completed and in use by October 1, 1982.

ORGANIZATION AND PERSONNEL

Personnel changes include: a business manager who handles all business functions, including verifying payment of seed testing bills of collection, thereby freeing technical specialists to concentrate on offering the best in seed testing, seed processing and training services.

On July 1, 1982, the Forest Service and the Georgia Forestry Commission mutually agreed to terminate their 29-year-old agreement on service testing. Since that date, only Forest Service employees have been employed at the Lab.

Beginning October 1, 1982, seed testing charges were invoiced on USDA Forest Service Bill of Collection, and the money collected by the Federal government.

Establishing a new mail box changed our address to: Route 1, Box 182-B; Dry Branch, GA 31020.

SERVICES

A microcomputer is now in place at the Lab, and is used extensively for various computations, technical and administrative reports. This equipment frees our technician to provide more attention to the actual tests rather than the laborious jobs of manual calculations. Future computer application will lead us to automated generation of test results, rapid response to telephone inquiries for early test results, or possibly direct telecommunication of test results from the Lab's computer to the nursery's computer.

Becoming a totally Federal Lab has cut our available labor sharply. Therefore, "RUSH" or Cone Analysis Services are not available for the 1983-84 testing season.

CHARGES

Germination test charges, unfortunately, have increased from $10 to $18 per sample and ISTA Certificates from $1.25 to $2.00, as of August 1, 1982. Charges for all other tests will remain unchanged. Increasing costs of crepe cellulose paper, salaries, and electricity necessitated these changes.

SUMMARY

In summary, the combined 21st and 22nd Laboratory Report was the last published report. Publication of future useful findings will be in Tree Planters' Notes, which will replace the Lab reports. We believe support to the nurserymen in the south from the National Tree Seed Laboratory will be the best possible. Earl Belcher remains Director of the Laboratory. Oscar Hall is the Seed Testing Specialist and Bob Karrfalt is the Seed Processing Specialist. Any member of this team is available for technical advice.

NET RETRIEVAL SYSTEM FOR PINE SEED COLLECTION

ROBERT E. MAJOR [1]

Abstract--Substantial savings in time and energy consumption could be achieved in seed collection operations for at least four species of pine, using equipment now being tested. When trees are shaken mechanically, the seed falls onto netting on the ground. A mechanical system for handling the netting and retrieving the seeds is described.

The basic principles for the net retrieval system of pine seed collection have been developed by the Georgia Forestry Commission over the past 10 to 12 years. About 5 years ago the Missoula Equipment Development Center and the Southern Region of the Forest Service began working with the Georgia Forestry Commission on a mechanized seed collection system. MEDC designed and built a prototype net retrieval and seed separation machine which was tested by the Georgia Forestry Commission and the Forest Service over the past two seasons at Georgia's Arrowhead Seed Orchard. The prototype has been modified and two additional units were fabricated in 1982 (figure 1). The units will be assigned to three Forest Service orchards: (Erambert in Mississippi; Stuart in Louisiana; Francis Marion & Sumter in South Carolina).

The net used in the system is a polypropylene fabric originally manufactured as carpet backing. A weave count of 6X8 per square inch is used to collect loblolly pine seeds. Other weave counts are available and can be used depending upon the size of seed to be collected. The net is spread over the orchard floor several weeks before cone opening is predicted. The Georgia Forestry Commission tried several types of material before choosing the carpet fabric. This netting is tough, light weight, durable, and readily available in various lengths, widths and weave counts. In 1982, the fabric cost about $1,354 per acre, or $1.55 per linear yard, for the 6X8 weave count, 16.5 feet wide. Expected life of the fabric is 10+ years if it is not mistreated. A special boom crane mounted on a 20-foot trailer has been built to move the netting rolls between a storage area and the field operation.

The power requirements to operate the net retrieval and seed separation equipment are less than 30 brake horsepower. This power is derived from a wheeled tractor's PTO shaft operating at 1000 RPM. This tractor is also used to transport the units in and to the fields. The PTO shaft drives a hydraulic pump and a 116 volt AC generator which supplies the necessary hydraulic pressure and electric energy to operate and provide controls for machinery. In some instances a speed increaser is required to increase the PTO RPM from 540 to 1000.

1/ USDA Forest Service, Southern Region, Atlanta, Georgia

An operator's station, with controls and gauges, is located at the rear of the retrieval vehicle. From this location, all machine functions can be controlled except the lowering of the full rolls of netting. This activity is controlled at a separate location adjacent to the roll drive mechanism.

When the equipment is towed, the tongue of the seed separator trailer hydraulically extends to allow proper tracking and turning clearance. To ensure the adequate delivery from the main conveyor to the seed separator unit, the tongue must be hydraulically retracted, positioning the main conveyor in the seed separator hopper.

EQUIPMENT OPERATION

Optimum seed fall in the South usually occurs in late October, November and early December, depending upon the weather. As weather fronts move through the area, humidity will rise for a day or two. After the front passes, several cool, dry and usually sunny days will produce good collecting conditions. The trees are then shaken mechanically, causing the seed to fall onto the net. Each tree is subjected to several short bursts of shaker power. Shaking dislodges far more from the tree than seed, i.e., pine straw, twigs, and cones. Thus, the need for a field seed separator device.

The net is placed in the orchard several weeks before seed fall; during this period its black color tends to collect heat and keeps the soil surface warm. This greenhouse effect stimulates growth of grass to the extent that the machine may not always produce enough pulling force to free the net from the grass. This potential problem varies with the type of grass growing in the various orchards. Force applied vertically tends to separate the grass and netting. This activity is probably the most labor-intensive procedure in the entire operation.

Once the net is separated from the grass, it is attached to the core on the net retrieval machine and rolled up. Hydraulically-powered hubs at each end of an aluminum core apply uniform power to wind the net from the orchard floor onto approximately 200-pound rolls. The net is pulled over an upper guide roller, which dumps the seeds and other material off the net onto the retrieval machine's main belt conveyor. From here they are conveyed into the receiving hopper of the seed separator. As the material passes through the separator, seed and small trash drop through the shakers and screens into seed collection drawers.

The shaking action moves the material, other than seed, to the back of the unit where it can be discharged to either side of the machine by a reversible conveyor belt. The seed is drawn out of the collection drawers by a vacuum system attached to a plastic drum. The drum container is then shipped to the cleaning and storage area where further processing of the seed takes place.

The net in the orchard alley is placed perpendicular to the row netting and is processed last. This step ensures pickup of any seed which may have been spilled during processing of the individual rows. The netting is very durable and can withstand vehicular traffic if a few precautions are observed.

SEED COLLECTION IN THE SOUTHERN REGION

The Forest Service's Southern Region has 230 acres of loblolly pine, 555 acres of shortleaf pine, 50 acres of Virginia pine, and 64 acres of white pine in orchards. Seeds of these pine species are considered difficult to collect because the cone is not easily removed from the tree branch. The seed from a large portion of these orchards can be collected using the net retrieval system. This system offers the same potential advantages to many other seed orchards of State agencies and private firms growing these species.

At present, seed collection is very labor-intensive because the cones must be picked one at a time by hand, using some type of man elevator, platform, bucket-truck, etc. The expense, both in time and energy consumption, of shipping large amounts of cones to a central seed kiln and seed processing plant, and the expense of operating the seed kiln, can be very high. In contrast, shipping only seed to a central location, and eliminating the need for a seed kiln can achieve substantial savings for the entire seed orchard operation. The overall objectives of the net retrieval system were to make this difficult job easier by managing the time of collection, rather than letting nature set the time to manually collect cones. Bringing the seed to the collector, rather than taking a collector to the seed accomplishes more with less personnel.

For additional information, drawings and specifications contact Bob Major, USDA Forest Service, 1720 Peachtree Road, N.W., Rm. 720, Atlanta, Georgia 30367, FTS 257-3748, commercial phone (404) 881-3748.

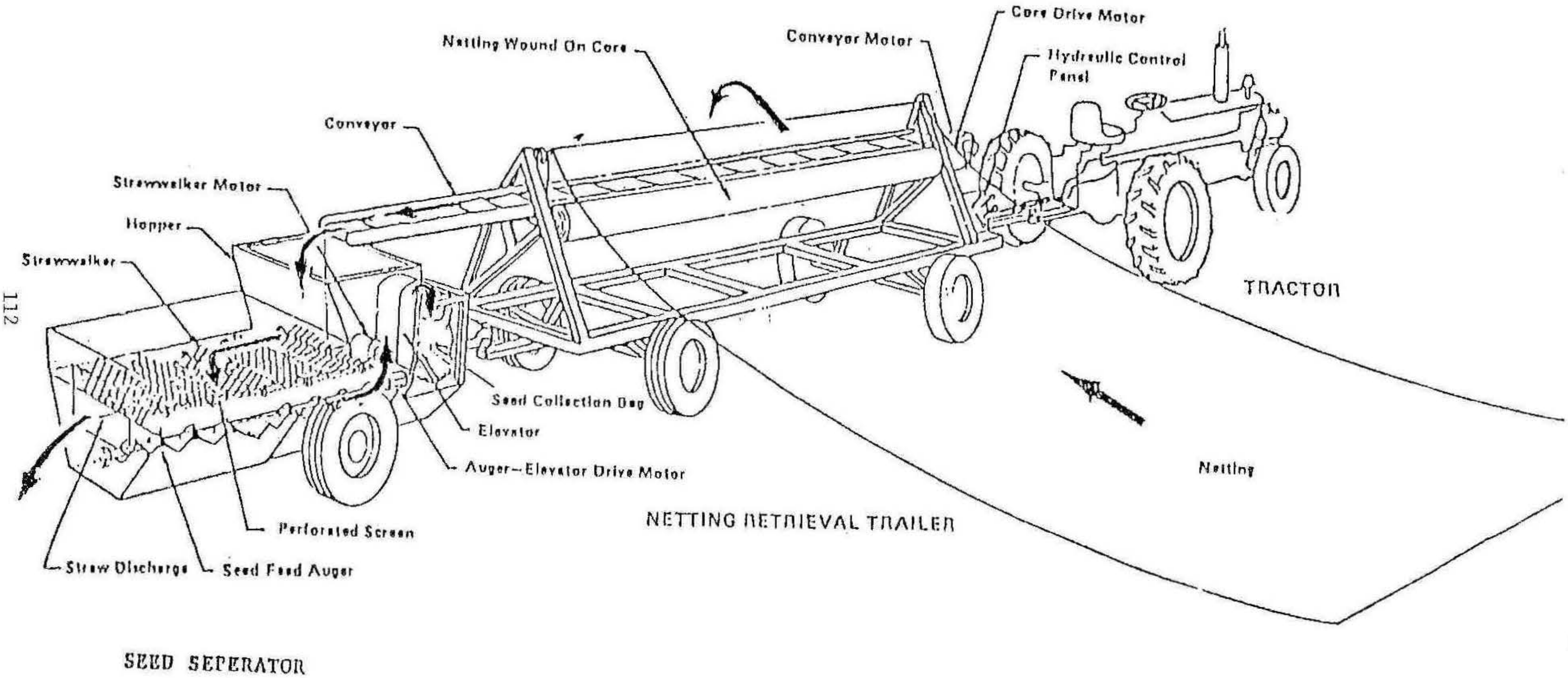


Figure 1. Net retrieval system.

SEWAGE SLUDGE AS AN ORGANIC SOIL AMENDMENT FOR GROWTH OF LOBLOLLY PINE SEEDLINGS

Charles R. Berry[1]

Abstract.--Different amounts of sewage sludge from Norman, Oklahoma and Athens, Georgia, and inorganic fertilizer were compared as soil amendments for growing loblolly pine seedlings in pots. Norman sludge contained higher concentrations of major plant nutrients than Athens sludge, but also contained higher concentrations of the undesirable elements sodium and cadmium. Seedlings grew as well in Athens sludge at 15 tons/acre as in 500 lbs/acre of 10-10-10 fertilizer. Significantly larger seedlings, however, were produced when the rate of Athens sludge application was 30 tons/acre rather than 15 tons/acre. Seedlings grew significantly larger and heavier with 15 tons/acre of Norman sludge than with 30 tons/acre of Athens sludge. Seedlings also grew larger in 15 tons/acre than they did in 30 tons/acre of Norman sludge. These data indicate that Norman sludge is an excellent soil amendment at a rate of application of about 15 tons/acre. Above this rate however, some other factor, or factors interfere with pine seedling growth.

Additional keywords: Cadmium, sodium, nutrients, *Pinus taeda*.

A comprehensive discussion of the functions and maintenance of organic matter in forest nursery soils was recently presented by Davey and Krause (1980). Although sewage sludge can supply organic matter as well as nutrients to nursery soils, many sludges contain heavy metals, excessive amounts of salts, and high concentrations of sodium that are potentially harmful to seedling growth (Bickelhaupt 1980). Favorable results were obtained in Florida where sewage sludge produced larger slash pine seedlings than the standard nursery fertilizer applications (Berry 1981). Screened compost (sewage sludge composted with wood chips) has been used successfully for production of high quality hardwood seedlings in Maryland (Gouin and Walker 1977, Gouin and others 1978).

This pot experiment was carried out in Athens, Georgia to compare the effects of sewage sludge from Norman, Oklahoma and Athens, Georgia on growth of loblolly pine seedlings as a preliminary test of the suitability of Norman sludge for use in forest nurseries.

MATERIALS AND METHODS

Batches of dried sewage sludge from Norman, Oklahoma and Athens, Georgia were mixed with a basic soil-mix (2:1:1, forest clay loam:sand:milled pine bark) at rates of 15 and 30 tons/acre. Athens sludge had been stockpiled out of doors for 1 year before use. Control pots received 500 lbs/acre of 10-10-10 fertilizer. Before amendments were added, the soil mix was chemically analyzed after extraction with a double acid solution (0.05 N HCl + 0.025 N (H_2SO_4). Phosphorus was determined colorimetrically and cations by atomic absorption spectroscopy. Total N was determined by Kjeldahl, organic matter by wet oxidation chromic acid digestion, and pH by glass electrode in a mixture of 2 parts water in 1 part soil (v:v).

[1]Plant Pathologist, Institute for Mycorrhizal Research and Development, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, Georgia.

Soil analyses are as follows:

Elements	ppm	Elements	ppm
N	330.0	Na	7.3
P	13.6	Fe	45.3
K	68.0	Cu	2.7
Ca	189.4	Zn	7.7
Mg	30.0	Cd	0.03
Mn	114.6		

The soil had a pH of 5.2, organic matter was 2.3 percent, and a mechanical analysis of 83:7:10 (sand:silt:clay). Soil analyses were performed by C. G. Wells, USDA Forest Service, Forestry Sciences Laboratory, Research Triangle Park, North Carolina.

Sewage sludge analyses were carried out as follows: Total N by Kjeldahl, organic matter by gravimetric analysis after ashing at 500°C for 4 hours, and P and cations by extraction with concentrated HNO_3 followed by plasma emission spectroscopy (Table 1).

Table 1.--Comparison of sewage sludges from Norman, Oklahoma and Athens, Georgia[1]

N	P	K	Ca	Mg	Mn	Fe	OM	Na	Cu	Zn	Cd
%								ppm			
Norman, Oklahoma											
2.24	1.79	0.07	2.1	0.38	0.012	0.43	45	436	164	793	22
Athens, Georgia											
1.50	0.45	0.01	0.4	0.02	0.004	0.38	50	10	110	418	4

[1]Sewage sludge analyses were performed by the Institute of Ecology and the Laboratory for Soil and Plant Analysis, University of Georgia, Athens.

The soil mix, with amendments added, was placed in six-inch black plastic pots. Stratified loblolly pine seed, obtained from the Norman nursery, were germinated in flats of moist vermiculite and transplanted three to a pot in mid-July. After survival was assured the two smallest seedlings were cut from each pot. Five pots for each of the five treatments were then placed in each of five replicate blocks in a lath house. All pots were watered to saturation two or three times a week as needed. In January seedlings were carefully removed from each pot, separated from the growing medium and growth data were recorded.

RESULTS AND DISCUSSION

Athens sludge, at the lowest rate used (15 tons/acre) induced about the same rate of growth of loblolly pine seedlings as a single pre-plant application of 10-10-10 fertilizer, equal to 500 lbs/acre (Table 2). Seedlings in pots with fertilizer or with 15 tons/acre of Athens sludge were small and had signs of nitrogen deficiency. Athens sludge at 30 tons/acre, however, permitted growth of slightly larger and heavier seedlings which, though of only medium size, did not display signs of nutrient deficiencies.

The 15 tons/acre rate of Norman sludge stimulated more seedling growth than 30 tons/acre of Athens sludge, reflecting the higher concentrations of nutrients in the Norman sludge. Increasing the rate of application of Norman sludge to 30 tons/acre, however, did not cause the seedlings to grow faster; instead they were smaller, did not weigh as much and displayed some foliar chlorosis (indicating a nutrient deficiency, nutrient imbalance, or microelement toxicity) compared to seedlings in pots amended with 15 tons/acre. The possibility of toxicity caused by the high concentration of sodium in the Norman sludge (60 times more than the Athens sludge) needs further study.

Table 2.--Effects of dried sewage sludge on loblolly pine seedlings in pots[1]

Treatment	Stem height (cm)	Stem diameter (mm)	Green weight (g)		
			Tops	Roots	Total
Fertilizer					
10-10-10 at 500 lbs/A	7.1cd	2.0d	0.6c	1.3b	1.8c
Athens sludge					
15 tons/A	6.2 d	1.8e	0.4c	1.1b	1.5c
30 tons/A	8.1c	3.2c	1.7b	3.2b	4.9bc
Norman sludge					
15 tons/A	13.1a	3.7a	2.8a	6.2a	9.0a
30 tons/A	11.0b	3.6b	2.5a	3.6b	6.1ab

[1]Means within a column followed by the same letter do not differ significantly at $P = 0.05$.

While cadmium is also somewhat higher in the Norman sludge, it is not regarded as a cause of reduced growth since in other work (unpublished), normal size seedlings were produced with a sludge containing 10 times more cadmium than Norman sludge.

Sewage sludge can be a worthwhile amendment that will furnish nutrients and organic matter for forest nursery soils. The amount of nutrients available, however, in sludges from different localities, or in batches of sludge of different ages from the same source may differ. In this experiment, it was found both from soil analyses and from seedling growth that the Norman sludge contained more nutrients than the Athens sludge. In later work (unpublished), it was found, however, that fresh Athens sludge contained more nutrients and induced a greater growth response of pine seedlings than Athens sludge that had been stored uncovered out of doors a year or more.

Therefore a direct comparison of chemical analyses of sewage sludge from different sources should be made only on samples fresh from the digestors, or at least stored under similar conditions for the same length of time. The primary reason for including Athens sludge in this experiment was to permit comparison of Norman sludge with a sludge of similar bulk density and organic matter content.

A small pot experiment similar in design to the one reported here is recommended as a study preliminary to applying sludge to a nursery. Since it is so difficult to duplicate field conditions, extreme caution is advised in field trials even after the completion of a pot experiment. There is a good probability that the local water supply would tend to accentuate many problems detected in sludges. In this case, Athens water is relatively low in sodium and dissolved salts and would tend to lessen the effects of these factors in Norman sludge by leaching. Norman sludge coupled with Norman water might induce worse symptoms of salt or sodium toxicity.

In summary, these data show that Norman sewage sludge has an adequate supply of nutrients to support good seedling growth for at least 1 year when applied at the 15 tons/acre rate. It appears, however that a small scale field test should precede full scale use of this sludge in order to understand better the factor or factors that limited growth of seedlings when the sludge was applied at 30 tons/acre.

LITERATURE CITED

Berry, C. R. 1981. Sewage sludge affects soil properties and growth of slash pine seedlings in a Florida nursery. p. 46-51. In: Proc. 1980 Southern Nursery Conference, Lake Barkley, Ky., Sept. 2-4, 1980. Tech. Publ. SA-TP 17, 123 p.

Bickelhaupt, D. H. 1980. Potential hazards of some organic wastes that may be used in nurseries. p. 166-173. In: Proc. North Am. Forest Tree Nursery Soils Workshop, Syracuse, N.Y., July 28-August 1, 1980. Sponsored by USDA Forest Serv., State & Private Forestry, Canadian Forestry Serv., and State Univ. of N.Y., College of Environmental Science and Forestry. 333 p.

Davey, C. B. and H. H. Krause. 1980. Functions and maintenance of organic matter in forest nursery soils. p. 130-145. In: Proc. North Am. Forest Tree Nursery Soils Workshop, Syracuse, N.Y., July 28-August 1, 1980. Sponsored by USDA Forest Serv., State & Private Forestry, Canadian Forestry Serv., and State Univ. of N.Y., College of Environmental Science and Forestry. 333 p.

Gouin, F. R. and J. M. Walker. 1977. Deciduous tree seedlings response to nursery soil amended with composted sewage sludge. Hort. Sci. 12:45-47.

Gouin, F. R., C. B. Link and J. F. Kundt. 1978. Forest seedlings thrive on composted sludge. Compost Sci./Land Utilization 19:28-30.

THE OPERATIONAL APPLICATION OF PISOLITHUS TINCTORIUS ECTOMYCORRHIZAE IN FOREST TREE NURSERIES FOR CUSTOM SEEDLING PRODUCTION

Charles E. Cordell and Donald H. Marx[1]

Abstract.--Forest tree nursery and field outplanting results continue to be encouraging for the effective practical application of P.t. ectomycorrhizae for custom seedling production. The use of this unique biological tool in container and bareroot nurseries, field forestation, and reclamation sites is progressing rapidly. Several alternative types of P.t. inoculum are available along with effective practical techniques for nursery seedbed inoculations. Major emphasis is being placed on the production of P.t. "tailored" seedlings for specific sites, selected tree species, and related, high-value forest products.

Additional key words: Pisolithus tinctorius (P.t.) ectomycorrhizae, P.t. mycelium inoculum, P.t. spore-encapsulated seed, ectomycorrhizal inoculum applicator - nursery seeder, bareroot nurseries, container nurseries, forestation sites, reclamation sites.

For several years, forestry agencies and firms have been interested in custom-grown ectomycorrhizal seedlings. Such seedlings may grow better than other seedlings when used to reclaim adverse sites. Better stands of specific tree species may also result, as well as high-value forest products. With these objectives, the national P.t. ectomycorrhizae program has developed techniques and procedures for use in container and bareroot tree nurseries (Cordell and Webb, 1980; Marx and others, 1982; Marx and others, 1983). This effort has been greatly enhanced by the commercial production of P.t. vegetative inoculum, production of P.t. spore-encapsulated seed and, more recently, by the development and commercial production of an ectomycorrhizal inoculum applicator - bareroot nursery seeder.

OPERATIONAL P.T. ECTOMYCORRHIZAE APPLICATIONS

Commercial Inoculum Availability

Mycelium inoculum.--During 1982, commercial P.t. mycelium inoculum (MycoRhiz) was available from Abbott Laboratories, Chicago, Ill., on a custom order basis. The cost was $16 per liter (about 1 quart) and was marketed with a moneyback guarantee. About 750 to 1,000 conifer seedlings (25 to 30 per square foot) were inoculated per liter of inoculum. Based on a tree plantation spacing of 6 x 10 feet, with 726 trees per acre, the use of treated seedlings raises plantation establishment costs by $11 to $15 per acre.

1/ National Mycorrhizae Applications Coordinator, Forest Pest Management Staff, Southern Region, Asheville, NC; and Director, Institute for Mycorrhizal Research and Development, Southeastern Forest Experiment Station, Athens, GA. Both are with the USDA Forest Service.

The future availability of MycoRhiz *P.t.* inoculum from Abbott Laboratories is questionable, primarily because of recurrent inoculum production problems and adverse economic conditions. The company is evaluating this issue and will soon decide on future plans. The Forest Service is now exploring other sources of commercial *P.t.* inoculum. Plans are in progress for cooperative nursery field tests of the Butler County Mushroom Farms' *P.t.* inoculum by that company and the Forest Service's Southeastern Forest Experiment Station and the Southern Region in 1983.

Spore-encapsulated seed.--An alternative *P.t.* nursery inoculation technique involves the spore-encapsulated seed treatment available on a custom order basis from International Tree Seed Co., Birmingham, Ala. This technique was developed in cooperation with the Institute for Mycorrhizal Research and Development (IMRD), USDA Forest Service, Athens, Ga. Results obtained from several *P.t.* spore-encapsulated seed nursery field tests conducted by IMRD during the past three years show considerable promise for the use of this technique in certain bareroot nurseries. The Edwards State Nursery in North Carolina has 300,000+ eastern white, loblolly, and Virginia pines custom inoculated with the *P.t.* spore-encapsulated seed treatment by International Tree Seed Co. for the Crescent Land and Timber Corp. International Tree Seed Co. also produces a *P.t.* spore pellet that is being field tested by IMRD as yet another technique.

Ectomycorrhizal Inoculum Applicator - Nursery Seeder

The applicator gave good results on several pine seedling species during the past 3 years (Conn, Cordell, and Marx, 1980; Cordell and others, 1981). This unique machine has produced practical, operational, bareroot nursery seedbed inoculations using commercial *P.t.* vegetative inoculum. A commercial *P.t.* inoculum applicator is available from R. A. Whitfield Forestry Manufacturing Co., Mableton, Ga. The applicator costs $4,500 and is designed either for separate or simultaneous use with conventional nursery seeders. During the spring of 1982, operational *P.t.* machine inoculations were made in 12 nurseries on six species of pines and over 1 million seedlings. These *P.t.* custom-tailored seedlings will be used on specific field planting sites, such as mine land reclamation and selected problem site forestation.

Future Applications

Reclamation sites.--The potential use of *P.t.* ectomycorrhizae in mine land reclamation has received accelerated interest and effort during the past 2 years (Wolf, Cordell, and Keller, 1982). Two nurseries in Vallonia, Ind., and Marietta, Ohio have scheduled more than 333,000 *P.t.* inoculated seedlings for reclamation site outplantings in southern Ohio. Pine species include Virginia (*Pinus virginiana*), eastern white (*P. strobus*), red (*P. resinosa*), and pitlolly (pitch - *P. rigida* X loblolly - *P. taeda* hybrid). Outplantings were established on eight abandoned coal mine sites in southern Ohio during the spring of 1982. Virginia pine survival varied among the sites, and was severely affected by adverse environmental factors (post-planting extended drought) and grass competition. Results obtained from four outplanting sites established by the Ohio Division of Mine Land Reclamation showed an average survival increase of 24 percent for *P.t.* inoculated Virginia pine seedlings over uninoculated seedlings after 1 month in the field (unpublished data).

Forestation sites.--During the past 2 to 3 years, considerable interest has been expressed by a number of private industries and others about the use of P.t. ectomycorrhizae on selected field forestation sites in the southern and central United States. For example, 10 of the 12 operational P.t. ectomycorrhizal inoculations established with either P.t. mycelium inoculum or spore-encapsulated seed treatments in 10 southern nurseries in 1982 were scheduled for forestation plantings. International Paper Co., Union Camp Corp., Champion International Corp., and Crown Zellerbach Co. recently made substantial commitments to the P.t. ectomycorrhizae applications program. In addition, the Wayne-Hoosier National Forest in Ohio and Indiana and the Savannah River Forest Station in South Carolina, along with the Georgia Forestry Commission and Ohio Division of Forestry, have made similar commitments.

Over 50 P.t. ectomycorrhizal outplantings have been established with over 12 species of conifers in some 20 States. Most of these outplantings have been established since 1979 and, consequently, tree survival and growth results are preliminary. However, outplantings with several conifer species in widespread locations show significant increases in tree survival and early growth on P.t. nursery-inoculated trees, compared to uninoculated check trees. A significant increase (25+ percent) in survival or growth is also still being observed on eastern white, loblolly, and Virginia pines after 8 years in western North Carolina. These results are very encouraging and further emphasize the potential forestation benefits and application of the previous results reported by Marx and others (1977). Similar outplantings with pine seedlings obtained from the 1982 operational nursery inoculations are scheduled for the 1982-83 planting season. All outplantings are scheduled for a 10-year duration.

DISCUSSION

Forest tree nursery and field planting results continue to be encouraging for the effective, practical use of P.t. ectomycorrhizae for custom seedling production. Nursery seedbed and container inoculations with this inoculum have repeatedly provided significant increases in seedling quality (nursery cull reduction), along with increased tree survival and growth in field plantings.

The need for quality, tailored nursery seedlings for successful field forestation and disturbed site reclamation by Federal, State, industry, and private forest land managers is becoming increasingly apparent. Although seedling costs represent a minor portion of forestation expense, seedling quality is perhaps the most significant factor in successful forestation. Consequently, a cost-benefit analysis of producing P.t. ectomycorrhizal seedlings for selected forestation and reclamation sites may be favorable in many cases when considering the total forestation and reclamation site expenses and the probable tree survival and growth benefits derived from these higher-quality, tailored seedlings. The recent emphasis on forestation nationwide, specifically in the South, to meet anticipated wood product demands in the future also places added attention on nursery seedling quality, as well as quantity. Certain ectomycorrhizal fungi have also demonstrated protection against some root disease fungi on southern pine seedling hosts in controlled research studies (Marx, 1973).

CONCLUSIONS

The operational use of P.t. ectomycorrhizae in container and bareroot tree nurseries, field forestation, and reclamation sites is progressing rapidly. Several alternative types of P.t. inoculum are available, along with effective, practical techniques for nursery seedbed inoculations. Major emphasis is on the production of P.t. tailored seedlings for specific sites, selected tree species, and related high-value forest products. Artificial nursery seedbed and container P.t. inoculations represent another potentially effective and practical nursery management tool.

LITERATURE CITED

Conn, John P.; Cordell, Charles E.; Marx, Donald H. The status and practical application of ectomycorrhizae in forest tree nurseries and field forestation. In: Lantz, Clark W. comp. Proceedings, 1980 Southern Nursery Conference, 1980 September 2-4; Lake Barkley, KY. Technical Pub. SA-TP 17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 1981 November: 96-99.

Cordell, Charles E. and Webb, David M. "PT"...A beneficial fungus that gives your trees a better start in life. General Report SA-GR 8. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region; 1980. 16p.

Cordell, Charles E.; Marx, Donald H.; Lott, James R.; Kenney, Donald S. The practical application of Pisolithus tinctorius ectomycorrhizal inoculum in forest tree nurseries. In: Forest regeneration - Proceedings of the American Society of Agr. Engineers - Symposium on engineering systems for forest regeneration. 1981 March 2-6; Raleigh, NC; 1981: 38-42.

Marx, Donald H. Growth of ectomycorrhizal and nonmycorrhizal shortleaf pine seedlings in soil with Phytophthora cinnamomi. Phytopathology 68: 18-23; 1973.

Marx, Donald H.; Bryan, William C.; Cordell, Charles E. Survival and growth of pine seedlings with Pisolithus tinctorius ectomycorrhizae after 2 years on reforestation sites in North Carolina and Florida. For. Sci. 23(3): 363-373; 1977.

Marx, D. H.; Ruehle, J. L.; Kenney, D. S.; [and others]. Commercial vegetative inoculum of Pisolithus tinctorius and inoculation techniques for development of ectomycorrhizae on container-grown tree seedlings. Forest Science 28: 373-400; 1982.

Marx, D. H.; Cordell, C. E.; Kenney, D. S.; [and others]. Commercial vegetative inoculum of Pisolithus tinctorius and inoculation techniques for development of ectomycorrhizae on bareroot tree seedlings. Bethesda, MD: Society of American Foresters; [in press].

Wolf, Charles H.; Cordell, Charles E.; Keller, Stephen M. Fungus speeds mine reclamation. Coal Age 87: 62-64; 1982.

DECOMPOSITION AND EFFECT ON pH OF VARIOUS ORGANIC SOIL AMENDMENTS

Kenneth R. Munson[1/]

Abstract.--Decomposition and effect on soil properties and seedling growth of peat, sewage sludge, shredded cones, and 20-year-old slash pine sawdust were tested in field plots installed in a forest nursery in north Florida. After 18 months, the loss rates of organic material at, respectively, the 22.4, 44.8, and 89.6 mt/ha additions were as follows: 62, 51, 51% for peat; 51, 54, 44% for sludge; 51, 68, 68% for cones; 73, 53, 50% for sawdust. Peat lowered soil reaction by 0.3 pH unit for each 1% increase in organic matter. Cones and sawdust lowered pH slightly after 12 months. Sludge increased pH from 5.7 to 6.5 initially, then reduced it to 4.8 after 3 months.

Additional Keywords: Organic matter, soil reaction, forest nursery soil, organic amendments.

Forest nursery managers currently use cover crops, exogenous organic materials or often a combination of both in an attempt to maintain soil organic matter (OM) levels (Davey and Krause 1980).

The declining availability at low costs of conventional amendments such as wood residues prompts a search for alternate sources of organic materials. Once a grower locates an adequate supply of a promising material, pragmatic questions arise concerning application rates, decomposition rate or residence time, and effects on seedling and soil chemical properties.

Full-scale field tests of various amendments consume space and effort, whereas greenhouse pot trials are subject to regimes of soil, temperature, leaching and moisture quite different than those of the field. Accordingly, a field microplot method was designed to study both thevalue of such a procedure and the performance of four common organic materials applied at three rates. The points of interest were decomposition rates, effects on selected soil properties, seedling growth, mycorrhizal development, and incidence of charcoal root rot. This paper focuses on decomposition rates and effect on soil reaction.

[1/] Currently, Visiting Assistant Professor, School of Forest Resources and Conservation, University of Florida. Project supported by the Cooperative Research in Forest Fertilization Program.

MATERIALS AND METHODS

Study Area

The study was conducted at the Container Corporation of America forest tree nursery near Archer, Florida. The soil in the study compartment is classified as Millhopper sand (loamy, siliceous hyperthermic Grossarenic Paleudult). Prior to clearing and grading as a nursery in 1970, the area had been successively cultivated, abandoned, and planted to slash pine (*Pinus elliottii* var. *elliottii* Engelm.). Mean July and January monthly temperatures are 27° and 14° C, respectively. Annual precipitation averages 1240 mm, most of which occurs in summer and winter.

Experimental Design and Conduct

The materials tested were peat, 20-year-old pine sawdust that had been exposed to normal weathering, municipal sewage sludge, and shredded pine cones. The peat was obtained from a commercial peat mine, 45 km distant. Activated sewage sludge was obtained from drying beds at the University of Florida waste treatment facility. Sawdust and cones (both principally from slash and loblolly pine) were obtained from the St. Regis Paper Company nursery near Lee, Florida. The application rates tested were 22.4, 44.8, and 89.6 mt/ha (dry weight), which would approximate 1, 2, and 4% increases above the native OM level of 1%. The chemical characteristics and particle size distribution of the materials tested are listed in Table 1.

The microplots consisted of plastic, 19-liter (5 gal.) buckets. Roughly 60% of the surface area of the sides and bottom of each bucket was perforated by 5 cm diameter holes to insure natural soil water drainage.

Several cubic meters of unfumigated topsoil from an area adjacent to the study were piled and mixed with a front-end loader and tractor. An appropriate amount of soil and organic material were mixed in a portable cement mixer. Samples for analysis were removed; then two buckets were filled with the mixture. Twenty-eight buckets were prepared in this manner, representing 4 materials x 3 rates x 2 replicates + 4 controls. After arrangement in a completely random fashion, the buckets were buried to the rim in a 14-m section of a nursery bed. The buckets were sturdy enough to withstand removal and replacement for successive crops.

Two-week-old slash pine seedlings were transplanted immediately after installation in mid-June 1980. In 1981, the buckets were in place when the entire bed was operationally sown on May 1. Subsequently, seedlings received the normal operational watering, fertilization, fungicide treatments and weed control. The fertilizer regime consisted of four maintenance applications (postemergent) of 168 kg/ha 10-10-10 in 1980 and only two in 1981. All fertilizer materials had a micronutrient mix of Mn (.2%), Fe (.1%), Zn (.05%), B (.05%), and Mg (.06%). The buckets were lifted at time of harvest and the soil + organic matter mixtures were stored between late February and mid-April 1981.

Table 1. Chemical characteristics and particle size distribution of four organic materials used as nursery soil amendments.

Material	pH	Ash	C	N	C/N	P	K	Ca	Mg	% within each size fraction			
										< 1.0 mm	1.0-2.0	2.0-6.0	>6.0
		----- %-----				---------ppm----------				----------%----------			
Peat	4.5	14	53.7	2.85	18.8	160	90	1250	415	29	20	38	12
Sludge	6.7	24	42.7	5.69	7.5	23900	2750	15500	4690	13	8	34	44
Cones	6.2	1	56.5	0.30	188.3	215	3400	225	405	21	18	35	25
Sawdust	4.5	4	61.6	0.19	342.2	25	55	325	70	22	35	37	6
Soil	5.7	99	0.7	0.02	35.0	44	35	149	9	100	—	—	—

Sampling Scheme

Soil samples were taken before and after the organic matter additions and composite samples at 3-month intervals, including the time between crops. Each composite sample consisted of four cores, 2.5 cm diameter by 30-cm deep, from each bucket.

At harvest, the soil mixture in each bucket was passed through 6 mm hardware cloth to remove all roots. Organic fragments larger than 6 mm were returned to the soil mixture.

Analyses

Soil and plant samples were processed and analyzed following routine procedures. Organic matter was determined by loss-on-ignition after combustion of a 25- to 30-gram sample at 550° C for 8 hours. Soil pH was measured in a 2:1 distilled water-to-soil ratio using a standard glass electrode.

Data analyses were conducted using procedures in the Statistical Analysis System. The change in soil OM over time was characterized by generated equations. Mean soil pH values within sample periods were compared using Duncan's multiple range test.

RESULTS AND DISCUSSION

Organic Matter Decomposition

The patterns of decomposition for the various organic materials and rates of application are described by linear equations (Fig. 1). The overall course of decomposition is linear despite seasonal variations in soil temperature and the disturbance associated with seedling harvest and reestablishment.

After 18 months, the peat treatments had lost 62, 51 and 51% of the amounts applied at the 1, 2, and 4% rates, respectively. This decomposition rate was much more rapid than observed in a large scale field study (Munson 1982) where 22.4, 44.8 and 67.2 mt/ha of peat lost 0, 21, and 19% of the amounts applied during the same time period. Possible reasons for the difference between the two studies are discussed later. The respective similarity in loss rate from the two higher applications within both studies, however, confirms that decomposition rate is roughly proportional to the amount added when this exceeds 22.4 mt/ha.

At the end of 18 months, the sludge treatments had lost 51, 54, and 44%, respectively, of the organic material added at the 1, 2, and 4% rates. These values would suggest that the sludge was more resistant to decomposition than any of the other three materials. A more likely explanation, however, is that decomposition was reduced by the large size and low porosity of the sludge particles. Initial air drying of the sludge produced firm aggregates, 78% of which were larger than 2 mm (Table 1). Hence, the area of soil-sludge contact was limited and exchange of O_2 and CO_2 with soil air restricted.

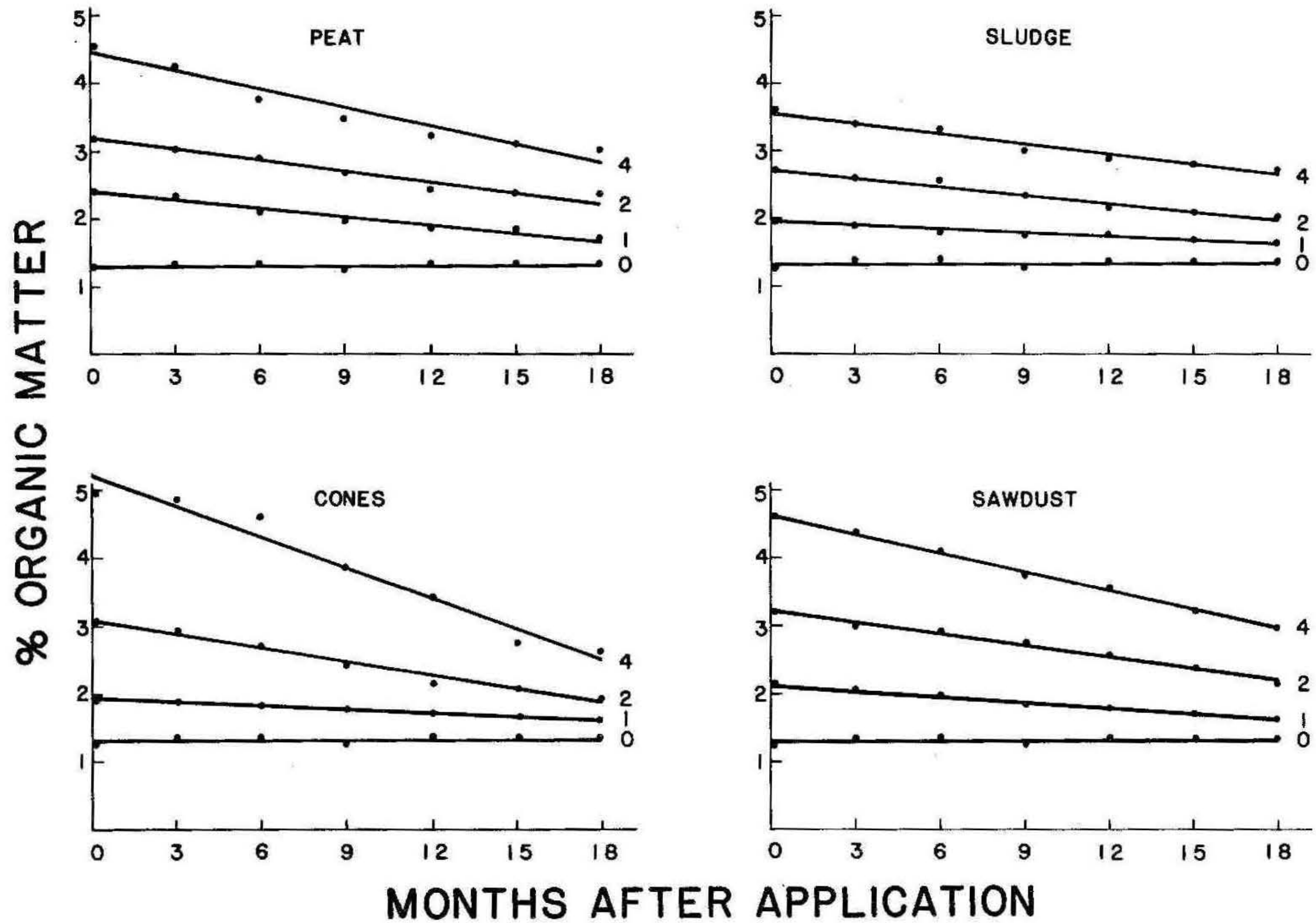


Figure 1. Organic matter decomposition in a nursery soil ammended with four organic materials at three rates. Points are observed values of best-fit lines. 0, 1, 2, and 4 at the end of the regression lines refer to application rates of 0, 22.4, 44.8, and 89.6 mt/ha, respectively. The 1980 crop was harvested in the seventh month.

Laboratory incubation and field studies have shown that decomposition of other sludges is generally more rapid than observed here (Terry et al., 1979; Varanka et al., 1976; Miller 1974). Thus, sludge decomposition rates observed in the present study may be underestimates.

Decomposition of the shredded cones proceeded rapidly: 51, 68, and 68% for the 1, 2, and 4% rates, respectively, after 18 months. The 68% loss is the largest of any material applied at 2 or 4%. No explanation can be offered for the lower loss rate at the 1% addition, a reversal contrary to results with the other three materials. Despite the coarse size (Table 1) and outward woodiness of the cone fragments, their internal structure seems susceptible to microbial attack.

Losses after 18 months from the 1, 2, and 4% sawdust treatments amounted to 73, 53, and 50%, respectively. The 73% was the greatest of those for all materials and rates. Loss from the 2% treatment may be compared with results from a laboratory incubation study (Allison and Murphy 1963) in which 2% fresh slash pine sawdust mixed with soil lost 28% of its carbon in 12 months. This would extrapolate to 42% in 18 months, less than the 53% loss observed in the present study.

If the sludge is excluded from comparison because of the particle characteristics discussed earlier, then the other three materials rank as follows in respect to decomposition after 18 months (actual percentages in parentheses):

Application Rate	Ranking
1%	sawdust (73) > peat (62) > cones (51)
2%	cones (68) > sawdust (53) $\simeq$ peat (51)
4%	cones (68) > sawdust (50) $\simeq$ peat (51)

Only the 1% cone treatment deviates from an overall decomposition ranking of 1% > 2% = 4%, within materials, and cones sawdust peat, within rates. Direct comparison of decomposition under actual field conditions is possible only for peat, used in both the field macroplot study (Munson 1982) and the microplots. As noted, decomposition in the macroplots was about 20% after 18 months for the 2 and 3% additions as compared with about 50% for the 2 and 4% rates of the present study. Factors which may have contributed to accelerated decomposition of the latter include a) better mixing of soil and peat that could not be duplicated even by repeated field tillage, b) fragmenting and remixing of the peat particles during the seedling harvest procedure, and c) possible air gaps between the microplot mixtures and surrounding soil which could have led to longer retention of moisture after rain or irrigation. If decomposition of the other materials was similarly accelerated, then the estimated residence times of such amendments should be extended 2-2½ times.

A general conception of the decomposition of green manures is that two-thirds of the added carbon will be respired away during the decay processes, with one-third remaining as part of a more stable organic matter fraction (Brady 1974). Application of this concept to the results of this study may provide a framework for an organic matter maintenance program. The linear extrapolations of the decomposition data to the point in time following application when one-third of the material is left are presented in Table 2. Also included in Table 2 are the adjusted values to compensate for the accelerated decomposition as discussed previously.

Table 2. Time required for decomposition of two-thirds of the applied organic material.

Material	Unadjusted			Adjusted[1/]		
	Application Rate (mt/ha)			Application Rate (mt/ha)		
	22.4	44.8	89.6	22.4	44.8	89.6
	- - - - - - - - - - - - - yrs - - - - - - - - - - - - -					
Peat	1.6	1.9	1.9	3.2	3.8	3.8
Cones	2.0	1.5	1.5	4.0	3.0	3.0
Sawdust	1.4	1.9	2.0	2.8	3.8	4.0

[1/] The unadjusted time periods were extended 2 times to estimate more closely the time required for two-thirds decomposition of the materials under actual field conditions.

From the practical standpoint, these lengths of time (adjusted) may serve as guidelines for application intervals with respect to the various materials and rates. In general, the results of this study would suggest that where maximizing residence time of applied organic materials is an objective, this may best be achieved by frequent applications at the lower rates rather than applications of the same total quantity in larger but less frequent additions.

Soil Reaction

Soil reactions between pH 5 and 6 are generally considered to be optimum for pine seedling production (Armson and Sadrieka 1979). The change in soil pH over the course of a growing season is influenced by nutrient uptake and leaching, by the effects of fertilizers and by addition of bases in irrigation water. As a result of these seasonal influences, comparisons were confined to those between materials and rates within each sampling date.

Reaction of the unamended control soil increased irregularly from about pH 5.7 to pH 6.0 at 18 months (Fig. 2).

Addition of acid peat lowered the pH 0.3 unit for each 1% increase in OM (Fig. 2). This effect persisted over both growing seasons with reaction more or less paralleling changes in the unamended control.

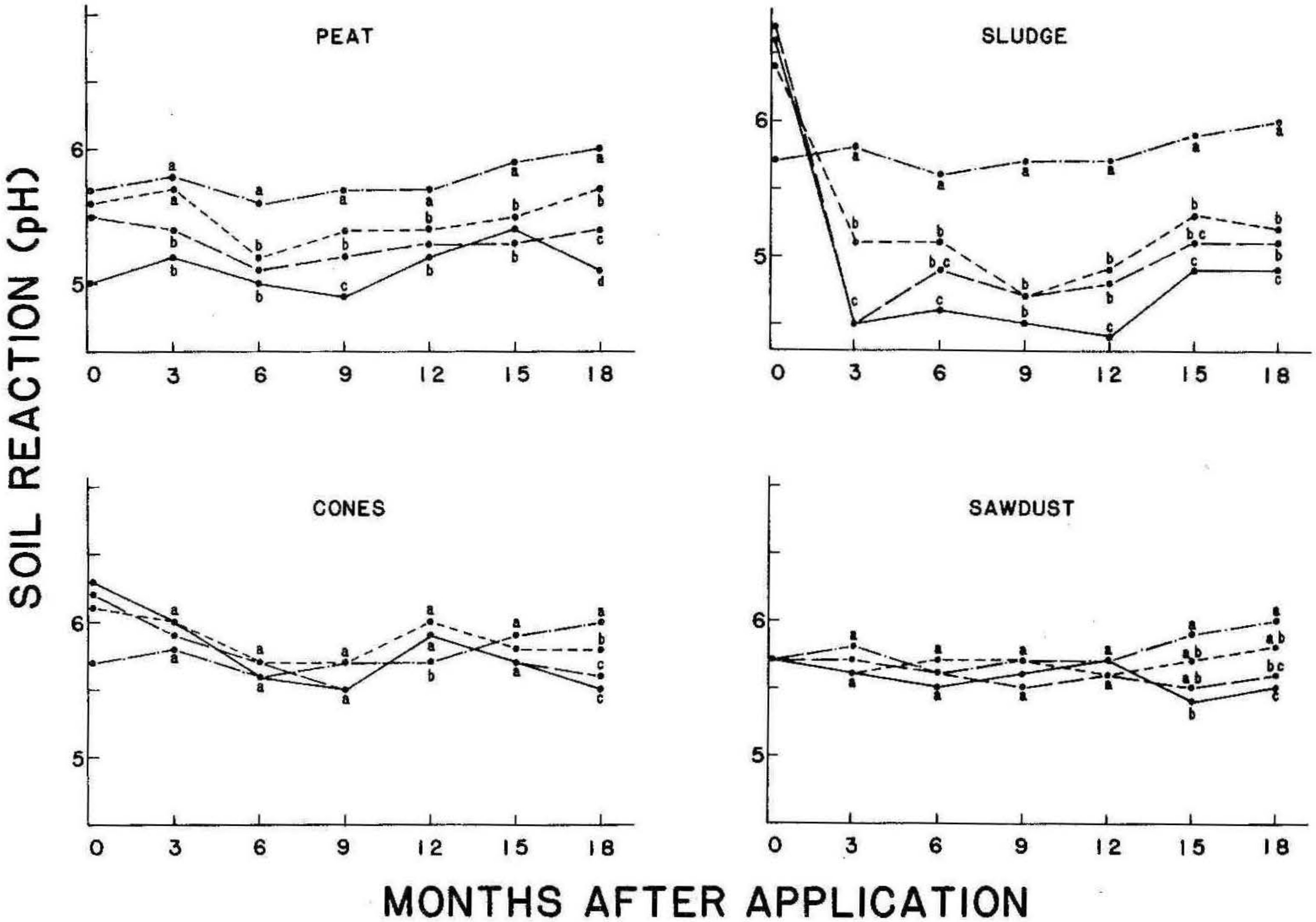


Figure 2. Soil reaction (pH) as influenced by four organic ammendments applied at three rates. The 1980 crop was harvested in the seventh month. Values at each sample period within materials with the same letter are not significantly different (Duncan's, a = .05)
Control = ____ . ____ . ____ Rate 1 = __ __ __ __ __ Rate 2 = ___ ___ ___ Rate 3 = __________

The high base content and reaction of the sludge initially increased the pH of the soil-sludge mixture. This increase was abruptly reversed, however, with the two higher treatments dropping from pH 6.6-6.7 to 4.5 after 3 months. The decrease in reaction during the first 12 months can be attributed to nitrification and rapid leaching of NO_3^- from the sludge, which had a narrow C/N ratio (Table 1). Leaching of NO_3^- also removes equivalent amounts of cations (Raney 1960). After 12 months, the slow rise in reaction is generally similar, although steeper, to that of comparable peat treatments.

The sharp increase in initial pH following addition of shredded cones apparently is due to the relatively high potassium content (.34%, Table 1), coupled with the low exchange capacity of the woody material. The drop in reaction to that of the control after 6 months probably reflects increased exchange capacity, hence lower base saturation, as decomposition occurred (Fig. 2). A lesser pulse of increase at 12 months (early in the second growing season) is unaccounted for, but again followed by a decrease.

Addition of 20-year-old sawdust lowered pH slightly below that of the controls during the first year, and more so between 12 and 18 months.

CONCLUSION

Fifty percent or more of the added OM decomposed in the 18-month study period, regardless of material or rate. The only exception was a 44% loss of sludge applied at the highest rate. In this case, decomposition was likely retarded by coarse particle size as well as drastic changes in the soil chemical environment. Losses from shredded cones, the only material not subjected to prior decomposition, were greater than from the other materials, which in turn were roughly comparable. For each material and rate, decomposition was a linear function of time. In contrast, the OM content of the control soil (1.3%) did not change significantly.

To coordinate decomposition rates and application intervals with the intent of maximizing OM residence time, it is suggested that light applications (22.4 mt/ha) every 3-4 years may be a suitable OM maintenance schedule.

The peat-amended soils maintained a lower reaction during the study period. Sawdust and cones lower pH only slightly after 12 months. Reaction of the sludge-treated plots initially increased to above pH, then dropped below pH 5.0. This decrease was in response to the high content of readily mineralized N in sludge, which resulted in leaching of excess NO_3^- and concurrent losses of cations.

Overall, the OM residence time and response of soil reaction varied with organic material and rate of application. Ideally, the nature of these responses and subsequent effects on seedling development should be determined before the full-scale operational use of any exogenous organic material.

LITERATURE CITED

Allison, F. E., and C. J. Klein. 1961. Comparative rates of decomposition in soil of wood and bark particles of several softwood species. Soil Sci. Soc. Am. Proc. 25:193-196.

Brady, N. C. 1974. The nature and properties of soils. Eight ed. Macmillan Publ. Co., New York. 639p.

Davey, C. B., and H. H. Krause. 1980. Functions and maintenance of organic matter in forest nursery soils. In: Proc. North Am. For. Tree Nursery Soils Workshop, July 28-August 1, 1980, Syracuse, New York.

Miller, R. H. 1974. Factors affecting the decomposition of an anaerobically digested sewage sludge in soil. J. Env. Qual. 3:76-380.

Munson, K. R. 1982. Decomposition, function, and maintenance of organic matter in a sandy nursery soil. Ph. D. Thesis. Univ. of Florida.

Raney, W. A. 1960. The dominant role of nitrogen in leaching losses from soils of humid regions. Agron. J. 52:563-566.

Terry, R. E., D. W. Nelson, and L. E. Sommers. 1979. Carbon cycling during sewage sludge decomposition in soils. Soil Sci. Soc. Am. J. 43:494-499.

Varanka, M. W., Z. M. Zablocki, and T. D. Hinesly. 1976. The effect of digestion sludge on soil biological activity. J. Water Pollut. Contr. Fed. 48:1728-1740.

PINE BARK AS A SOIL AMENDMENT[1/]

Franklin A. Pokorny[2/]

Abstract.--Milled pine bark added to nursery soils increases total porosity, water retention, air space, percolation rate, cation exchange capacity, lowers soil bulk density, and suppresses plant pathogens. Advantages of milled pine bark as a soil amendment are: 1) a slow rate of decomposition, 2) reduced nitrogen tie-up in comparison to other wood fragments, 3) ready availability, 4) processibility into a uniform standard product, and, 5) suppression of certain soil-borne plant pathogens.

Additional keywords: Hardwood bark, sawdust, peat moss, chemical properties, particle size, lignin

Pine bark and other organic materials such as hardwood bark and sawdust are increasingly being used as a peat moss substitute in container plant production, soil conditioning for growing crops and landscape maintenance. The scarcity and high cost of peat moss have forced growers to utilize other readily available organic materials, formerly waste products of the forest industry. These organic residues can provide long-term improvement in the physical and chemical characteristics of soil. Pine bark, in particular, serves as an excellent alternative as a soil medium amendment.

DESIRABLE PARTICLE SIZING OF SOFTWOOD BARK

Pine bark is removed from the log in large slabs or pieces and in this condition is generally unusable as a soil conditioner. Hammer-milling and screening are required to reduce large bark pieces to a suitable size for soil conditioning purposes. Lunt and Clark (1959) suggest that milled pine bark with a particle range of 1 mm to 8 mm in diameter is satisfactory for most soil amendment uses. Bollen and Glennie (1963) used Douglas fir bark soil conditioner with particles in the range of 0.42 mm to 2.00 mm while Harder and Baker (1971) worked with mixed softwood bark with particles less than 3.35 mm in diameter. Research at the University of Georgia has shown that milled pine bark with 70-80% of the particles in the range of 0.59 mm to 4.76 mm in diameter and with 20-30% of the particles smaller than 0.59 mm is satisfactory as a potting medium component and/or soil amendment (Pokorny 1979). This particle distribution is similar to that reported by Gartner _et al_. (1970, 1972, 1973) for hardwood bark.

[1/] A contribution of the University of Georgia Agricultural Experiment Station, College Station, Athens. This work was supported by State and Hatch funds allocated to the University of Georgia Agricultural Experiment Stations.

[2/] Professor of Horticulture, University of Georgia, Athens, GA 30602.

South (personal communication) currently is evaluating coarse grades of pine bark as a soil amendment in four forest tree nurseries. Three nurseries are located in Florida and one in Texas (table 1).

Table 1.--Particle size distribution of pine bark tested as a soil amendment in four forest tree seedling nurseries[z/]

Nursery location	Particle size classes			
	>25 mm (1 inch)	25 mm-12.5 mm (1-½ inch)	12.5-6.25 mm (½-¼ inch)	<6.25 mm (¼ inch)
	% by wt			
St. Regis - Florida	4	12	26	58
St. Regis - Texas	4	9	25	62
Container Corp. - Florida	6	16	28	50
Chiefland (State) - Florida	7	14	18	61

z/ Unpublished data supplied by David South, Auburn University, 1982.

PHYSICAL PROPERTIES OF ORGANICALLY AMENDED SOILS

Generally, milled pine bark is mixed with existing soil at the rate of 10 to 33% by volume. Thus, ½ to 2 inches of bark mixed into the upper 4 to 6 inches of soil will provide the necessary volume mixture (table 2). The influence of various volume additions of bark, peat, and sawdust to soil on soil moisture equivalent and permeability are reported by Harder and Baker (1971) (table 3). Bark and peat amended soil exhibited similar soil moisture equivalents and permeability over the range of 8-33% volume additions to the soil. Fine sawdust had a greater influence than either bark or peat moss only on water permeability as moisture equivalent and plant yields were less in the sawdust amended soils (Harder and Baker 1971). In experiments at the University of Georgia, Thurman (1967) found that the addition of 25 to 50% by volume milled pine bark to a sandy soil decreased bulk density and increased total pore space, water retention, and air space of the soil-bark mixtures. Addition of milled pine bark or other organic residues in quantities greater than 33% by volume to existing soil for amendment purposes is probably not economically feasible.

THE DEGRADATION PROCESS OF SOFTWOOD BARK

An important characteristic of softwood barks, especially pine, is their resistance to decay (Allison and Murphy 1962, 1963). Complete decomposition may require from 5 to 7 years (Lunt and Clark 1959). Though the high C/N ratio of pine bark would indicate the need for a substantial nitrogen addition to accommodate the needs of microorganisms involved in organic matter decomposition, approximately ¼ lb N/cu yd will overcome the problem of nitrogen draft (Pokorny 1979). It would appear that reduced need for high supplemental N

Table 2.--Equivalent quantity of bark expressed as inches applied or tons applied and mixed with soil when compared to percentage by volume of bark applied

Percentage bark applied (vol)	Tons of bark applied	Inches of bark applied	Inches of soil applied
0	0	0	6.0
8	25.5	0.5	5.5
16	51	1.0	5.0
33	102	2.0	4.0
50	153	3.0	3.0

(Adapted from: Harder and Baker 1971.)

Table 3.--Influence of additions of different volume ratios of bark, peat and sawdust to a Palouse silt loam soil on moisture equivalent and permeability

	Bark added (%/v)				
Organic amendment	0	8	16	33	50
Bark					
Moisture equivalent	26.8	27.3	27.4	29.4	31.8
Permeability (ml/10 min)	29.5	30.5	78.8	90.3	132.0
Peat					
Moisture equivalent	26.8	26.7	28.4	32.6	35.6
Permeability (ml/10 min)	29.5	60.8	73.0	123.3	132.3
Fine sawdust					
Moisture equivalent	26.8	25.9	26.4	28.0	31.3
Permeability (ml/10 min)	29.5	71.5	113.0	276.0	459.0

(Adapted from: Harder and Baker 1971.)

rate with southern pine bark is related to its high lignin and low cellulose content (table 4) and its slow rate of decomposition (Allison and Murphy 1962, 1963). Lunt and Clark (1959) suggest that the degree of nitrogen deficiency is directly related to the rate of decomposition of added wood fragments. Another approach to overcoming the problem of nitrogen tie-up by the application of raw wood wastes to the soil for amendment purposes is to compost the material prior to soil application. Composting is the controlled process of biological degradation of waste organic matter removing mostly cellulose (wood and cambium) and toxic substances which may be present in wood and bark

Table 4.--Carbon nitrogen ratio, lignin and cellulose content of bark and sawdust of pine and hardwoods and of sphagnum peat moss

Organic soil amendment	C/N ratio	Lignin %	Cellulose %
Pine bark	112--144	50	5-30
Pine sawdust	327-1313	27-30	42-46
Hardwood bark	110--167	25-40	40
Hardwood sawdust	134--253	18-25	45-58
Sphagnum peat moss	53---96	18-64	0.6-24

(Sources: Baxter 1969; Bollen and Glennie 1961; Bollen and Glennie 1963; Forest Products Laboratory 1957; Fuchsman 1980; Giddens and Baxter 1965; Hoitink 1980; Koch 1972.)

fragments. Gartner et al. (1973) have shown that fresh barks of certain hardwood species inhibit plant growth (table 5). Certain softwood tree barks also are reported to suppress plant growth (Hoitink et al. 1978, Lunt and Clark 1959). These plant growth inhibitors are dissipated after at least 30 days of composting (Gartner et al. 1973, Hoitink et al. 1978). Factors affecting the composting of tree barks are detailed by Hoitink et al. (1978, 1980).

Table 5.--Reported phytotoxicity of bark used as a soil amendment of some hardwood and softwood species

Hardwood species	Softwood species
Ash	Douglas fir
Cottonwood	Incense fir
Hackberry	Norway Spruce
Red oak	Redwood
Silver maple	Sitka spruce
Sycamore	
White oak	

(Sources: Gartner et al. 1973; Hoitink 1980; Lunt and Clark 1959.)

CHEMICAL CHANGES IN A PINE BARK/SOIL MIX

Pine bark, as well as other wood wastes, has substantial cation exchange capacity (CEC) (table 6) which greatly exceeds that of a silt loam soil (Bollen and Glennie 1963). Addition of pine bark to sand or sandy soils will increase the CEC of the bark amended soil, depending upon the quantity of bark applied (Brown and Pokorny 1975). Further decomposition of pine bark will additionally increase CEC and prevent leaching of cations from the soil (Bollen and Glennie 1963).

Pine and hardwood barks and sawdust are slightly to strongly acidic (table 6) with the pH of pine bark closely approximating that of sphagnum peat moss. Although the addition of pine bark to a soil may initially slightly depress acidity, for crops requiring a soil pH of near 7.0, the addition of agricultural limestone is necessary (Lunt and Clark 1959). No agricultural limestone need be applied when acid requiring crops are grown (Baxter 1969).

Pine bark, other wood fragments, and peat moss contain small quantities of all the macro- and micronutrients needed for plant growth (table 6). Lunt and Clark (1959) suggest that, in some cases, phosphorous and potassium derived from bark may initially contribute to the soil fertility. The contribution of the soil microelement content of barks and sawdusts is unknown.

PATHOGEN SUPPRESSION BY TREE BARKS

Hardwood and pine barks have been shown to suppress soil-borne pathogens (Bollen and Glennie 1963, Gugino et al. 1973, Hoitink et al. 1978, Hoitink 1980). In addition to decomposition of easily degradable compounds and cellulose during the composting operation, sufficiently high temperatures in the range of 40-80°C (104-176°F) are generated to kill most pathogens. Hoitink (1980) reports that the incidence of a wide range of soil-borne diseases has been reduced in nursery, floricultural and in foliage plants when the potting medium contains 50% or more by volume of composted hardwood or pine bark (table 7). Red stele of strawberry, caused by the organism *Phytophthora fragariae*, has been suppressed for several years after the application of 90-225 tons/ha (36-91 tons/acre) of ammoniated Douglas fir bark (Bollen and Glennie 1963). Conversely, Douglas fir sawdust incorporated into the soil increased incidence of this disease.

The first suggestion of pathogen suppression utilizing pine bark in container media was reported by Gugino et al. (1973). 'Helleri' holly root weights were increased with increasing increments of pine bark in a container medium irrespective of high *Pythium irregulare* populations recovered from the medium.

Sekiguchi, as reported by Hoitink (1980), found that Fusarium wilt of Chinese yam was controlled by incorporation of 30 tons/ha (12 tons/acre) of pine bark into field soil. Fusarium control was similar to that obtained with methyl bromide fumigation or with the application of benomyl fungicide. Generally, the suppressive effects of tree barks on soil-borne pathogens is rapidly diminished when the bark is contaminated with high percentages of wood.

The mechanism of pathogen suppression by tree bark is currently unknown. However, it is thought that the incidence of soil-borne diseases is diminished because: 1) improvement in physical properties of the soil creating an environment more favorable for root development, 2) bark amended soils support high levels of organisms antagonistic to pathogens, and/or 3) bark contains natural chemicals which are fungicidal in nature. Evidence indicates that the mechanism of pathogen suppression is complex and that all of the postulated means for pathogen suppression are involved to some degree (Gugino et al. 1973, Hoitink 1980).

Table 6.--Cation exchange capacity, pH, and mineral element content of pine and hardwood barks, sawdusts, and sphagnum peat moss soil amendments

Chemical property	Soil amendment				
	Pine bark	Pine sawdust	Hardwood bark	Hardwood sawdust	Peat moss
CEC - me/100 g	30-57	28	--	77	30-120
pH	3.5-5.0	4.1-6.0	5.0-6.4	4.1-7.0	3.0-5.0
N - %	0.28-0.39	0.14	0.28-0.61	0.08-0.11	0.5-2.1
P - %	0.02	0.02	0.03-0.12	0.003-0.02	0.05
K - %	0.10	0.10	0.15-0.62	0.03-0.12	0.01
Ca - %	0.51	0.06	0.88-3.96	0.003-0.02	0.27
Mg - %	0.14	0.03	0.02-0.11	0.01-0.03	0.04
Mn - ppm	119	1115	169-1195	29-72	95
Cu - ppm	77	--	4-10	4- 7	Trace
Zn - ppm	112	--	9-53	17-28	13
B - ppm	9	--	4-24	1- 2	--
Fe - ppm	790	64	174-743	10-12	30

(Source: Allison and Murphy 1962; Baxter 1969; Brown and Pokorny 1975; Fuchsman 1980; Gartner *et al*. 1972; Goh 1979; Haramaki *et al*. 1971; Koch 1972; Lunt and Clark 1959; Maas and Adamson 1972; Martin and Gray 1971; Murphy and Rishel 1977; Pokorny 1979; Self *et al*. 1967; Young and Guinn 1966.)

Table 7.--Soil-borne pathogens suppressed by composted hardwood and softwood bark soil amendments

Pathogen	Suppressed by Hardwood bark	Suppressed by Softwood bark
Pythium irregulare	Yes	Yes
Phytophthora spp.	Yes	Yes
Phytophthora cinnamomi	Yes	Yes
Fusarium spp.	Yes	Yes
Pythium ultimum	Yes	?
Verticillium albo-atrum	Yes	?
Rhizoctonia solani	Yes	No
Thielaviopsis basicola	Yes	?
Some nematodes	Yes	?

(Sources: Gugino *et al*. 1973; Hoitink 1980; Hoitink and Poole 1980; Hoitink *et al*. 1978; Malek and Gartner 1975.)

CONCLUSIONS

Milled pine bark as a soil conditioner is advantageous in several respects. Pine bark is available, especially in the South, and can be processed by hammer-milling and screening into a uniform standard product. It is slow to decompose, thus providing a relatively long term conditioning effect when mixed with soil. Pine bark suppresses certain soil-borne plant pathogens and offers an alternative means of controlling diseases which attack root systems of plants.

Large scale use of milled pine bark in forest tree seedling nurseries should be determined by cost in relation to benefits derived. This will need to be analyzed by each nurseryman based on operational requirements.

LITERATURE CITED

Allison, F. E., and Murphy, R. M. 1962. Comparative rates of decomposition in the soil of wood and bark particles of several hardwood species. Soil Sci. Soc. Amer. Proc. 26:463-466.

Allison, F. E., and Murphy, R. M. 1963. Comparative rates of decomposition in soil of wood and bark particles of several species of pine. Soil Sci. Soc. Amer. Proc. 27:309-312.

Baxter, H. O. 1969. Summary of research on sawdust and bark for agricultural uses. Univ. Ga. Agr. Ext. Ser. Mimeo. 16 p.

Bollen, W. B., and Glennie, D. W. 1961. Sawdust, bark, and other wood wastes for soil conditioning and mulching. For. Prod. J. 11:38-46.

Bollen, W. B., and Glennie, D. W. 1963. Fortified bark for mulching and soil conditioning. For. Prod. J. 13:209-215.

Brown, E. F., and Pokorny, F. A. 1975. Physical and chemical properties of media composed of milled pine bark and sand. J. Amer. Soc. Hort. Sci. 100:119-121.

Forest Products Laboratory. 1957. Chemical composition and uses of bark. USDA Forest Serv. Rept. 1666-5. 6 p.

Fuchsman, C. H. 1980. Peat and industrial chemistry and technology. 279 p. N. Y.: Academic Press.

Gartner, J. B., Hughes, T. D., and Klett, J. E. 1972. Using hardwood bark in container growing mediums. Amer. Nurseryman 135:10-11, 77-79.

Gartner, J. B., Saupe, D. C., Klett, J. E., and Yocom, T. R. 1970. Hardwood bark as a medium for container growing. Amer. Nurseryman 131:11, 40, 42-44.

Gartner, J. B., Still, S. M., and Klett, J. E. 1973. The use of hardwood bark as a growth medium. Proc. Inter. Plant Prop. Soc. 23:222-229.

Giddens, J., and Baxter, H. O. 1965. Use of wood residues for soil improvement. Ga. Agr. Res. 6:8.

Goh, K. M. 1979. Chemical characteristics of some commonly used media and their components. In Development and use of soilless media for horticulture. Hort. Res. Centre, Levin, N. Z. Paper 6-1.

Gugino, J. L., Pokorny, F. A., and Hendrix, F. F., Jr. 1973. Population dynamics of Pythium irregulare Buis. in container plant production as influenced by physical structure of media. Plant and Soil 39:591-602.

Haramaki, C., Nuss, J. R., Oliver, C. S., and Williams, P. H. 1971. Water soluble extractives in bark. In Progress report on the study of the feasibility of using deciduous tree bark as a soil substitute and as a mulch material for ornamental plants, 1969-1970, p. 12-26. Penn. State Univ., Dept. of Hort.

Harder, R. W., and Baker, G. O. 1971. Utilization of waste bark as a soil conditioner. Compost Sci. 12:6-9.

Hoitink, H. A. J. 1980. Composted bark, a lightweight growth medium with fungicidal properties. Plant Disease 64:142-147.

Hoitink, H. A. J., and Poole, H. A. 1980. Factors affecting quality of composts for utilization in container media. HortScience 15:171-173.

Hoitink, H. A. J., Wilson, J. H., and Poole, H. A. 1978. Factors affecting composting of hardwood tree bark. In Proc. Second Woody Ornamental Disease Workshop, p. 11-18. Univ. of Mo., Columbia.

Koch, P. 1972. Utilization of southern pines. I. The raw material. 730 p. USDA Forest Serv. Ag. Handbook 420.

Lunt, O. R., and Clark, B. 1959. Horticultural applications for bark and wood fragments. For. Prod. J. 9:39A-42A.

Maas, E. F., and Adamson, R. M. 1972. Resistance of sawdust, peats, and bark to decomposition in the presence of soil and nutrient solution. Soil Sci. Soc. Amer. Proc. 36:769-772.

Malek, R. B., and Gartner, J. B. 1975. Hardwood bark as a soil amendment for suppression of plant parasitic nematodes on container-grown plants. HortScience 10:33-35.

Martin, R. E., and Gray, G. R. 1971. pH of southern pine barks. For. Prod. J. 21:49-52.

Murphy, W. K., and Rishel, L. E. 1977. Properties and potentials of bark as a raw material. Penn. State Univ. Prog. Rept. 363. 15 p.

Pokorny, F. A. 1979. Pine bark container media - an overview. Proc. Inter. Plant Prop. Soc. 29:484-495.

Self, R. L., Wear, J. I., Rouse, R. D., and Orr, H. P. 1967. Potting mixtures and fertilization practices for container grown ornamental plants. 10 p. Auburn Agr. Exp. Sta. Circ. 157.

Thurman, P. C. 1967. The relationship of several amended soils and compaction rates on vegetative growth, root development, and cold tolerance of Tifgreen burmuda grass [_Cynodon dactylon_ (L.) Pers.]. M. S. Thesis, Univ. of Ga., Athens, Ga. 83 p.

Young, H. E., and Guinn, V. P. 1966. Chemical elements in complete mature trees of seven species in Maine. Tappi 49:190-197.

THE SOUTHERN FOREST NURSERY SOIL TESTING PROGRAM

David B. South and Charles B. Davey[1]

Abstract.--In 1980, a committee was established to address the problem of soil testing and interpretation for southern forest nurseries. Subsequently, a program has been developed primarily for the nurseries in the southern coastal plain and involves (1) soil testing from a single lab; (2) soil fertility interpretation and suggestions for amendments; and (3) computer storage and retrieval of data. In 1982, 25 southern nurseries used the services of the Southern Forest Nursery Soil Testing Program.

At the 1980 Southern Nurseryman's Conference, the Nursery Technical Committee discussed the problems of soil testing and interpretation for forest nurseries in the South. Dr. John Mexal was appointed chairman of a committee to address this problem. The committee met at Raleigh, N.C. on June 23, 1981 and as a result, the Southern Forest Nursery Soil Testing Program was formed.

This program consists of three seperate but integrated parts:
(1) Soil testing performed by - A&L Agricultural Labs in Memphis, TN.
(2) Soil fertility suggestions by - Dr. Chuck Davey.
(3) Soil data storage by - the Auburn University Southern Forest Nursery Management Cooperative.

The program works as follows.
(A) The nurseryman takes soil samples from his nursery by block or unit. It is very important that the acreage and sampling code should remain the same from one sampling period until the next. This means that in 1990 the analysis from sample 1A will be comparable to the analysis from sample 1A in 1982. This is essential if balance sheets are to be made for each sampled area.
(B) The samples should be taken during the "cold" season (October to January) prior to the crop being sown. Taking samples after January increases the risk of late recommendations which may cause problems in ordering the correct fertilizers. To ensure sampling consistency, the same person should take and handle all soil samples.
(C) Each sample should be a composite of 25-30 cores taken at random. If there are visible differences in soils or nursery stock growth in a block, a separate sample should be taken from each uniform soil area.
(D) The cores should be taken with a soil probe tube and to a consistent depth of 15 cm (6 inches). Collect the cores forming a single sample in a clean plastic pail. Mix the cores thoroughly and remove a half-liter (pint) sample.
(E) The soil samples should be air dried and sent to A & L Labs in Memphis, Tennessee. The results of the analysis are usually returned within two weeks. Copies of the analysis should be sent to Dr. Davey and one copy should be sent to the Auburn Coop. Figure 1 illustrates an example of the soil report from A&L.
(F) For each soil sample, the nursery should fill out a History Data Form (Figure 2). This form should include all the amendments (organic, fertilizer,

[1] Project Leader, Auburn University Southern Forest Nursery Management Cooperative, Forestry Department, Auburn University, AL. 36849, and Professor of Forest Soils, North Carolina State University, Raleigh, NC 27650.

lime etc. that have been applied since the previous soil test. The crop species grown for each year should be recorded in addition to the next crop which will be grown on the area. The soil texture of the area should also be included. One copy of this form should be sent to Dr. Davey and one copy sent to the Auburn Cooperative.

(G) Dr. Davey will review the soil analysis, history forms, balance sheets and will make suggestions for amendments. These suggestions are sent directly to the nursery.

(H) The Auburn Cooperative will place the data from the soil analysis and history forms into the computer. This data bank will be utilized for two functions.

(1)For each nursery, balance sheets will be prepared for each soil sampling unit (Figure 3). This information will aid the nurseryman in determining how his soil management practices have affected soil fertility. The balance sheet should help avoid large fluctuations in soil factors which may result in reduced productivity. For example, Figure 4 indicates the change in calcium over a 13-year period from one block in a forest nursery. This type of fluctuation is undesirable and could have been avoided with the use of a balance sheet.

(2)The data bank will be used to combine analysis from nurseries with similar soil textures. By comparing data among nurseries with similar textures, it can be more readily determined what is "normal" and what is "out of line". This method of analysis has already benefited several nurseries by defining soil fertility problems which were causing decreases in seedling productivity. The remainder of this paper will present some preliminary data which will illustrate how southern forest nurseries will benefit from having their soil analyzed at one lab.

MATERIALS AND METHODS

Soil samples were collected by the Auburn Cooperative between 1977 and 1980. Most of the samples were collected in conjunction with pre- and postemergence herbicide experiments and therefore they were usually collected from April until June (after the preplant fertilizer application). Samples were not representative of the entire nursery but were only representative of an area of two acres or less. Four soil samples were collected from each herbicide test area. Soil texture was determined by the hydrometer method at the Auburn Forestry Department. Chemical analysis was performed by A & L Laboratories in Memphis, Tennessee on a composite sample from each nursery. Phosphorus was extracted with the Weak Bray and Strong Bray methods. Calcium, magnesium, potassium, sodium, and sulfur were extracted with 1M ammonium acetate. Zinc, manganese, iron, and copper were extracted with 0.1N hydrochloric acid. Boron was extracted with boiling water. Organic matter was determined with a modified Walkley-Black method. Soil pH was determined using a 1:1 ratio of water to soil. Correlations between soil texture and chemical analysis were determined with the aid of the Statistical Analysis System (Table 1). When significant correlations occurred, nurseries were separated into three soil texture groups. Twenty-five nurseries were in Group A (>75% sand); twelve nurseries were in Group B (between 75% and 50% sand); and eight nurseries were in Group C (<50% sand).. Median, minimum, and maximum values for each soil group were determined for each variable (Table 2).

RESULTS AND DISCUSSION

Of the nurseries sampled, 38 were located in the Coastal Plain (Figure 5). Nurseries in this geographic province tended to have soil textures that were sands, loamy sands, and sandy loams. The three nurseries in the Mississippi Alluvial Valley had silt loam textures and were among the finest textures sampled. The remaining nurseries were located in the Ridge and Valley, Lower Plateau, and Piedmont provinces and were normally located on alluvial terrace soils. One nursery in the Valley and Ridge province in Alabama was not located on a river terrace. However, in 1980 and 1981, the entire nursery was covered with approximately 25 cm (10 inches) of river terrace soil which was moved to the nursery site. The original soil contained 54% sand and the new soil has 77% sand.

A coarse textured soil is desirable for pine nurseries because it allows seedbed preparation, lifting, and other work to be carried out sooner under wetter condition than fine-textured soils. For pine nurseries, many authors suggest soil texture having no less than 75% sand (Aldhous 1972, Armson and Sadreike 1979, Stoeckler and Jones 1957, Wakeley 1954, Wilde 1958). Only 25 of the nurseries had textures which met this requirement.

It is apparent that many nurseries established before 1960 had finer soil texture than those established later (Figure 6). This trend is in part due to the increased usage of mechanical harvesting after 1960. With hand lifting, soil texture was of little importance; however, mechanical harvesters perform better on loamy sands or sands. Of the 18 nurseries established after 1960, 14 had textures greater than 75% sands. This fact has implications to soil management in that the coarser textured soils will have a lower nutrient holding capacity and therefore monitoring essential elements is of more importance on these soils.

SOIL ACIDITY

The hydrogen ion activity of the soil, expressed as the pH value, is perhaps the most important chemical property. Soil acidity not only influences the availability of elements but also has a direct influence on the microbial population of the soil. The forest nurseryman is well aware of the influences of the soil acidity on seedling growth and has the ability to change the pH value with either liming, acid-forming fertilizers, or sulfur applications.

Figure 7 indicates that many of the nurserymen have kept soil acidity in pine nurseries in the South between pH 5.0 and 6.0, and this range is optimum for most tree species (Wilde 1958, May 1982). However, because conditions for growth of some pathogens are more favorable at a higher pH value, the senior author recommends a level between pH 5.0 and 5.5 for loblolly pine. Nutrients may become less available in soils with soil acidity levels below 5.0. The three hardwood nurseries were more alkaline, with pH levels between pH 6.2 and 6.4. However, some hardwood species can grow well at pH levels as low as 4.5 (Stone 1980, Kormanic 1980). The assumption that pH 6.2 is the optimum acidity level for hardwood growth is based on natural bottomland hardwood stands and <u>not</u> on studies from the nursery (Stone 1980).

Figure 8 indicates the history of one compartment at a nursery in the South which has alkaline irrigation water that is well buffered with calcium.

Between 1955 and 1965 the primary source of fertilizer nitrogen was ammonium nitrate. Because of the calcium level in irrigation water, the pH steadily rose until it reached a maximum of 6.6 in 1966. In 1967 the nursery began using ammonium sulfate and sulfur in order to lower soil pH. This practice was continued and eventually the pH was lowered to the desired range of 5.5 in 1975.

Because the cation exchange capacity (CEC) of this nursery was high (12 meq/100g), the change in pH took place gradually. The amount of sulfur required to lower the soil pH varies with the cation exchange capacity of the soil. The higher the cation exchange capacity the greater the amount of sulfur required. The cation exchange capacity for most of the nurseries in the south is below 5 meq/100g (Figure 9). In Florida nurseries, 448 kg/ha (400 lb/a) of sulfur have been used in March before planting loblolly and up to 224 lg/ha (200 lb/a) have been directly applied to the seedlings (Mizell 1980). Sulfur applications of more than 1,600 kg/ha has reduced survival of red pine in Ontario (Mullen 1969) but rates this high are not needed in southern pine nurseries.

Organic Matter

A&L Labs normally determines the percent organic matter content by the Walkley-Black method. However, the results from A&L are consistently higher than from other labs (Peter 1982). Table 3 indicates the organic matter values reported by A&L labs are about 25% higher than those from Auburn (Auburn uses a Leco Carbon Analyzer). This difference is attributable to the extra heating of the sample by A&L in their variation of the basic method.

Incorporation of organic matter in the soil usually improves physical and chemical properties (Armson & Sadredika 1979). Organic levels are often correlated with soil texture. The more clay and silt in the soil the higher the organic matter. This is a result of less macropores in a fine textured soil which favor slower decomposition of organic matter.

Organic matter maintenance is considered basic to good soil management programs. In the 50s and early 60s organic matter amendments were routine practice in most forest nurseries in the South with sawdust being one of the primary sources. However, today less than 2/3 of the southern nurseries routinely add organic amendments. With the A&L analysis, two percent organic matter is considered to be the minimum desired level for southern nurseries. However, over 2/3 of the nurseries sampled had organic levels below 2.0% (Figure 10). In the Pacific Northwest 19 of 20 Douglas-fir nurseries routinely apply organic amendments for each rotation (van den Driessche 1979).

It seems ironic that in the Northwest (where the decomposition rates are much lower than the South) such emphasis is placed on organic amendments. Whereas in Florida (where decomposition rates are extremely high) until recently, none of the six forest nurseries were routinely adding organic amendments. One nursery in Georgia with 87% sand had an organic matter content of 2.8% (A&L) in 1981. This supports the observations by May (1958) that "organic matter content of 1.5 to 2.5 percent can be developed and maintained in sands and loamy sands..."

Organic matter provides numerous benefits to soil management, including increased water-holding capacity; improved soil physical properties; increased cation exchange capacity; a source for nutrients such as nitrogen and phosphorus; a regulator of micronutrients such as manganese, boron, copper, zinc, and iron; reduces toxicity of certain herbicides; favors mycorrhizal development; and may suppress certain pathogens. It is possible for a nurseryman to grow good seedlings with soil having a low organic matter content, however, he cannot afford to make mistakes in fertilizer application, irrigation, pesticide application, management of microbial populations, or management of soil physical properties. The benefit of organic matter is that it provides a buffer against such mistakes. Some nurserymen say they can't afford to grow seedlings without this buffer. Other nurserymen say they can't afford to spend money for it.

It is doubtful that the use of cover crop will substantially increase soil organic matter levels. This is supported by several experts in forest soils. In 1948 Dr. Earl Stone (1948) stated that, "It is now appreciated that organic matter content will not be built up by green manures as is commonly employed unless the initial level is very low. Even their frequent inclusion will not prevent a decline in organic matter under most circumstances." Dr. Allison (1973) stated that "it is now well established that green manures have a negligible effect on total soil organic matter levels if cultivation is continued. Although they do replenish the supply of active, rapidly decomposing organic matter." Davey and Krause (1980) stated that "cover crops, catch crops and green manures are very benefical in nursery management, but current wisdom indicated that they will not suffice for the total needed soil organic matter... The realistic nurseryman will not depend on cover crops to substain his soil organic matter content." Dr. May (1982) stated that "in many soils the organic matter content cannot be maintained or increased much above the irreducible minimum 0.3 to 0.8 % using a 1 to 1 rotation without the addition of large quantities of organic matter."

A recent study by Sumner and Bouton (1981) has indicated that growing cover crops for two years only increased soil organic matter levels at the Morgan Nursery in Georgia by 0.23 to 0.34%. Recent soil analysis from these plots have indicated that one year of seedling production reduced the level by 0.21 to 0.37%, therefore negating the benefit of the cover crops. The production of the cover crop was approximately 12.1 to 13.2 metric tons per hectare (5.4 to 5.9 short tons per acre) per year. The addition of 45 metric tons per hectare (20 short tons per acre) of sawdust can easily increase soil organic matter levels by 1.5%. The amount of lignin contained in sawdust and/or pine bark greatly exceeds that contained in cover crops such as corn or sorghum. Pine bark is reported to have between 31 and 50% lignin and sawdust is reported to have 27 to 30% lignin. Corn can contain 15% lignin and sorghum-sudangrass can contain between 5 and 14% lignin depending on the stage of development. Therefore the maximum amount of lignin added in a two year cover crop of sorghum-sudangrass would be 3.8 metric tons/hectare. The minimum amount of lignin added in a 2.5-cm addition of sawdust or bark would be 12 metric tons/hectare. Lignin is a desirable organic amendment because of its slow decomposition rate. It degrades much slower than starch or carbohydrates and degrades slower than cellulose and hemicellulose. In addition, lignin is the source of the substances that provide for the increase in cation exchange capacity.

SOIL NUTRIENTS

Figure 11 indicates a generalized response of seedling growth as affected by nutrient level. The forest nurseryman should not wait until he sees a deficiency symptom before deciding to fertilize nor should he keep his seedlings in the hidden hunger area of the curve. Although no distinct deficiency will be noted, productivity will be reduced. However, the nurseryman should not over fertilize to the degree where other nutrients become unavailable or toxic symptoms occur. It is the goal of our program to help keep the nurseryman's soil fertility in the area where maximum productivity will be achieved at the most economical cost.

NITROGEN

Nitrogen is the nutrient which is most frequently limiting to plant growth and is needed in greatest quantities for production of tree seedlings. Scientists have been unable to develop a reliable test to determine the nitrogen supplying capacity of soils. There are several reasons for this; first, a majority of the nitrogen is stored in soil organic matter. The rate of nitrogen release is affected by the amount of soil organic matter, the carbon/nitrogen ratio of the organic matter, the soil temperature, soil moisture, and length of growing season. These and other factors make it impractical to predict the amount of nitrogen that will be supplied by the soil in one growing season. Second, most forest nurseries are low in organic matter content and do not vary much in their capacity to supply nitrogen. Therefore nitrogen recommendations are based primarily on the crop to be grown.

The estimated nitrogen return (ENR) as reported by A&L Laboratories is an attempt to estimate the amount of nitrogen available from decomposition of organic matter. This figure is computed directly from the soil organic matter. The assumption is the higher the organic matter in the soil, the higher the carbon/nitrogen ratio. For soils having 3% organic matter, 116 kg/ha (104 lb/A) of nitrogen is estimated to be released through the growing season. However, soils with 1% organic matter would be calculated to release only 72 kg/ha (64 lb/A) of nitrogen. On fields where the organic matter level is lower than 1%, some preplant nitrogen is suggested. Otherwise, it is more efficient to apply all the nitrogen as summer top dressings. Where preplant nitrogen is used, 56 kg/ha (50 lb/A) of nitrogen should be applied preplant, with additional top dressings during the summer totaling 140 kg/ha (125 lb/A). Where no preplant nitrogen is applied, a total of 170 kg/ha (150 lb/A) of nitrogen during the growing season should be sufficient. In some instances, (i.e., Hauss nursery, 1981) loblolly and longleaf seedlings have been grown with no preplant or top dressed nitrogen.

If the pH is high, or the soil sulfur test is low, or concentrated fertilizers are used, then some or all of the nitrogen should be applied as ammonium sulfate. Otherwise ammonium nitrate can be used. Light applications of nitrogen during the growing season are recommended to prevent summer chlorosis in loblolly pine (Carter 1964). The application rate should range from 22 to 33 kg/ha (20 to 30 lb/A) of nitrogen per application. Therefore five to seven applications of nitrogen would be required when applying 170

SOIL NUTRIENTS

Figure 11 indicates a generalized response of seedling growth as affected by nutrient level. The forest nurseryman should not wait until he sees a deficiency symptom before deciding to fertilize nor should he keep his seedlings in the hidden hunger area of the curve. Although no distinct deficiency will be noted, productivity will be reduced. However, the nurseryman should not over fertilize to the degree where other nutrients become unavailable or toxic symptoms occur. It is the goal of our program to help keep the nurseryman's soil fertility in the area where maximum productivity will be achieved at the most economical cost.

NITROGEN

Nitrogen is the nutrient which is most frequently limiting to plant growth and is needed in greatest quantities for production of tree seedlings. Scientists have been unable to develop a reliable test to determine the nitrogen supplying capacity of soils. There are several reasons for this; first, a majority of the nitrogen is stored in soil organic matter. The rate of nitrogen release is affected by the amount of soil organic matter, the carbon/nitrogen ratio of the organic matter, the soil temperature, soil moisture, and length of growing season. These and other factors make it impractical to predict the amount of nitrogen that will be supplied by the soil in one growing season. Second, most forest nurseries are low in organic matter content and do not vary much in their capacity to supply nitrogen. Therefore nitrogen recommendations are based primarily on the crop to be grown.

The estimated nitrogen return (ENR) as reported by A&L Laboratories is an attempt to estimate the amount of nitrogen available from decomposition of organic matter. This figure is computed directly from the soil organic matter. The assumption is the higher the organic matter in the soil, the higher the carbon/nitrogen ratio. For soils having 3% organic matter, 116 kg/ha (104 lb/A) of nitrogen is estimated to be released through the growing season. However, soils with 1% organic matter would be calculated to release only 72 kg/ha (64 lb/A) of nitrogen. On fields where the organic matter level is lower than 1%, some preplant nitrogen is suggested. Otherwise, it is more efficient to apply all the nitrogen as summer top dressings. Where preplant nitrogen is used, 56 kg/ha (50 lb/A) of nitrogen should be applied preplant, with additional top dressings during the summer totaling 140 kg/ha (125 lb/A). Where no preplant nitrogen is applied, a total of 170 kg/ha (150 lb/A) of nitrogen during the growing season should be sufficient.

If the pH is high, or the soil sulfur test is low, or concentrated fertilizers are used, then some or all of the nitrogen should be applied as ammonium sulfate. Otherwise ammonium nitrate can be used. Light applications of nitrogen during the growing season are recommended to prevent summer chlorosis in loblolly pine (Carter 1964). The application rate should range from 22 to 33 kg/ha (20 to 30 lb/A) of nitrogen per application. Therefore five to seven applications of nitrogen would be required when applying 170 kg/ha (150 lb/A) of nitrogen during the growing season. The first application of nitrogen is usually applied six weeks after seeding.

PHOSPHORUS

The level of available phosphorus (Weak Bray) is not strongly correlated with soil texture. For loblolly, the minimum desired level of phosphorus using Weak Bray extraction is 40 ppm (25 ppm if a Double-Acid extraction is used). For hardwood seedlings, Paul Kormanic (1980) has recommended soil phosphorus levels of 75 to 100 ppm using weak Bray. Too high a level of phosphorus can be undesirable. Our analysis indicated that four nurseries had phosphorus levels greater than 120 ppm (Weak Bray)(Figure 12). By using our previous records at Auburn University, we found that these nurseries were high in phosphorus because of management practices. In the late 1950s, these nurseries had lower phosphorus levels. However the practices in those days were to apply 1,100 kg/ha (1000 lb/A) of superphosphate.

Phosphorus does not leach through the soil but forms compounds with calcium, iron, and aluminum in the soil which release it slowly. It is doubtful whether much of the phosphorus in a top dressing of superphosphate ever becomes available to the current seasons crop due to phosphorus immobility and fixation in the soil. Where needed, phosphorus should be applied preplant. If a top dressing of phosphorus is needed, ammonium phosphate should be used. Crops require much smaller quantities of phosphorus than nitrogen and potassium. One crop of pine seedlings would usually remove less than 8 kg/ha of phosphorus. Therefore, under continuous fertilization, soil content of phosphorus has increased at some forest nurseries to high levels. High phosphrous levels are undesirable because of potential decreases in the availability of iron, zinc, and copper.

In addition, Youngberg(1980) suggests that when the ratio between phosphorus and potassium becomes out-of-line, seedlings may have problems in hardening-off in the fall. Figure 13 indicates the phosphorus/potassium ratio of the sampled nurseries. According to Youngberg, nurseries with twice as much phosphorus as potassium may have hardening-off problems. This helps explain why some nurseries have had trouble hardening seedlings off in the fall. This may also explain some of the responses observed after late applications of phosphorus. In 1982, two nurseries reported that seedlings fertilized with diammonium phosphate were delayed in hardening-off and also broke bud earlier in the spring. At one nursery, seedlings that were fertilized with 140 kg/ha (125 lb/a) of diammonium phosphate on September 24 broke bud early the following spring and had produced 15 cm of growth by March 9. Research needs to be conducted to confirm the role phosphorus plays in the dormancy of loblolly.

POTASSIUM

Potassium levels were also significantly correlated with soil textures. The junior author suggests a minimum of 90 ppm of potassium. Of the 45 nurseries in our sample, 26 nurseries had less than this minimum level (Figure 14). This suggests that of the major nutrients, potassium may be the one which is most often neglected. The ratio of potassium to other cations may indicate whether potassium may be deficient. The % base saturation for potassium should be greater than 5% (Figure 15). A crop of loblolly seedlings can remove up to 100 kg/ha of potassium. Leaching of potassium in sandy soils is usually a common occurrence and potassium top dressings may be required even during the growing seasons at some nurseries where leaching is great. Use of more potassium than is needed may cause magnesium deficiencies especially on sandy soils.

CALCIUM

Calcium is positively correlated with the silt and clay content and therefore the absolute amounts will vary with texture (Figure 16). For sands and loamy sands, at least 200 ppm of calcium is recommended. However, the absolute amount of exchangeable calcium present is frequently not so important to plant nutrition as the amount present in relation to the quantities and kinds of other cations present. Figure 17 shows the % base saturation of calcium for the 45 nurseries sampled. This distribution suggests that nurseries with less than 40% base saturation of calcium are either too low in pH, or too low in calcium.

When an increase in pH is desired, dolomitic or calcitic limestone can be used. When an increase in pH value is not desired, calcium sulfate (gypsum) can be applied. Low calcium levels are undesirable in a conifer nursery since deficiencies can result in serious injury to meristematic regions (Davis 1949; Lyle 1969; Sucoff 1961).

MAGNESIUM

Magnesium is also correlated with silt and clay content (Figure 18). For nursery soils with more than 75% sand, we recommend at least 25 ppm. For those with sandy loams, we recommend at least 35 ppm. Loams and silt loams should have at least 40 ppm. The % base saturation for Magnesium should be between 10 and 25% (Figure 19). As a general rule, if the soil test indicates that the ppm of exchangeable potassium to exchangeable magnesium ratio is more than 3 to 1, then a magnesium deficiency could occur. Magnesium is important in chlorophyll formation. Magnesium deficiency yields a needle color similar to nitrogen deficiency (Lyle 1969).

SODIUM

Sodium is not usually regarded as an essential element. However, the sodium level in the soil can greatly affect the production of quality seedlings. Problems may arise if the exchangeable sodium in the soil exceeds 10%. By testing irrigation water, the Auburn Cooperative identified three nurseries that had high sodium absorption ratios (Figure 20). Irrigation water with a sodium absorpion ratio of 3 to 5 indicates slight to medium hazard. Values above 5 indicate that problems with permeability are likely to occur, especially for fine textured soils. One of these nurseries was having difficulty producing loblolly seedlings. When the soil was tested, up to 21% exchangable sodium was reported. This was causing problems with soil structure and was probably causing a nutrient imbalance. Now that the problem has been identified, steps have been taken to remedy the situation. Calcium sulfate additions helped in reducing the sodium absorption ratio in the soil. Up to

780 kg/ha of gypsum was applied directly to the seedlings. Sodium usually does not need to be monitored except at those nurseries that have a high sodium absorption ratio in their irrigation water.

SULFUR

Sulfur is essential for efficient nitrogen utilization by the plant. In the past, when sulfur "contaminated" fertilizers were used, sulfur was normally added in sufficient amounts to avoid deficiencies. However, today with the use of highly concentrated fertilizers and leaching losses from irrigation, sulfur deficiencies can and have occurred in forest nurseries. Sulfur deficiencies have been documented for at least three southern nurseries (Lyle and Pearce 1968, Morris 1980, Stone 1980). Response of loblolly seedlings at the Ft. Towson nursery in Oklahoma was dramatic (Morris 1980). For the present, the junior author recommends maintaining at least 10 ppm of sulfur (Figure 21). The ratio of nitrogen to sulfur in the plant tissue may be a better indicator of sulfur requirement. On the average, loblolly seedlings require approximately 1 kg of available sulfur for each 15 kg of available nitrogen. Because most sulfur-containing fertilizers are highly soluble and the sulfate portion is subject to leaching, the best way of building sulfur reserves in soils is by maintaining an adequate organic matter content. Where organic sulfur reserves are not maintained, ammonium sulfate or other sulfur containing fertilizers will need to be applied.

IRON

Deficiency of iron is one of the most common and conspicuous micronutrient deficiencies of trees and occurs chiefly on alkaline and calcareous soils where absorption is inhibited. This is the main reason why loblolly does not grow well above pH 6. Iron chlorosis occurring after heavy applications of nitrogen or during hot weather are known as nitrate-induced chlorosis or heat-induced chlorosis. High levels of phosphorus can tie up iron by forming insoluble iron-phosphate compounds. Soil analysis for iron is probably only useful if a low level is indicated (Figure 22). A soil test with medium or high levels of iron is almost meaningless since the iron may not be in an available form. Much of the iron in the leaves occurs in the chloroplasts where it plays a role in the synthesis of chloroplast proteins. Iron is relatively immobile and therefore chlorosis develops first at the terminal needles. Iron chlorosis is usually corrected by either acidifying the soil with sulfur, or with the application of iron-chelates. The iron-chelates produce favorable results more quickly.

MANGANESE

Plants can use manganese over and over; therefore, only small amounts are required. The junior author suggest a minimum level of 5 ppm. None of the nurseries sampled had less than 7 ppm of Manganese (Figure 23). This element is also essential for the synthesis of chlorophyll and also probably affects the avaliability of iron. For this reason, the symptoms of manganese deficiency are easily confused with iron chlorosis.

ZINC

Zinc is essential for the transformation of carbohydrates and for regulation of the consumption of sugar. The junir author suggests a minimum level of 1 ppm for zinc. The lowest level of zinc for the nurseries sampled was 1.1 ppm (Figure 24). However, in 1981 three nurseries had levels as low as 0.7 ppm. Those nuseries with sandy, easily leached soils and high in phosphorus are subject to zinc deficiency. Heavy applications of phosphate to the soil or soils with high levels of phosphates are often low in available zinc. It has been found that fumigation of soils low in zinc can result in increased plant uptake of zinc (Thorne 1957).

COPPER

Copper plays an important role in plant growth as an enzyme activator. The junior author suggests a minimum level of 0.8 ppm. Of the 45 nurseries sampled, 19 had less than this level (Figure 25). On sandy soils containing little organic matter, copper generally becomes less available to plants as the pH value increases. High levels of phosphorus in the soil can reduce the uptake of copper by the seedling. The nursery with 4 ppm of copper in figure 25 is high because of the frequent use of bordeaux mixture as a fungicide.

BORON

A recent paper in the Southern Journal of applied Forestry by Stone et al.(1982) has pointed out the importance of monitoring the boron level in sandy nurseries. In a sandy soil, organic matter is the sole means or boron retention. This points out the importance of maintaining an adequate level of organic matter. In addition, soil acidity above pH 6 in conjunction with high calcium level resulted in less available boron. The lowest level of boron reported by A&L Labs for the St. Regis nursery in Florida was 0.2 PPM. (Figure 26). Several other nurseries had soils with this low level in 1981. The junior author suggests maintaining the level of boron above 0.3 ppm. Boron deficiency causes serious injury and death of the apical meristem and is well illustrated in the paper by Stone et al, (1981).

CONCLUSION

Thus far, 25 southern nurseries have used the services of the Southern Forest Soil Testing Program. Although we have only just begun, several nurseries have already improved their seedling production as a result of this program. The primary goal of this soil testing program is to provide the nurseryman with help so that he can avoid imbalances in soil nutrients as well as avoid dramatic fluctuations in nutrient levels. We hope that with this Program, nursery soil productivity will be maximized throughout the South.

LITERATURE CITED

Aldhous, J.R. 1972. Nursery Practice. Forestry Commission Bull. 43. Her Majesty's Stationary Office. London. 184 pp.

Allison, F.A. 1973. Soil Organic Matter And Its Role In Crop Production. Elsevier Scientific Publishing Co., New York. p. 637.

Armson, K.A. and Sadreika, U. 1979. Forest tree nursery soil management and related practices. Ontario Ministry of Natural Resources. Toronto, Ontario. 179 p.

Carter, Mason C. 1964. Nitrogen and "summer chlorosis" in loblolly pine. Tree Planter's Notes. #64 p. 18-19.

Davis, Donald E. 1949. Some effects of calcium deficiency on the anatomy of Pinus taeda. American Journal of Botany. 336:276-282.

Davey, C.B. and H.H. Krause. 1980. Functions and maintenance of organic matter in forest nursery soils. Pages 130-165. in: Proceedings North American Forest Tree Nursery Soils Workshop. SUNY, Syracuse, New York.

Kormanic, Paul P. 1980. Effects of nursery practices on vesicular-arbuscular mycorrhizal development and hardwood seedling production. Pages 63-67 in: Proc 1980 Southern Nursery Conf. U.S.D.A. For. Ser. Tech. Pub.

Lyle, E.S., 1969. Mineral deficiency symptoms in loblolly pine seedlings. Agronomy Journal 61:395-398.

Lyle, E.S. and N.D. Pearce. 1968. Sulfur deficiency in nursery seedlings may be caused by concentrated fertilizers. Tree Planter's Notes. 19:1.

May, Jack T. 1958. Soil management in southern pine nurseries. IN Proc. First North American Forest Soils Conference, p.141-146. Michigan State University Ag. Exp. St., East Lansing Mich. 226 p.

May, Jack T. 1982. Southern Pine Nursery Handbook. USDA Forest Service, Southeastern Area State & Private Forestry, Atlanta, GA.

Mizell, Levoy. 1980. Maintaining optimum soil pH in sandy forest tree nurseries. Pages 295-296. in: Proceedings of the North American Forest Tree Nursery soils Workshop. SUNY, Syracuse, New York.

Morris, William G. 1979. Comparison of sulfur coated urea, nitroform and ammonium sulfate as a source of nitrogen for loblolly pine nursery production. Weyerhaeuser Co. Tech. Rep. 042-2008/79/1.

Mullen, R.E. 1969. Soil acidification with sulfur in a forest tree nursery. Sulfur Institute Journal 5:2-3

Peter, C.J. 1982. Adsorption, mobility, and efficacy of selected herbicides as influenced by soil properties. Ph.D. Dissertation. North Carolina State University, Dept. of Crop Science, Raleigh, North Carolina.

Stoeckeler, J.H. and G.W. Jones. 1957. Forest Nursery Practice in the Lake States. USDA Forest Service. Agric. Handbook No. 279. 93 pp.

Stone, E.L., C.A. Hollis and E.L. Barnard. 1982. Boron Deficiency in a southern pine nursery. South. J. Appl. For. 6:108-112.

Stone, E.L. 1948. An appraisal of the Ashe Nursery problem, with special reference to seedling nutrition and soil management. US Forest Service. Special Technical Report. 43 pp.

Stone, J.M. 1980. Hardwood seedling production: what are the fertility requirements? Pages 121-128. in: Proceedings of the North American Forest Tree Nursery Soils Workshop. SUNY, Syracuse, New York.

Sucoff, Edward I. 1961. Potassium, magnesium, and calcium deficiency symptoms of loblolly and virginia pine seedlings. USDA Forest Service, NE. For. Exp. St. Station Pap. No. 164. 18 pp.

Sumner, M.E. and J.H. Bouton. 1981. Organic matter maintenance in forest nurseries. Georgia Forestry Commission Georgia Forest Research Paper #24 6pp.

Thorne, D.W. 1957. Zinc deficiency and its control. Adv. Agron. 9:31-65.

van den Driessche, R. 1979. Soil management in Douglas-fir nurseries. pp 278-292 in Forest Soils of the Douglas Fir Region ed. P.E. Heilman, H.W. Anderson and D.M. Baumgartner. Wash. State Univ. Coop. Extension Serv., Pullman, Wash.

Wakeley, P.C. 1954. Planting the southern pines. Agric. Monogr. 18. Forest Service, USDA.

Wilde, S.A. 1958. Forest Soils. The Ronald Press Company, New York. p. 537.

Youngberg, C.T. 1980. Benefits of soil and plant analysis to nursery management. Pages 261-268. in: Proceedings of the North American Forest Tree Nursery Soils Workshop. SUNY, Syracuse, New York.

Table 1. A&L CORRELATION COEFFICIENTS AND PROBABILITIES OF A GREATER r VALUE1/

	OM	PH	CEC	SAND	SILT	CLAY
OM	1.00000 0.0000	0.01033 0.9476	0.30024 0.0504	-0.28438 0.0583	0.23548 0.1194	0.33392 0.0250
pH	0.01033 0.9476	1.00000 0.0000	0.23727 0.1255	0.05741 0.7146	-0.07246 0.6442	-0.00130 0.9934
CEC	0.30024 0.0504	0.23727 0.1255	1.00000 0.0000	-0.86540 0.0001	0.83231 0.0001	0.71183 0.0001
P1	0.10734 0.4933	-0.03572 0.8201	-0.25102 0.1044	0.26579 0.0850	-0.32230 0.0350	-0.02036 0.8969
P2	0.18884 0.2252	0.01310 0.9336	-0.16841 0.2803	0.19638 0.2069	-0.26954 0.0805	0.07793 0.6194
K	0.49984 0.0006	0.06338 0.6864	0.59714 0.0001	-0.58231 0.0001	0.46514 0.0015	0.74002 0.0001
Mg	0.26241 0.0853	0.41512 0.0056	0.90644 0.0001	-0.63875 0.0001	0.57178 0.0001	0.62557 0.0001
Ca	0.28687 0.0590	0.45628 0.0021	0.95673 0.0001	-0.76855 0.0001	0.75126 0.0001	0.56787 0.0001
SO4	0.23049 0.1277	-0.23377 0.1314	0.26704 0.0834	-0.38207 0.00096	-0.41512 0.0046	0.15955 0.2951
Zn	0.09941 0.5159	0.05338 0.7339	0.11572 0.4599	-0.09373 0.5403	0.08294 0.5880	0.09622 0.5295
Mn	0.21060 0.1659	0.06587 0.6747	0.45290 0.0023	-0.54081 0.0001	0.44549 0.0022	0.63822 0.0001
Fe	0.17975 0.2374	0.03123 0.8424	0.40074 0.0077	-0.41553 0.0045	0.48765 0.0007	0.07949 0.6037
Cu	0.01151 0.9402	-0.00212 0.9892	0.15335 0.3262	-0.25148 0.0956	0.25747 0.0877	0.15051 0.3237
B	0.34443 0.0205	-0.10497 0.5029	0.52361 0.0003	-0.65993 0.0001	0.62467 0.0001	0.55740 0.0001
% BASE SAT. K	0.22594 0.1452	-0.18127 0.2247	-0.37186 0.0141	0.28649 0.0625	-0.33783 0.0267	-0.05445 0.7288
% BASE SAT Mg.	0.08858 0.5722	0.39372 0.0090	-0.07555 0.6301	0.26844 0.0818	-0.32492 0.0335	-0.03400 0.8286
% BASE SAT. Ca	-0.09059 0.5635	0.84911 0.0001	0.29692 0.0532	-0.08882 0.5711	0.11157 0.4763	-0.00402 0.9796
% OF CEC H	-0.03017 0.8477	-0.97419 0.0001	-0.14431 0.3559	-0.12947 0.4080	0.15536 0.3198	0.02163 0.8905
H meq/100g	0.19112 0.2196	-0.57571 0.0001	0.55013 0.0001	-0.71499 0.0001	0.72185 0.0001	0.49259 0.0008

1/ the top value is the linear correlation coefficent and the bottom value is the probability of a greater correlation coefficent.

Table 2. Median, minimum, and maximum values for soil characteristics from 45 southern forest nurseries.

Variable	Group A Sands + loamy sands (25 nurseries)			Group B Sandy loams + sandy clay loams (12 nurseries)			Group C Loams + silt loams (8 nurseries)		
	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.
p.H.	5.7	5.2	6.0	5.6	4.5	6.1	5.7	4.6	6.4
C.E.C.	1.7	1.1	2.8	2.8	1.9	3.5	4.8	4.0	9.2
% O.M.	1.6	0.7	2.8	1.6	0.9	3.4	1.9	1.3	3.0
% Sand	83	76	95	66	55	71	38	15	49
% Slit	8	2	15	21	23	28	46	37	67
% Clay	7	1	12	14	11	25	17	7	23
	----------	----------	----------	----------	p.p.m.	----------	----------	----------	----------
P1	76	27	167	67	40	136	48	28	114
P2	92	36	186	87	46	166	79	38	138
K	58	20	126	103	47	136	111	68	138
Mg	40	15	85	55	25	90	82	35	250
Ca	200	100	300	300	100	400	550	300	1200
Mn	25	4	144	132	26	278	108	63	260
S-	14	5	60	16.5	5.0	50.0	33	13	100
Fe	47	13	102	45	24	105	84	43	217
Cu	0.7	0.4	2.3	0.8	0.5	4.3	0.9	0.5	2.4
Zn	2.2	1.1	11.4	4.4	1.9	29.4	3.4	1.6	4.7
B	0.4	0.3	1.4	1.2	0.9	1.8	1.2	0.9	2.5
Base saturation	----------	----------	----------	----------	----------	----------	----------	----------	----------
%K	8.3	3.3	17.0	8.8	6.3	12.9	5.0	3.2	8.8
%Mg	19.8	8.9	27.2	17.6	11.0	21.4	15.4	10.6	22.6
%Ca	53.6	35.7	62.5	48.1	26.3	62.5	58.5	31.3	65.2
%H	21.4	12.5	35.3	23.3	14.3	57.9	20.0	8.7	54.2

Table 3. Regressions of Auburn Soil Lab Analysis on A&L Soil Analysis of 45 Nursery Soils

Auburn soil test		Intercept		A&L soil test	R^2
Organic matter	=	NS*	+	.8(O.M)	.56
pH	=	1.35	+	.745(pH)	.56
C.E.C.	=	1.18	+	1.283(C.E.C)	.75
P**	=	NS	+	.62(p weak Bray)	.44
P	=	NS	+	.58(p-$NaHCO_3$-p)	.45
K	=	NS	+	.71(K)	.63
Mg	=	NS	+	.94(Mg)	.75
Ca	=	NS	+	1.13(Ca)	.83
Fe	=	9.6	+	.356(Fe)	.72
Mn	=	NS	+	.80(Mn)	.93
S-SO_4	=	9.3	+	.25(S-SO_4)	.40
Cu	=	NS	+	.88(Cu)	.59
Zn	=	1.24	+	.23(Zn)	.26
B	=	NS	+	.165(B)	.49

* NS = intercept not significantly different from zero.

** Auburn soils lab uses Double Acid Extraction.

FIGURE 1

REPORT NUMBER 169-9

A & L AGRICULTURAL LABORATORIES, INC.

411 N. THIRD ST., MEMPHIS, TN 38105 * (901) 527-2780

SEND TO: AUBURN U. (D. SOUTH)
DEPT. OF FORESTRY
AUBURN UNIVERSITY,
ALABAMA 36849

GROWER:

SAMPLES SUBMITTED BY: DAVID SOUTH

DATE OF REPORT 06/21/82 PAGE 1

SOIL ANALYSIS REPORT

SAMPLE NUMBER	LAB NUMBER	ORGANIC MATTER % * RATE	ORGANIC MATTER ** ENR lbs./A	PHOSPHORUS P1 (Weak Bray) * **** ppm-P RATE	PHOSPHORUS P2 N_aHCO_3-P * **** ppm-P RATE	POTASSIUM K * ***** ppm-K RATE	MAGNESIUM Mg * *** ppm-Mg RATE	CALCIUM Ca * *** ppm-Ca RATE	SODIUM Na * *** ppm-Na RATE	pH SOIL pH	pH BUFFER pH	HYDROGEN H meq/100g	Cation Exchange Capacity C.E.C. meq/100g	PERCENT BASE SATURATION (COMPUTED) % K	% Mg	% Ca	% H	% Na
1L	4094	2.2	88 M	49VH	52 H	102 VH	39 L	250 L	35 M	5.2	6.90	1.0	3.0	8.7	10.8	41.7	33.3	5.1
2U	4095	1.5	74 L	60VH	61VH	96 VH	38 L	250 L	35 M	5.3	6.90	0.9	2.9	8.5	10.9	43.1	31.0	5.2
3	4096	1.3	70 L	36VH	39 M	100 VH	19VL	200 L	84VH	5.0	6.80	1.2	3.0	8.5	5.3	33.3	40.0	12.2
4	4097	1.5	74 L	37VH	38 M	108 VH	28 L	250 L	101VH	5.1	6.80	1.3	3.5	7.9	6.7	35.7	37.1	12.5

156

(SEE EXPLANATION ON BACK)

SAMPLE NUMBER	NITRATE NO_3 ppm-NO_3-N RATE	SULFUR S ppm-S RATE	ZINC Zn ppm-Zn RATE	MANGANESE Mn ppm-Mn RATE	IRON Fe ppm-Fe RATE	COPPER Cu ppm-Cu RATE	BORON B ppm-B RATE	EXCESS LIME RATE	SOLUBLE SALTS mmhos/cm RATE	CHLORIDE Cl ppm-Cl RATE	MOLYBDENUM Mo ppm-Mo RATE	PARTICAL SIZE ANALYSIS % SAND	% SILT	% CLAY	SOIL TEXTURE
1L		8 M	1.3 L	20 M	50VH	1.9 H	.4 L	N	.4 L						
2U		12 M	1.2 L	12 M	26 H	2.4 H	.3VL	N	.4 L						
3		10 M	4.2 H	118VH	62VH	6.1VH	.8 M	N	.7 M						
4		21VH	3.7 H	108VH	74VH	6.1VH	1.0 M	L	.8 M						

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

A & L AGRICULTURAL LABORATORIES, INC.

BY R.L. LARGE 8JL

* CODE TO RATING: VERY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), VERY HIGH (VH), AND NONE (N).
** ENR - ESTIMATED NITROGEN RELEASE
*** MULTIPLY THE RESULTS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM
**** MULTIPLY THE RESULTS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P_2O_5
***** MULTIPLY THE RESULTS IN ppm BY 2.4 TO CONVERT TO LBS. PER ACRE K_2O
MOST SOILS WEIGH TWO (2) MILLION POUNDS (DRY WEIGHT) FOR AN ACRE OF SOIL 6-2/3 INCHES DEEP.

Figure 2. SOUTHERN NURSERY SOIL MANAGEMENT HISTORY FORM

NURSERY:____________________ PHONE:________________

SUPERINTENDENT:____________________

ADDRESS:____________________

COMPARTMENT (BLOCK):____________ UNIT (S):________________

SOIL TEXTURE:________ % SAND:____ % SILT:____ % CLAY:____

NEXT CROP TO BE GROWN:____________________

CONDITION OF LAST CROP OF PINE SEEDLINGS
Chlorotic ☐ Stunted ☐ Below average ☐ Average ☐ Above average ☐

Other____________________

	DATE APPLIED	RATE APPLIED	DATE APPLIED	RATE APPLIED
Crop Grown[1]				
FERTILIZERS APPLIED				
Ammonium nitrate				
Ammonium sulfate				
Calcium nitrate				
Calcium sulfate (Gypsum)				
Magnesium sulfate (Epsom salt)				
Diammonium phosphate				
Nitrate of Soda-potash				
Potassium chloride (Muriate)				
Potassium nitrate				
Potassium sulfate				
Sulfate of Potash Magnesia				
Sulfur				
Superphosphate, normal				
Superphosphate, double				
Superphosphate, triple				
Urea				
Other				
MICRONUTRIENTS (list form)				
Boron				
Copper				
Manganese				
Zinc				
Iron				
LIME				
Calcite				
Dolomite				
ORGANIC MATTER				
Pine bark				
Hardwood bark				
Pine sawdust				
Hardwood sawdust				
Pine chips				
Hardwood chips				
Other				

[1] If cover crop, include both winter and summer covercrop.

Is irrigation water high in calcium? No ☐ Yes ☐

Is irrigation water high in sodium? No ☐ Yes ☐

AUBURN UNIVERSITY SOUTHERN FOREST NURSERY MANAGEMENT COOPERATIVE
SOIL NUTRIENT BALANCE SHEET

NURSERY Greentree ORGANIZATION Ace Paper Co. ADDRESS Greenbay, Mississippi DATE 11/12/81

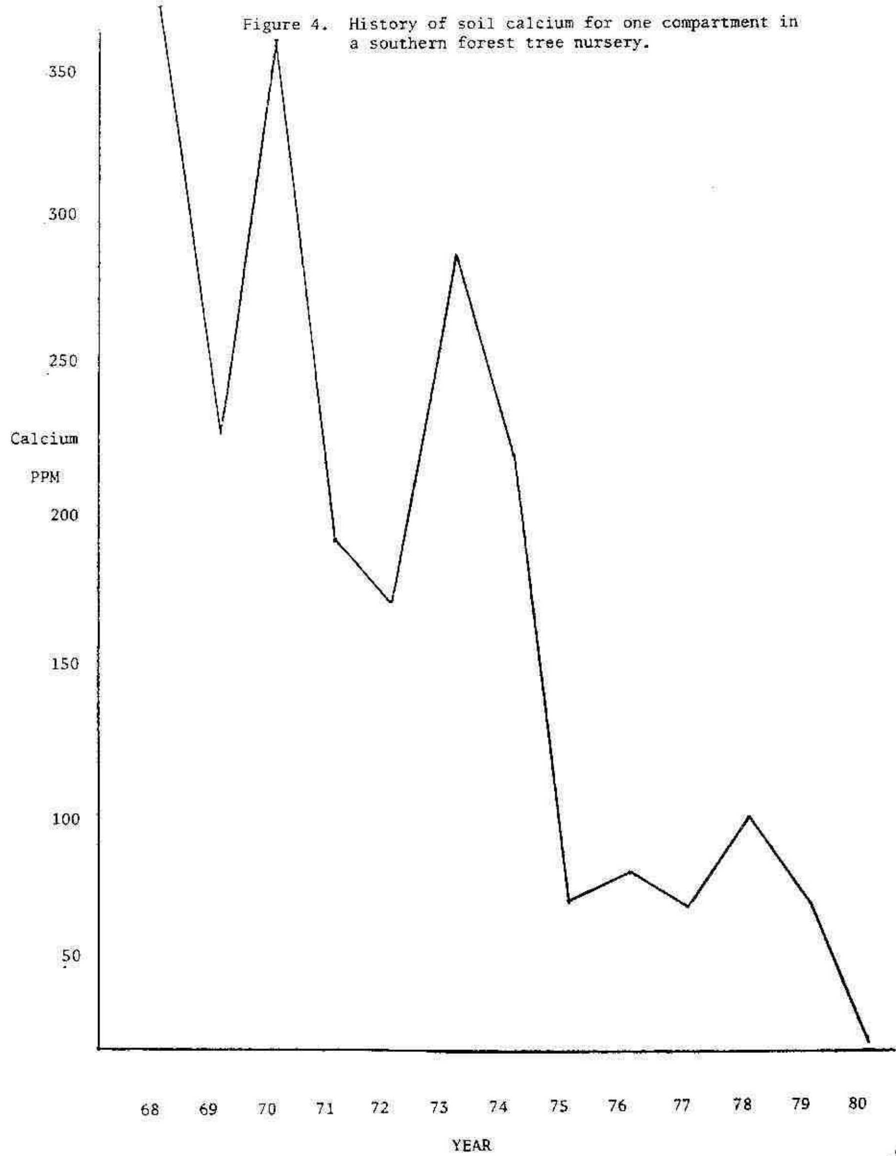
NURSERYMAN Sam Wood SOIL SAMPLE NO. 10A LABORATORY NO. 1616 SOIL SERIES NAME Lucedale

COMPARTMENT 10N UNITS 1-8 AREA IN UNIT 6 A %SAND:SILT:CLAY 55:31:14 APPROX. BULK DENSITY 1.3

SOIL VARIABLE	OLD SOIL TEST 8/28/80	AMENDMENTS FIRST / /	AMENDMENTS SECOND / /	AMENDMENTS THIRD / /	REMOVED BY SEEDLINGS	ADDITIONAL LOSSES OR GAINS	NEW SOIL TEST 11/12/81	CHANGE LBS PPM	COMMENTS
PH	6.4						6.4 VH	0	Too High use A-sulfate
% ORGANIC MATTER	1.6	1" sawdust	7 yds chicken litter				2.6 M	+	
C.E.C. MEQ/100G	5.2						4.9	0	
NITROGEN LB/A		39 (A-nitrate)	33(A-N) 33(A-N)	33(A-N)	-140				
PHOSPHURUS (P1) (WEAK) LB/A PPM	43	17 8.5			-6	+0.5	45 M	+2	
PHORPHORUS (P2) (STRONG) LB/A PPM	64	17 8.5			-6	+5.5	72 M	+8	
POTASSIUM (K) LB/A PPM	142	32 16			-35	+55	178 M	+36	
MAGNESIUM (MG) LB/A PPM	35				-3	+38	70 M	+35	
CALCIUM (CA) LB/A PPM	800				-20	-80	700 M	-100	
SODIUM (NA) LB/A PPM									
SULFUR (S) LB/A PPM	51				-4	-12	35 M	-16	
ZINC (ZN) LB/A PPM	1.0				-0.1	+0.6	1.5 L	+0.5	
MANGANESE (MN) LB/A PPM	48				-1.5	+2.5	49 L	+1	Add Mn
IRON (FE) LB/A PPM	21				-0.5	-3.5	17 L	-4	
COPPER (CU) LB/A PPM	0.8				-0.1	+1.1	1.8 M	+1	
BORON (B) LB/A PPM	0.6				-0.1	+0.4	0.9 M	+0.3	
% BASE SAT.-K	7.0						9.3 H	+	
% BASE SAT.-MG	5.6						11.9 L	+	
% BASE SAT.-CA	79.9						71.4 H	-	
% BASE SAT.-H	9.6						8.2 L	-	
% BASE SAT.-NA									

FIGURE 3

Figure 4. History of soil calcium for one compartment in a southern forest tree nursery.



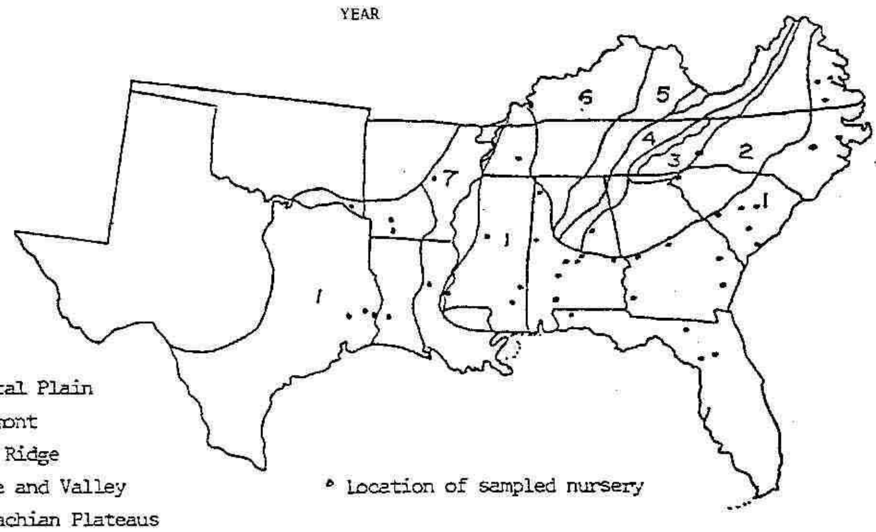


Figure 5. Physiographic Division of the Southeastern States.

FIGURE 6

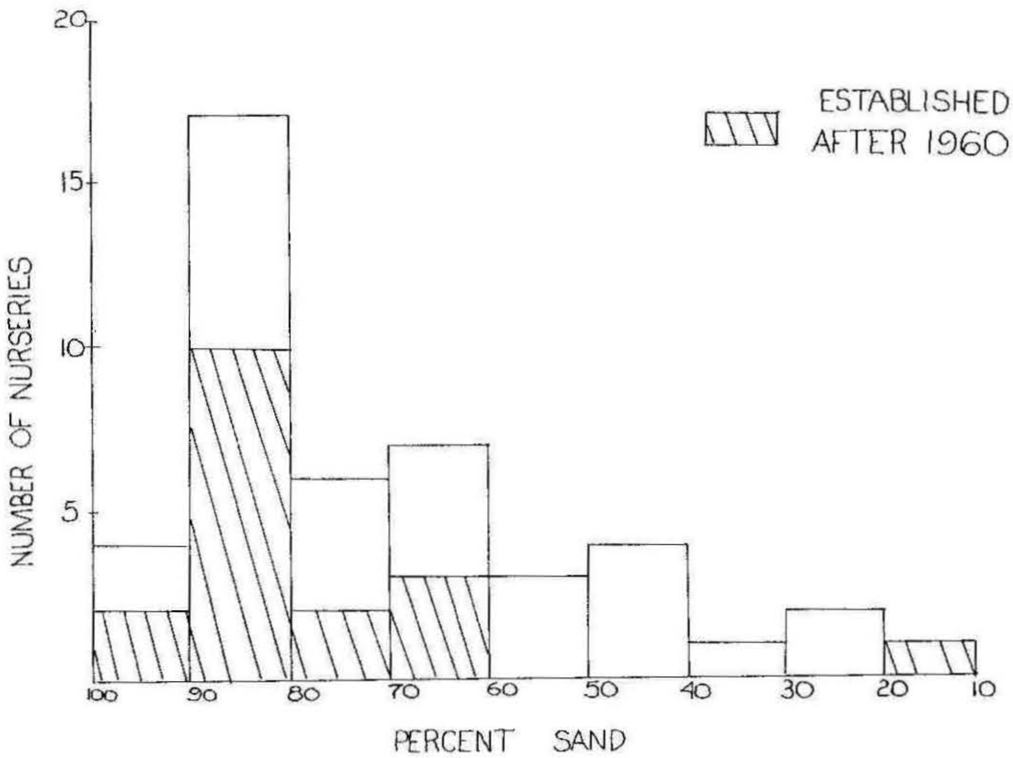


FIGURE 7

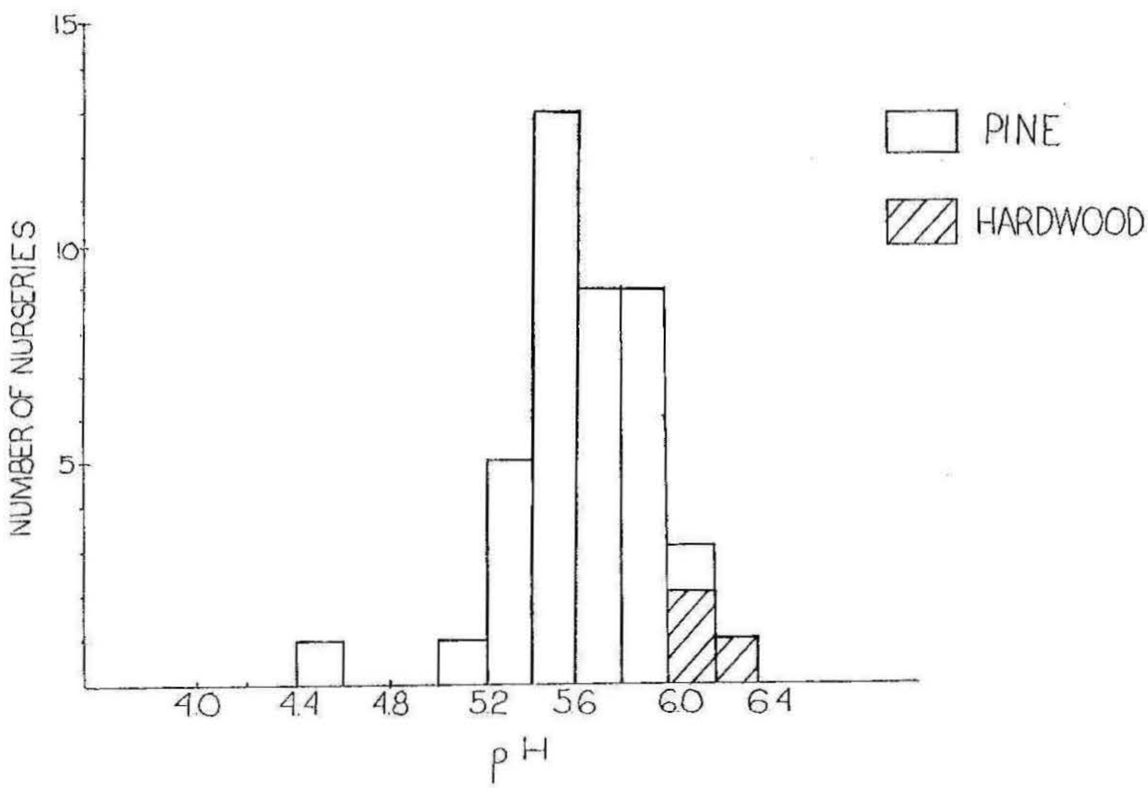


Figure 8. History of soil acidity for one compartment in a southern forest tree nursery.

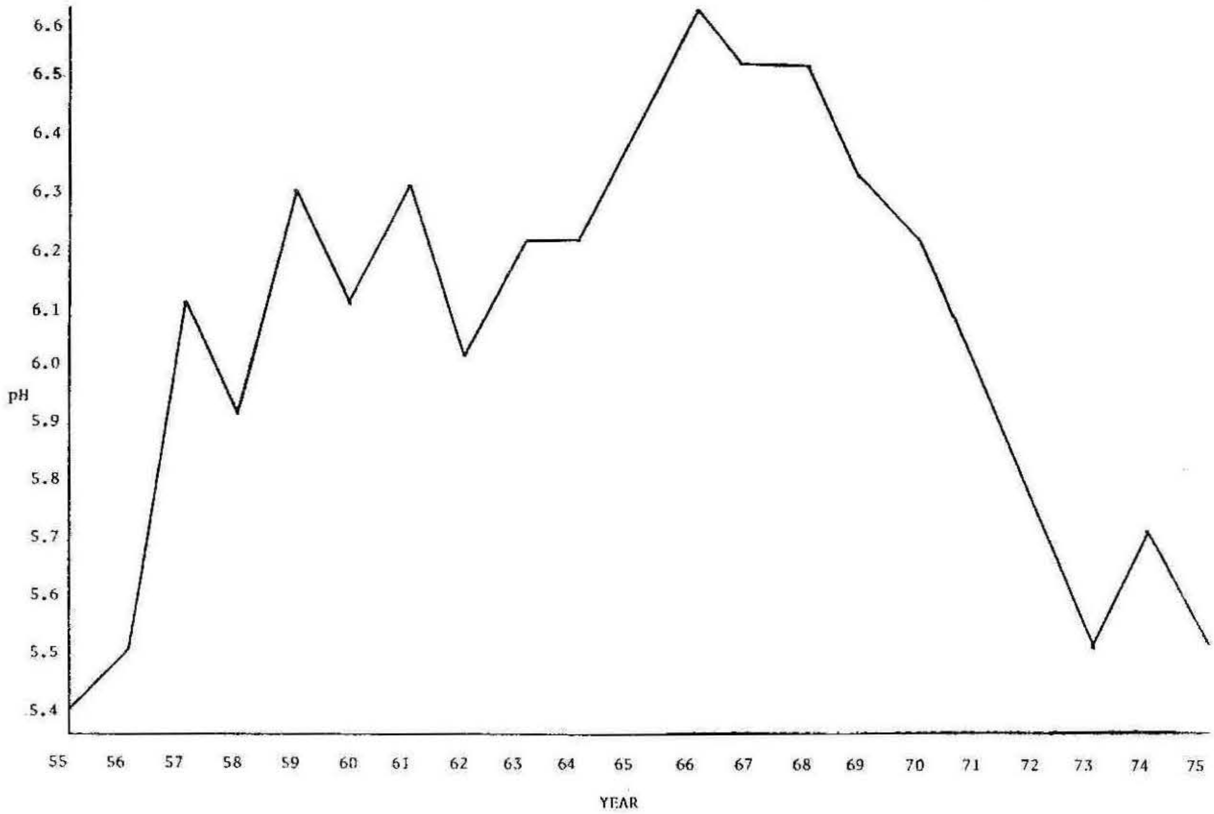


FIGURE 9

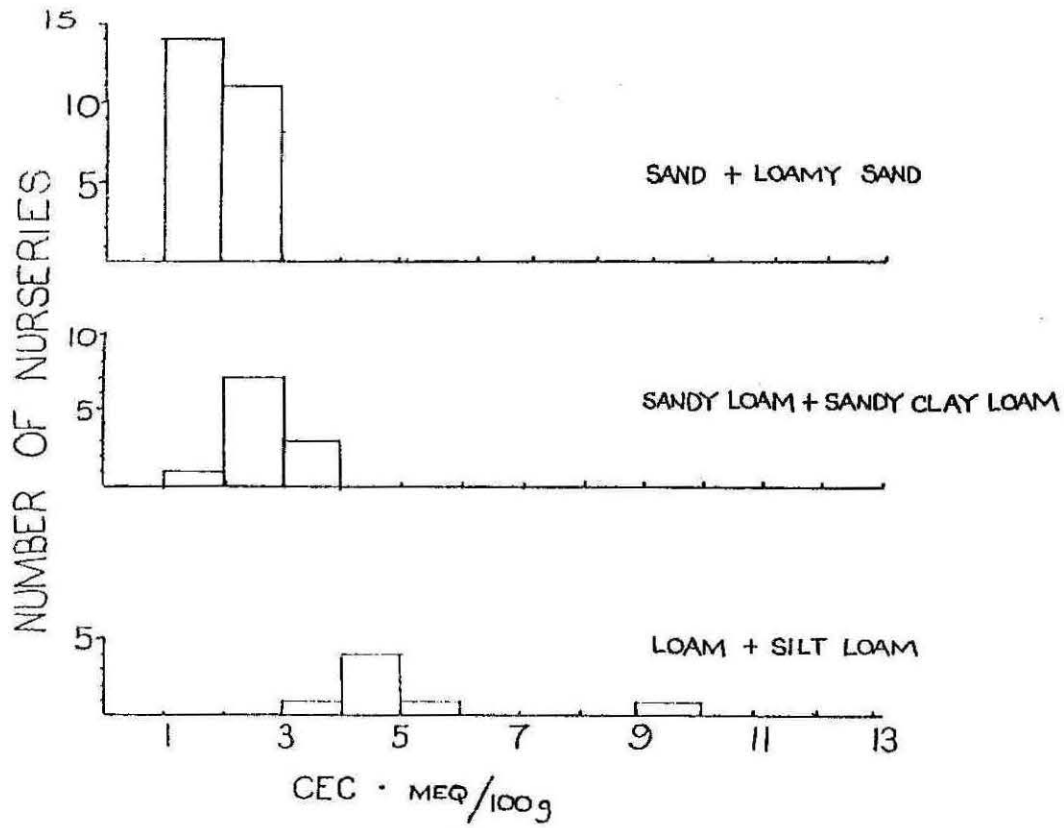
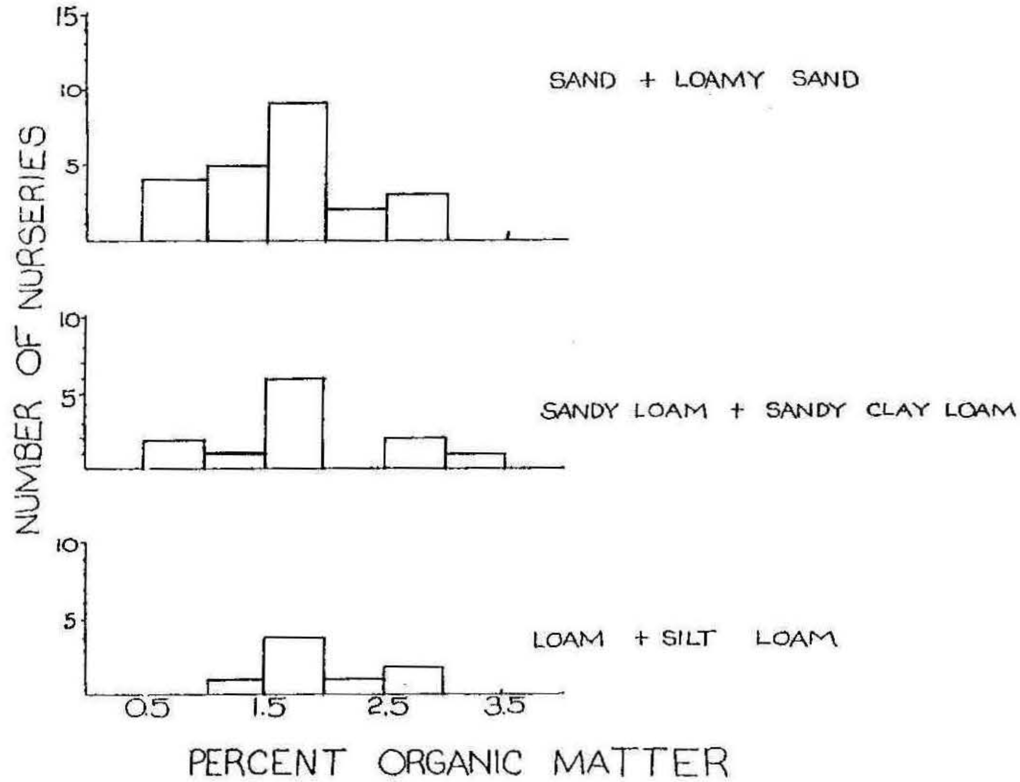


FIGURE 10



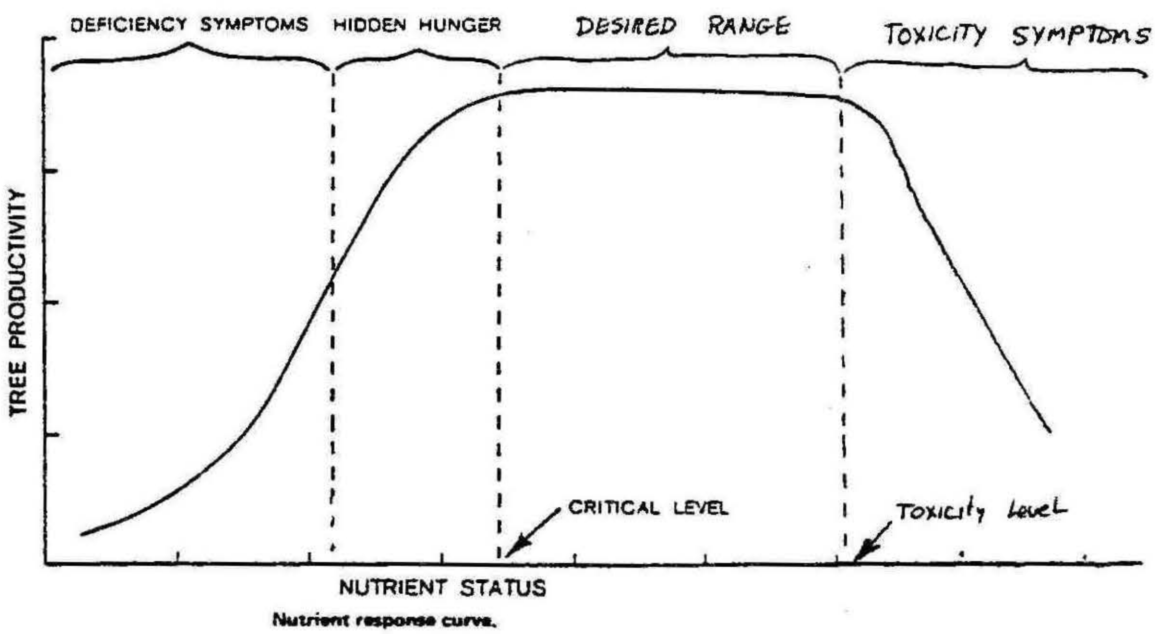


Figure 11 Relationship between tree productivity and nutrient status.

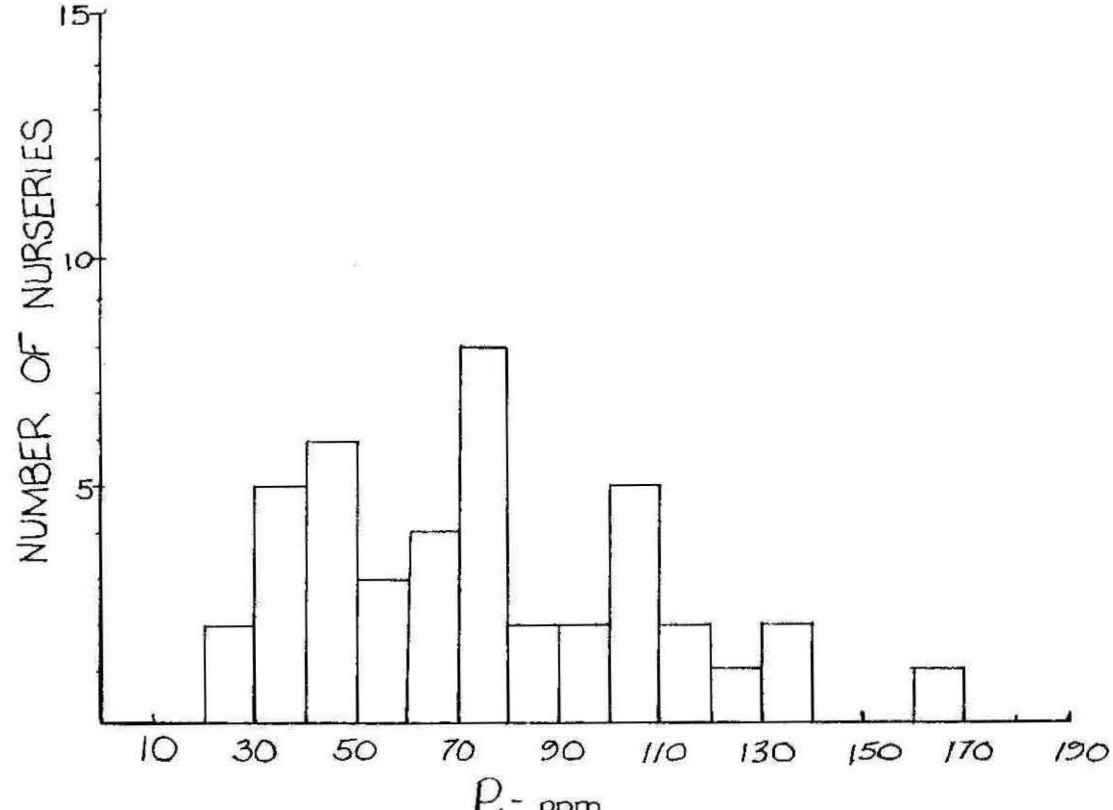

15
10
5
NUMBER OF NURSERIES
10
30
50
70
90
110
130
150
170
190
P_i - ppm

FIGURE 13

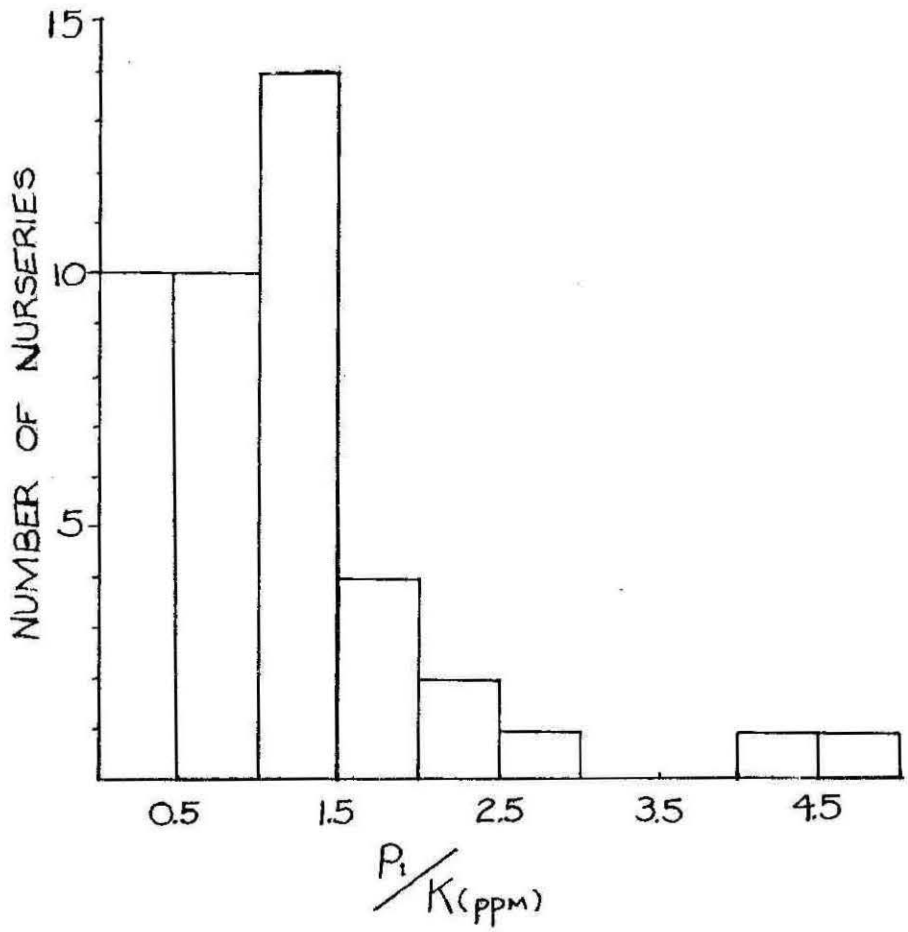

15
10
5
NUMBER OF NURSERIES
0.5
1.5
2.5
3.5
4.5
P_i/K(ppm)

Figure 14

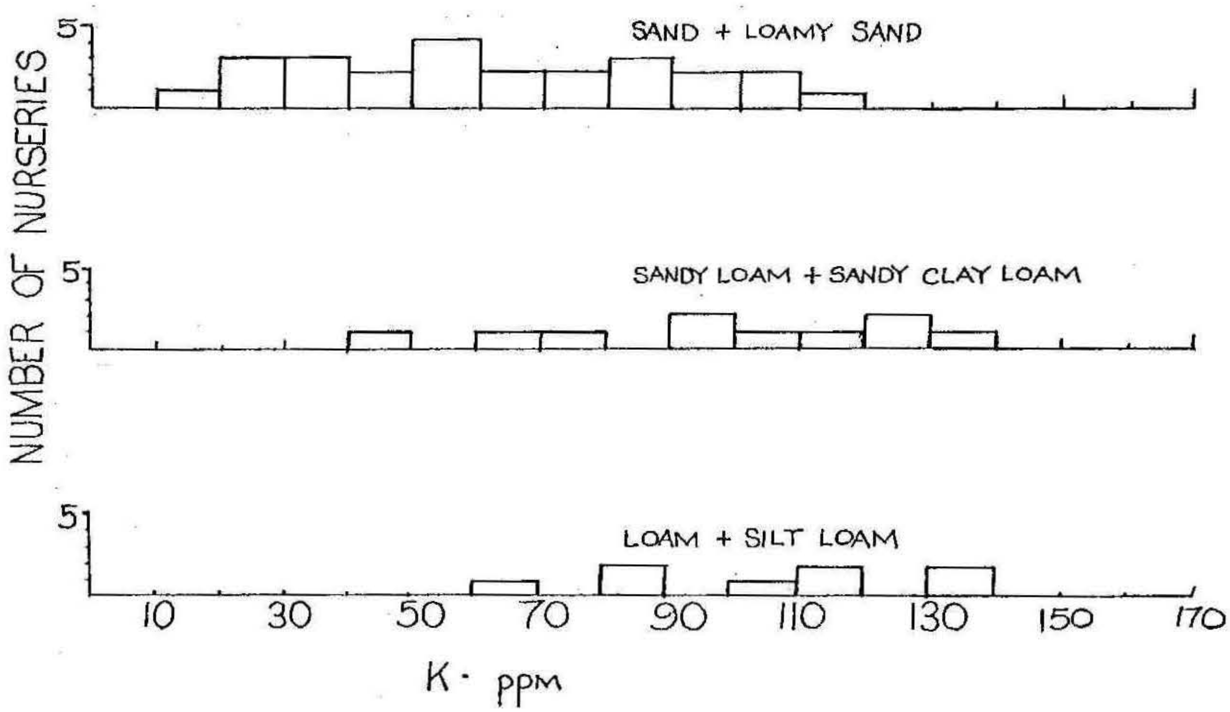


FIGURE 15

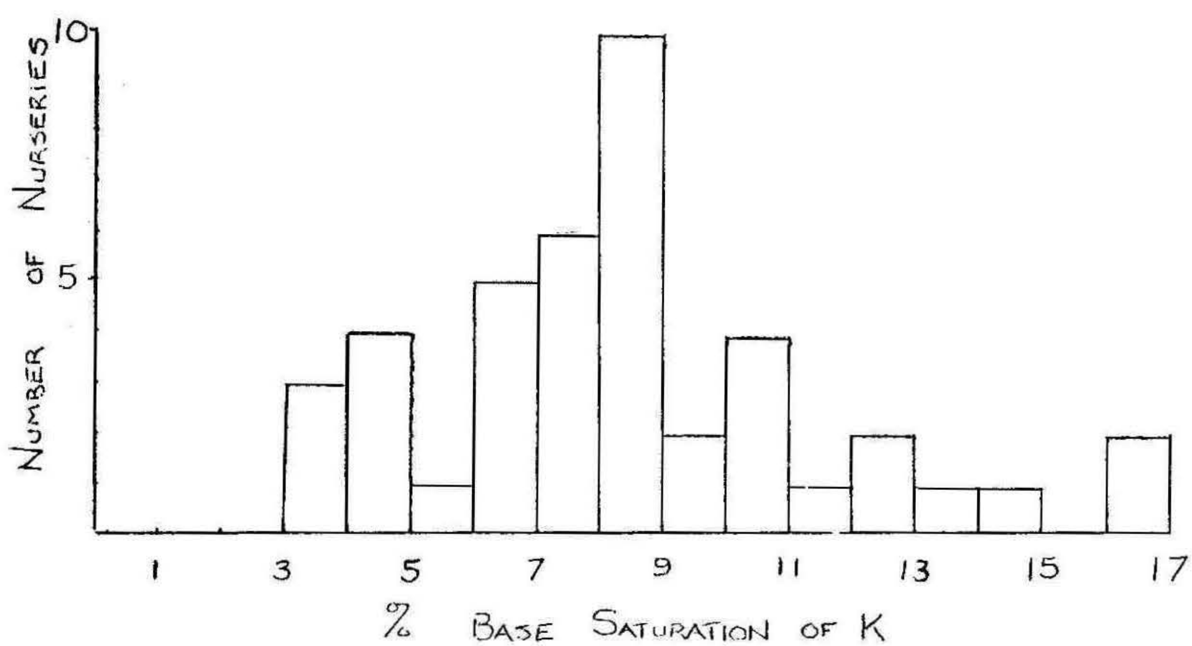


FIGURE 16

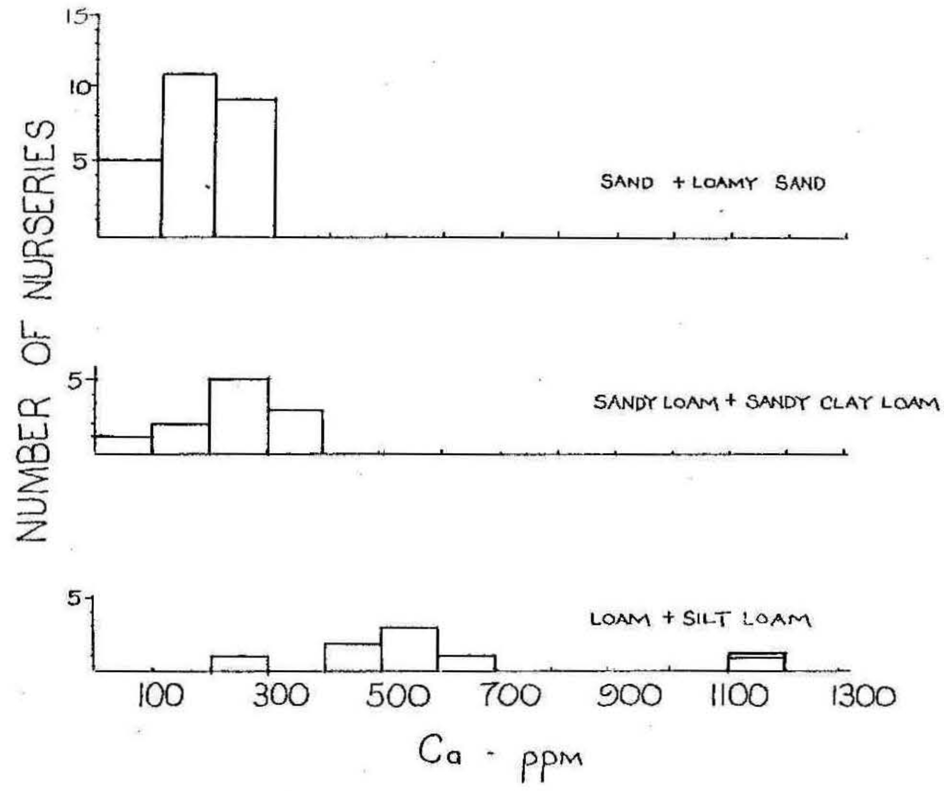


FIGURE 17

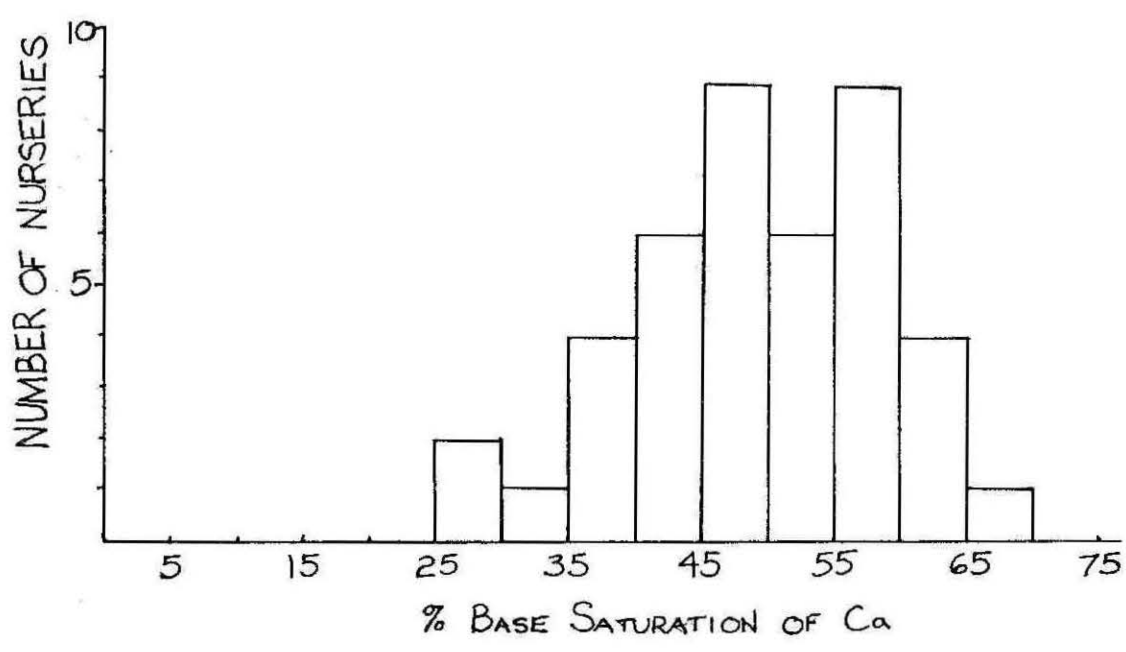


FIGURE 18

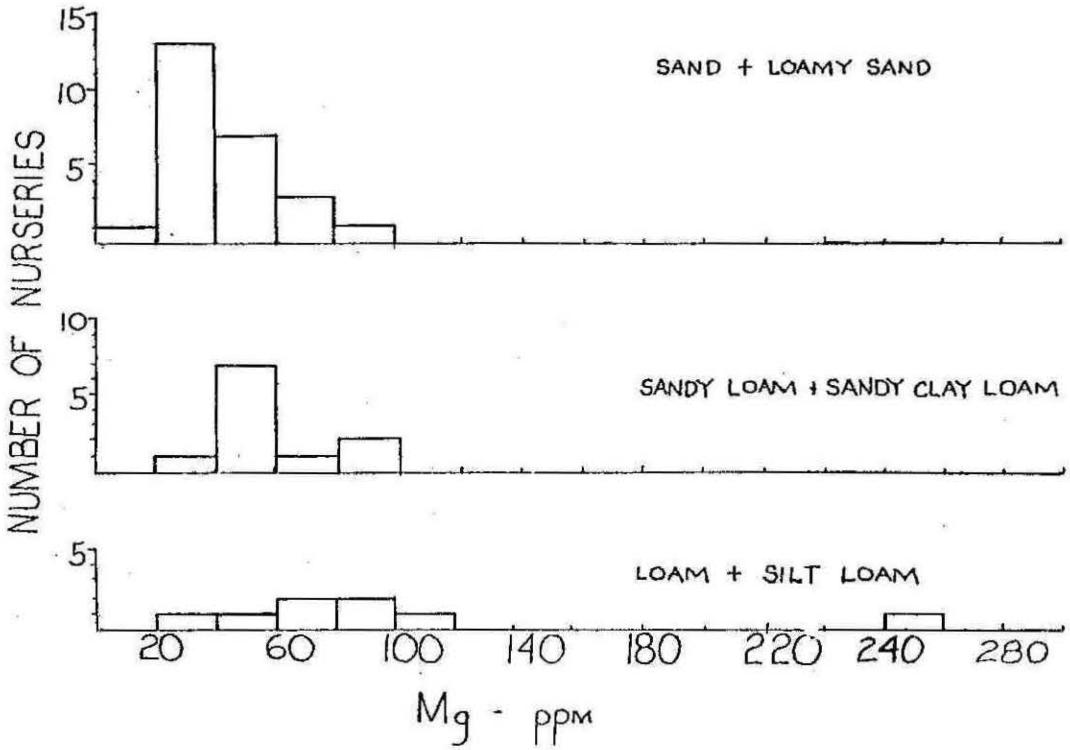


FIGURE 19

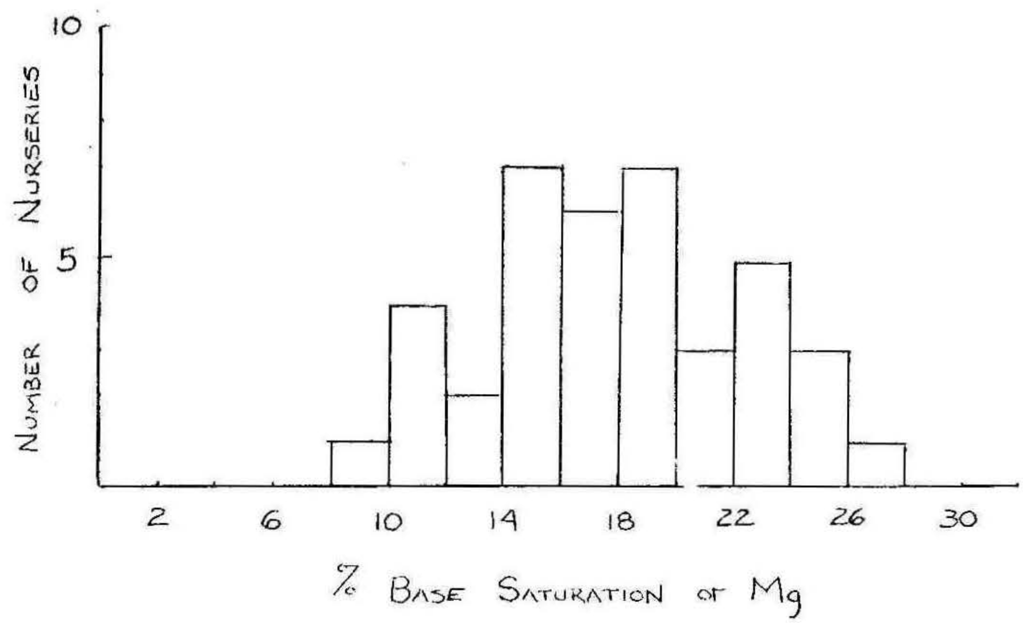


FIGURE 20

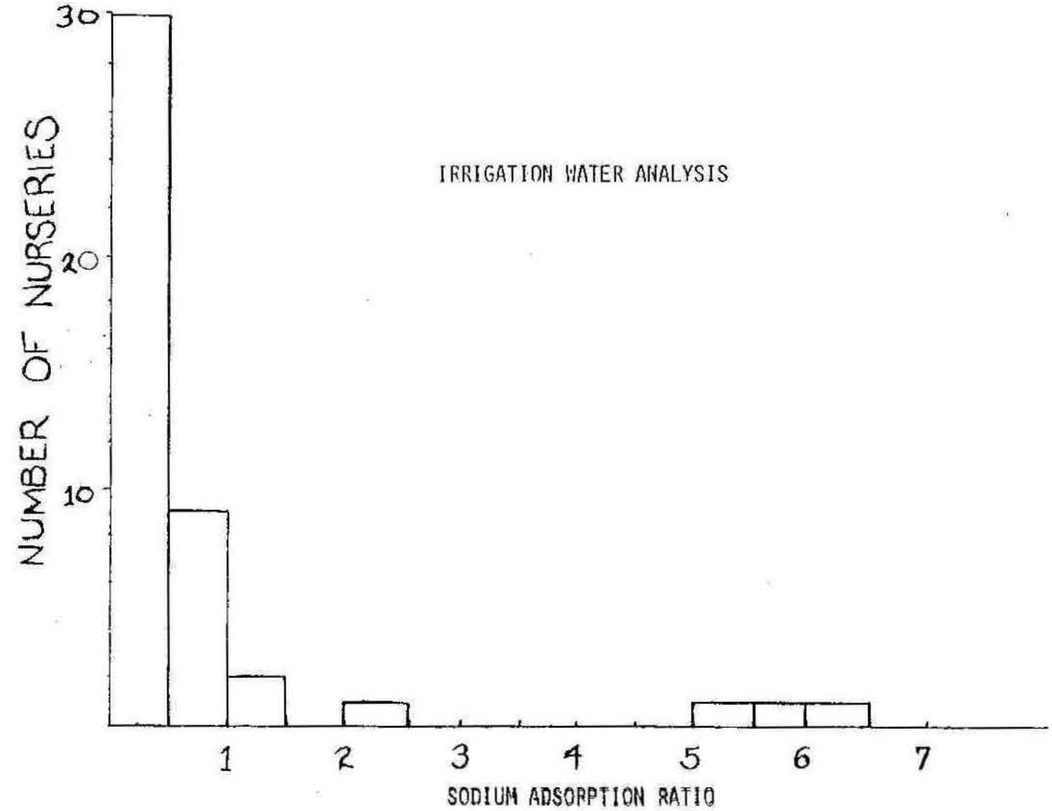


FIGURE 21

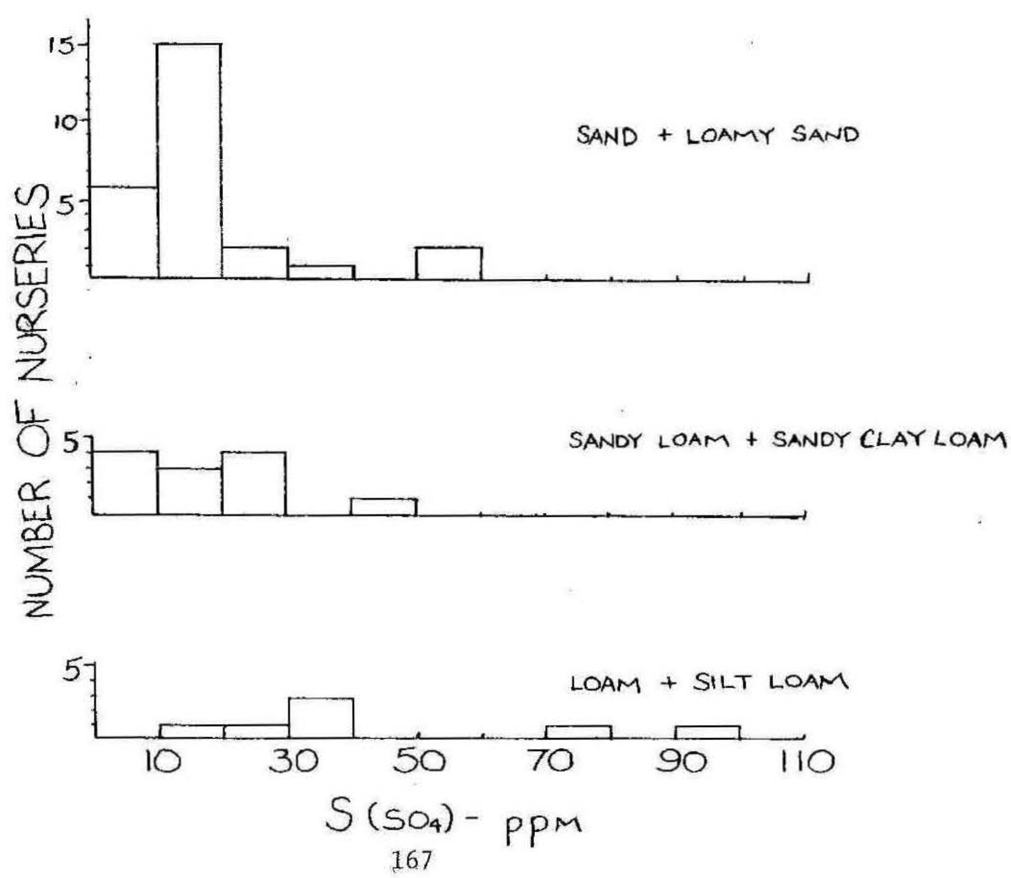


FIGURE 22

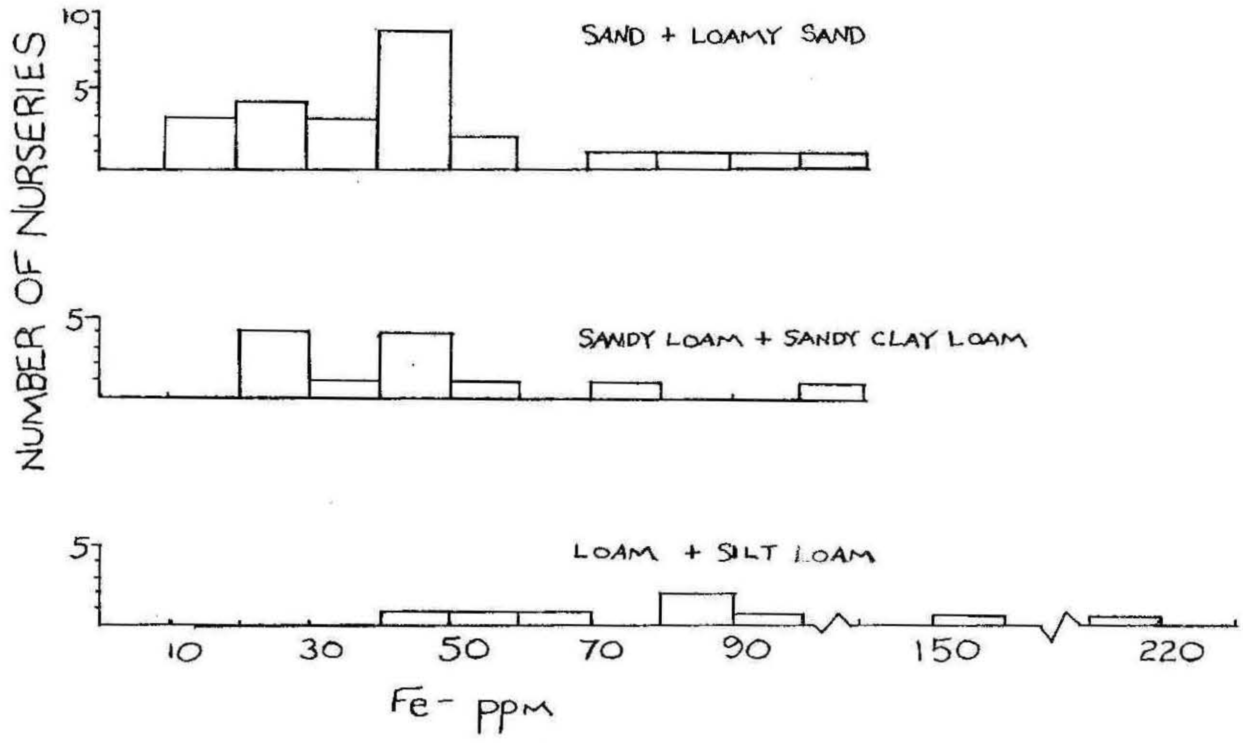


FIGURE 23

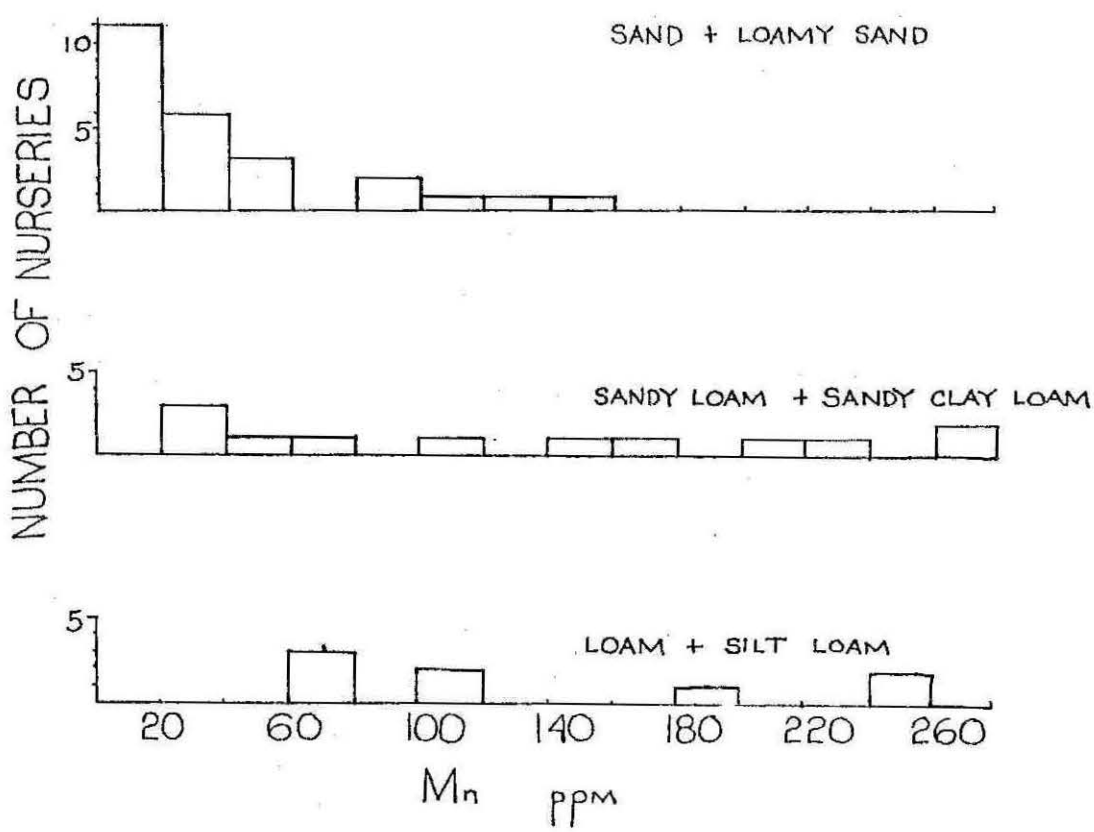


FIGURE 24

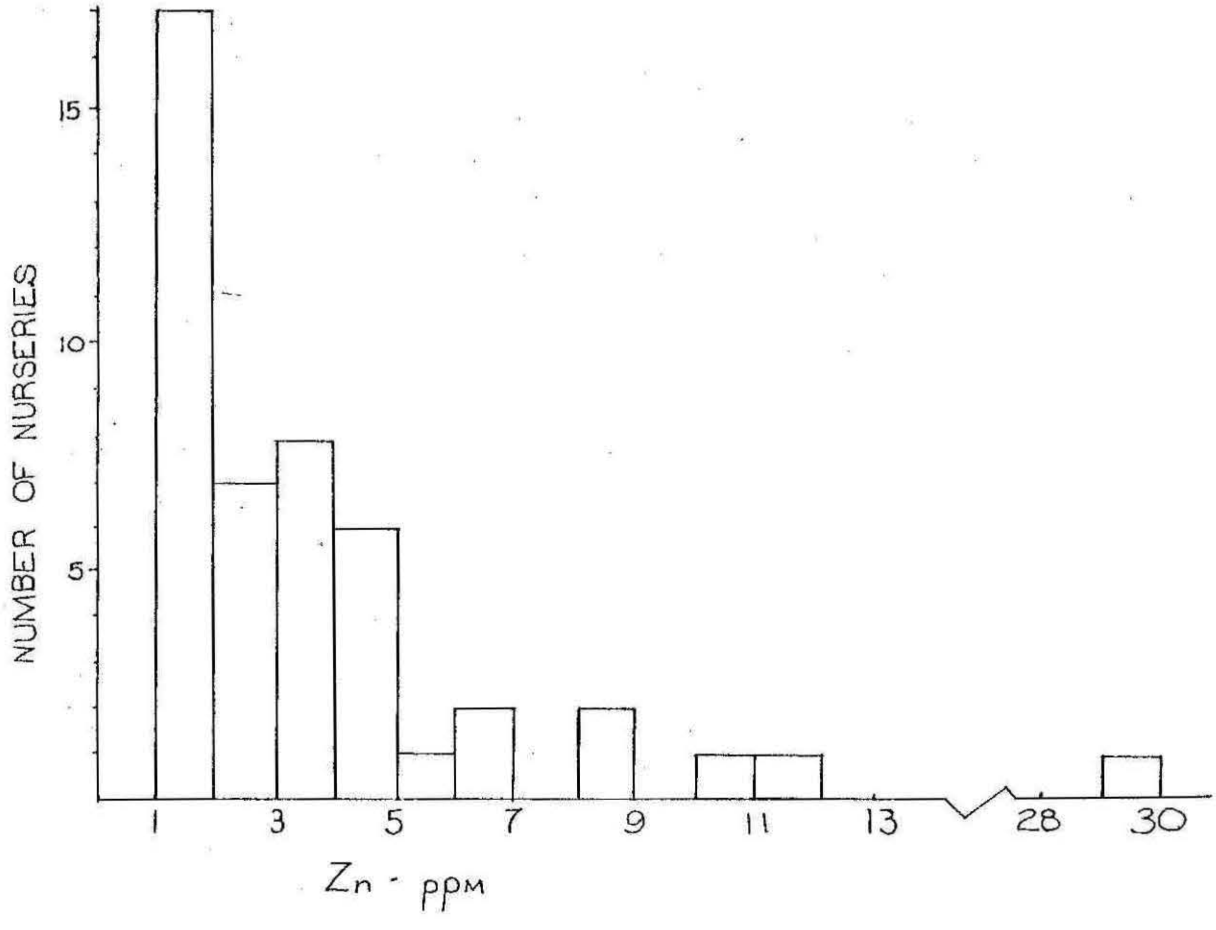


FIGURE 25

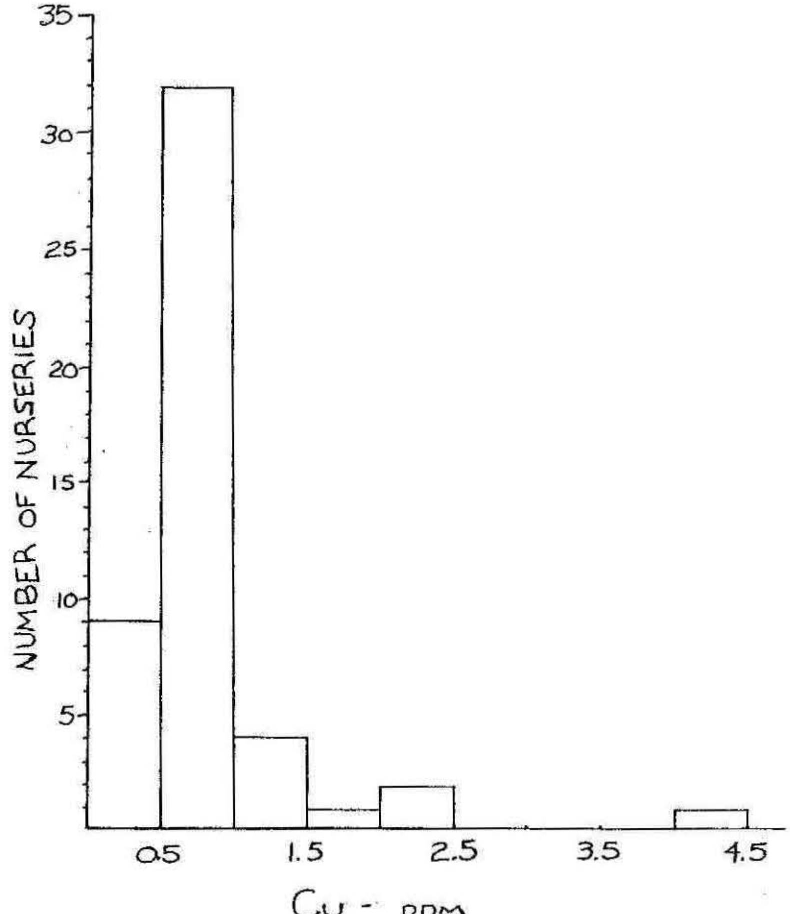
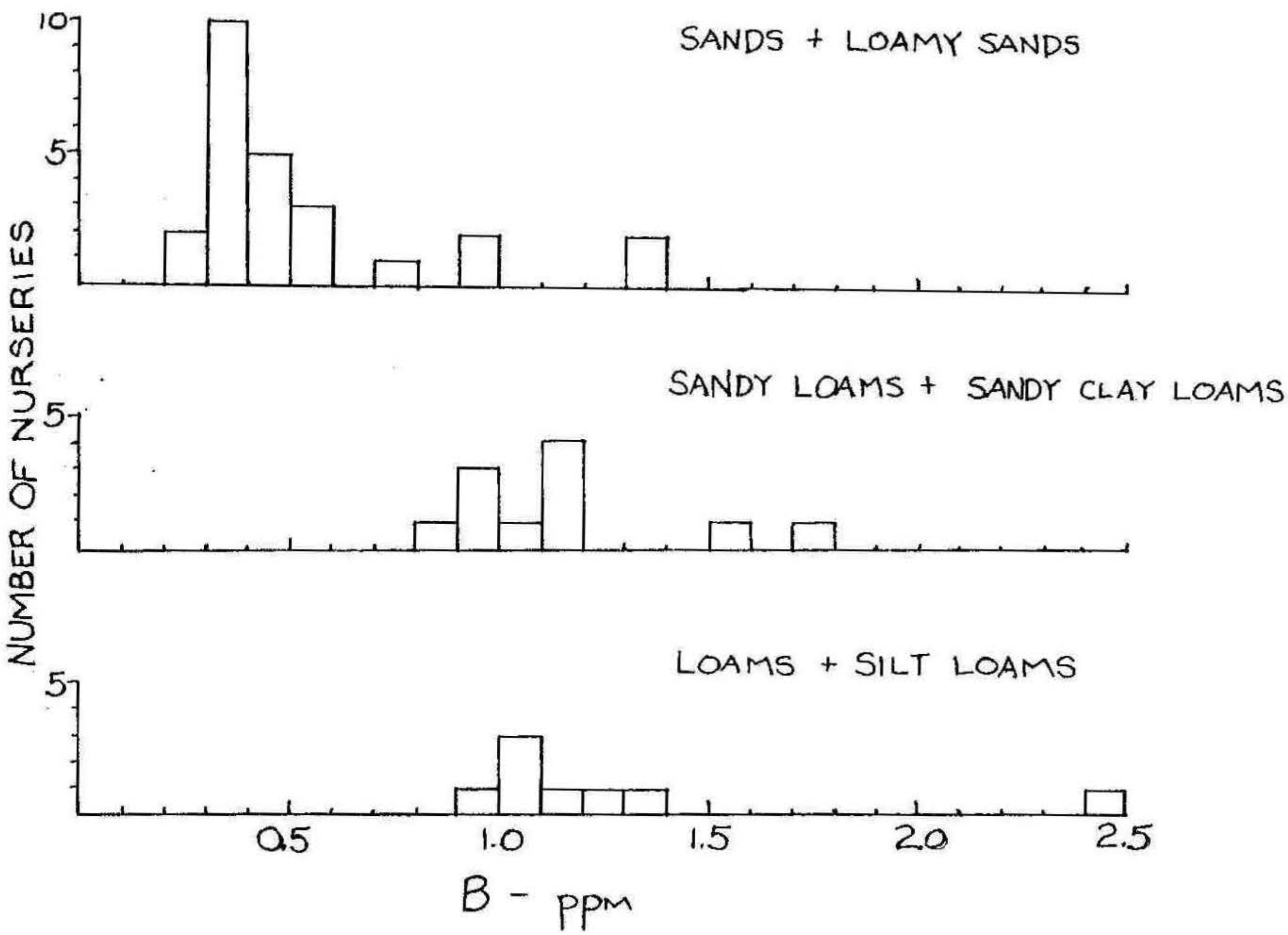


FIGURE 26


SANDS + LOAMY SANDS
SANDY LOAMS + SANDY CLAY LOAMS
LOAMS + SILT LOAMS
NUMBER OF NURSERIES
10
5
5
5
0.5
1.0
1.5
2.0
2.5
B - ppm

HERBICIDES, AN IMPORTANT COMPONENT OF THE WEED CONTROL PROGRAM AT OKLAHOMA STATE (NORMAN) NURSERY

Lawrence P. Abrahamson[1]

Abstract.--Ten herbicides were evaluated at the Oklahoma State Nursery for weed control on raising one-year seedling nursery beds. Phytotoxicity of DCPA, napropamide, oxyfluorfen, bifenox, and a napropamide plus bifenox tank mix was studied for three years on spring-sown Austrian and loblolly pine, and fall-sown eastern redcedar. Bifenox (on loblolly and Austrian pine) and oxyfluorfen (on Austrian pine) reduced germination when applied at time of sowing, but not when applied post-germination. Time required to hand weed nursery beds was reduced by 80-87 percent when using the above herbicides applied at sowing time alone or with a second application four to six weeks later. Over $4,500 per acre of seedbed could be saved by using herbicides over hand-weeding at the Norman Nursery.

Additional keywords: Dacthal®, Modown®, trifluralin, Treflan®, Devrinol®, Goal®, *Pinus taeda, P. nigra, Juniperus virginiana*.

Nursery herbicide screening and demonstration projects were initiated at the Norman Nursery in 1978 as part of a three-year study sponsored by State and Private Forestry (S & PF), U.S. Forest Service for the Great Plains forest tree nurseries (Abrahamson, 1981; Abrahamson and Burns, 1979). The USDA Forest Service's nursery herbicide projects developed out of a recognition of the potential benefits of herbicidal control of weeds in nursery seedbeds. The first of these projects started in 1970 when the Southeastern Area, S & PF and Auburn University began the Cooperative Forest Nursery Weed Control Project for the 13-state southeastern area (Gjerstad et al., 1980). In 1976, a cooperative western nursery herbicide project was initiated with cooperation among state, private and federal nurseries, Forest Service Research, State and Private Forestry, National Forest Systems, and State University of New York out of Syracuse. Twenty-eight nurseries in 12 states were involved in this effort which was broken down into three segments, each of three-year duration; the Pacific Coast started in 1976 (Stewart, 1977, Owston et al., 1980), the Intermountain-Great Basin in 1977 (Ryker and Abrahamson, 1980), and the Great Plains, of which Oklahoma was a part, in 1978. In 1979 the Northeastern (NE) Area started an eastern nursery herbicide project in five states cooperating with Purdue University and State University of New York (SUNY) at Syracuse (Holt and Abrahamson, 1980). In 1981 the NE Area expanded the eastern nursery herbicide project to the Great Lakes area with eight nurseries (state, federal and private) in three Lake States cooperating with SUNY. During 1982 Oklahoma State also sponsored a nursery herbicide project of their own in cooperation with SUNY to help the nursery expand on the herbicide studies using different herbicides, tree species and

---

[1]Senior Research Associate, State University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210.

sowing times. What is important in these projects is that all studies have similar objectives and methodologies and that information developed from one region or study project is supportive of that from other regions. In all these studies the objectives were to identify promising herbicides, develop data for product registration, and demonstrate safe and effective weed control practices for nursery seed beds.

METHODS

During the first year of the three-year study initiated in 1978, ten herbicides (Table 1) were screened on two species of spring-sown conifers, Austrian (Pinus nigra) and loblolly pine (P. taeda), one species of spring-sown hardwood, mulberry (Morus rubra), and on fall-sown redcedar (Juniperous virginiana). Analysis of soils at the Norman Nursery shows soil types of loam to sandy loam and a range in pH from 6.0 to 8.3 (Table 2).

Treatments were applied to three-foot long plots in four-foot wide nursery beds with a one-foot untreated buffer between plots. All treatments were installed in a randomized block design with three replications per species. The fall-sown redcedar plots were installed using the same method. Herbicides were applied with a modified AZ plot pressurized sprayer equipped with check valves and four flat fan 8001 nozzles operated at 20 psi in a water carrier at a volume equivalent to 85 ppa (100 ml/plot). Granular formulations were ocularly applied from a hand shaker uniformly over the plot.

Pre-seeding incorporated treatments (INC) were applied no more than one day before seeding and incorporated into the top two inches of soil using a garden rake. Post-seeding treatments (Ps) were applied within two days after seeding, except on the fall-sown redcedar which was applied any time after fall seeding but before mulching. Post-germination treatments (Pg) were applied four to six weeks after seedling emergence, except on the fall-sown redcedar which was applied in the spring after mulch was removed and most seedlings had emerged.

All plots were hand-weeded before application of post-germination treatments to obtain weed pre-emergence applications. Plots were then periodically weeded during the remainder of the growing season. Weeds were collected from each plot, counted, and/or weighed after drying for 72 hours at 65° C to estimate weed control. Herbicidal damage to conifers/hardwoods at the end of the first growing season was evaluated using a ten-point rating scale (0 is complete kill, 10 is no effect) proposed by Anderson (1963). Height of nine randomly selected seedlings and number of seedlings per foot in three randomly selected rows in each plot were also measured to determine chemical effects on seedling growth and survival.

The objectives of the second-year studies were to evaluate the phytotoxicity and weed control effectiveness of DCPA, oxyfluorfen, napropamide, bifenox and a napropamide + bifenox tank mix on first year spring-sown Austrian and loblolly pine species and on fall-sown redcedar. Weed control effectiveness of these herbicides was determined by the time required to hand-weed nursery beds (min) or weed number at the normal rate of application applied post-seeding and/or post-germination. Phytotoxicity was

Table 1. Herbicides, rates, and application timings used at Norman Nursery as Part of the Western Nursery Herbicides Study.

Herbicide	Formulation	Manufacturer	Rate (lb. ai./A)	Application timing[1]		
				Pre-seeding Incorporation	Post-Seeding	Post-Germination
Untreated						
Diphenamid	Enid 50W	Upjohn	4	--	x	x
Trifluralin	Treflan 4EC	Elanco	0.75	x	--	--
DCPA	Dacthal W-75	Diamond-Shamrock	10.5	--	x	x
Chloramben	Ornamental Weeder (Granule)	Amchem	4	--	--	x
Napropamide	Devrinol 50W	Stauffer	1.5	--	x	x
Butralin	Amex-820 (4EC)	Amchem	3	--	x	--
Bifenox	Modown 80WP	Mobil	3	--	x	x
Oxyfluorfen	Goal 2E	Rohm & Haas	0.5	--	x	x
Oxadiazon	Ronstar 2G	Rhodia	1	--	x	x
Napropamide & Bifenox	Tank mix		1 + 3	--	x	x

[1] Pre-seeding incorporation: incorporated into top 2 inches of soil immediately before seeding.
Post-seeding: broadcast applied to soil immediately after seeding.
Post-germination: broadcast applied to soil 4 to 5 weeks after seedling emergence.

Table 2. Properties of soils at the Norman Nursery.

Soil Type	pH	Percent Organic Matter	Percent Particle Size Distribution			Cation Exchange Capacity (meg/100g)
			Sand	Silt	Clay	
Loam	8.3	1.00	47.0	40.4	12.6	14.5
Loam	6.8	1.40	39.4	48.0	12.6	16.9
Loam	6.6	0.97	48.7	41.0	10.3	16.5
Sandy loam	6.0	1.19	72.7	22.0	5.3	15.4

evaluated by using herbicidal damage ratings (Anderson 1963), seedling survival (number/foot, and height growth (cm)) with dosages of 1X, 2X, and 1X + 1X) of these herbicides applied post-seeding and/or post-germination. The weed control plots were evaluated as a separate study using twenty-foot long plots in four-foot wide beds while the phytoxicity plots were evaluated using three-foot long plots in four-foot wide beds with a one-foot untreated buffer between plots. All treatments were installed using a randomized block design with three replications per species (phytotoxicity study) or study (weed control study).

Herbicide treatments were applied by small pressurized sprayer or hand shaker as was done the first year of these studies. The liquid sprays were applied in a water carrier at a volume equivalent to 85 gpa (100 ml/plot) in the phytotoxicity plots and a volume equivalent to 64 gpa (500 ml/plot) on the weed control plots.

All plots were weeded when necessary based on weed development on the most weedy plot, but the plots were weeded before post-germination treatments. The time of hand weeding the weed control plots was determined by using the same weeding crew for all plots. Each replication was completed before starting the next and all weeding was completed within a two-day period. The time was recorded to the nearest tenth of a minute and computed to man hours per 60 feet of nursery bed. A similar weed control had been installed the first year on loblolly pine using only bifenox which was registered for use on loblolly pine in other southern states. All other nursery operations including irrigation and fertilization were conducted by nursery personnel as needed.

Weed control effectiveness of the best treatments selected from the second year study were evaluated the third year under operational use using nursery application equipment on 100-foot test plots. DCPA, napropamide, bifenox, oxyfluorfen, and the napropamide + bifenox tank mix were evaluated for weed control under operational use at the 1X rate of application applied post-seeding alone, or post-seeding and post-germination. Weed control effectiveness was determined by time required to hand weed the 100-foot treatment plots in the same way as during the second-year weed control study using twenty-foot plots. However, in this study the time was converted to man hours per 100-feet of nursery bed instead of 60 feet. Phytotoxicity rating, survival and height measurements were also recorded from these operational plots.

RESULTS AND DISCUSSION

Phytotoxicity

The spring-sown conifer species evaluated at Norman were Austrian and loblolly pine (Tables 3, 4, 5 and 6). Mulberry was also evaluated the first year (Table 3), but due to seed germination problems was dropped from the study after the first year. Redcedar as the fall-sown species was evaluated the first two years (Tables 7 and 8), but not the third year because of a germination failure.

Table 3. Phytotoxic effects[1] of herbicide treatments on conifer/hardwood species at Norman Nursery in 1978.

		Austrian Pine					Loblolly Pine					Mulberry[2]				
		Damage rating		Percent Survival		Percent	Damage rating		Percent Survival		Percent	Damage rating		Percent Survival		Percent
Treatment		Spring	Fall	Spring	Fall	Height	Spring	Fall	Spring	Fall	Height	Spring	Fall	Spring	Fall	Height
Control		9.7	5.7	100	100	100	9.3	9.7	100	100	100	---	5.0	---	100	100
Diphenamid	Ps	8.7	9.0	214	264	145	8.7	10.0	84	96	122	---	0.0*	---	0.0*	---
Diphenamid	Pg	---	7.7	163	156	144	---	8.7	121	117	.103	---	---	---	---	---
Trifluralin		8.7	9.0	226	248	174*	9.0	8.7	143	119	126	---	2.3*	---	12*	147
DCPA	Ps	8.0	7.3	186	132	122	9.7	9.3	97	96	125	---	1.0*	---	0.0*	---
DCPA	Pg	---	6.3	116	164	110	---	9.7	95	98	124	---	---	---	---	---
Chloramben	Pg	---	8.0	228	200	124	---	9.3	96	87	106	---	---	---	---	---
Oxyfluorfen	Ps	9.0	8.7	202	224	127	8.7	9.7	87	77	106	---	4.0	---	30*	145
Oxyfluorfen	Pg	---	7.7	202	232	140	---	9.3	85	73	112	---	---	---	---	---
Chloroxuron	Ps	---	---	---	---	---	---	---	---	---	---	---	0.0*	---	0.0*	---
Napropamide	Ps	9.0	7.0	186	184	143	9.0	9.7	92	101	122	---	4.0	---	18*	106
Napropamide	Pg	---	6.7	181	172	134	---	10.0	86	89	130*	---	---	---	---	---
Butralin	Ps	8.7	6.3	181	208	123	8.7	9.3	110	112	119	---	7.3	---	44*	104
Bifenox	Ps	8.7	5.0	133	124	131	8.0	7.7*	73	63	111	---	0.0*	---	0.0*	---
Bifenox	Pg	---	7.7	186	260	148	---	9.3	111	115	115	---	---	---	---	---
Napropamide + Bifenox	Ps	8.3	4.7	147	132	120	9.0	7.3*	61	60	103	---	0.0*	---	0.0*	---
Napropamide + Bifenox	Pg	---	6.7	153	176	129	---	9.7	107	96	114	---	---	---	---	---

[1]Damage ratings shown are the means of all plots of each treatment for each species. Survival and height are expressed as percent of the untreated plots.

[2]Two sowings of mulberry were attempted due to poor germination of the first sowing. The second sowing also had germination problems, but some phototoxicity data was collected. Post-germination treatments were not done.

*Significantly different from the untreated plots at the 5% level of probability.

Table 4. Phytotoxic effects[1] of herbicide treatments on conifer species at Norman Nursery in 1979.

Treatment		Austrian Pine: Damage rating Spring	Damage rating Fall	Survival Spring	Survival Fall	Height	Loblolly Pine: Damage rating Spring	Damage rating Fall	Survival: Seedlings per foot Spring	Seedlings per foot Fall	Total trees[2] in plot Spring	Total trees in plot Fall	Height
				Percent					Percent				
Control		9.7	8.3	100	100	100	9.3	9.3	-	100	100	100	100
DCPA	Ps 1X	10.0	10.0	110	118	119	9.0	9.0	-	73	93	105	95
DCPA	Ps 2X	9.3	9.3	115	122	117	8.7	9.3	-	40	98	111	99
DCPA	Ps+Pg 1X+1X	9.0	9.0	126	135	119	9.3	9.7	-	47	99	121	120
DCPA	Pg 1X	9.3	8.3	83	89	97	9.7	9.0	-	80	120	123	119
DCPA	Pg 2X	9.0	9.0	131	150	121	9.7	7.7	-	60	86	88	87
Oxyfluorfen	Ps 1X	8.7	7.7	77	76	107	9.3	8.3	-	60	95	111	78
Oxyfluorfen	Ps 2X	9.0	5.7	38	35*	81	8.3	7.7	-	53	84	82	57
Oxyfluorfen	Ps+Pg 1X+1X	9.0	7.7	81	82	109	9.0	7.3	-	80	81	91	91
Oxyfluorfen	Pg 1X	9.7	9.7	101	104	117	9.3	9.7	-	153	127	118	101
Oxyfluorfen	Pg 2X	9.3	9.3	114	107	104	9.7	8.7	-	93	111	126	76
Napropamide	Ps 1X	9.3	8.7	111	115	126	9.3	9.0	-	80	114	119	95
Napropamide	Ps 2X	9.3	8.7	118	127	107	8.7	7.0	-	67	102	107	67
Napropamide	Ps+Pg 1X+1X	9.3	8.7	104	109	110	9.7	7.7	-	87	74	89	81
Napropamide	Pg 1X	9.3	8.7	137	138	98	9.7	9.3	-	107	114	128	100
Napropamide	Pg 2X	9.3	9.0	102	101	109	10.0	8.0	-	73	98	89	82
Bifenox	Ps 1X	9.3	8.0	100	105	107	9.3	8.0	-	67	94	105	89
Bifenox	Ps 2X	8.7	5.7	72	76	104	9.7	9.0	-	60	68	84	94
Bifenox	Ps+Pg 1X+1X	9.0	6.7	71	74	105	9.3	9.3	-	80	94	118	76
Bifenox	Pg 1X	9.7	8.3	89	97	103	9.0	8.7	-	40	98	114	92
Bifenox	Pg 2X	9.0	9.0	99	100	110	9.0	8.3	-	33	117	135	91
Nap/bif[3]	Ps 1X	9.0	7.0	74	72	110	9.0	8.0	-	67	94	109	88
Nap/bif[3]	Ps 2X	8.7	7.0	69	61	109	8.7	6.0*	-	47	67	65	66
Nap/bif[3]	Ps+Pg 1X+1X	8.7	7.0	60	61	108	9.3	9.7	-	113	102	118	105
Nap/bif[3]	Pg 1X	9.7	9.7	116	123	122	9.7	9.3	-	67	101	121	94
Nap/bif[3]	Pg 2X	9.3	9.3	117	121	113	9.7	7.3	-	47	93	86	91

[1] Damage ratings shown are the means of all plots of each treatment for each species. Survival and height are expressed as percent of the untreated plots.

[2] Because of poor germination in most of the Loblolly Pine plots, total trees per plot was also recorded.

[3] Tank mix of napropamide plus bifenox.

*Significantly different from the untreated plots at the 5 percent level of probability.

Table 5. Phytotoxic effects of herbicide treatments on conifer species at the Norman Nursery during the 1980 weed control study.

Treatment		Loblolly pine damage rating	Austrian pine damage rating
Untreated		7.5	8.0
Oxyfluorfen	ps	7.5	3.5*
	ps+pg	8.0	4.5*
Napropamide	ps	6.0	6.5
	ps+pg	6.5	7.0
Bifenox	ps	4.0*	5.0*
	ps+pg	5.0*	5.0*
Napropamide	ps	4.0*	5.5*
+ Bifenox	ps+pg	4.0*	5.0*

*Significantly different from the untreated plots at the 5 percent level of probability.

Table 6. Weed control and phytotoxic effects of bifenox treatments on Loblolly Pine in a special weed control timing study at Norman Nursery on 20' by 4.5' plots during 1978.

	Phytotoxic effects[1]					Weed control based on weeding time[2]		
			Percent					
	Damage rating		Survival		Height	First weeding time/plot	Subsequent weeding time/plot	Total weeding time/plot
Treatment	Spring	Fall	Spring	Fall				
Untreated	---	9.3	100	100	100	1.14 mh[3]	0.53 mh	0.68 mh
Bifenox at 3# ai/acre post-seeding	---	7.0*	51*	56*	119	0.01 mh*	0.19 mh*	0.14 mh*
Bifenox at 3# ai/acre post-germination	---	9.3	112	110	101	1.50 mh	0.10 mh*	0.45 mh*
Bifenox at 6# ai/acre 3# ai post-seeding 3# ai post-germination	---	6.0*	37*	40*	100	0.01 mh*	0.05 mh*	0.04 mh*

[1]Damage ratings shown are the means of all plots of each treatment for each species. Survival and height are expressed as percent of the untreated plots.

[2]Weed control is expressed in mean man hours requires to hand weed the treatment plots (20' by 4.5') based on 6 hand weeders per weeding time.

[3]mh = man hours

*Significantly different from the untreated plots at the 5% level of probability.

Table 7. Phytotoxic effects[1] of herbicide screening treatments on Eastern Redcedar at Norman Nursery in 1978-79.

Treatment		Eastern Red Cedar: Damage rating Spring	Damage rating Fall	Survival Spring	Survival Fall	Height
				Percent		
Applied Fall 1978 (Ps plots)						
Control		8.0	9.7	100	100	100
Diphenamid	Ps	8.0	9.0	100	86	80
DCPA	Ps	8.0	7.7	158	138	95
Trifluralin	Inc.	8.0	9.3	118	122	96
Napropamide	Ps	8.0	8.3	125	103	80
Bifenox	Ps	8.0	6.0*	92	92	72
Oxyfluorfen	Ps	7.7	7.7	72	86	84
Napropamide + Bifenox	Ps	8.0	7.7	105	108	78
Applied Spring 1979 (Pg plots)						
Control		10.0	9.3	100	100	100
Diphenamid	Pg	8.7	5.7*	123	93	82
DCPA	Pg	9.3	8.7	114	94	95
Napropamide	Pg	10.0	9.0	131	101	94
Bifenox	Pg	10.0	8.3	140*	103	101
Nap/bif[2]	Pg	9.3	8.7	103	99	97
Oxyfluorfen	Pg	10.0	8.3	106	91	91
Oxadiazon	Pg	10.0	7.3	126	97	91

[1] Damage ratings shown are the means of all plots of each treatment for each species. Survival and height are expressed as percent of the untreated plots.

[2] Tank mix of napropamide plus bifenox.

* Significantly different from the untreated plots at the 5 percent level of probability.

Table 8. Phytotoxic effects[1] of herbicide treatments on eastern redcedar at Norman Nursery in 1979-80.

Treatment		Damage rating Spring[2]	Damage rating Fall[2]	Survival Fall[2]	Percent Height[2]
Control		7.0	7.0	100	100
DCPA	Ps	5.7	3.7	51	76
DCPA	Pg	5.0	5.0	78	85
DCPA	Ps+Pg	6.0	5.3	69	96
DCPA	Pg+Pg	6.7	7.0	88	105
DCPA	Ps(2x)	5.7	5.7	64	102
DCPA	Pg(2x)	7.7	7.0	103	108
Oxy fluorfen	Ps	5.3	5.7	60	94
Oxyfluorfen	Pg	7.3	6.7	85	101
Oxyfluorfen	Ps+Pg	6.3	4.3	74	99
Oxyfluorfen	Pg+Pg	6.7	5.3	60	87
Oxyfluorfen	Ps(2x)	4.7	3.7	40	78
Oxyfluorfen	Pg(2x)	5.0	3.7	31	75
Napropamide	Ps	6.7	5.7	92	94
Napropamide	Pg	8.0	7.0	87	107
Napropamide	Ps+Pg	5.0	5.0	76	83
Napropamide	Pg+Pg	6.7	5.7	104	98
Napropamide	Ps(2x)	5.7	5.7	54	90
Napropamide	Pg(2x)	5.7	4.0	67	90
Bifenox	Ps	4.3	3.7	31	78
Bifenox	Pg	5.7	4.3	56	91
Bifenox	Ps+Pg	7.3	8.0	108	118
Bifenox	Pg+Pg	5.0	3.7	47	77
Bifenox	Ps(2x)	6.7	6.0	70	102
Bifenox	Pg(2x)	7.0	6.7	89	100

[1]Damage rating, shown are the means of all plots of each treatment for each species. Survival and height are expressed as percent of the untreated plots.

[2]No significant differences; wide variability in data, due to germination problems and adverse climatic conditions (water) which affected only parts of the study area.

DCPA, napropamide, oxyfluorfen, bifenox and the napropamide + bifenox tank mix were the promising herbicides that were tested for the full three years at Norman.

Austrian pine was tolerant of all the herbicides and application timing tested, except oxyfluorfen and bifenox applied post-seeding (Tables 4 and 5) which reduced the percent germination. Oxyfluorfen and bifenox produced no phytotoxic effects when applied post-germination to Austrian pine.

Loblolly pine was tolerant of all herbicides and application timing tested except bifenox and the bifenox + napropamide tank mix when applied post-seeding (Tables 3, 4, 5 and 6) which reduced the percent germination. Post-germination applications of these treatments produced no phytotoxic effects on loblolly pine.

These phytotoxic effects of bifenox on loblolly and Austrian pine were not recorded from other southern nurseries where it was being used and oxyfluorfen has been applied post-seeding to Austrian pine in other nurseries without any phytotoxic problems. The Norman Nursery experienced very heavy rains after application of the herbicides and before germination of these pines in all three years of the study. This and the low organic matter present at the Norman Nursery may have led to these phytotoxic effects with oxyfluorfen and bifenox on Austrian pine and bifenox (and the bifenox plus napropamide tank mix) on loblolly pine.

Fall-sown redcedar was tolerant of all herbicides and application timing tested (Tables 7 and 8). This was true of redcedar at four other Great Plain's nurseries where these herbicides were also tested without all the variability in data due to germination problems and heavy rains. Bifenox and oxyfluorfen applied post-seeding were the only herbicides in all the tests on redcedar at five Great Plains nurseries that may have produced a slight reduction in survival, however, this was not a significant reduction.

None of the post-germination applications of the herbicides tested the full three years at Norman caused any significant phytotoxic effects on spring-sown Austrian and loblolly pine or on fall-sown redcedar. DCPA and napropamide are the only herbicides tested for the full three years which did not cause any phytotoxic effects on any species when applied post-seeding (Table 9).

Weed Control Studies

The herbicides DCPA, napropamide, oxyfluorfen, bifenox and the napropamide + bifenox tank mix were evaluated all three years on spring-sown species at Norman with promising results in the reduction of herbaceous weeds, mainly broad leaf type which occurred about six times as numerous as the grass type (Tables 6, 10, 11 and 12). The results from the large operational study the third year reflect the true value of these weed control chemicals in actual time saved which can be converted into dollars saved.

Table 9. Herbicides producing acceptable weed control at the Norman Nursery without significant seedling damage by tree-species and application timing.

Species	Application timing: Post-seeding or Soil incorporation	Post-Germination	Post-seeding or Soil incorporation plus Post-germination
Austrian pine	Trifluralin	--	--
	DCPA	DCPA	DCPA
	Napropamide	Napropamide	Napropamide
	--	Bifenox	--
	--	Oxyfluorfen	--
Loblolly pine	Trifluralin	--	--
	DCPA	DCPA	DCPA
	Napropamide	Napropamide	Napropamide
	Oxyfluorfen	Oxyfluorfen	Oxyfluorfen
	--	Bifenox	--
Eastern redcedar (fall-sown)	Trifluralin	--	--
	DCPA	DCPA	DCPA
	Oxyfluorfen	Oxyfluorfen	Oxyfluorfen
	Napropamide	Napropamide	Napropamide
	Bifenox	Bifenox	Bifenox
	Oxadiazon	Oxadiazon	Oxadiazon

Table 10. Weed control[1] of herbicide treatments[2] at the Norman Nursery expressed in terms of oven-dry weight of herbaceous weeds during 1978.

		Weed control rating by weeding(s)			Percent Dry weight of weeds		
Treatment		1st	2nd	3rd	1st weeding	Subsequent weedings	Total season
Control		0.0	---	---	100.0	100.0	100.0
Diphenamid	Ps	8.5*	---	---	9.1*	84.8	58.2*
Diphenamid	Pg	---	---	---	-----	93.1	95.5
Trifluralin		8.2*	---	---	5.8*	84.5	56.9*
DCPA	Ps	9.5*	---	---	0.2*	93.5	60.8*
DCPA	Pg	---	---	---	---	92.4	95.0
Chloramben	Pg	---	---	---	---	91.5	94.5
Oxyfluorfen	Ps	9.8*	---	---	0.03*	88.8	57.7*
Oxyfluorfen	Pg	---	---	---	----	88.3	92.4
Napropamide	Ps	7.0*	---	---	16.2*	86.9	62.1*
Napropamide	Pg	---	---	---	----	63.8	76.5
Butralin	Ps	9.0*	---	---	1.5*	110.0	71.9*
Bifenox	Ps	9.7*	---	---	0.3*	100.6	65.4*
Bifenox	Pg	---	---	---	----	58.1*	72.8*
Napropamide + Bifenox	Ps	9.3*	---	---	2.1*	83.4	53.9*
Napropamide + Bifenox	Pg	---	---	---	---	59.5*	73.7*

[1]Weed control ratings shown are the means of all plots of each treatment. Dry weight of weeds are expressed as percent of the untreated plots.

[2]Weed control data compiled from the loblolly and Austrian pine treatments only.

*Significantly different from the untreated plots at the 5% level of probability.

Table 11. Weed control study of herbicide treatments at Norman Nursery expressed in actual weeding times during 1979.

Treatment		1st[1] Weeding Time (60 ft. bed)			2nd[2] Weeding Time (60 ft. bed)			3rd[2] Weeding Time (40 ft. bed)			Season Totals (160 ft. bed)	
		Weeding time	No. of Weeders	Total man hours	Weeding time	No. of Weeders	Total man hours	Weeding[3] time	No. of weeders	Total man hours	Weeding time	Total man hours
Control		2.58	4	0.17	4.34	4	0.29	2.67	4	0.18	9.59	0.64
DCPA	Ps	0.41	4	0.03	6.08	4	0.41	3.08	4	0.21	9.57	0.65
DCPA	Ps+Pg	0.75	4	0.05	14.73	4	0.98	10.91	4	0.73*	26.39	1.76
DCPA	Pg	15.92	4	1.06	10.42	4	0.69	5.09	4	0.34	31.43	2.09
Oxyfluorfen	Ps	0.83	4	0.05	14.17	4	0.94	8.83	4	0.59*	23.83	1.58
Oxyfluorfen	Ps+Pg	0.99	4	0.07	3.34	4	0.22	5.09	4	0.34	9.42	0.63
Oxyfluorfen	Pg	4.34	4	0.29	4.92	4	0.33	3.16	4	0.21	12.42	0.83
Napropamide	Ps	0.33	4	0.02	4.42	4	0.29	2.08	4	0.14	6.83	0.45
Napropamide	Ps+Pg	0.66	4	0.04	3.92	4	0.26	4.75	4	0.32	9.33	0.62
Napropamide	Pg	13.00	4	0.87	9.92	4	0.66	7.84	4	0.52	30.76	2.05
Bifenox	Ps	0.49	4	0.03	5.08	4	0.34	4.50	4	0.30	10.07	0.67
Bifenox	Ps+Pg	0.49	4	0.03	4.00	4	0.27	2.67	4	0.18	7.16	0.48
Bifenox	Pg	10.00	4	0.67	5.83	4	0.39	2.83	4	0.19	18.66	1.25
Nap/Bif[4]	Ps	0.33	4	0.02	3.08	4	0.21	3.75	4	0.25	7.16	0.48
Nap/bif[4]	Ps+Pg	0.24	4	0.02	0.41	4	0.03	0.42	4	0.03	1.07	0.08
Nap/bif[4]	Pg	13.92	4	0.93	1.67	4	0.11	4.08	4	0.27	19.67	1.31

Note: Weeding times are expressed in minutes and hundredths of minutes.

[1] Weeded after 1st application (Ps).

[2] Weeded after 2nd application (Pg).

[3] Weeding times are for white and blue plots only (No data for red block).

[4] Tank mix of napropamide plus bifenox.

*Significantly different from the untreated plots at the 5 percent level of probability.

Table 12. Weed control time study of herbicide treatment at Norman Nursery for 100' plots expressed in actual weed times during 1980.

Treatment		Post seeding application (2)[1]			Post germination application (4)[1]			Season total (6)[1]	
		Average number of weeders	Man hours	Percent reduction	Average number of weeders	Man hours	Percent reduction	Total Man hours	Percent reduction
Control		5.5	9.89	0	6	6.05	0	15.94	0
Oxyfluorfen	Ps	5.5	0.41*	96	6	2.98*	51	3.39*	79
Oxyfluorfen	Ps + Pg	5.5	0.34*	97	6	1.68*	72	2.02*	87
Napropamide	Ps	5.5	0.43*	96	6	3.18*	47	3.61*	77
Napropamide	Ps+Pg	5.5	0.32*	97	6	2.16*	64	2.48*	84
Bifenox	Ps	5.5	0.56*	94	6	3.28*	46	3.84*	76
Bifenox	Ps+Pg	5.5	0.53*	95	6	1.67*	72	2.20*	86
Napropamide + Bifenox	Ps	5.5	0.21*	98	6	1.72*	71	1.93*	88
Napropamide + Bifenox	Ps+Pg	5.5	0.24*	98	6	1.06*	82	1.30*	92

[1]Number of weedings

*Significantly different from the control at the 5 percent level of probability.

Weed control of these herbicides expressed in hand-weeding time are summarized in Figure 1 and Table 12. In general, post-seeding applications were as effective as the post-seeding plus post-germination treatments for total season weed control. This reflects the greater number and vigor of weeds germinating and emerging earlier in the season and suggests that post-seeding weed control is the most critical. All herbicides and herbicide combinations produced effective weed control (at least 75 percent reduction in hand-weeding time) when applied as post-seeding, or post-seeding plus post-germination applications.

Hand weeding time was reduced by an average of 80 percent for all herbicides applied only in the spring (Ps) while those applied in both the spring and a second application five to six weeks later (Ps + Pg) reduced hand weeding time by an average of 87 percent. This amounted to an average saving of 12.6 man hours per 100 by four-foot plot per year, or based on minimum wage of $3.35 per hour, a saving of $42.21 for a 100 by 4 foot plot weeded up to six times per year. This would amount to an average gross savings of $4,600 per acre of seedbed (without figuring in cost of herbicide or application costs) weeded six times with a mean weeding time of 283 man hours per acre (2.6 man hours per 100 by 4 foot plot) for untreated seedbeds at Norman.

The third year weed control data from the 100 foot plots on eastern redcedar was lost in the fire which destroyed the office building at the Norman Nursery in 1981. However, in a companion study with bifenox, oxyfluorfen, and napropamide at the Big Sioux Conifer Nursery at Watertown, SD, oxyfluorfen (Ps + Pg) reduced weeding time by 88% and bifenox (Ps + Pg) by 77%. Similar reductions in weeding times have been shown at other Great Plains nurseries. The first two years of study at Norman (Tables 13 and 14) on weed control in fall-sown redcedar have shown variable results with up to 60-80% reduction in weeds and/or weeding time. Similar studies at the other Great Plains nurseries on fall-sown redcedar demonstrated consistent weed time reduction of 80-90 percent with these same herbicides.

Continuing studies with herbicides are being conducted by SUNY at the Norman Nursery. Studies looking into the possibility of mixing herbicides with the hydromulch are being conducted, earlier studies have shown promising results. We are also conducting screening studies of the more promising herbicides on the many hardwood species being grown here at the Nursery. These studies are in progress and no results will be presented here.

SUMMARY

Three years of herbicide studies on spring-sown Austrian and loblolly pine and fall-sown eastern redcedar were completed between 1978 and 1981 at the Oklahoma State Nursery (Norman Nursery) located at Washington, OK. Results from these studies have been incorporated into the Nursery's weed control program. On conifers (both spring- and fall-sown) the nursery is using treflan® (trifluralin) as an incorporated preplant treatment followed by post-germination applications of Devrinol®(napropamide) plus Modown® (bifenox) tank mix or Goal®(oxyfluorfen).

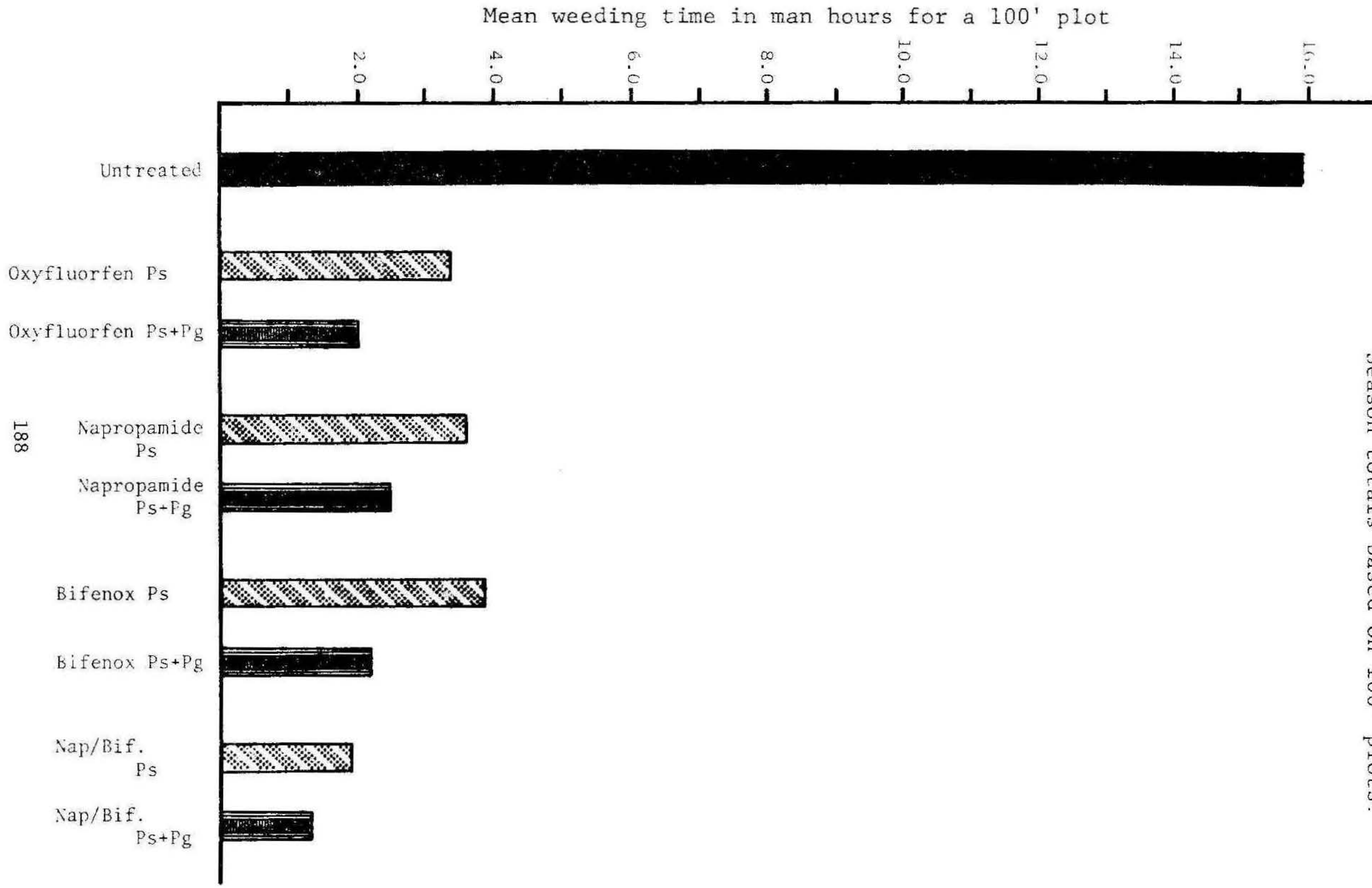


Figure 1. Mean weeding times for Norman Nursery. Season totals based on 100' plots.

Table 13. Weed control[1] of herbicide screening treatments on Eastern Redcedar at the Norman Nursery expressed in terms of number and/or oven-dry weight of herbaceous weeds during 1978-79.

Treatment		Weed control rating by weedings				Percent Number of Weeds				
		1st	2nd	3rd	4th	1st Weeding	2nd Weeding	3rd Weeding	4th Weeding	Total Season
Applied Fall 1978 (Ps plots)										
Control		2.7	1.7	2.0	6.0	100.0	100.0	100.0	100.0	100.0
Diphenamid	Ps	6.7*	1.0	6.0*	6.0	36.6*	91.9	69.0	142.1	71.1*
DCPA	Ps	9.0*	5.0	6.0*	7.0	4.9*	44.6*	69.0	73.7	34.8*
Trifluralin	Inc.	8.7*	7.3*	9.3*	8.3	7.3*	23.0*	10.3*	42.1	16.7*
Napropamide	Ps	9.3*	1.3	4.3	6.3	3.7*	68.9	82.8	121.0	49.5*
Bifenox	Ps	9.3*	3.7	7.7*	4.3	2.4*	44.6*	51.7*	136.8	37.3*
Oxyfluorfen	Ps	8.3*	3.0	7.3*	8.0	13.4*	52.7	37.9*	42.1	33.8*
Nap/bif[2]	Ps	9.0*	5.3	6.7*	6.3	4.9*	29.7*	51.7*	63.2	26.0*
Applied Spring 1979 (Pg plots)										
Control		-	8.0	8.7	9.0	-	100.0	100.0	100.0	100.0
Diphenamid	Pg	-	8.0	9.3	8.3	-	85.7	60.0	160.0	100.0
DCPA	Pg	-	7.0	6.3	5.7	-	142.9	360.0	2200.0	811.8
Napropamide	Pg	-	9.3	8.0	6.0	-	28.6	140.0	1800.0	582.4
Bifenox	Pg	-	8.3	8.3	6.7	-	85.7	160.0	1780.0	605.9
Nap/bif[2]	Pg	-	9.0	10.0	8.3	-	42.9	0.0	940.0	294.1
Oxyfluorfen	Pg	-	8.3	9.7	9.3	-	85.7	20.0	40.0	52.9
Oxadiazon	Pg	-	8.3	9.3	9.0	-	71.4	40.0	120.0	76.5

[1] Weed control ratings shown are the means of all plots of each treatment. Numbers of weeds are expressed as percent of the untreated plots.

[2] Tank mix of napropamide plus bifenox.

* Significantly different from the untreated plots at the 5 percent level of probability.

Table 14. Weed control study of herbicide treatments at Norman Nursery on fall-sown eastern redcedar expressed in actual weeding times during 1979-80.

Treatment		Post seeding application (1)[1]			Post germination application (4)[1]			Season total (5)[1]	
		Average number of weeders	Man hours	Percent reduction	Average number of weeders	Man hours	Percent reduction	Total Man hours	Percent reduction
Control		5	0.22	0	6	1.84	0	2.06	0
DCPA	Ps	5	0.14	36	6	1.17	36	1.31	36
DCPA	Ps+Pg	5	0.28	0	6	0.99	46	1.27	38
Oxyfluorfen	Ps	5	0.08	64	6	0.75	59	0.83	60
Oxyfluorfen	Ps+Pg	5	0.10	55	6	0.94	49	1.04	50
Napropamide	Ps	5	0.15	32	6	2.23	0	2.38	0
Napropamide	Ps+Pg	5	0.12	45	6	1.24	33	1.36	34
Bifenox	Ps	5	0.19	14	6	2.40	0	2.59	0
Bifenox	Ps+Pg	5	0.14	36	6	1.35	27	1.49	28

[1]Number of weedings.

*Significantly different from the control at the 5 percent level of probability.

We are presently working in cooperation with the nursery on herbicide treatments for the many hardwood species grown there and on replacement treatments for preplant incorporated trifluralin.

The herbicide treatment are reducing the nursery's hand-weeding times (and costs) by 60-87%. In one large study at the nursery this amounted to a savings of approximately $4,500 per acre of seedbed if minimum wage was paid.

LITERATURE CITED

Abrahamson, L.P. 1981. Herbicide trials for weed control in Great Plains forest tree nurseries. In: Proceedings of the 33rd Annual Meeting of the Forestry Committee, Great Plains Agr. Council, June, 1981, Lubbock, TX, Great Plains Agr. Council Publ. #102; p. 65-102.

Abrahamson, L.P. and K.F. Burns. 1979. Herbicide screening for weed control in western forest tree nurseries - Great Plains Segment. AFRI, Syracuse, NY, Res. Report. No. 41; 15 pp.

Anderson, W.H. 1963. A system for evaluating effective weed control in forest nurseries. Tree Planter's Notes (Oct.):19-23.

Gjerstad, D.H., D.B. South, C.W. Brewer and W.D. Kelley. 1980. 1979-80 Annual Report - Auburn University Forest Nursery Cooperative. Dept. For., Auburn Univ., Auburn, AL; 109 pp.

Holt, H.A. and L.P. Abrahamson. 1980. Developing weed control programs for forest nurseries in central U.S. In: Abstracts - 1980 Meeting of Weed Sci. Soc. of Amer., Feb. 5-7, 1980, Toronto, Canada, p. 51.

Owston, P.W., R.E. Stewart, N.W. Callan, and L.P. Abrahamson. 1980. Evaluation of herbicides for weed control in Pacific Coast forest tree nurseries. In: Abstracts - 1980 Meeting of Weed Sci. Soc. of Amer., Feb. 5-7, 1980, Toronto, Canada, p. 51-52.

Ryker, R.A. and L.P. Abrahamson. 1980. Western forest nursery herbicides study, Rocky Mountain-Great Basin Segment. In: Abstracts - 1980 Meeting of Weed Sci. Soc. of Amer., Feb. 5-7, 1980, Toronto, Canada, p. 52.

Stewart, R.E. 1977. Herbicides for weed control in western forest tree nurseries. Proceedings, Western Society of Weed Science, 30: 78-79.

THE EFFECT OF TIP BLIGHT ON SURVIVAL AND GROWTH OF OUTPLANTED LOBLOLLY PINE AFTER TWO YEARS

by

Charles E. Affeltranger[1/]

Abstract

Survival, height and diameter growth of loblolly pine infected with tip blight were not affected two years after planting on a wet site. At a mesic site, survival after the first year and survival, height and diameter growth were reduced at the .01 level of significance after two years. Drought in the first year of outplanting contributed to the growth reduction on the mesic site.

INTRODUCTION

In the forest nursery, terminal dieback and reddening of needle tips of southern pines is called tip blight. The basal portion of the foliage may also be affected. Two fungi, *Fusarium moniliforme* var. *subglutinans* Wr. and Reink. and *Diplodia gossypina* Cke., are considered strongly pathogenic while *Pestalotia* sp. and *Phomopsis* sp. (weak pathogens), despite generally being present, may not be involved (Rowan, 1982).

Throughout the Southeast the summer of 1979 was wet. Tip blight appears to follow this type of weather. In December 1979 two sites, a wet one (standing water near the planting perimeter) on the Bienville National Forest (Strong River Ranger District) in Mississippi and a mesic one (sufficient moisture, but without standing water) at the Stuart Seed Orchard (Kisatchie National Forest) near Pollock, Louisiana, were outplanted with control (no tip blight) and tip-blighted loblolly seedlings.

Data at outplanting indicated that tip-blighted seedlings were .03 to .04 inches smaller in diameter than control seedlings. Also, diseased seedlings averaged 1.5 to 2.5 inches shorter as a result of loss of terminal growth.

METHODS

Twenty-five seedlings per row were handplanted at the two sites. The two treatments (diseased and controls) were replicated five times in a randomized complete block design (8' x 8' spacing). In June and December 1980 and December 1981, survival, heights, and diameters were evaluated.

1/ Plant Pathologist, USDA Forest Service, Southern Region, Forest Pest Management, Pineville, LA 71360.

No survival and growth readings were made in June 1980 at the Bienville National Forest.

RESULTS

Data from seedlings at the Bienville National Forest showed non-significant differences (> .05 level) in survival one and two years after outplanting; the Stuart Seed Orchard site had a small difference after six months, but a significant difference (.01 level) one and two years after outplanting (table 1).

Table 1. Percent survival of tip-blighted and control loblolly pine seedlings at the Bienville National Forest site (BNF) and the Stuart Seed Orchard (STU) six months, one year, and two years after outplanting. A significant difference (.01 level) is indicated by an asterisk.

		Time After Outplanting		
Location	Seedling Condition	6 Months	1 Year	2 Years
BNF	Tip-blighted	-	79	77
	Control	-	89	86
STU	Tip-blighted	91	44*	41*
	Control	99	69*	67*

Height differences were not significant at the Bienville National Forest for either year, while at the Stuart Orchard they were significant at the .01 level after two years.

Table 2. Heights (in.) of tip-blighted and control loblolly pine seedlings at the BNF and the STU one and two years after outplanting. A significant difference (.01 level) is indicated by an asterisk.

		Height (in.)	
		Time After Outplanting	
Location	Seedling Condition	1 Year	2 Years
BNF	Tip-blighted	12.0	27.2
	Control	14.7	32.7
STU	Tip-blighted	15.6	24.8*
	Control	17.3	30.4*

Diameter readings at the Bienville National Forest were not significantly different (> .05 level) for either years. However, differences at the Stuart Seed Orchard were significant at the .005 level after two years.

Table 3. Diameter (in.) of tip-blighted and control loblolly pine seedlings at the BNF and the STU one and two years after outplanting. A significant difference (.005 level) is indicated by an asterisk.

		Diameter (in.)	
		Time After Outplanting	
Location	Seedling Condition	1 Year	2 Years
BNF	Tip-blighted	.19	.39
	Control	.24	.50
STU	Tip-blighted	.23	.42*
	Control	.26	.61*

DISCUSSION

Results of this evaluation are preliminary since a third year's observations on survival and growth are planned. However, trends at the wet site (Bienville National Forest) have been noted. Survival, height, and diameter differences are not expected to increase to a significant level on the wet site since they did not increase greatly between the first and second years after outplanting. The disease has declined on both sites and differences in survival and growth rates are not expected to increase. While differences increased on the mesic site (Stuart Seed Orchard) to significant levels, it must be remembered that the diseased seedlings were smaller in diameter and height at the time of outplanting. Also, the seedlings on the mesic site went through a severe drought (summer 1980) which saw only 4 to 5 inches of rainfall for the official summer. Rainfall at the Bienville National Forest site, where more water was present at outplanting, was higher during the same summer.

Rowan (1982) concluded that tip blight did not appear to be of significant concern to nurserymen and stated that 2-year old plantings of slash and loblolly pine indicated no differences in survival and growth. This work supports that position, except that small seedlings, slightly larger than that which would normally be culled (normally 1/8 inch root collar diameter), did not survive outplanting when they experienced a severe drought in the first year.

LITERATURE CITED

Rowan, S. J. Tip dieback in southern pine nurseries. Plant Disease 66: 258-259; 1982.

EFFECTIVE SOIL FUMIGATION

Charles E. Cordell[1/]

Abstract.--Methyl bromide soil fumigation can be effectively, efficiently, and safely applied in bareroot forest tree nurseries. The primary target organisms are the soilborne, pathogenic fungi that cause recurrent damaging root rot and damping-off losses on both conifer and hardwood seedlings. The MC-33 fumigant formulation has consistently and repeatedly provided the most effective control of these disease problems. Precautions are needed concerning the non-target, beneficial, soil organisms, particularly the endomycorrhizae on hardwood seedlings and when artificial ectomycorrhizal inoculations are utilized on conifer and some hardwood seedlings. Guidelines and precautions are presented concerning the biological (target organisms), chemical (soil fumigant), and environmental (soil) factors affecting consistent, effective, soil fumigation results.

Additional key words: Methyl bromide, methyl bromide-chloropicrin, MC-33, MC-2, target organisms, non-target, beneficial organisms, biological characteristics, chemical activity, environmental factors.

Pest control by fumigation is not a new practice. Attempts to control soil nematodes chemically date back to 1881. Carbon disulphide was extensively used for control of phylloxera of grape in Europe during the close of the last century. The practice of soil fumigation, however, has become widespread only since World War II. Since then, a number of fumigants, such as methyl bromide, chloropicrin, dichloropropenes, and ethylene dibromide, have been widely developed; and today, fumigation with these materials is an accepted practice in many agricultural areas. In fact, methyl bromide is the most widely used, general-purpose fumigant in the world (Cordell and Wortendyke, 1972).

Soil fumigation has been routinely practiced in southern forest tree nurseries during the past two decades. During more recent years, this chemical soil treatment practice has also been expanded to nurseries in the northeastern, central, north-central, and western United States. Several types of soil fumigants, such as methyl bromide, chloropicrin, vapam, vorlex, and mylone, have been tested and utilized, with varying degrees of success. However, the methyl bromide-chloropicrin fumigant formulations have consistently provided the most effective and efficient soil treatment results (Cordell and Wortendyke, 1972; Seymour and Cordell, 1979).

METHODS

A variety of methyl bromide-chloropicrin formulations are available and registered by the United States Environmental Protection Agency for specific forest tree nursery pest problems. These formulations range from the "broad

---

1/ Nursery Disease Specialist, USDA Forest Service, Southern Region, Forest Pest Management, Asheville, N.C.

spectrum" fumigants, such as methyl bromide - 98 percent; chloropicrin - 2 percent (MC-2), to stronger formulations, such as methyl bromide - 67 percent; chloropicrin - 33 percent (MC-33). The MC-2 formulation is effective against most weed seeds, nematodes, soil insects, and some soil fungus pathogens. The MC-33 formulation is particularly effective against difficult-to-control fungus pathogens on both conifer and hardwood seedling host species (Cordell and Wortendyke, 1972). The primary target pest organisms in nursery soil fumigation practices are soilborne, pathogenic fungi responsible for the recurrent damaging root rots and damping-off in southern nurseries. In the past, annual weeds were the primary target pests. However, the recent development of equally effective and less expensive herbicides has resulted in major modifications in nursery pest control objectives (South and Gjerstad, 1980).

The methyl bromide fumigant is most commonly applied by a chisel injection method beneath the soil. This method involves a tractor-drawn, soil injection rig equipped with chisels not over 12 inches apart and set to inject the fumigant at an optimum 8-10 inch depth (Great Lakes Chemical Corporation, 1976). More recently, soil injection rigs have been developed that permit fumigant injections at soil depths of 12 inches or more where particularly damaging disease problems threaten the production of deeper-rooted hardwood seedlings, such as black walnut and yellow poplar. Fumigant dosage rates vary between 250-600 pounds methyl bromide active ingredient per acre (Miller and Norris, 1970). A dosage rate of 350 pounds per acre is standard as a "broad spectrum" treatment and is the maximum registered dosage rate for the MC-33 formulation. The fumigant dosage rate is equal to the concentration times the exposure time (Table 1; Dow Chemical Company, 1967). Therefore, both the fumigant concentration and the exposure time must be adequate to obtain effective control results. The fumigated soil is covered immediately with a clear polyethylene plastic covering, preferably a minimum 2 ml thickness. The fumigation and tarping can be effectively applied in either alternate strips or as continuous fumigated and tarped fields using custom application equipment. The major advantages of the continuous fumigation and tarp method are outlined in table 1. A major disadvantage in some localities is the wind factor, which makes the continuous, large-area tarping much more difficult.

The effectiveness and efficiency of methyl bromide soil fumigation can be increased and extended by following the guidelines and precautions outlined in table 1 (Seymour and Cordell, 1979).

RESULTS

Target Organisms

Difficult to control soil fungus diseases, such as cylindrocladium root rot, charcoal or black root rot, and phytophthora root rot, have caused severe, widespread damage to both conifer and hardwood nurseries throughout the United States during recent years. Soilborne, pathogenic fungi, such as *Macrophomina phaseolina* (charcoal root rot) and *Cylindrocladium* spp. (cylindrocladium root rot), with their tough, resistant, sclerotial fungus stages, are two of the most difficult soil fungi to control in nursery seedbeds. The MC-33 type formulations have repeatedly and consistently provided the most effective control of these disease problems. The soil pathogenic fungi have been either eliminated or reduced to tolerable levels, along with the consistent production of

Table 1. Suggested guidelines and precautions for effective soil fumigation with methyl bromide.[1]

Soil fumigation factors	Guidelines and precautions
Soil preparation	Work into fine, loose, friable condition to minimum depth of 8 to 10 inches. Soil should be as free of clods as possible.
Organic matter	Do not use nondecayed organic matter. Organic matter can render fumigant ineffective and harbor fungi and nematodes. Cut or chop green organic matter into the soil a minimum of 3 to 4 weeks prior to fumigation.
Soil moisture	Soil moisture neither too high nor too low. Light sandy soils—slightly below field capacity.[2] Heavy clay soils—50-75 percent field capacity.
Soil temperature	Soil temperature above 50°F at 6-inch depth. Air and soil temperatures not usually correlated.
Soil fumigants and target pests	Mixtures of 98% methyl bromide/2% chloropicrin fumigant: broad spectrum for nematodes, weeds, and most soilborne fungi. Mixtures of 67% methyl bromide/33% chloropicrin fumigant: particularly effective against soilborne fungi with tough resistant stages. Mixtures of 98% methyl bromide/2% chloropicrin diluted with 30% solvent inert ingredients least effective against soilborne fungi.
Calibrating and monitoring soil fumigation equipment	Fumigant dosage = concentration X time. Dosage determined by injector nozzle size, fumigant pressure, and tractor speed. Fumigant injected at minimum 8-inch soil depth. Maintain constant pressure, tractor speed, and fumigant flow through all nozzles for uniform, effective coverage.
Soil tarping	Apply minimum 2-mil-thickness clear polyethylene tarp immediately after fumigation for maximum effectiveness. Alternate strips require longer fumigation and time intervals and afford opportunity for contamination from adjacent nonfumigated soil strips. Solid tarping requires shorter fumigation time interval and minimizes opportunity for soil contamination. Repair and seal any holes and open glue joints immediately.
Fumigation exposure period	See fumigant label for recommendations. Minimum of 48 hours at soil temperature above 60°F at 6-inch depth. At lower temperatures and during wet weather (following fumigation) double the exposure period.
Fumigation aeration period	See fumigant label for recommendations. Minimum of 48-72 hours; varies with fumigant, soil, temperature, moisture, and crop to be planted. Double aeration period in wet weather or at temperatures below 60°F.
Extended aeration for seedbeds receiving artificial inoculations of mycorrhizal fungi	Aerate soil at least 3 weeks following mixture of 67% methyl bromide/33% chloropicrin fumigation. This strong fumigant has extended residual toxicity to all soil fungi, including those which form mycorrhizae.
Contamination of fumigated soil	Avoid possible contamination by movement of soil, plants, mulches, *etc.*, into fumigated areas. Clean, by steam or equivalent, all equipment: plows, bed shapers, tractor tires, etc. Avoid transplanting from nonfumigated soils.
Fumigation of mulch materials	Prefumigate mulch materials such as pine needles, straw, and sawdust with mixture of 67% methyl bromide/33% chloropicrin or mixture of 98% methyl bromide/2% chloropicrin formulations at dosage rate of one lb/yd³. Tightly compacted or baled materials should be a maximum of 18 inches deep. Loose pine needles, straw, etc., may be 3-4 feet deep. Fumigation procedures and precautions (tarping, temperature, moisture, exposure, aeration periods, *etc.*) are same as for soil fumigation.
Soil nutrient alterations	Level of soluble salts and ammonia nitrogen may be increased due to decreased populations of nitrifying bacteria. Do not use ammonia fertilizers on plants requiring nitrates or those sensitive to ammonia. Apply only nitrate fertilizers until seedlings are established and soil temperature is above 65°F. Base your fertilizer applications on soil tests made after fumigation.
Water requirements	Water requirements per unit of plant production are generally less. Water requirements per acre are increased due to generally larger plants and increased production.
Cover crops	Green manure cover crop plants such as corn, peas, and soybeans are highly susceptible hosts for *M. phaseolina*. Grain crops such as millet or rye are considered nonhosts.
Safety	The methyl bromide/chloropicrin formulations are highly toxic to animals (including humans) and plants. Handle fumigants with care and only by certified competent personnel. **ALWAYS READ FUMIGANT LABEL PRIOR TO USE AND FOLLOW ALL DIRECTIONS AND PRECAUTIONS CLOSELY.**

[1] *Cordell and Wortendyke 1972.*

[2] *Water-holding capacity of the soil against the force of gravity.*

1/ Seymour, C. P. and C. E. Cordell. 1979. Control of charcoal root rot with methyl bromide in forest nurseries. Southern Journal of Applied Forestry, Vol. 3:3, pp. 104-108.

higher quality tree seedlings with significantly increased field survival and growth capabilities (Affeltranger and Cordell, 1970; Seymour, 1969; Smith and Bega, 1964; Hodges, 1962; Foster, 1961; Peterson and Smith, 1975; Seymour and Cordell, 1979).

Non-target Organisms

Methyl bromide soil fumigation either eliminates or significantly reduces all living organisms within treated soils. The beneficial ectomycorrhizal and saprophytic soil fungi, however, usually re-invade fumigated soils first and build up to higher populations than in unfumigated soils. A distinction must be made between the ecto- or primarily "conifer-type" mycorrhizae and the endo- or primarily "hardwood-type" mycorrhizae. The conifer- or pine-type ectomycorrhizae produce an abundance of airborne spores that readily infest fumigated soils, while the hardwood-type endomycorrhizae are exclusively soilborne and, thereby, are very limited in fumigated soil reinfestation capabilities. Research and field evaluations are currently in progress concerning the practical application of specific ecto- and endo- mycorrhizal fungi in both conifer and hardwood nurseries (Marx, 1977). Special precautions are needed when soil fumigation is followed by artificial ectomycorrhizal inoculations in nursery seedbeds. When the stronger MC-33 formulation is used, a minimum two-week soil aeration period is required prior to the ectomycorrhizal inoculations. Also, methyl bromide soil fumigation, preferably spring fumigation, is considered mandatory for effective, artificial ectomycorrhizal inoculations in bareroot nursery seedbeds.

DISCUSSION

Effective, efficient soil fumigation has been repeatedly obtained with the methyl bromide-chloropicrin formulations previously described. As previously pointed out, the MC-33 formulation has been most effective for controlling soilborne, fungus-caused disease problems, such as the root rots, while the MC-2 formulation has been most effective as a broad spectrum fumigant for controlling nematodes, soil insects, weeds and grasses, and some soilborne fungi.

The present cost of methyl bromide fumigation ranges between $800 to $1,000 per acre ($1,975 to $2,475 per hectare). The cost varies with the methyl bromide-chloropicrin formulation, dosage rate, tarp cover thickness, acreage fumigated, and commercial or private application. Based on an average conifer seedling production in southern nurseries of 750,000 seedlings per acre, the cost ranges between $1.07 to $1.33 per thousand seedlings. The potential pest threats without fumigation, along with the benefits derived from fumigation, clearly demonstrates that this practice represents a profitable, economic investment to help ensure the sustained production of higher quality tree seedlings with improved survival capabilities for field plantings.

CONCLUSIONS

Methyl bromide soil fumigation can be effectively, efficiently, and safely applied in bareroot forest tree nurseries. The primary target organisms are the soilborne, pathogenic fungi that cause recurrent damaging root rot and damping-off losses. The MC-33 fumigant formulation has consistently and repeatedly provided the most effective control of these disease problems. Due consideration and utilization of the basic biological (target organisms), chemical (soil fumigant), and environmental (soil) factors involved, however, are required to obtain consistent successful results.

REGISTRATION AND SAFETY

Registered Uses and Safety

Methyl bromide and methyl bromide-chloropicrin formulations are specifically registered through the U.S. Environmental Protection Agency as preplanting soil fumigants for the control of a variety of soil fungus organisms, nematodes, soil insects, weeds, and grasses in forest tree nurseries. Although these fumigants are highly toxic to humans, animals, and plants, they can be as safely employed as any other chemical pesticide when maintaining due consideration and precaution for their potential toxicity and accompanying safety hazards.

The specific fumigant formulation label should be read and understood prior to use. All handling and application directions and safety precautions should be closely followed. The fumigant is applied only by nursery personnel that are certified by the respective state pesticide regulatory agency. Recommended protective equipment should always be utilized as directed.

Remember, methyl bromide and methyl bromide-chloropicrin formulations are listed as restricted use pesticides by the U.S. Environmental Protection Agency.

LITERATURE CITED

Affeltranger, C. E. and Cordell, C. E. A root rot plagues forest nurseries. Forest Farmer 29:12,16. 1970.

Cordell, Charles E. and Wortendyke, John T. Background document for methyl bromide. USDA Forest Service Technical Report. 1972. 70 p. (unpublished).

Dow Chemical Company. Calibration of soil fumigation equipment for gaseous fumigants. Midland, Mi. The Dow Chemical Company. Form No. 138-651-67R. 1967. 6 p. (unpublished).

Foster, Alfred A. Control of black root rot of pine seedlings by soil fumigation in the nursery. Georgia Forestry Research Council Report No. 8. Macon, Ga.: Georgia Forestry Research Council. 1961. 5 p.

Great Lakes Chemical Corporation. The handbook of agricultural fumigation. West Lafayette, In. Great Lakes Chemical Corporation. Technical Bulletin. 1976. 19 p.

Hodges, Charles S., Jr. Black root rot of pine seedlings. Phytopathology 52:210-219. 1962.

Marx, Donald H. The role of mycorrhizae in forest production. In Proceedings, TAPPI Annual Meeting, Feb. 14-16, 1977. Atlanta, Ga. Technical Association of the Pulp and Paper Industry. 1977. p. 151-161.

Miller, W. O. and Norris, M. G. A new review of soil fumigation practices for use in forest nurseries. Down to Earth 26: 9-12. 1970.

Peterson, Glenn W. and Smith, Richard S., Jr. (Technical Coordinators). Forest nursery diseases in the United States. USDA Agric. Handbook No. 470. Washington: U.S. Department of Agriculture; 1975. 125 p.

Seymour, C. P. Charcoal root rot of nursery-grown pines in Florida. Phytopathology 59:89-92. 1969.

Seymour, C. P. and Cordell, C. E. Control of charcoal root rot with methyl bromide in forest nurseries. Southern Journal of Applied Forestry 3(3):104-108. 1979.

Smith, Richard S., Jr. and Bega, Robert V. Macrophomina phaseolina in the forest tree nurseries of California. Plant Dis. Rptr. 48:206. 1964.

South, David B. and Gjerstad, Dean H. Nursery weed control with herbicides and fumigation - an economic evaluation. Southern Journal of Applied Forestry 4(1):40-45. 1980.

Bayleton® for Fusiform Rust Control - An Update of Research Findings

by

S.J. Rowan and W.D. Kelley[1/]

Abstract.--Based on a series of studies, a spray schedule is presented that should improve the efficacy of Bayleton for fusiform rust control in nurseries. Many adjuvants appear to be useful in formulations with Bayleton. A seed soak treatment is an approved use in some states under the 24-C label. Use of Bayleton as a seed treatment combined with foliar sprays will improve rust control during the critical germination period. Observations of roots of seedlings at time of lifting indicate little, if any, suppression of mycorrhizal development of foliar sprays of Bayleton.

Although Bayleton (triadimefon) has provided excellent control of fusiform rust in greenhouse and nursery studies, operational use of this fungicide in nurseries using the recommended spray schedule resulted in unacceptable levels of rust losses in some nurseries. Among 32 nurseries using Bayleton on their 1981-1982 crops, 15 reported no rust (the desired goal), 15 reported less than 1 percent, and 2 reported less than 2 percent rust. In the same crop year, however, plots in Florida's Munson nursery had approximately 7 percent infection after 3 foliar sprays of Bayleton and plots at St. Joe Paper Company's nursery in Florida had approximately 3 percent infection after 3 foliar sprays[2/].

[1/] Respectively, Principal Research Plant Pathologist, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Carlton Street, Athens GA 30602 and Professor, Department of Botany, Plant Pathology and Microbiology, Auburn University Agriculture Experiment Station, Auburn, AL 36830.

[2/] Personal Communication, Dr. Ed Bernard, Florida Division of Forestry, P. O. Box 1269, Gainesville, FL 32602.

In attempts to improve the control obtained with Bayleton, a series of studies were conducted. Results of these studies either have been or are being published elsewhere. One study was designed to determine if Bayleton foliar sprays, like ferbam sprays, must dry before irrigation or rain for rust control. Table 1 shows simulated rain 5 minutes or more after application of sprays did not reduce efficacy of the treatment. Theoretically, however, more fungicide would be on and in pine seedling tissues if sprays were allowed to dry fully before irrigating seedbeds.

Table 1. Effects of simulated rain on efficacy of Bayleton sprays for control of fusiform rust

Time after spray (Minutes)	Seedlings infected[1/] (Percent)
Nonsprayed check	86.8 a
0.25	1.2 b
1	1.2 b
5	0.0 c
15	0.0 c
30	0.0 c
60	0.0 c
120	0.0 c

[1/] Means followed by a common letter do not differ (P=0.05) according to Duncan's Multiple Range Test.

A total of 18 adjuvants were compared for use in formulations with Bayleton for control of fusiform rust in pine seedlings. Results of this test show that, without rain, all tested adjuvants were of equal quality. After 5 cm of rain, however, two of the 18 adjuvants, Bond spreader sticker and Ortho X-77, were slightly inferior.

Table 2. Efficacy of 18 adjuvants in Bayleton sprays for control of fusiform rust of loblolly pine seedlings when applied 2 days before seedlings were exposed to 0 and 5 cm of artificial rain [1/]

Adjuvant	Rate (ml) per liter	Rainfall (cm) 0	5
		% Galled seedlings	
Nu-film-17	1.25	0.0a[2/]	0.0a
Security Spreader-Sticker	0.63	0.0a	0.0a
Exhalt-800	1.25	0.0a	0.0a
Triton X-45	1.25	0.0a	0.0a
Triton X-100	1.25	0.0a	0.0a
Atlas Sur-fac	5.0	0.0a	0.0a
Ortho X-77	0.47	0.0a	1.1b
Olde Worlde	1.25	0.0a	0.0a
Plantgard	200.0	0.0a	0.0a
Bio-film	0.47	0.0a	0.0a
Plyac	1.25	0.0a	0.0a
Dupont Spreader-Sticker	0.31	0.0a	0.0a
Ortho-Chevron Spray-Sticker	0.63	0.0a	0.0a
Agri-Dex	2.5	0.0a	0.0a
Agway Target NL	0.63	0.0a	0.0a
Wex	0.78	0.0a	0.0a
Bio-88	0.63	0.0a	0.0a
Bond Spreader-Sticker	2.5	0.0a	1.2b
No adjuvant	-	1.2b	1.2b
No Bayleton	-	56.0c	69.8c

[1/] Infection percentages are the average of five 20-tree-replicates determined 9 months after inoculation. Sprays contained 0.6 grams active Bayleton ingredient per liter.

[2/] Means followed by a common letter do not differ significantly (P=0.05). Duncan's new Multiple Range Test was used to compare column means and Student's T test was used to compare rainfall effects. Zero percentages were excluded from these analyses.

The high speed at which Bayleton is absorbed by pine seedling tissues (Table 1) probably explains why the adjuvants varied so little. Proper agitation of the spray mix during preparation and application should make most, if not all, adjuvants tested of equal value when used with Bayleton.

In a test to determine how effective a seed soak treatment was for control of fusiform rust, significant reduction in rust incidence was evident through 35 days after seedling emergence (Table 3) and complete control by the seed treatment was obtained through 7 days.

Table 3. Efficacy of Bayleton[1/] is preventing fusiform rust infections in slash pine seedlings originating from Bayleton treated and nontreated seed and inoculated at differing time intervals after seed germination.

Seedling age at inoculation (days after emergence)	Seedling galled[2/] (%)	
	Untreated Checks	Seed treatment only
7	39.0 b	0.0 f
14	49.7 b	4.1 e
21	74.8 a	13.1 de
28	81.7 a	42.3 bc
35	77.7 a	33.7 c
42	79.0 a	62.6 ab
49	82.2 a	53.8 b
56	88.7 a	71.1 a
63	79.1 a	76.7 a
70	86.5 a	70.9 a

[1/]Bayleton was formulated in aqueous suspension at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used to soak seed at room temperature for 24 hours.

[2/]Infection percentages are the average of five 20-tree replicates determined 10 months after inoculation. In each column, means followed by a common letter are not significantly different (P=0.05). In each row, means underlined are not significantly different (P=0.05) according to Duncan's Multiple Range Test.

Because a seed soak is a preventative measure and foliar sprays have both preventative and eradicative properties, it was reasoned that the combination of the two treatments may increase the degree of rust control. A test was therefore devised in which foliar sprays were applied at differing time intervals before and after inoculation with the rust fungus to seedlings originating from both treated and nontreated seeds. Results of this study show that foliar sprays alone will prevent infections for up to 28 days after spray applications (Table 4) and will eradicate infections up to 7 days old. When both a foliar spray and seed treatment are combined, however, infections up to 14 days old were eradicated. Therefore, when seeds are treated, seedlings need not be sprayed until 14 days after emergence begins.

Table 4. Efficacy of Bayleton[1/] in preventing or eradicating fusiform rust infections in slash pine seedlings when foliar sprays are applied (with and without seed treatment) at differing time intervals before and after inoculation with the rust fungus

Treatment schedule	Seedlings galled[2/] (%)			
	Sprayed before inoculation		Sprayed after inoculation	
(days before or after inoculation)	Foliar spray only	Foliar spray and seed treatment	Foliar spray only	Foliar spray and seed treatment
1	--	--	0.0a	0.0a
7	0.0a	0.0a	0.0a	0.0a
14	0.0a	0.0a	8.7b	0.0a
21	0.0a	0.0a	20.2c	5.5b
28	0.0a	0.0a	48.9d	28.4c

[1/] Bayleton was formulated in aqueous suspensions at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used as foliar sprays and to soak seed for 24 hours at room temperature.

[2/] Means followed by a common letter do not differ significantly (P=0.05) according to Duncan's Multiple Range Test. Infection percentages are the average of five 20-tree replicates determined 10 months after inoculation. Untreated checks were 79.0 percent infected which differed significantly from 48.9 percent infection at 28 days.

Bayleton did not eradicate infections on 4 year old loblolly pines when applied topically (Table 5), giving additional proof that this fungicide will eradicate only the very young infections.

Table 5. Aecial sporulation of fusiform rust galls after topical application of of two fungicides

Treatment[1/] and rate of	Year of observation			
a.i. (mg/liter)	1977	1978	1979	1980
	--------------Percent---------------------			
Benodanil				
0	76 a	94 a	36 a	60 a
150	66 a	56 b	10 a	30 a
300	68 a	55 b	7 b	40 a
600	56 a	46 b	11 b	50 a
Bayleton				
0		75 a	16 a	30 a
500		75 a	15 a	40 a
1000		77 a	10 a	30 a
2000		65 a	13 a	20 a

[1/] Benodanil was applied 3/18/77 and Bayleton 10/13/77 at the average rate of 260 ml/gall (runoff) with a paint brush after the outer, rough bark was removed with a gloved hand.

Means within each treatment column followed by a common letter do not differ (P=0.05) according to Duncan's Multiple Range Test.

Bayleton is registered for use in forest nurseries as foliar sprays, and is approved under the 24-C label for use as a seed treatment in the states of Georgia, Arkansas, Virginia, South Carolina, and Florida. All other southern states have not granted approval of this use and nurserymen is these states must await federal or state approval. If seeds germinate over a period of several weeks, repeated spraying appears to be necessary during the emergence period unless seed are treated or sufficient quantities of the fungicide are absorbed by seed sprayed before their germination. A test was therefore, designed in which Bayleton was applied as a spray at intervals during the germination period to seedlings originating from both treated and nontreated seed. The results of this test clearly show that insufficient quantities of Bayleton are absorbed by seed when sprays are applied before germination (Table 6).

Table 6. Efficacy of Bayleton[1/] in controlling fusiform rust in slash pine seedlings when foliar sprays are applied at intervals during seed germination to seedlings originating from Bayleton treated and nontreated seed

Treatment schedule (days after seed sown)	Seed germination (%) at treatment date	Seedlings galled[2/] (%) Untreated checks	Foliar spray only	Foliar Spray & seed treatment
7	48.9	82.0 ab	66.3 d	0.0 a
9	62.9	86.0 b	48.1 c	0.0 a
11	72.2	69.8 a	36.1 c	0.0 a
13	83.0	75.4 ab	22.0 b	0.0 a
15	87.9	79.0 ab	15.7 b	0.0 a
21	100.0	77.1 ab	0.0 a	0.0 a

[1/]Bayleton was formulated in aqueous suspensions at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used as foliar sprays and to soak seed at room temperature for 24 hours.

[2/]Infection percentages are the average of five 30-48 tree replicates (50 seed sown/replicate) determined 10 months after inoculation. Inoculations were made 30 days after seed were sown. In each column means followed by a common letter are not significantly different (P-0.05) according to Duncan's new Multiple Range Test. All row means not underlined differed (P=0.05) according to Fishers F and Duncan's Multiple Range Test.

Incidence of fusiform rust in nurseries having used Bayleton operationally may, therefore, be attributed to: (1) its inability to protect seedlings emerging between any two sprays applied at intervals greater than 7 days; (2) its inability to eradicate infections 14 or more days old; and (3) inadequate coverage of seedling foliage with any spray application. An improved spray schedule is to (a) apply a first spray 7 days after germination begins or no later than 7 days after the first infection period following the beginning of germination; (b) apply a second spray 7 days later or no later than 7 days after the first infection period following the first spray; (c) thereafter, apply two additional sprays during the remaining rust hazard season (until the first week of July) at intervals not to exceed 35 days. Ferbam sprays can be used to help prevent infections where seedlots germinate over an extended period. In states where Bayleton can be used as a seed treatment, the first spray must be applied 14 days after germination begins or no later than 7 days after the first infection period following the first 14 days of seed germination. Thereafter, sprays should be applied at intervals not to exceed 35 days.

In an attempt to determine if operational use of foliar sprays in nurseries are detrimental to the development of mycorrhizae, Bayleton was applied at differing rates and frequencies to slash and loblolly pine seedlings. Roots were examined at the end of the growing season to evaluate mycorrhizal development. Applications of 4 (0.28 kg/ha), 6 (0.42 kg/ha), and 8 (0.56 kg/ha) ounces active ingredient per acre in multiple applications (up to 4) did not harm mycorrhizal development on slash and loblolly pine seedlings (Tables 7 and 8). First year data from a study designed to determine if Bayleton accumulates in soil from operational sprays indicate very little effect on mycorrhizal development even when 24 ounces of the active ingredient are applied per acre (Table 9).

Table 7. Effect of field applications of Bayleton on production of short roots with mycorrhizae by slash pine seedlings

Treatment[1/]	Rate (Kg / ha)		Spray interval	No. of applications	Short roots with mycorrhizae (%)[2/]
Control	--		--	--	52.7 a[3/]
Bayleton	SS	--	--	--	49.0 a
Bayleton	SS+FS	0.28	2-wk	4	45.4 a
Bayleton	SS+FS	0.28	3-wk	3	49.0 a
Bayleton	SS+FS	0.42	2-wk	4	43.5 a
Bayleton	SS+FS	0.42	3-wk	3	39.2 a
Bayleton	SS+FS	0.56	3-wk	3	43.7 a
Bayleton	SS+FS	0.56	4-wk	2	44.1 a
Bayleton	PPI	0.56	--	1	44.0 a
Bayleton	PPI	1.12	--	1	37.7 a

1/Abbreviations: SS=seed soak (800 mg Bayleton/l for 24 hr); FS=foliar spray; PPI=preplant soil incorporated.

2/Each figure represents the average of 10 seedlings from each of 8 replicate plots.

3/Means followed by the same letter do not differ (P = 0.01) according to Duncan's Multiple Range Test.

Table 8. Effect of field applications of Bayleton on production of short root with mycorrhizae by loblolly pine seedlings

Treatment[1/]	Rate (kg / ha)		Spray interval	No. of applications	Short roots with mycorrhizae (%)[2/]
Control	--		--	--	35.4 a[3/]
Bayleton	SS	--	--	--	32.1 a
Bayleton	SS+FS	0.28	2-wk	4	32.0 a
Bayleton	SS+FS	0.28	3-wk	3	35.2 a
Bayleton	SS+FS	0.42	2-wk	4	28.5 a
Bayleton	SS+FS	0.42	3-wk	3	35.3 a
Bayleton	SS+FS	0.56	3-wk	3	24.8 a
Bayleton	SS+FS	0.56	4-wk	2	30.4 a
Bayleton	PPI	0.56	--	1	35.9 a
Bayleton	PPI	1.12	--	1	34.3 a

1/Abbreviations: SS=seed soak (800 mg Bayleton/l for 24 hr); FS=foliar spray; PPI=preplant soil incorporated.

2/Each figure represents the average of 10 seedlings from each of 8 replicate plots.

3/Means followed by the same letter do not differ (P = 0.01) according to Duncan's Multiple Range Test.

Table 9. Effect of Bayleton foliar sprays applied to the same seed beds annually on production of mycorrhizal roots by loblolly pine seedlings: first-year-data from MacMillan-Bloedel nursery, 1981-1982.

Treatment	No. mycorrhizal roots/ 10 cm of laterals
Control	33.3
Bayleton 1 X*	34.4
Bayleton 2 X	30.6
Bayleton 4 X	28.6

*1 X rate = 6 oz. a.i./acre

Bayleton was also tested on 1-0 loblolly nursery stock applied at different rates as a top-dip, root-dip, or as a clay-slurry root-dip to determine if such treatments would provide protection against rust infections during the first year in the plantation. The results of this study show that Bayleton applied in a clay-slurry root dip provides control during the first year after outplanting (Table 10).

Table 10. Efficacy of Bayleton[1/] for control of fusiform rust in 1-0 loblolly pine nursery stock when applied at different rates and methods before artificial inoculation 3 months after treatment or exposure to first year natural-field inoculum

Treatment	Bayleton concentration (mg/liter)	Seedlings galled[2/] (%) Greenhouse-artificial inoculations	Nursery-natural infections
Checks	0	10.9 a	4.0 a
Check-clay slurry	0	4.8 a	6.3 a
Top dip	600	0.0 b	4.0 a
	800	0.0 b	4.2 a
	1,000	0.0 b	2.1 b
	1,500	0.0 b	0.0 c
Root dip	600	0.0 b	2.0 b
	800	0.0 b	4.2 a
	1,000	0.0 b	2.0 b
	1,500	0.0 b	0.0 c
Clay-slurry	600	0.0 b	0.0 c
	800	0.0 b	0.0 c
	1,000	0.0 b	0.0 c
	1,500	0.0 b	0.0 c

[1/] Bayleton was formulated to contain 2.5 ml of the adjuvant, Agri-dex, per liter. The clay slurry contained 45.35 percent kaolinitic clay (weight/volume).

[2/] In each column, means followed by a common letter do not differ (P = 0.05) according to Duncan's Multiple Range Test.

OPERATIONAL GUIDELINES FOR HANDLING SEEDLINGS

Kenneth F. Jeffries[1/]

Abstract.-- Realizing that seedling mortality is not caused by any one phase of the reforestation process, the North Carolina Division of Forest Resources has developed seedling handling standards for lifting, delivery and storage, and field planting.

Like most of you, we have experienced varying degrees of seedling survival problems over the last few years. The high cost of site preparation and the increased use of improved seedlings make poor survival much harder to take and also harder to explain to the boss and/or landowner.

We feel that poor practices in the nursery will reduce survival to some degree. If improper practices continue through storage, transport and planting, the cumulative effect will mostly likely end in a planting failure.

We have developed standards for seedling processing in three general categories: (1) Nursery Lifting and Processing Standards, (2) District/County Delivery and Storage Standards, and (3) Field Handling and Planting Standards.

These three stages of the reforestation process are divided into three classes of days: (1) Normal Conditions, (2) Critical Conditions, and (3) Severe Conditions.

As you might expect, any one of these requirements could be below par, but excellent conditions in the other requirements could compensate and allow a Normal Condition to exist. Just as in setting fire readiness plans, some experience and judgement is required. I will go through the highlights of these standards.

NURSERY LIFTING AND PROCESSING STANDARDS

NORMAL CONDITIONS

Temperature:	35^{o}F to 75^{o}F
Relative Humidity:	50% +
Wind:	Less than 10 miles/hour
Soil Moisture:	75% to field capacity (100%)

Lifting

1. Use of all types of seedling lifters permissible.
2. Roots of seedlings on lifter conveyor will be exposed maximum of three minutes.
3. Full, tightly packed boxes will be removed from the field and placed in the packing shed within 20 minutes. Partially filled boxes where roots are exposed will be covered with moist burlap, etc. to prevent drying out.

1/ Senior Staff Forester, Nursery and Tree Improvement, North Carolina Division of Forest Resources, Department of Natural Resources and Community Development, Raleigh, North Carolina.

Packing

1. Boxes of seedlings on conveyors in packing room will be protected from heat and direct sunlight.
2. Seedling roots will be exposed a maximum of two minutes from time removed from box to weighing for packing.
3. Standard amount of moisture retention material will be added to bag.
4. Packed bags will be protected from heat and direct sunlight until placed in storage.
5. Unrefrigerated bags may be loaded on non-refrigerated transports without pre-chilling when properly loaded (see transporting).
6. Full boxes of seedlings may be left on the packing room coveyors overnight if properly watered and temperature maintained from $35^{o}F$ to $55^{o}F$.

Loading and Delivery

A. Non-refrigerated transports
   1. Must be covered to protect from direct sunlight.
   2. Bags not stacked over three deep per layer.
   3. Spacers used to provide air circulation between layers.
   4. At least 12" of air space between top of bags and cover.
   5. Vehicle must not be parked in direct sunlight. In case of emergency, stops should not exceed more than 45 minutes in direct sunlight. Advise supervisor if exposure exceeds this amount.
   6. Torn bags will be repaired immediately.

B. Refrigerated transports
   1. Pre-chilled seedlings (36 hours) may be transported for up to five hours without spacers for air circulation.
   2. Seedlings that have not been pre-chilled must be loaded as if the van were not refrigerated, i.e., with no more than three layers deep with spacers being used.

CRITICAL CONDITIONS

Temperature:	$76^{o}F$ to $85^{o}F$
Relative Humidity:	30% to 50%
Wind:	10 miles/hour +
Soil Moisture:	50% to 75%

Lifting

1. Use of Grayco harvesters given top priority (if other lifters must be used -- entire beds will not be undercut ahead of lifters).
2. Roots of seedlings on lifter conveyor will be exposed maximum of three minutes.
3. Full, tightly packed boxes will be removed from the field and placed in the packing building within 10 to 15 minutes. Partially filled boxes of seedlings will be covered immediately with moist burlap, etc. to prevent drying out.
   a. Lift fields close to facility, when possible.
   b. Use additional tractor(s) for delivery from field to packing building.
4. When soil moisture reaches less than 50%, fields will be irrigated prior to lifting.

Packing

1. Boxes of seedlings on conveyors in packing room will be protected from heat and direct sunlight, and boxes not processed within 30 minutes after arriving in packing building will be watered.
2. Seedling roots will be exposed a maximum of two minutes from time of removal from box to weighing for packing.
3. Roots of seedlings will be watered (or sprayed with other material) just prior to being packed.
4. Packed bags will be protected from heat and direct sunlight until placed in storage.
5. Without exception, seedlings will be chilled for 36 hours before loading.
6. All boxes of seedlings in the packing room will be processed daily and none left unfinished.

Loading and Delivery

A. Only pre-chilled seedlings will be loaded for transport.
B. Non-refrigerated transport
    1. Use only if absolutely necessary.
    2. Must be covered to protect from direct sunlight.
    3. Bags not stacked over two deep in layers.
    4. Spacers must be used to provide air circulation between layers.
    5. At least 12" of air space between top of bags and cover.
    6. Emergency stops only, advise supervisor if stops made.
    7. Early evening transportation should be utilized when possible.
    8. Torn bags will be repaired immediately.
C. Refrigerated transport
   Pre-chilled seedlings (36 hours) may be transported for up to five hours without spacers for air circulation if unloaded promptly upon arrival at destination.

SEVERE CONDITIONS

(Freezing Conditions)

Temperature: 32^{o}F or less and/or frozen ground conditions
Relative Humidity:
Wind:

Lifting

All lifting operations will cease.

Packing

1. If seedlings have been stored properly in packing building, packing may be done.
2. Seedlings stored in boxes for packing will be protected by maintaining a temperature between 32^{o}F and 55^{o}F in the packing building and will be watered as needed to prevent drying out.

3. Seedling roots will be exposed a maximum of two minutes from the time removed from box to weighing for packing.
4. Packed bags will be protected from heat, direct sunlight, and/or freezing until placed in storage.
5. Unrefrigerated bags may be loaded without pre-chilling only on insulated or refrigerated vans using proper loading techniques. Do not ship on transports without adequate protection.

Loading and Delivery

A. Non-refrigerated transports

Transportation of seedlings on vehicles without proper protection from freezing is not allowed.

B. Refrigerated transport
   1. Pre-chilled seedlings (36 hours) may be transported for up to five hours without spacers for air circulation.
   2. Seedlings that have not been pre-chilled must be loaded as if the van were not refrigerated, i.e., with no more than three layers deep with spacers being used.

(Hot, Dry Conditions)

Temperature:	$85^{o}F$ +
Relative Humidity:	30% or less
Wind:	15 miles/hour +
Soil Moisture:	Less than 50%

Lifting

Usually will cease; however, Senior Staff Forester, Nursery and Tree Improvement, will be notified of conditions, and he will make final decision. If lifting is done:
1. Fields will be irrigated. Do not lift in sandy soil.
2. Only Grayco harvesters will be used. (Roots of seedlings on lifter conveyor will be sprayed).
3. Roots of seedlings on lifter conveyor will be exposed maximum of three minutes.
4. Full, tightly packed boxes will be removed from the field and placed in the packing building within ten minutes. Partially filled boxes of seedlings will be covered immediately with burlap, etc. to prevent drying out.
   a. Lift fields close to facility.
   b. Use additional tractors for delivery from fields to packing building.

Packing

1. Boxes of seedlings on conveyors in packing room will be protected from heat and direct sunlight, and boxes not processed within 30 minutes after arriving in packing building will be watered.
2. Seedling roots will be exposed a maximum of two minutes from time of removal from box to weighing for packing.

3. Roots of seedlings will be watered (or sprayed with other material) just prior to being packed.
4. Packed bags will be protected from heat and direct sunlight until placed in storage.
5. Bags will not be loaded on transports without pre-chilling (36 hours).
6. All boxes of seedlings in the packing room will be processed and not left overnight.

Loading and Delivery

A. Only pre-chilled seedlings will be loaded for transport.
B. Non-refrigerated transport
   Seedlings will not be transported on units without refrigeration.
C. Refrigerated transport
   Pre-chilled seedlings (36 hours) may be transported for up to five hours without spacers for air circulation if unloaded promptly upon arrival at destination.

DISTRICT/CONTRACTOR DELIVERY AND STORAGE STANDARDS

NORMAL DAY

Temperature: $35^{o}F$ to $75^{o}F$
Relative Humidity: 50% +

Delivery

1. Vehicles used for transporting seedlings will have a cover to shade and protect seedlings.
2. Bags/bundles will not be stacked over three deep per layer unless spacers are used to provide air circulation between layers.
3. At least 12" of air space between top of bags/bundles and cover will be left to avoid heat build-up.
4. Vehicles will not be parked in direct sunlight. In case of emergency stops or breakdowns when stops exceed 45 minutes, seedlings should not be planted until their condition has been determined.

   a. Things that indicate seedling deterioration:

      (1) Sour smell -- fermentation
      (2) Yellow needles
      (3) Trees hot to the touch
      (4) Mold developing

      If any of these conditions exist, contact the District Staff Planting Coordinator prior to planting.

   b. Things that indicate dead seedlings:

      (1) Bark, especially on roots, slips off easily
      (2) Cambium layer has turned brown

      (Do not plant if these conditions exist.)

5. Inspect and repair torn bags immediately.

Storage

1. Store seedlings in building, shed, etc. that will protect from freezing, heating, and direct sunlight.

   a. Ideal temperature 35° to 38°F. (These temperatures usually can be maintained only with refrigerated units.)

      (1) Bags stored under ideal conditions can be kept at least three months (usually longer.)
      (2) Bales with seedlings dipped in clay slurry will keep from eight to ten weeks.
      (3) Bales with seedlings packed in moss will keep from eight to ten weeks, but will require watering of bales at least two times per week.

   b. Termperatures inside storage area from 38° to 50°F.

      (1) Bags stored under these conditions can be kept up to three or four weeks.
      (2) Bales with seedlings dipped in clay slurry will keep two to three weeks.
      (3) Bales with seedlings packed in moss will keep two to three weeks, but will require watering at least two times per week.

   c. Temperatures inside storage area above 50° not exceeding 75°F -- seedlings should be removed within three to five days.

2. Bags/bundles should be stacked on pallets or slats and should not be stacked over two deep without spacers to allow air circulation between layers.

CRITICAL DAY

Temperature: 76°F to 85°F
Relative Humidity: 30% to 50%

Delivery

1. Field delivery in non-refrigerated vehicles should be held to a minimum. Seedling delivery from a non-refrigerated storage point to destination should not exceed one hour's time.
2. Vehicles used for transporting seedlings will have a cover to shade and protect seedlings.
3. Bags/bundles will not be stacked over two deep per layer unless spacers are used to provide air circulation between layers.
4. At least 12" of air space between top of bags/bundles and cover will be left to avoid heat build-up.
5. Vehicle will not be parked in direct sunlight. In case of emergency stops or breakdowns, seedlings should not be planted until their condition has been determined.

a. Things that indicate seedling deterioration:

(1) Sour smell -- fermentation
(2) Yellow needles
(3) Trees hot to the touch
(4) Mold developing

If any of these conditions exist, contact the District Staff Planting Coordinator prior to planting.

b. Things that indicate dead seedlings:

(1) Bark, especially on roots, slips off easily.
(2) Cambium layer has turned down.

Do not plant if these conditions exist.

6. Inspect and repair torn bags immediately.

Storage

1. Store seedlings in building, shed, etc. that will protect from freezing and heating. If temperatures inside storage area is above 75°F, do not store seedlings more than 24 hours.
2. Bags/bundles should be stacked on pallets or slats and should not be stacked over two deep without spacers to allow air circulation.

SEVERE DAY

Temperature:	85°F + or 32°F or less
Relative Humidity:	30% or less

Delivery

1. Field delivery in non-refrigerated units should not be made when the temperature is 85°F or higher.
2. Field delivery in non-insulated units when the temperature is 32°F or less will be made only if the vehicle is covered adequately to prevent freezing.
   a. Caution -- seedlings can heat excessively on a cold day if vehicle is parked in the sun and seedlings are dead packed, preventing air circulation.
   b. Unload seedlings immediately upon arriving at destination.
3. Inspect and repair torn bags immediately.

Storage

1. Seedlings should not be stored in bags/bundles for more than a few hours at temperatures above 85°F.
   -- Lethal temperatures occur in bags/bundles at 118°F, but seedlings can be weakened or damaged if the temperature in the bag/bundle remains at 85°F for very long.

2. Do not store seedlings in an area where the temperature is 32°F or less.
   a. Do not allow seedlings to freeze.
   b. If trees have not been frozen more than 36 hours:
      (1) Thaw seedlings slowly
      (2) Determine condition
   c. If frozen more than 36 hours, then seedlings most likely have been severely damaged and should not be planted.

FIELD HANDLING AND PLANTING STANDARDS

NORMAL CONDITIONS

Temperature:	35°-75°F
Relative Humidity:	50% +
Wind:	Less than 10 miles/hour
Soil Moisture:	0-30 build-up

On-Site Storage of Seedlings

1. Bags/bundles should not have prolonged exposure to direct sunlight. Store the seedlings in a shaded location at all times.
2. If no shade is available at planting site, improvise a portable shelter such as a lean-to made of opaque plastic, canvas, or plywood.
3. Bags/bundles should not be stacked in layers more than two deep without spacers. Spacers allow air to circulate freely around the seedlings and keep them cool. (Heat builds up even at low storage temperatures when the seedlings are stored in direct sunlight or without air circulation--especially in sealed bags).
4. Keep close check on seedlings stored at the planting site and water uncoated roots of seedlings in bags or bundles if roots begin to dry. Be careful not to puddle water in bags as excess water can drown root tips or promote mold on the seedlings.
5. Do not water coated roots of seedlings since the water will remove the coating. Since the coating of roots will not give absolute protection against moisture loss, restrict the exposure of the roots the same as if they were uncoated.
6. Inspect and repair torn bags immediately.
7. Keep opened bags closed tightly by folding flap over bag and laying flat-side down or by placing a band or cord firmly around bag. Keep in shade.
8. Keep opened bundles covered at all times with wet burlap. Keep in shade.
9. If opened bags of seedlings, coated or uncoated, must be kept for over two days before planting, seedling roots must be dipped in water and bag tightly closed, or heel seedlings in.
10. If opened bundles of seedlings are not used shortly after opening, they should be heeled in.
11. Store trays of containerized seedlings in shade and keep root plugs wet until seedlings are planted. During storage, open book-type containers and check moisture of root plugs.

Culling Non-Plantable Seedlings

1. Open only one bag/bundle at a time. Be careful not to leave open more than a few minutes.
2. Remove only a small number (handful) of seedlings at a time. Do not allow the roots to be exposed to the sun or wind any longer than five minutes.
3. Cull 1-0 loblolly or 2-0 white pine seedlings that have:
   a. Broken, skinned or weak stem
   b. Fermented smell
   c. Mold on needles
   d. Slippery bark
   e. Root collar smaller than 1/8 inch
   f. Root collar larger than 3/8 inch (large seedlings must be balanced; have a balanced root-to-top ratio)
   g. Root systems less than four to five inches long
   h. Root systems longer than 12 inches if more than 50% of the laterals must be pruned in order to plant
4. Cull 1-0 longleaf seedlings if root collars are smaller than 1/4 inch or tap roots shorter than seven inches.
5. Cull containerized pine seedlings that are very small and poorly developed. Also, cull seedlings if root plug has become dry and hard.
6. Cull hardwood seedlings having root collars smaller than 1/4 inch. Also, cull broken or skinned seedlings and seedlings with stems that have not hardened off.
7. Roots must be kept visibly moist at all times. If not visibly moist, dip roots in water. If being placed back in bag, shake excess water from roots prior to placing in bag to prevent puddling. (Do not dip coated seedlings). Close bags properly.
8. For best results, assign one trained person to be responsible for culling seedlings. Closely supervise and check on culling procedures. Be sure person(s) properly trained.

Root Pruning Seedlings

1. Assign only properly trained persons to be responsible for root pruning. For best results, assign only one well-trained person to root prune. Closely supervise and check on root pruning.
2. Remove only a small number (handful) of seedlings at a time. Do not allow the roots to be exposed to the sun or wind any longer than five minutes. Root prune seedlings at same time as being culled, if feasible.
3. Roots must be kept visibly moist at all times. If not visibly moist, dip roots in water. If being placed back in bag, shake excess water from roots prior to placing in bag to prevent puddling. (Do not dip coated seedlings). Close bags properly.
4. Do not root prune unless necessary to plant seedlings at proper depth and to avoid J-rooting. Planting tongs must be used to plant long roots that are not pruned.
5. If pruning is necessary, do not remove more than 50% of lateral roots. (Will reduce survival and growth).
6. Prune roots to uniform lengths. This can be done by aligning root collars in bunches before pruning roots.

7. Use a sharp knife, machete, axe, or hatchet for root pruning. Never break or twist roots off by hand.
8. Do not prune roots of small loblolly and white pine seedlings (5-8 inch tops) shorter than five inches in length.
9. Do not prune roots of larger loblolly and white pine seedlings (8-12 inch tops) shorter than seven inches in length.
10. Prune longleaf tap or lateral roots only if absolutely necessary. Limit pruning to excessively long roots. Clip longleaf needles back to 4 to 5 inches, if feasible.

Tree Planting Operations

1. Train all new personnel prior to allowing them to plant. Give refresher training to experienced planters at start of seasons (and later if poor techniques are observed). Do not assume labor is trained or skilled.
2. While hand planting, carry seedlings in a canvas bag, bucket, etc. to protect the roots. Bags should contain wet hydro-mulch, wet sawdust, etc. Be sure roots are visibly moist before placing in container. If not, dip roots of uncoated seedlings in water. (Do not carry seedlings in hand with roots exposed).
3. If machine planting, be sure roots are visibly moist before placing in seedling box on planter. If not, dip roots of uncoated seedlings in water. Cover roots in seedling box with wet burlap to protect from exposure.
4. When handling, carefully separate seedlings to reduce damage or breaking lateral roots. (Damage to laterals will reduce survival).
5. When hand planting, make a fairly straight hole 8 to 10 inches deep. Do not use dibbles or other tools that will not make a hole or slit at least eight inches in depth.
6. Remove only one seedling at a time from container.
7. Insert root system to bottom of hole and lift seedling to proper planting depth. Be sure not to bend, ball, or leave roots outside hole.
8. Adjust planting depth according to drainage or soil type:
   a. On well-drained sites (sandy loams and sandy soils) plant root collars two to three inches below ground line, except for longleaf. Plant the longleaf collars at ground level when hand planting. Machine plant by lightly covering bud to allow for soil washing away.
   b. On poorly-drained sites (silt and clay soils) plant root collars one inch below ground line.
   c. Plant containerized seedlings deep enough to allow tops of plugs to be covered with soil (prevents drying by wicking effect).
   d. Warning -- seedlings should not be planted in excessively wet, sticky soils or in standing water. Allow the site to dry before planting.
9. Close hole properly. (If soil not tightly compressed around roots, moisture cannot be taken up by the seedling). Make sure hole firmly closed at bottom.
10. Periodically check machine planting to insure proper seedling depth and proper packing by the machine.
11. Space seedlings at approximate spacing prescribed for tract. Avoid planting seedlings in areas of loose soil that cannot be compressed around roots or closer than 2 to 3 feet of hardwood stumps and sprouts.
12. Plant seedlings just as near the edge of windrows as possible.
13. Closely supervise and maintain quality control of all planting.

CRITICAL CONDITIONS

Temperature:	$76^{o}F - 85^{o}F$
Relative Humidity:	30% - 50%
Wind:	10 miles/hour +
Soil Moisture:	30 - 80 build-up

On-Site Storage of Seedlings

1. Bags/bundles should have minimum exposure to direct sunlight.
2. Otherwise, very closely follow same standards for Normal Conditions.

Culling Non-Plantable Seedlings

1. Make a special effort to keep roots of seedlings exposed to sun and wind for no longer than three minutes.
2. Otherwise, very closely follow same standards for Normal Conditions.

Root Pruning Seedlings

1. Make a special effort to keep roots of seedlings exposed to sun and wind for no longer than three minutes.
2. Roots must be kept visibly moist at all times. Prior to placing back in bag or planting containers, dip uncoated roots in one of the following:
   a. Super water gel (one ounce of Terra Sorb gel/gallon water).
   b. Clay slurry (five pounds Kaolin Clay/gallon water).
   c. Plain water (shake excess from roots before placing in bag).
3. Otherwise, very closely follow same standards for Normal Conditions.

Tree Planting Operation

1. If seedling roots have not been coated with gel or clay as described above, they must be carried in water. Also, tops of seedlings should be wet (reduces transpiration).
2. Otherwise, very closely follow same instructions for Normal Conditions.

SEVERE CONDITIONS

Temperature:	$32^{o}F$ or less; ground frozen* or $85^{o}F$ +
Relative Humidity:	30% or less
Wind:	15 miles/hour +
Soil Moisture:	80+ build-up

*NOTE: If weather forecast indicates cold temperatures that will freeze ground for several days immediately after planting; do not plant.

On-Site Storage of Seedlings

1. Seedlings will not be stored at planting site under these conditions. Bags/bundles should be stored in buildings, sheds, etc. that will protect from freezing and/or heating.

2. Refer to Storage Standards as given under DISTRICT/CONTRACTOR DELIVERY AND STORAGE STANDARDS, Severe Conditions.

Culling Non-Plantable Seedlings

1. Culling will not take place at planting site.
2. Culling is permissable in a building, shed, or other protected area.
3. When culling in such an area, follow very closely the same standards for Normal Conditions.

Root Pruning Seedlings

1. Pruning will not take place at planting site.
2. Pruning is permissible in a building, shed, or other protected area.
3. When pruning in such an area, follow very closely the same standards for Normal Conditions.

Tree Planting Operation

All planting should STOP, unless localized site exceptions exist.

Localized Site Exceptions

If a localized site exception to the severe soil or weather conditions does exist, planting may continue. Follow the standards for Critical Conditions.

SUMMARY

We realize this system will not solve all problems with survival, but we believe it is a start in the right direction.

Pressures from tree planters and from within our own organization will probably prevent strict adherence to the guidelines, but if we can reduce plantation failures by 50%, we will have made the effort worthwhile.

ETHYLENE ACCUMULATION DURING COLD STORAGE OF PINE SEEDLINGS: IS IT A PROBLEM?

Jon D. Johnson[1]

Abstract.--Ethylene is a plant growth regulator that can inhibit root and shoot growth in plants. The atmospheres of two loblolly pine seedling cold storage facilities were sampled over a three month period during the winter of 1981-1982 to determine the extent of ethylene accumulation. Ethylene concentration reached physiologically significant levels (2300 ppb) in the storage facility which employed open seedling bales. The use of K-P bags for seedling packaging in the other facility precluded the accumulation of ethylene in the atmosphere during storage. There was evidence of ethylene addition by the operation of gasoline-powered forklifts in one of the storage facilities. Gas samples from within seedling bales and K-P bags indicate that loblolly pine seedlings do produce ethylene.

Additional keywords: *Pinus taeda*

Ethylene is a naturally-occurring plant growth regulator which has been implicated in a number of physiological processes (Abeles 1973; Galston and Davies 1970). Of importance to nursery operations are the reports of root growth and bud development inhibition by ethylene, and the stimulation of ethylene production as a result of mechanical injury such as occurs during lifting of seedlings from nursery beds (Burg and Burg 1968; Kramer and Kozlowski 1979; Wareing and Phillips 1973; Yang and Pratt 1978).

The effect of ethylene on tree seedlings has received increasingly more attention in recent years. Barnett (1980) reported a five percent increase in survival and a 75 percent increase in root regeneration potential of loblolly pine (*Pinus taeda* L.) seedlings stored for six weeks in the presence of an ethylene adsorbent. Fraser fir (*Abies fraseri* (Pursh) Poir.) seedlings exposed to 17.5 ppm ethylene for eight weeks in cold storage exhibited a 22 percent reduction in terminal growth (Hinesley and Saltveit 1980). Graham and Linderman (1981) found that lateral root growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings was inhibited at ethylene concentrations greater than 150 ppb.

This study examined the *in situ* changes in ethylene concentration during cold storage of loblolly pine seedlings.

---

[1] Assistant Professor of Tree Physiology, Dept. of Forestry, V.P.I. & SU., Blacksburg, VA. Financial support was provided by USDA Forest Service, Southern Forest Experiment Station, Pineville, LA under cooperative agreement number 19-82-6. Cooperators were Jake Stone, Union Camp Hardwood Nursery, Capron VA, and Tom Dierauf, Bill King and Donald Hickson, Virginia Division of Forestry, New Kent Forestry Center, Providence Forge, VA.

METHODS

The atmospheres of the cold storage facilities at the Union Camp Hardwood Nursery, Capron, VA and the Virginia Division of Forestry, New Kent Forestry Center, Providence Forge, VA were sampled throughout the winter of 1981-1982 using Vacu-Samplers®. At the Union Camp facility monthly samples, replicated twice, were taken beginning 30 November 1981 prior to seedling storage and continued for three months. Biweekly samples, replicated four times, were obtained at the VDF facility also beginning 30 November 1981 prior to seedling storage and continued for 14 weeks.

The two facilities were chosen for their contrasting storage practices of loblolly pine seedlings. The VDF uses open-ended seedling bales and operates gasoline-powered forklifts in the storage facility. Union Camp employs K-P bags and uses only hand-operated lifts. Although the Union Camp facility is used primarily for storing hardwood seedlings, between 120,000 and 350,000 loblolly pine seedlings were present during the sampling period.

The samples were analyzed on a Bendix 2500 gas chromatograph equipped with a flame ionization detector and a six foot, glass Poropak N column. Column conditions were: carries gas (He) - 28 ml min^{-1}; hydrogen flame gas - 30 ml min^{-1}; column temperature - 60° C. Ethylene was identified in the samples by co-chromatography with a known ethylene standard.

The data were statistically examined using analysis of variance and Duncan's Multiple Range test.

To further examine packaging differences between the two facilities, gas samples from within a VDF bale was obtained on 8 March 1982 and samples from within three K-P bags were taken on 27, 28 and 29 April 1982.

RESULTS AND DISCUSSION

Ethylene concentration in the VDF facility varied significantly (P=0.001) over the 14 week storage period whereas the variation in ethylene concentration in the Union Camp facility was not statistically different (P=0.05) (Figure 1). At the VDF facility ethylene accumulation apparently began immediately after seedlings were placed into cold storage with the maximum concentration of 2369 ppb being achieved on 28 December 1981. This maximum was followed by a precipitous drop in ethylene concentration to the minimum of 174 ppb on 25 January 1982. This minimum corresponded to cessation of seedling lifting due to extremely cold weather and frozen soils. The resumption of lifting and subsequent storage resulted again in an increase, although smaller, in the ethylene concentration to 431 ppb. Ethylene concentration then decreased to control levels on 8 March 1982. The ethylene concentration in Union Camp's facility remained virtually constant at or slightly above the control concentration (30 November 1981) of 200 ppb. This lack of change in ethylene concentration was attributed to Union Camp's use of K-P bags for seedling packaging. Any ethylene produced by the seedlings would presumably accumulate in the K-P bags and hence would not be detected in the atmosphere of the storage facility.

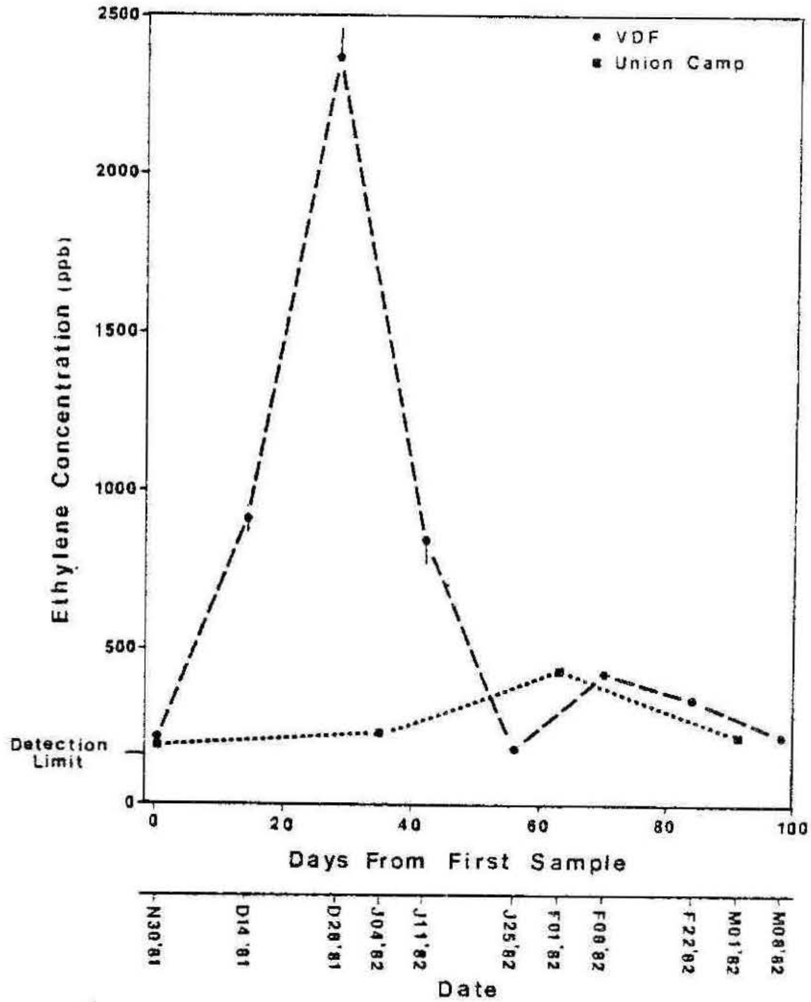


Figure 1.--Ethylene concentration in the VDF and Union Camp cold storage facility during the 1981-82 season. Standard errors are represented by vertical lines where they were larger than the symbols.

During the gas analysis all of the VDF samples with the exception of the controls (30 November 1981) exhibited a yet to be positively identified gas that was never detected in the Union Camp samples. A comparison of the retention time of the unknown gas with published values of hydrocarbons suggest that the unknown gas was acetylene. The significance of this finding is that both acetylene and ethylene are major components of engine exhaust (Abeles 1973). Thus, the VDF by operating gasoline-powered forklifts in their storage facility may be increasing the ethylene concentration to which their seedlings are exposed.

The pattern of ethylene accumulation in the VDF facility is difficult to explain based solely on the number of seedlings in storage. From personal observation the storage facility was about one-third full the first of January whereas it was completely full the first of March. The number of seedlings in storage would be reflective of forklift activity. Hence, one would expect more ethylene in March due to a greater number of seedlings present and to greater forklift activity. The ethylene concentrations at these two times do not support this argument (Figure 1). An alternative explanation is that the majority of the ethylene is seedling origin and that ethylene production is a function of seedling dormancy and hence varies with the time of lifting.

In order to verify that loblolly pine seedlings do produce ethylene, gas samples were analyzed from a VDF bale and three K-P bags containing loblolly pine seedlings (Table 1). Loblolly pine seedlings in the VDF bale exhibited a four-fold increase in the ethylene concentration over the K-P bags when expressed on a per seedling basis. This difference, however, is confounded by lifting time. The VDF seedlings were lifted in early February whereas the seedlings in the K-P bags were lifted in early April. These preliminary data support the above hypothesis that ethylene production changes with lifting time over the winter.

Table 1.--Ethylene concentration within loblolly pine seedling packages. The K-P bags contained 500 seedlings per bag and the VDF bale contained 1000 seedlings.

	ETHYLENE CONCENTRATION (ppb)			
Package	root region		shoot region	
	per bag	per seedling	per bag	per seedling
K-P Bag				
bag 1	76	.15	50	.10
bag 2	145	.29	136	.27
bag 3	98	.20	81	.16
VDF Bale				
bag 1	782	.78		

CONCLUSIONS

Ethylene can accumulate to physiologically significant concentrations during the cold storage of loblolly pine seedlings. Seedling packaging appeared to have a large control over the atmospheric ethylene concentrations. Ethylene accumulated to greater concentrations with seedling bales whereas K-P bags appeared to retain the ethylene. Lifting date tentatively appeared to strongly influence ethylene production from seedlings, regardless of packaging method. The operation of gasoline-powered forklifts within a storage facility appeared to add ethylene to the storage atmosphere.

LITERATURE CITED

Abeles, F. B. 1973. Ethylene in Plant Biology. Academic Press, New York. 302 p.

Barnett, J. P. 1980. Ethylene absorbent increases storability of loblolly pine seedlings. In Proc. 1980 S. Nursery Conference, Lake Burkley, KY. p. 86-88.

Burg, S. P. and E. A. Burg. 1968. Ethylene formation in pea seedlings: Its relation to the inhibition of and growth caused by indoleacetic acid. Plant Physiol. 43:1069-1074.

Galston, A. W. and P. J. Davies. 1970. Control Mechanisms in Plant Development. Prentice-Hall, New Jersey. 184 p.

Graham, J. H. and R. G. Linderman. 1981. Effect of ethylene on root growth, eclomycorrhizae formation and *Fusarium* infection of Douglas-fir. Can. J. Bot. 59:149-155.

Hinesley, L. E. and M. E. Saltveit. 1980. Ethylene adversely affects Fraser fir planting stock in cold storage. S. J. Appl. For. 4:188-189.

Kramer, P. J. and T. T. Kozlowski. 1979. Physiology of Woody Plants. Academic Press, New York. 811 p.

Wareing, P. F. and I. D. J. Phillips. 1973. The Control of Growth and Differentiation in Plants. Pergamon Press, New York, 303 p.

Yang, S. F. and H. K. Pratt. 1978. The physiology of ethylene in Wounded plant tissues. In Biochemistry of Wounded Plant Tissues, G. Kahl (ed). Walter de Grayter and Co., New York. p. 595-622.

FIELD PACKING OF SOUTHERN PINE SEEDLINGS AT THE COLUMBIA NURSERY

Dewey A. "Tony" Simms[1/]

Abstract.--Implementation of field packing of pine seedlings at Columbia Nursery was successful despite problems. The Louisiana Office of Forestry decided to try field packing as a method of increasing seedling quality by reducing exposure time of roots to drying air and as a method of reducing labor required to harvest the seedlings.

Modification of existing equipment and purchasing new equipment was necessary.

Problems encountered included ensuring the proper number of seedlings per bag and developing an alternative system for use during times of unfavorable conditions.

The necessity to hire large numbers of seasonal workers, and the long transition time from lifting to packing of seedlings, are two problems that tree nurseries have experienced for many years. Efforts to reduce the number of workers through the use of machinery have been relatively successful in the past and different methods of caring for lifted seedlings, prior to packing, such as covering and misting, have helped. However, after twenty-four years of operation, seedlings at the Louisiana Office of Forestry (LOF) Columbia Nursery were still held for hours before they were packed.

In an effort to reduce the magnitude of these problems, field packing was implemented at Columbia. This decision was made after observing a field packing demonstration and many hours of deliberation on the advantages and disadvantages.

During the summer of 1981, two Grayco seedling harvesters were modified to accomplish field packing. The 1975 model Grayco required extensive modification including the raising of the conveyor table on the personnel carrier to the proper working height and building an extension onto the rear of the carrier. The extension was necessary to increase space for the packing equipment. Extra structural braces were added to help support the weight of the extension and additional personnel. Other modifications were performed to update the older carrier to ensure smooth operation. Both the 1975 and the new 1981 model personnel carriers were covered with a fiberglass roof to protect the seedlings from the sun, and for employee convenience. Electrical wiring and hoses for transferring the superabsorbent material were installed on each harvester.

To carry the superabsorbent, tanks were purchased to mount on the front of two tractors. Each polyethylene tank was mounted and connected to a centrifugal pump. The pump was attached to the tank mounting frame and belt driven from the tractor's alternator. Installation of a double-belt pulley on the alternator was necessary. The pump, equipped with a 12 volt d.c. activated magnetic clutch, may be engaged and disengaged as desired. A belt driven pump was chosen in preference to a gasoline engine driven pump to reduce the associated maintenance.

1/ Nursery Superintendent, Columbia Nursery-Louisiana Office of Forestry, Columbia, Louisiana

This type pump is capable of 55 gpm at 40 psi, which is sufficient to provide material to the rear of the personnel carrier for packing, and to provide recirculation for agitation of the superabsorbent material in the tank.

For counting purposes, a spring scale was hung in the packing area of each carrier, but early in the lifting season these proved unsuitable due to variations in the number of seedlings per bag. These scales were replaced with another type of spring scale, then a platform balance, and finally with an electronic platform scale.

Two twelve volt d.c. operated sewing machines were purchased and suspended on the rear of the carrier for closing the K-P seedling bags.

Old seedling trailers were rebuilt to accept Jarke stacking pallets so that bags of seedlings could be loaded directly onto the pallets in the field. When full, the pallets were taken to the cold storage facility and unloaded with a forklift.

During discussions prior to the decision to implement field packing, three major concerns surfaced. First, since the Grayco harvester works poorly in wet silt loam soils such as that at Columbia, could an alternative system be developed for use during periods of excessive soil moisture. This problem was faced twice during the 1981-82 season and was dealt with by hand lifting, then packing on the Grayco carrier. This method, although not highly productive, did suffice until normal operations could resume.

Another major concern was the problem of grading the seedlings while field packing. Due to the high rate of production per person, very little grading could be done. The damaged or evidently small seedlings were culled, but borderline size discriminations could not be made. This problem was not considered major, but efforts were made to see that each bag contained at least 1000 plantable seedlings.

The third problem faced was how to ensure that each bag contained 1000 plantables. Solving this problem was important because of the large number of small orders processed at Columbia. The electronic scales proved to be effective for providing the accuracy necessary. After installation of these scales, bag count deviation from 1000 plantables averaged less than five percent.

The following table shows the cost of equipment and modifications necessary to implement the system at Columbia. The additional harvester was required to maintain the necessary production rate. Normal production from one harvester during 1981-82 was approximately 300,000 per day.

Cost of Implementation

1.	Grayco Harvester	$19,600
2.	K-Tron electronic scales	7,000
3.	Tanks and mounting racks	805
4.	Ace centrifugal pumps	465
5.	Fischbein twelve volt sewing machines	1,200
6.	Equipment modification (steel, fiberglass, hoses, wiring, etc.)	2,400
7.	Labor (estimated)	1,600
TOTAL		$33,070

The goals set for field packing were achieved and additional benefits realized. Time between lifting and packing was reduced to about three minutes as compared to hours when using the packing shed method. This reduction of root and foliage exposure to the air should result in better seedling condition.

Field packing proved to be a viable method of reducing labor cost. During each of the three years preceeding field packing, an average of 80 seasonal workers were employed to harvest an average 30 million seedlings. In contrast, the 1981-82 crop required only 43 workers to harvest 27 million seedlings. (These average figures also include the labor used to lift and pack approximately 600,000 hardwood seedlings each year.) When adjusted for the crop size difference, 27 million seedlings were field packed with a savings of $21,290 relative to the previous year.

A serendipitous result of field packing over shed packing at Columbia, was that normally low-productive workers produced at a higher rate due to a more favorable worker to supervisor ratio. Morale of nursery administrative and supervisory personnel was higher also.

The LOF considers field packing at Columbia a success and will continue this process. Efforts will be made to further improve the system and further reduce costs. In addition, plans are being made to field pack at Louisiana's other nurseries.

QUALITY CONTROL FOR TREE PROCESSING AT

WIND RIVER NURSERY[1]

Stuart H. Slayton[2]

ABSTRACT

Discusses some methods and procedures for seedling quality control at U.S. Forest Service, Wind River Nursery, Carson, Washington. Describes why and how the training of people and good communications with the field improves stock quality and thus field survival.

The Wind River Nursery is located on the Gifford Pinchot National Forest in the State of Washington. We are ten miles north of the Columbia River which separates Washington from Oregon. We are fifty miles east of Portland, Oregon. As to Mt. St. Helens, we are only 25 miles SE of the now famous mountain.

Our production has averaged thirty million seedlings annually the past eight years. Our production capacity is 18 million. We produce for 19 National Forests in Oregon and Washington, The Bureau of Land Management, and Bureau of Indian Affairs on both sides of the Cascade Range. We grow 15-20 species. Douglas-fir accounts for 55% of the production while true firs (Abies) account for about 25% of production. The remaining production is in pines, spruce, larch and cedars.

Annual precipitation is 110-120", including 80" of snowfall. The elevation is 1200-1300 feet. Our soils are derived from glaciated material and of course from volcanic origins. Consecutive frost free days are usually 120-150 days with warm, dry summer days with cool evenings in the 50's and 60's. Our winters are varied from being almost completely open to totally snow covered. Most years the snow cover is intermittent and winter temperatures are moderated by Pacific marine air.

---

[1] Paper presented at the Western Session of the Southern Nursery Conference at Oklahoma City, Oklahoma, August 9-12, 1982.

[2] Nursery Superintendent, U.S.D.A., Forest Service, Gifford Pinchot National Forest, Wind River Nursery, Carson, Washington.

At Wind River Nursery we sow approximately 500 individual seed lots per year. The genetic origin may be adjacent to the moist Pacific Ocean at 1000' elevation to the much drier interior east of the Cascade Range upwards to 7000' elevation.

We would like to think that everything would go according to Hoyle, but realistically it never has and probably never will with the variables encountered in producing and planting seedlings.

To produce quality stock research specialists and experience have indicated the acceptable regimes of soil productivity, density parameters, pest control methods and cultural practices. Engineering has provided specific equipment and facilities that accomodate the sensitivity and perishableness of seedlings.

The nursery staff is assigned the task of assimilating and implementing this information through a systems approach at the nursery. Out of this comes a management plan that coordinates facilities, equipment, seedlings and people. The nursery employees anticipate and take corrective action prior to and during adverse weather conditions to protect the seedlings.

After all this has been accomplished to produce what we feel to be good planting stock we occasionally hear distant negative reports from the silviculturists and reforestation people in the field.

The field people have basically two complaints. One, you didn't accomodate our specific field problems; or two, nursery performance. There are several ways to respond to complaints. My personal preference for reducing the number and severity of complaints is what I refer to as the mutual triple E method - Educate, Enhance and Encourage, which boils down to communication and documentation.

Dealing with a problem is a lot like a geometry problem. You have to identify the given. There are many givens but the predominant given is the <u>CUSTOMER</u> who has to plant the seedlings. If you want to please management, please the customer.

There are probably as many approaches to pleasing the customer as there are customers, but the basic rules we work with are to be honest with the customer even when it hurts our pride and to communicate in such a manner that there are no surprises to the customer.

You can't deal with another person's problems until you have taken care of your own. So at the nursery we attempt to educate our employees so survival and growth in the field is enhanced. From this we are all encouraged.

Sometimes the simplest of items makes the difference between a great success and a satisfactory accomplishment. We have an orientation session for our employees at the time of employment which consists of an employee receiving a handout orientation book which gives information the employee desires immediately. The employees are given a slide tape presentation and tour of the nursery and given general information as to their specific tasks and the importance of the roles they are playing in the reforestation effort. The positive results of their effort have played a significant role in our quality control program. The culmination of all the effort in producing the seedlings is left in the hands and minds of these temporary employees.

When employees are assigned to tasks such as pulling, grading, packaging and storage, written procedures and standards are again discussed.

In the processing building the employee is kept informed of changing specifications, and instructions by means of grading informational boards which provide information for all concerned. With this type of informational display it is amazing how well employees react and interchange with each other.

Our permanent employees, including equipment operators, maintenance workers, supervisors and laborers, participate in silvicultural training sessions and meetings, make visitations to various planting units, and meet with field people at the nursery. They become more knowledgable so better leadership and decision making can be accomplished through the myriad of details encountered.

In dealing with over 100 customers there is always change in personnel. Some of the change brings inexperienced personnel. To assist the inexperienced person we have produced a stock catalog that is updated biannually. The stock catalog deals with very basic information as to nursery administration, field relationships and provided services and costs. The catalog's main intent is to present photographs of all the species and age classes and to correlate size and density. The person is better able to identify what the nursery is producing at any point in time and when ordering seedlings to be sown will not be surprised as to what they thought they should receive. The catalog has a soliciting intent; it suggests we are available for inquiries and assistance.

When sowing requests are made we urge our customers to specify the size class they desire. At first we had extremes. The customers are presently accomplishing a good job of specifying size classes and even justifying why they selected such a size class. We can't always deliver, but at least the customer knows we understand their problem and appreciates us striving to compensate for special requests. Within two to three crops their requests are usually met.

In most cases it has been my experience that positive relations turn sour when the nursery fails to communicate with field units the identification of a problem lot far enough in advance so timely, corrective adjustments can be made. When a problem lot has been reported in a timely manner, by working together to make the best out of a bad situation, a high level of trust is maintained. All of us have a certain amount of flexibility. The field people at least like to have an adjustment period where they may be able to enhance a poor situation.

A very good informal communication is to encourage field visitation to the nursery where first hand observations can be made of the forthcoming seedlings. Any stock or logistical support problems can be dealt with very satisfactorily far enough in advance so surprises are eliminated or reduced in scope. It has been our experience that this visitation is probably the most cost effective ingredient in all the steps of reforestation. In addition, the visitation establishes a long-range relationship by keeping current on subtle changes both at the nursery and in the field.

The key to success is for the producer of stock to totally inform the customer of the condition of the customer's trees. It's a humbling experience, but we found the customer to be a very adept person in reconciling nursery performance to planting site conditions. It's much easier for the producer to describe the lot of seedlings rather than have the customer explain his varied site conditions.

Visitation works in reverse; we, the people who produce seedlings make numerous visitations to the planting sites. When you see the effects of big game browsing, vegetative competition, restricted planting spot selection, extremes of sites and weather it makes you think twice about your grading specifications and the withholding of information that may be important for the survival and growth of the seedling.

Sometimes the best laid plans go astray. When this happens individuals like to know what went wrong. Thus we provide a seedling information card that tells our actions in mathematics. For example, if the density is too high we can determine the reason and the accountable individual. The seedling information card is a historical record of the seedling lot as to cultural practices, allocations, inventory and occurrences that affected the seedling's condition.

In addition, a silvicultural sheet is used to document the conditions, the steps and the responsible person(s) through lifting to delivery. Hopefully the customers will do the same on their end of operations. This has helped greatly in determining any planting loss so the problem can be identified and corrected. It has greatly helped reduce customer suspicion of the nursery activities and conditions. It has increased awareness that an accumulation of little misdeeds reduces survival and growth.

We monitor plant moisture stress in the field prior to lifting as required and always upon receipt at the pre-cold storage rooms. At readings of 8-10 PMS, pulling crews are alerted and necessary adjustments are made to hold PMS under 8. If this cannot be accomplished we stop field operations at a 12 PMS reading.

Our laboratory personnel also determine the shoot-root ratio by a volumetric measure of water displacement.

At any time during our operations that we suspicion any ill effects to seedlings, we order a seedling vigor test to determine if trees were stressed and estimate predicted field survival. This test requires 4 weeks for bud burst and 8 weeks for predicted survival. The time lag is long but understanding can be gained as to why the plantation failed or succeeded. I prefer this delay rather than lingering doubt as to what was the real problem. The BLM is testing a planting contract this year where tree planters will be paid on the survival and growth of their planting and care of the plantation over a three year period. To remove any claims as to the quality of seedlings furnished the seedling vigor test will be used in all their contracts. This seedling vigor test was developed by Professors of Forestry, Richard K. Hermann and Denis P. Lavender, at Oregon State University, School of Forestry. In a private communication with Bill Lopushinsky, Plant Physiologist at Forestry Science Lab at Wenatchee, Washington he felt this was the best test we now have available as it helps the forester to understand the performance of a plantation.

In the conditioning and processing of seedlings we feel refrigeration and humidity are most important in maintaining seedlings that have to be stored up to six months.

Temperatures and humidities are constantly monitored and documented. Flucuations are only about one degree for temperature and 5% for relative humidity.

Our processing room is made up of 8 grading tables. A quality control person is assigned to each table. This person is accountable to employees being informed of specifications and instructions. Some lots are graded into different sizes, or combining of species if desired. The conveyor belts have target lines for various root lengths. Water is available for moistening or washing. A underground tunnel runs beneath the processing building. It is used to dispose of culls, soil, debris and excess water. Between each seedling lot, culls are placed into the tunnel to avoid potential contamination to the seedling lot.

We identify all bags to be shipped to field with appropriate nomenclature which includes table number. This is in the event of a complaint so we can track the responsible quality control person to identify and correct the problem. Every step of our nursery operations includes monitoring by the certification agency for the State of Washington.

Deliveries are made in refrigerated trucks. We attempt to deliver in one day. Temperatures are monitored by thermographs placed in strategic parts of the load. Our people are instructed to handle the bags as if they were soft-shelled eggs.

Slide Presentation.

I have appreciated this opportunity to present this paper on Quality Control at Wind River Nursery. As is the usual case, I have learned much more than I have given. Reforestation is big business and dealing with a perishable commodity intertwined with sometimes uncontrolable and unpredictable variables, quality control of all activities must be communicated and documented so a cost-effective job is accomplished. Quality Control comes about through communication with people.

FIELD PACKAGING

Frank Vande Linde[1/]

Abstract.--Field packaging minimizes labor requirements at the nursery and reduces seedling exposure. Uniform seedbed density and accurate inventories are important prerequisites.

The real test of a good nurseryman is field survival. Efforts to grow quality seedlings can be negated by improper handling from the nursery bed to the planting site. Lifting and packaging for shipment is one of the most important steps in any nursery operation.

Seedlings cannot be transferred from nursery beds to planting sites without some exposure time and root damage. However, field performance can be greatly improved by minimizing root damage and exposure time during lifting.

To suceed, a lifting operation must be geared to the needs of your organization. Sometimes we are prone to criticize without knowing the circumstances. If you have a good program underway, stay with it, but never be happy with the status quo. There will always be room for improvement.

Everyone in the nursery business is dedicated to the job of producing quality seedlings at a reasonable cost. However, rising costs of fuel, machinery, labor, and chemicals have dictated many changes. One big change that has progressed steadily over the past 20 years is the development of mechanical harvesters. These machines come in many forms and with many different names. They are designed to handle one, two, four, seven or eight rows. The amazing thing about seedling lifters is that no two are exactly alike. All have been modified to fit needs peculiar to the owner. Nearly every nursery throughout the South has some form of a mechanical seedling lifter.

Even though seedling harvesters take on different forms, their lifting abilities are quite similar. A belt transfers the seedlings from the beds to a conveyor platform. At this point, depending upon company, seedlings are either transported to packing sheds or packaged directly on the machine.

Two methods of field packaging are most common: KP bags and bales. In either case the back end of the seedling lifter is modified to handle bag closer or strapping equipment, packaging material, and limited storage. Seedlings are placed directly into bags or bales, with exposure limited to 30 to 45 seconds. Some machines are equipped to spray water on seedlings before packing, while others add a moisture-holding material such as peat, sphagnum, cotton batting or hydro mulch. Bags are closed with a sewing machine powered

1/ Tree Improvement Forester, Brunswick Pulp Company, Brunswick, GA

by a 12-volt battery. An air compressor is used to strap metal bands around bales. The packaged seedlings are stored at the rear of the machine. Adequate storage space is available on our machine to make one complete round with the lifter. Bagged seedlings are trucked to storage facilities.

Seedbed uniformity, with limited culls and accurate seedbed inventories, are prerequisites to field packaging.

Field packaging minimizes labor and improves overall efficiency during the lifting operation.

THE EFFECTIVENESS OF SUPERABSORBENT MATERIALS FOR MAINTAINING SOUTHERN PINE SEEDLINGS DURING COLD STORAGE

Charles R. Venator and John C. Brissette [1]

Abstract.--First-year survival and growth of loblolly pine (Pinus taeda L.) seedlings packaged with seven different superabsorben polymers, and planted within 48 hours or after 30 days cold storage, were evaluated in Mississippi and Louisiana. Differences in survival were significant at the Mississippi site with several superabsorbent treatments being superior to the clay slurry control. Total height differences among treatments were not significant at either the Mississippi or Louisiana site.

INTRODUCTION

The use of more expensive genetically improved southern pine seedlings and high site preparation costs demand a high plantation survival. It is also essential that the seedlings begin root regeneration and height growth as quickly as possible to overcome weed competition.

The method of seedling packing and storage following lifting influences the survival and growth of pine seedlings. Many southern nurserymen pack seedlings in Kraft-polyethylene bags, just before the bags are sealed, the seedling roots are sprayed with a kaolin clay slurry to help maintain a moist root surface and provide protection from exposure. This packing process is felt by tree planters to be superior to the Forest Service bale system which has been used for many years and is still used in some areas.

In 1973, a research team at the USDA Northern Regional Research Center discovered that a starch-poly-acrylonitrile polymer was capable of absorbing up to 300 times its weight in water. Since this product (commonly called a superabsorbent) has been in the public domain, it has been tested for several uses in agriculture and related disciplines. Among the potential uses are seed coatings, soil amendments, rooting media, and root coatings to retard drying (Doane and Mayberry 1979, Copley 1980).

Superabsorbents are used at some forest tree nurseries as a root coating to prevent drying. However, the effects of superabsorbents on seedling survival and growth have not been reported in detail. In a North Carolina study, seedlings dipped in a superabsorbent immediately prior to outplanting did not survive as well as seedlings dipped in water or clay slurry (Goodwin 1982).

Superabsorbents are produced in several formulations by various manufacturers. Differences among superabsorbents are primarily in the base material and in their texture. Finer textured materials generally have greater water-

[1] Authors are Research Plant Physiologist, Southern Forest Experiment Station, Pineville, Louisiana and Nursery and Tree Improvement Specialist, Southern Region, USDA Forest Service, Jackson, MS, respectively.

holding capacity.

This study examined the effects of several different superabsorbents in seedling packaging on survival and growth after a period of cold storage.

MATERIALS AND METHODS

In mid-January 1981, seven water absorbing substrates[2/] were mixed at the W. W. Ashe Nursery in Mississippi according to the instructions supplied by their respective manufacturers. The superabsorbents varied in texture from coarse, sawdust-like material to a flour-like powder. Five of the absorbents were starch based, two were synthetic based. Bundles of 50 loblolly pine (*Pinus taeda* L.) seedlings were collected from a single seed lot that had been processed normally on a grading table. Seedlings were graded to Wakeley's grades 1 and 2. These seedlings were then hand dipped into one of the water-absorbing substrates and packed inside a Kraft-polyethylene bag. As a control, graded seedlings operationally sprayed with clay slurry and then bagged were used. Separate groups of treatments were planted within 48 hours after lifting at sandy loam sites on Erambert Seed Orchard in Brooklyn, Mississippi and the J. K. Johnson Tract of the Palustris Experimental Forest in central Louisiana. In addition, two groups of treatments were packaged and stored at 34°F for 30 days prior to outplanting at the same planting sites. The seedlings were planted in four complete blocks of randomized row plots. Each plot consisted of 50 seedlings spaced two feet within the row. The individual rows were also spaced at two feet. The seedlings were hand planted with dibbles.

RESULTS AND DISCUSSION

Survival

Differences in first year survival among treatments were statistically significant at the Mississippi planting site but not in Louisiana. At the Johnson Tract in Louisiana, the trend was for better survival among seedlings packed with some of the superabsorbents (table 1). With no storage, the best survival was observed for seedlings packed in Terra-Sorb 200 and ES 148 fine. Survival of these two treatments was uniform throughout the four blocks. However, the remaining treatments had highly variable results as indicated by the very high standard errors associated with the treatment means. The same problem was observed for seedlings stored 30 days. Terra-Sorb 200, 201, 250, and Water-Lock B-100 had high survival rates and relatively low standard errors of the means. The remaining treatments had high standard errors associated with their means.

[2/] The use of trade, firm, or corporation names of materials is for the reader's information and convenience. Such use does not constitute offical endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1.--Percent survival of loblolly seedlings root dipped with various water absorbents prior to outplanting in central Louisiana in January and February 1981. The seedlings were checked for survival in December 1981. Fifty seedlings were planted in each plot. Differences among the means were not statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	% survival				
Outplanted within 48 hours					
Terra-Sorb 200	86	84	84	82	84.0 ± 1.6
Terra-Sorb 201	90	88	78	48	76.0 ± 19.3
Terra-Sorb 250	88	78	22	86	68.5 ± 31.3
Terra-Sorb 1000	94	12	10	94	52.5 ± 47.9
ES 148, fine	78	62	88	78	76.5 ± 10.8
ES 148, 20 mesh	64	90	18	82	63.5 ± 32.2
Water-Lock B-100	86	2	54	42	46.0 ± 34.7
Kaolin slurry	72	76	20	28	49.0 ± 29.1
Stored for 30 days					
Terra-Sorb 200	66	78	84	62	72.5 ± 10.2
Terra-Sorb 201	92	92	80	88	88.0 ± 5.7
Terra-Sorb 250	68	84	94	90	84.0 ± 11.4
Terra-Sorb 1000	82	96	86	6	67.5 ± 41.4
ES-148 fine	18	12	86	6	38.5 ± 33.6
ES-148, 20 mesh	14	72	78	64	57.0 ± 29.2
Water-Lock B-100	90	70	60	82	75.5 ± 13.2
Kaolin slurry	18	82	90	92	70.5 ± 35.3

At the Erambert Seed Orchard site in Mississippi, seedlings treated with Terra-Sorb 1000, ES 148 20 mesh, and Water-Lock B-100 had significantly better survival, whether stored or planted within 48 hours (table 2). Clay slurry, Terra-Sorb 200, and Terra-Sorb 201 treatments gave the poorest survival, with significant reductions in survival of seedlings stored 30 days versus those planted within 48 hours. Survival of seedlings treated with Terra-Sorb 250 was better after 30-day storage than without storage.

That statistically significant differences were detected among treatments planted in Mississippi but not in Louisiana can be attributed to different survival variations at the two sites. The standard error of the mean of each treatment was much lower for the Mississippi planting than for the Louisiana planting. High variability of the standard errors reflects a wider range in percent survival among individual plots of each treatment, and consequently a lack of statistical significance among the means of the Louisiana data.

At the Louisiana site, poor survival was often associated with individual row plots. This is illustrated by the plot survival data for Terra-Sorb 1000 stored 30 days; this was the best treatment in Mississippi, averaging 94.5 percent survival, but in Louisiana the 4 plots had 82, 96, 86, and 6 percent survival, respectively. Other treatments showed similar trends which raise suspicion that some factor other than drought stress was responsible for low survival of individual plots.

Table 2.--Percent survival of loblolly seedlings root dipped with various water absorbents prior to outplanting in Mississippi in January and February 1981. The seedlings were checked for survival in December 1981. Fifty seedlings were planted in each plot. Means and standard errors followed by different letters are statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	% survival				
Outplanted within 48 hours					
Terra-Sorb 200	82	78	86	80	81.5 ± 3.4 cd
Terra-Sorb 201	80	88	76	78	80.5 ± 5.3 cd
Terra-Sorb 250	68	82	78	76	76.0 ± 5.9 d
Terra-Sorb 1000	92	98	88	90	92.0 ± 4.3 a
ES 148, fine	84	94	94	92	91.0 ± 4.8 ab
ES 148, 20 mesh	88	90	98	94	92.5 ± 4.4 a
Water-Lock B-100	80	94	98	90	90.5 ± 7.7 ab
Kaolin slurry	72	86	88	90	84.0 ± 8.2 bc
Stored for 30 days					
Terra-Sorb 200	64	46	56	44	52.5 ± 9.3 c
Terra-Sorb 201	58	30	70	52	52.5 ± 16.8 c
Terra-Sorb 250	76	84	92	94	86.5 ± 8.2 a
Terra-Sorb 1000	88	92	98	100	94.5 ± 5.5 a
ES 148, fine	88	82	80	96	86.5 ± 7.2 a
ES 148, 20 mesh	94	100	90	94	94.5 ± 4.1 a
Water-Lock B-100	90	94	90	90	91.0 ± 2.0 a
Kaolin slurry	66	58	58	86	67.0 ± 13.2 b

Height growth

There were no statistically significant differences in first-year total height among the treatments planted at each site, whether the seedlings were planted within 48 hours or stored for 30 days. Mean heights of treatments ranged from 19.2 cm to 25.9 cm at the Louisiana planting site (table 3). Seedlings planted without storage averaged only 0.4 cm taller than those planted after 30 days storage. At the Mississippi planting site, treatment means ranged from 25.4 cm to 31.7 cm tall (table 4). The mean of seedlings planted within 48 hours was 1.1 cm greater than the mean height of seedlings planted after 30 days storage. Better height growth was expected from seedlings planted at the Mississippi site as it is more productive than the Louisiana site tested in this study.

Table 3.--Height growth of loblolly pine seedlings which were root dipped with various water absorbents prior to outplanting in central Louisiana in January and February 1981. The data represents the mean height of the surviving seedlings from 50 tree plots in December 1981. Differences among the means were not statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	Heights in cm				
Outplanted within 48 hours					
Terra-Sorb 200	24.8	26.6	25.8	11.9	22.3 ± 6.9
Terra-Sorb 201	27.0	28.1	24.2	24.5	25.9 ± 1.9
Terra-Sorb 250	27.6	23.1	18.9	23.8	23.4 ± 3.6
Terra-Sorb 1000	27.3	15.5	20.2	26.3	22.3 ± 5.5
ES 148, fine	22.8	22.2	26.4	19.8	22.8 ± 2.7
ES 148, 20 mesh	23.3	27.7	19.0	24.3	23.6 ± 3.6
Water-Lock B-100	18.4	19.0	23.0	20.2	20.2 ± 2.0
Kaolin slurry	22.8	23.5	15.1	15.4	19.2 ± 4.6
Stored for 30 days					
Terra-Sorb 200	28.5	20.4	24.7	18.9	23.1 ± 4.4
Terra-Sorb 201	22.2	24.2	20.9	22.6	22.5 ± 1.4
Terra-Sorb 250	25.8	22.7	22.5	24.5	23.9 ± 1.6
Terra-Sorb 1000	23.1	25.6	23.2	13.0	21.2 ± 5.2
ES 148, fine	24.4	18.0	27.7	16.9	21.8 ± 5.2
ES 148, 20 mesh	18.3	18.0	25.0	20.0	20.3 ± 3.2
Water-Lock B-100	26.0	19.8	24.5	26.8	24.3 ± 3.1
Kaolin slurry	25.6	19.8	22.6	21.1	22.3 ± 2.5

CONCLUSIONS

The survival results of this study indicate that some superabsorbents are effective root packing media for maintaining bare-root seedlings, either for prompt planting or for holding in cold storage up to 30 days storage. Those superabosrbents that were best were the finer textured matierals which apparently have greater water holding capacity.

Based on one year results, superabsorbents do not appear to offer any growth advantages over treatment with clay slurry. However, there do not appear to be any negative effects of superabsorbents on seedling growth either. At least three southern forest tree nurseries have converted their pine seedling packing operations from kaolin clay slurry to a superabsorbent without any reported negative effects.

Of course, seedlings packed in Kraft-polyethylene bags with superabsorbents, as with clay slurry, must be kept in cold storage between 1/2°C and 5°C until they are planted.

The results of this study show that superabsorbents represent a promising packing material for bare-root pine seedlings.

Table 4.--Height growth of loblolly pine seedlings which were root dipped with various water absorbents prior to outplanting in central Mississippi in January and February 1981. The data represents the mean height of the surviving seedlings from 50 tree plots in December 1981. Differences among the means were not statistically significant at the P < 0.05 level.

Treatments	Blocks				
	1	2	3	4	$\bar{x}$ ± S.E.
	Height in cm				
Outplanted within 48 hours					
Terra-Sorb 200	28.6	32.9	29.0	29.7	30.1 ± 2.0
Terra-Sorb 201	29.8	29.1	29.9	33.9	30.2 ± 2.6
Terra-Sorb 250	24.8	30.2	31.2	32.4	29.7 ± 3.4
Terra-Sorb 1000	30.3	28.8	25.9	41.6	31.7 ± 6.9
ES 148, fine	27.9	29.4	24.9	32.7	28.7 ± 3.2
ES 148, 20 mesh	26.8	28.8	26.5	32.2	28.6 ± 2.6
Water-Lock B-100	30.3	31.1	31.1	31.1	30.9 ± 0.4
Kaolin slurry	25.4	24.9	27.3	25.9	25.9 ± 1.0
Stored for 30 days					
Terra-Sorb 200	25.2	29.1	24.0	31.4	27.4 ± 3.4
Terra-Sorb 201	25.2	26.6	24.7	24.9	25.4 ± 0.9
Terra-Sorb 250	27.6	27.4	28.7	33.1	29.2 ± 2.7
Terra-Sorb 1000	25.8	27.8	30.9	36.6	30.3 ± 4.7
ES 148, fine	24.3	27.1	26.7	37.1	28.8 ± 5.7
ES 148, 20 mesh	24.8	29.4	27.3	29.3	27.7 ± 2.1
Water-Lock B-100	25.2	29.8	28.6	29.2	28.2 ± 2.1
Kaolin slurry	25.7	29.2	30.3	36.4	30.4 ± 4.5

LITERATURE CITED

Copley, Kathy.
1980. Super absorbent expands into horticultural uses. Grounds Maintenance, May 1980, pp. 66-68.

Doane, W. M. and Mayberry, J. C.
1979. Super slurper swells "out all over" in crop, conservation plantings. Research News, SEA Agricultural Research, North Central Region NC-226, 10-15-79.

NURSERY EQUIPMENT DEVELOPMENT FOR AUTOMATIC FEEDING OF BARE ROOT SEEDLINGS

Awatif E. Hassan[1/]

Abstract.--The development of an unmanned tree planting machine requires automatic control, detection, sorting, and feeding of pine seedlings prior to or during the planting operation. A tree nursery spacing study indicated that seedling spacing of 2" x 3" resulted in uniform seedlings and was recommended for future adaptation.

The design and development of a precision drum seeder is discussed. Originally designed for precision seeding of loblolly pine seeds, the machine's application can be extended to a variety of forestry and agricultural applications. For the Southern pine nursery application, the seeds are placed on the prepared seedbed with 3" spacing between rows and 2" between seeds in the row. The drum is capable of metering, transporting, releasing, and packing or pressing the seeds into the soil of the prepared bed. A one-half scale prototype was field tested. There were a few missing seeds and multiple seeding was not significant.

The proposed seeded tape-sheet system utilized a combination of non-degradable tape material attached to a sheet of degradable material where single seeds are positioned in a special array for future handling of seedlings during field planting. The seeds germinate and grow in the holes or through perforations of the non-degradable tape material and the degradable sheet loses its structure and disintegrates after seed emergence. The seedlings growing in the tape will be harvested by pulling the tape after undercutting the roots and forming a seedling roll. The seedling rolls are then ready for field transplanting.

Optical and mechanical linear displacement devices for detecting and sorting of pine trees were compared in the laboratory using taped seedlings. Test variables such as operating speed, width of acceptance window or diameter range for selection, and seedling diameter were investigated for determining the performance characteristics of each device. Both systems were found suitable for future implementation on an unmanned tree planting machine with minor design modifications.

INTRODUCTION

The need for a regional forest management equipment development center to meet the increasing demand for wood was recognized by the forest industry and the School of Forest Resources. The Forestry Equipment Cooperative (FECO) program was started officially on January 1, 1976. The first project undertaken

---

1/ Professor and Director of the Forestry Equipment Cooperative - North Carolina State University, Raleigh, NC.

by FECO was the design and development of an energy-efficient unmanned tree planter capable of operating under adverse forest conditions.

Since the Cooperative was conceived, the interaction between the planting machine design criteria and other forest management inputs such as tree nursery practice and site preparation techniques was evident. Constraints imposed by these inputs were recognized in the development and design of the FECO tree planter. The system approach necessitated the expansion of the Cooperative task and objective to include the impact of existing nursery practice and to develop alternative designs at the nursery level such that bare root seedling singularization and automatic feeding of the planting machine becomes possible.

The main objectives of this paper are to discuss the results of nursery and greenhouse studies, to present new concepts in nursery practice for future tree singularization, and to describe the machine development at North Carolina State University.

TREE NURSERY PRACTICE

Today's nursery practices for growing southern pine seedlings call for surface sowing 4-ft wide beds, either broadcast or drilled (eight rows). The seeds are covered by mulching material to maintain optimum soil moisture for germination. Root pruning, weed control, and fertilization are conducted periodically during the growing season. Bed lifting takes place in November-March, depending on the region, using a single- or multi-row bed lifter. The seedlings are bagged or bundled for field planting. Seedling grading before packaging has lost favor in recent years, even though some organizations put high value on the practice. Within the kraft bag or bundle, the seedlings are tightly packed; the interlaced roots and variability in seedling size caused by a lack of grading makes separation and singularization of trees a difficult task.

Seedling Singularization for Automatic Feeding

Seedlings will need to be singularized for automatic feeding from existing bagged or bundled seedlings. Root meshing and interlacing cause great difficulty in handling and separating the seedlings. Lack of uniformity of seedlings is another factor responsible for hampering singularization of seedlings from existing nursery stock.

The following observations summarize our views pertaining to future automation:

1. Before lifting, the seedlings are secured and self-supported in the bed. Perhaps stitching or taping the seedlings in the row can be completed before or during the lifting operation.

2. During lifting, using either the single-row or the 8-row bed lifter, the seedlings are held tightly between two belts and are geometrically oriented, i.e., tops up and roots down. Again stitching or taping of the seedlings can be accomplished before they leave the belts.

3. The seedlings released from the lifter belts are loose and have lost the gripping control; however, they do maintain some geometric orientation. If they are bagged on the lifter, sorting and feeding of seedlings might be achieved at the time of planting.

4. If shed-sorting is required, the seedlings are handled again either on a belt or manually. Here the seedlings are controlled and re-oriented. Perhaps it may be possible to stitch, glue, or tape them together at that time.

There are two schools of thought regarding automation of tree planting machine systems. One approach could be achieved by revising existing nursery practices, i.e., controlling the seedlings in status 1 or 2 above by taping or stitching before or during lifting, or loading the seedlings in status 4 above on tapes as in the Whitfield, Nissula, and Brika systems (Hassan, 1980). The other approach is based on direct handling of bagged or bundled bare root seedlings in status 3 above on the unmanned tree planter by utilizing a combination of a mechanical and pressure differential system (Graham and Rohrback, 1981) or by using the hook and saddle concept (Bowen, 1981).

Results of several singularization studies conducted at North Carolina State University indicated that stitched or glued (using hot melt) seedlings did not survive after planting. However, the presence of the filament taping material on the seedlings did not affect survival or growth compared to the control untaped seedlings (Hassan, 1976, 1977). The singularization efficiency of the mechanical-pressure differential system was reported to be 76.4 percent (Graham and Rohrback, 1981).

The above literature review and previous research efforts at NCSU resulted in the need for new approaches for controlling and/or growing singularized bare root seedlings.

Nursery Bed Spacing Study

Seedling singularization might be achieved if beds were seeded such that seedlings are uniformly spaced which could be accomplished by closer rows, perhaps as many as 12 or 16 for the four-foot bed, and larger distances between seedlings in the row. A 90-ft. bed at the N. C. Forest Service nursery (Griffiths State Nursery) at Clayton was utilized for this seeding study. The seeding spacing between and within rows was accurately controlled. Seeding was completed using templates designed especially to provide the required seeding density. Ten rows spaced at 6, 4, and 3" were seeded at densities varying between 16-48 seeds/ft^2. Table 1 summarizes the treatments and results. The averages appearing in Table 1 were determined from six 2-foot plots along the bed.

It is evident that the highest percent stand was achieved for the closer rows 3 and 4 inches where the pine seeds were placed at 2 and 1.5" apart, respectively (Table 1). These are very important findings, especially when improved pine seeds are used. Undoubtedly a bed seeded at 2" x 3" will permit lateral root pruning in two directions, along and across the bed, resulting in uniform seedlings.

Table 1.--Seeding Experiment and Results - Griffiths State Nursery, Clayton, N.C. Seeded in April, 1976 and Sampled in January, 1977.

Row No. & Treatment Length	Distance Between Seeds	Distance[a] On Left of Row	Distance[a] On Right of Row	Seeding Density Per Row	Average Standing Seedlings	Stand %	Average Seedling Height
	in.	in.	in.	$Seeds/Ft^2$	$Trees/Ft^2$		in.
1/(0-90')[b]	1	3	3	24	20	83	13.0
2/(0-45')	1/2	3	3	48	35	73	11.9
2/(45-90')	1	3	3	24	18	75	12.8
3/(0-45')	3/4	3	3	32	24	75	11.9
3/(46'-90')	1	3	3	24	19	79	12.0
4/(0-90')[c]	2	3	3	24	19	79	12.8
5/(0-90')	2	1.5	3	16	14	88	11.8
6/(0-90')	2	1.5	1.5	24	22	92	12.4
7/(0-90')	2	2	1.5	21	20	95	12.3
8/(0-90')	1.5	2	2	24	22	92	12.3
9/(0-90')	1.5	2	2	24	21	88	12.5
10/(0-90')[b]	1.5	2	2	24	22	92	12.8
Broadcast Bed Seeded at the Same Time				40	22	55	11.6

[a] Half the distance to the adjacent row on either left or right of the row in question.

[b] Boundary row.

[c] Staggered two rows 1-inch apart and 2 inches between seeds.

In order to examine the uniformity of seedlings, 50 seedlings were lifted representing seeding spacings 1/2" x 6", 3/4" x 6", 1" x 6", (2-2")[2/] x 6", 2" x 3", and 1 1/2" x 4", respectively. The seventh treatment was taken from an adjacent bed which was broadcast-seeded at 40 $seeds/ft^2$. The seedlings were lifted very carefully to avoid root damage, brought to the laboratory where data on root length, total green length (from root collar to terminal bud), and stem diameter for each seedling were recorded on magnetic tape. The results of the statistical analysis are shown in Table 2. Again the closer row treatment (2" x 3") resulted in the largest diameter seedlings; however, the most uniform seedlings were from 1" x 6" treatment, keeping in mind that all treatments except for 1 and 2 had seeding density of approximately 24 $seeds/ft^2$.

Stitching trials.--Trials were conducted on the 90-foot experimental bed discussed in the above section using an industrial bag stitcher. The machine jammed with the fresh needles and injured and broke seedling stems, when tried in August before the seedlings were hardened. However, when paper tape was placed between the sewing head and the seedlings, the results were very

2/ Staggered two rows one-inch apart and two inches between seeds.

Table 2.--Effects of Spacing and Seeding Density on Uniformity of Seedlings.

VARIABLE	MEAN	MIN VALUE	MAX VALUE	STANDARD DEVIATION
	mm	mm	mm	
TREATMENT 1	SPACING 1/2" x 6"		SEEDING DENSITY - 48 SEEDS/FT^2	
Root Length (mm)	177.1	110.0	240.0	26.67
Green Length (mm)	282.4	154.0	372.0	50.67
Stem Diameter (mm)	4.6	2.5	7.1	1.03
TREATMENT 2	SPACING 3/4" x 6"		SEEDING DENSITY - 32 SEEDS/FT^2	
Root Length (mm)	203.2	144.0	264.0	25.98
Green Length (mm)	315.5	229.0	413.0	49.72
Stem Diameter (mm)	5.0	2.5	7.2	1.04
TREATMENT 3	SPACING 1" x 6"		SEEDING DENSITY - 24 SEEDS/FT^2	
Root Length (mm)	200.0	132.0	245.0	20.52
Green Length (mm)	286.5	200.0	372.0	39.38
Stem Diameter (mm)	5.0	3.4	7.9	0.8
TREATMENT 4	SPACING (2-2")* x 6"		SEEDING DENSITY - 24 SEEDS/FT^2	
Root Length (mm)	206.3	132.0	283.0	33.68
Green Length (mm)	328.9	192.0	423.0	56.93
Stem Diameter (mm)	5.6	3.5	8.3	1.09
TREATMENT 5	SPACING 2" x 3"		SEEDING DENSITY - 24 SEEDS/FT^2	
Root Length (mm)	185.4	135.0	235.0	26.22
Green Length (mm)	311.2	207.0	456.0	61.30
Stem Diameter (mm)	5.7	3.6	8.8	1.07
TREATMENT 6	SPACING 1 1/2" x 4"		SEEDING DENSITY - 24 SEEDS/FT^2	
Root Length (mm)	177.0	143.0	215.0	18.80
Green Length (mm)	294.1	196.0	396.0	46.94
Stem Diameter (mm)	5.3	2.5	7.4	1.07
TREATMENT 7	BROADCAST BED		SEEDING DENSITY - 40 SEEDS/FT^2	
Root Length (mm)	162.7	95.0	258.0	35.52
Green Length (mm)	275.7	169.0	373.0	43.16
Stem Diameter (mm)	4.6	3.1	6.9	0.74

* Staggered two rows one-inch apart.

successful. More design studies and development are required to adapt the bag stitcher to this system.

Taping trials.--Another trial to singularize and control seedlings for automatic feeding was completed through the use of filament tapes of 1/4" and 1/2" width. This method is the most promising investigated to date and can be implemented on existing bed lifters by taping the seedlings directly underneath the belt and then rolling the tape and seedlings on a roller to contain 500-1000 seedlings each. It would then be possible to spray the roots with a clay suspension and bag in the field, thus eliminating all packing shed operations.

Gluing trials.--Using paper tape and plastic glue (hot melt) to hold seedlings together was tried and might be adapted to shed operation. Plastic glue plugs with melting temperatures of 325° and 450°F were available and used to hold seedlings to paper tape. These high temperatures caused some concern as to their effects on the tree's cambium layer and seedling survival.

Greenhouse Survival Study

A greenhouse study was conducted to plant trees receiving various treatments (taping, gluing, and stitching) which might be used in tree singularization for automatic machine feeding, and to determine the effects of these treatments on seedling survival and growth rate as compared with a control. Each treatment contained 10 seedlings obtained from the nursery spacing studies distributed randomly on a bench in the greenhouse. The study started in January, 1977, and data were monitored for two months. The results of seedling survival for the different treatments are shown in Table 3. It is obvious that the taped treatments, with tape removed or not, have some merit for future application.

Table 3.--Effect of singularization treatment on seedling survival, January, 1977 - Greenhouse Study, NCSU.

Treatment	Percent Survival After			
	15 Days	30 Days	45 Days	60 Days
Taped	60	50	40	40
Tape removed	80	60	60	60
Hot melt (325°F)	70	20	0	0
Hot melt (450°F)	60	20	0	0
Stitched	20	0	0	0
Control (not treated)	80	80	70	60

PRECISION DRUM SEEDER

The results of early studies indicated that applying vacuum to the apertures of pipes embedded into, and uniformly spaced, on the circumference of a drum made the metering of singularized pine seeds possible and feasible (Hassan, 1981).

Figures 1 and 2 illustrate the design details of a field prototype. One revolution of this drum would sow 400 seeds in 16 rows. The left side ends of the 25 pipes of the drum seeder are sealed, while the right side ends are connected to a vacuum chamber by means of flexible rubber hoses, which are clamped to a cam follower circular disk by means of a flexible strip. The vacuum chamber is rigidly connected to the drum's hollow shaft. Vacuum is applied to the chamber through a swivel portion of the shaft which is within the vacuum chamber to permit evacuation of the chamber and pipes.

Seeder Operational Functions

The drum rolls in a hopper filled with seeds and rigidly bolted to the frame. The air jet, located above the drum surface, is applied to blow excess seeds off the drum holes leaving single seeds. As the drum rolls further, it brings the seeds to the seedbed. At that time, the vacuum on the particular pipe in contact with the seedbed surface is cut off by means of a cam squeezing the flexible rubber hose which connects the vacuum to the pipe, fig. 2. As the vacuum to that particular pipe is cut off, the seeds attached to it are released and packed into the ground by weight of the rolling drum. The vacuum to that particular pipe is disconnected until the pipe gets back into the hopper, and the cycle is then repeated.

The four basic operational functions of the seeding system - metering single seeds, conveying, releasing, and pressing the seeds into the prepared seed bed - are accomplished by use of the vacuum assist cylindrical drum and cam arrangement. The seeds are held by vacuum and released only when they are in contact with the ground, thus, seed impact and scattering is eliminated. The seeding density is independent of the tractor ground speed since the drum rolls freely with minimum or no slippage. The complete drum seeder assembly is simple and compact; however, the system requires a vacuum pump, an air compressor, and a power source, fig. 1.

Field Testing Unit and Results

In order to evaluate this drum seeding concept, a one-half scale field testing unit, similar to the one shown in fig. 1, to sow 8 rows with seeding spacing of 2" x 3" was designed and constructed.

The field unit was tested on beds at the Griffiths State Nursery, Clayton, NC, in August, 1977, and at the Weyerhaeuser Nursery, Washington, NC, in April, 1978. The tractor operational speed was approximately 0.3 mph.

All components of the drum seeder - the vacuum pump, the air compressor, and the generators - performed properly. The loblolly pine seeds were sown precisely at 2" x 3" spacing and packed by action of the rolling drum seeder.

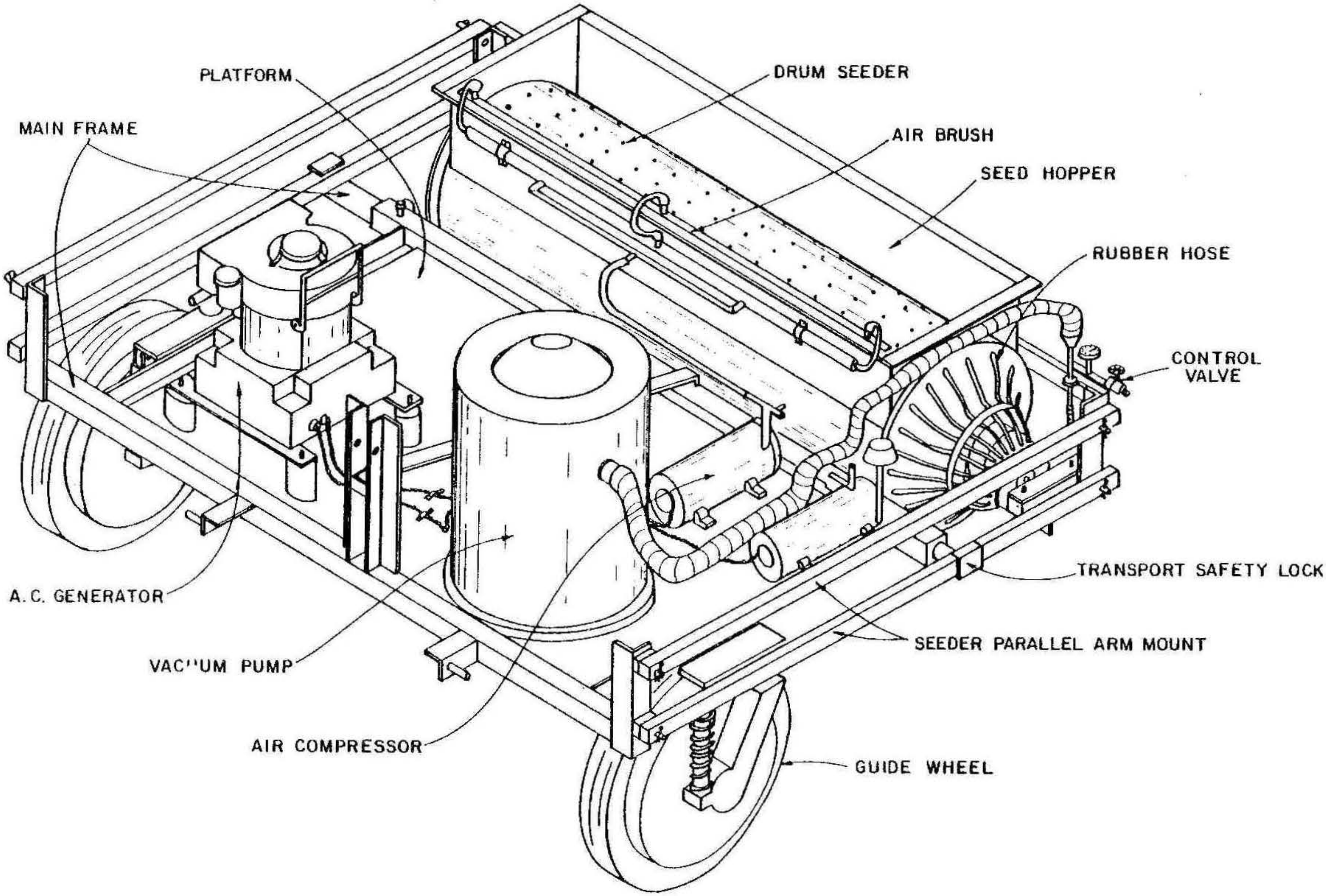


Figure 1.--Schematic drawing of the precision drum seeder and the housing assembly complete with a three point hitch attachment.

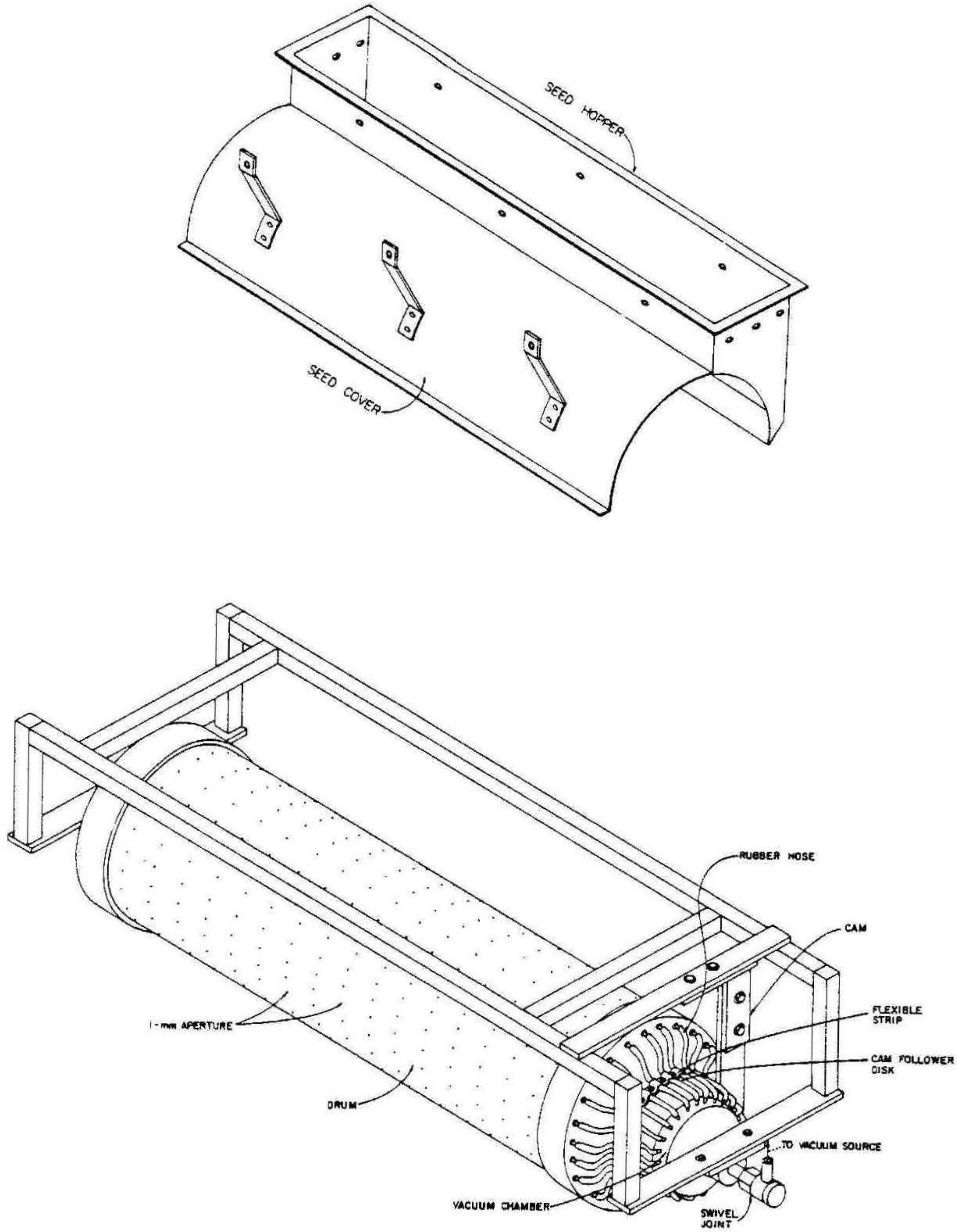


Figure 2.--Three dimensional view of the vacuum drum seeder showing detailed design of the seed hopper (top) and vacuum chamber, cam mounting, rubber hose attachment, and drum seeder.

The unit was found to be speed sensitive; the higher the ground speed the greater the number of seed misses, which could be due to the lack of seed contact with the apertures at high speed. It was felt that this problem might be eliminated if the seeds were agitated, which might bring the seeds closer to the apertures and minimize the seed pick up height.

Mechanical agitation of seeds was tried using a spring-loaded roller powered by means of friction on the portion of the drum surface within the seed hopper. This design turned out to be very successful in minimizing the percentage of misses and allowing operation at higher speeds. Design modifications and improvements are needed to optimize the shape of the mechanical agitator.

Excessive vibration transmitted from the power unit to the drum seeder resulted in increases in the percentage of misses. The vibration problem might be eliminated if the engine driven portable AC generator was isolated or powered differently. Also, it was noted that the seeds tend to accumulate to one side in the hopper especially if the nursery bed was not level. This problem can be avoided if dividers or partitions are included in the hopper design.

Conclusions

The following comments summarize the experience gained from the field testing of the precision drum seeder over two seasons and offer alternatives for future modifications.

1. The drum surface should be cleaned of dirt and debris before entering the hopper. A stiff wire brush rubbing on the drum should clean soil and debris from the drum surface and help to reduce hole clogging.

2. Metal fittings should be used between the seeder pipes and the rubber hoses to prevent the hoses from touching the ground and protect them from breakage and cuts.

3. The bed surface has to be level to prevent seed accumulation in one side of the hopper causing seed spilling. Partitions in the hopper might minimize problems resulting from the seed movement.

4. Multi-unit seeders to sow three beds or more could be utilized to increase the machinery productivity. However, it should be emphasized that the width of the nursery bed is 4 ft hence, mounting the three widths or more might represent some frame structural problems.

5. The results of the field tests indicated that the vacuum drum seeder had sown the loblolly pine seeds precisely. This result is of great importance since the available mechanical bed seeders drill the seeds in the rows, and as the seeds drop through the drop tubes, they scatter on impact with the ground.

6. Precision seeding might facilitate seedling lifting and enhance automation of tree planting.

SEEDED TAPE-SHEET ROLL SYSTEM

The proposed seeded tape-sheet system utilizes a combination of non-degradable adhesive tape material attached to a sheet of degradable material where single seeds are positioned in a special array, for future handling of seedlings during planting. The original seeded tape-sheet roll concept was based on the removal of the hole material from the adhesive non-degradable tape and employing external glue to secure the seeds to the degradable blanket material (Hassan, 1982). The main functions of this wide sheet are to hold the seeds, to be spread upon a prepared seed bed, and to disintegrate after the seeds germinate and sprout.

A schematic of the proposed system is shown in fig. 3. The non-degradable rolls are positioned at a particular space that is recommended by the nursery practice for the crop under consideration. The tapes are then perforated at equal intervals by a tape puncher. This operation might be eliminated if the tapes could be furnished with the proper perforations (flaps). A precision seeder similar to the one discussed in the previous section will deposit single seeds within the perforations on the tape adhesive side. The seeded tapes are then assembled to the wide sheet or blanket made of degradable material. A spring loaded take-up reel will wind the seeded tape-sheet in rolls of desired length to suit the length of the nursery beds. A positive power drive is implemented throughout the system (fig. 3). Details of the drive mechanism, controls, tape guides, and accessories are not shown in fig. 3.

The degradable sheet should be 12" to 16" wider than the seed bed to cover the edges with soil to prevent wind damage to the sheet. The seed-side of the sheet should be faced down to place the seeds in contact with the soil particles to assure the seed-mineral contact needed for germination. After the seeds germinate, the seedlings grow through the openings of the nondegradable tapes. The degradable sheet loses its structure and disintegrates after seed emergence.

The proposed system assumes that the nondegradable tape will retain its strength during a growing season of 8 months or longer. At harvest, the seedlings growing in the tape will be lifted using existing bed lifters modified with a take-up reel to roll the tape with the seedlings. The seedling roll is ready for handling and transport to planting sites, where it will be mounted on an unmanned automatic planting machine.

1981-1982 Greenhouse Study

A single-row portable hand-operated perforation unit made of two rollers and positively driven was constructed to perforate the 1" filament tape (non-degradable material) at a distance of 2 inches. Single seeds were then placed on the 1/2" flap prior to adhering the tape to the cheesecloth (degradable material). Several greenhouse studies were conducted to test the validity of this concept. The results of the early 1980-1981 study indicated that laying the seeded tape-sheet roll with the sheet material facing the soil particles resulted in a better stand than with the tape side facing the soil surface.

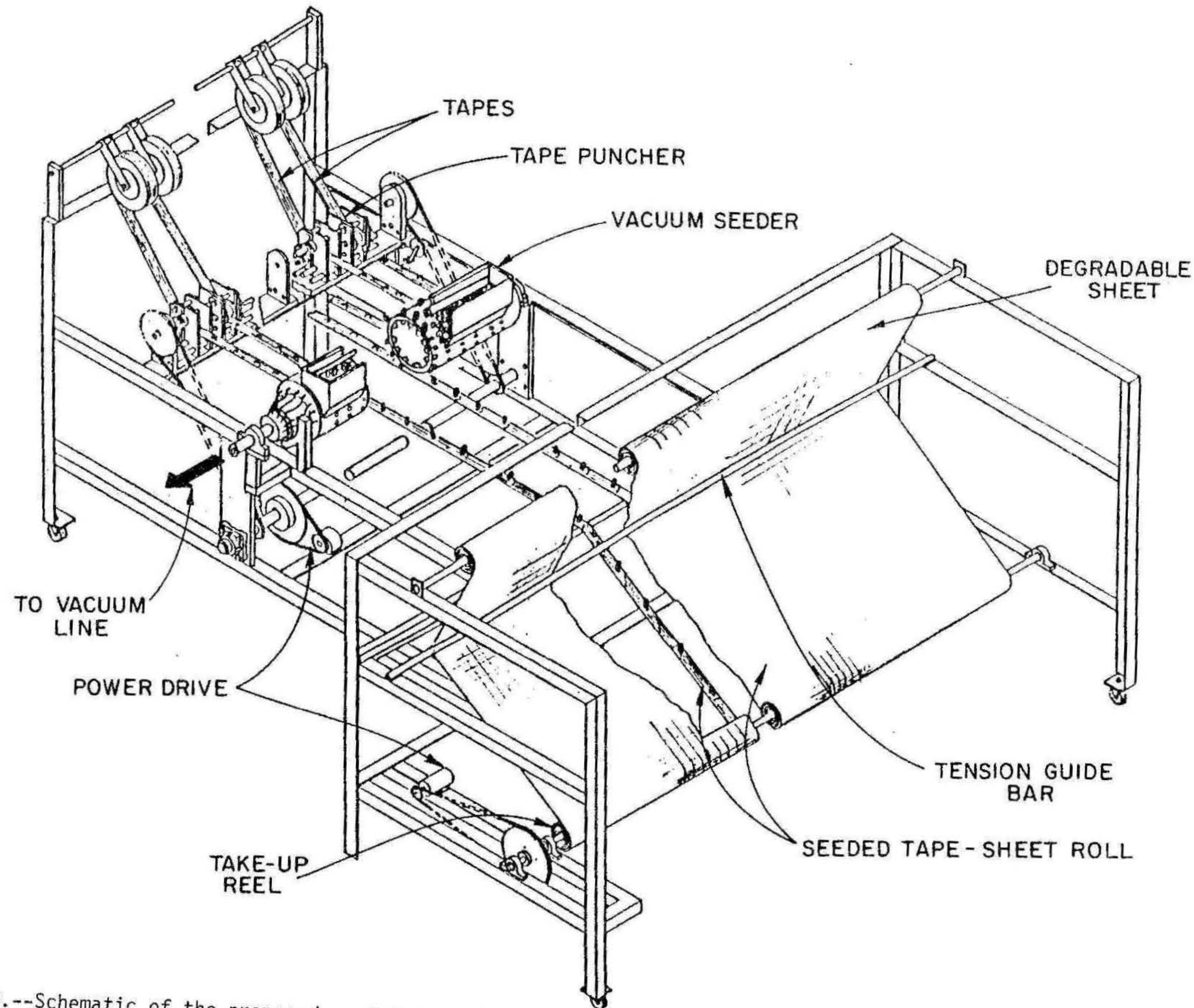


Figure 3.--Schematic of the proposed seeded tape-sheet system for growing bare root seedlings for future automation of the tree planting machine system.

A four-replication greenhouse study was initiated in March, 1981, to test the germination and stand establishment of seeded tape with different treatments. The perforations were semi-circular with direction either along the tape fiber (0°) or 45° as shown in Table 4, to test the effect of angle of perforation on the strength property of the tape material. The perforated flaps were cut in the middle to reduce the impact of the tape material on the seed germination (treatment #3, Table 4). Seeds were placed on the untreated tape of treatment #5 at 50 mm and glued to the cheesecloth material within the tape holes in treatment #4 representing the original concept. The seeds were placed directly on the soil in the control treatment. Each treatment consisted of 30 seeds with four replications randomly placed in trays on a greenhouse bench equipped with a controlled mist irrigation system. The seedlings were allowed to grow for 13 months until harvest in April, 1982.

Table 4.--Greenhouse study comparing the tape perforations with punched holes and other treatments (March 81-April 82).

Treatment	No. of Seedlings/Treatment		Seedling Stand per Treatment	Tape Strength
	Grown in Tape	Total	%	lbs
1. 0°-perforation	41	44	34.2	35
2. 45°-perforation	30	33	25.0	34
3. 0°-perforation with slit	67	71	55.8	32
4. Punched holes	71	72	59.2	31
5. Untreated tape	0	10	0	52
6. Control - no tape	86	86	71.7	--
7. Unused control tape with 1/2" hole	--	--	--	125

Results of the Greenhouse Study

The results of this study are summarized in Table 4 which shows that the angle of perforation has no effect on the strength properties of the tape material and that, in general, the perforated tape exhibited higher strength than the punched tape. The presence of the tape flap and glue affected the seed germination and resulted in a less dense stand than the control. Perhaps two seeds should be placed at each perforation to increase the germination percentage in future applications. Only 10 seedlings out of the 120 seeds placed on the untreated tape germinated with root systems extending on the tape surface. The tap root and shoots were unable to penetrate the filament tape material; thus tape punching or perforation cannot be eliminated.

Conclusions

The filament tape and cheesecloth are suitable materials for future applications of the seeded tape-sheet roll system. Tape perforation concept offers a much simpler system than the hole punching concept. The seedlings grown in the tape are singularized and controlled and lend themselves to future application of the unmanned tree transplanter for planting bare root seedlings.

SEEDLING DETECTION DEVICES

The detection device for feeding and sorting of bare root seedlings should satisfy the following design criteria in order to be compatible with FECO's development goals for the unmanned tree planter:

1. Seedlings grown in tapes or taped (Maw, 1980) should be spaced at random intervals which vary between 1 and 8 inches.

2. Only seedlings with root collar diameter in the specified range will be selected.

3. Suitable seedlings must be available for each planting cycle, i.e., every 2.75 seconds for a planting rate of 1300 seedlings/hour.

Two spools of 30 taped seedlings each were prepared and used for testing the two detection systems described below. Pine seedlings of various diameters were taped at an average distance of 2.5 in. The seedling diameter range was 0.08 to 0.51 in. The average seedling diameters for Tape-I and Tape-II were 0.27 and 0.12 in., respectively.

Optical Detection System

Figure 4 shows the major components of the optical detection device. The taped seedlings are wound on an aluminum spool mounted on two conical supports. Friction between the supports and the spool is adjusted by means of a spring-loaded bolt system for controlling the seedlings' tape tension.

The taped seedlings are guided and fed between two feeding rollers, which are rotating in opposite directions. These rollers are made of plastic tubing, 4-in. in diameter, covered with a thick rubber foam to avoid seedling damage and to introduce enough friction to pull the tape through. The lower roller is powered by a magnetic clutch/brake, and the top roller free rolls by means of the friction between the two rollers.

When an acceptable seedling is detected, a generated signal stops the feeding rollers, bringing the seedling tape to a halt, positioning the seedling on a cutter guide platform. The tape on either side of the positioned seedling is cut by a blade mechanism. A holding finger is lowered to hold the tape during the cutting process. The cutter blade mechanism is a rotating eccentric knife which rotates with the same speed as the tree insertion mechanism. Therefore, when the cutter blades complete one revolution, one seedling is available for automatic feeding.

The seedling-holding fingers device is made of three rubber fingers connected to an arm which is activated by a cam/follower mechanism. The cam is synchronized with the cutter blade motion such that the fingers are holding the seedling during the cutting action. The same cam activates a microswitch to reset the total system after each successful tape cutting action. The complete circuit block diagram can be found in Sasan and Hassan, 1982, and Hassan, 1977.

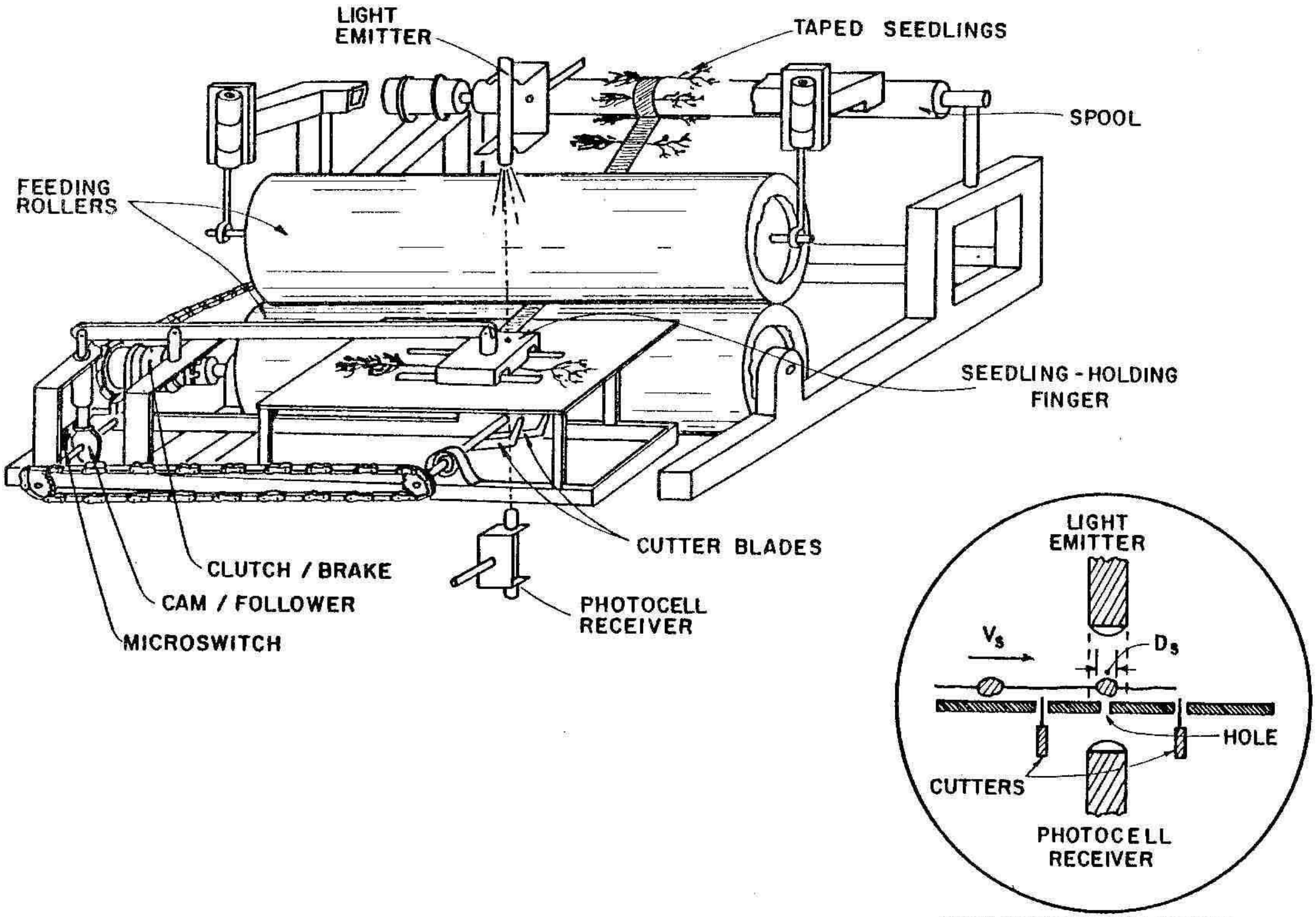


Figure 4.--Optical sorting and feeding device for taped seedlings.

Testing procedure.--Testing of the optical detection device was achieved by feeding taped pine seedlings (Tape-I and Tape-II) and recording the acceptance or rejection of each seedling. The test device was powered by a hydraulic motor which controlled the feeding speed. A minimum of four repetitions for each test condition was conducted.

Linear Displacement System

The linear displacement detection device was a simple, manually operated set-up that included a linear vertical potentiometer. As the tape loaded with seedlings was pulled through the apparatus, the seedling forced up the roller which was fastened to the linear potentiometer lever (fig. 5). A voltage proportional to the seedling diameter was obtained regardless of feeding speeds. This voltage was compared with the preset ranges adjusted by circuit potentiometers.

Testing procedure.--The two tapes, Tape-I and Tape-II, were used for this study. The tape was manually wound while the seedling was passing under the wheel (fig. 5). The vertical displacement potentiometer output and a marker indicating the circuit rejection or acceptance were recorded on an 8-channel strip chart recorder, Hewlett-Packard, Model 7758A. The tests were conducted at high and low speeds (8.9 and 1.5 in./s).

Results of Laboratory Testing

Optical detection device.--The taped seedlings (Tape-I) were fed through the device four times at a constant speed of 5.7 in./s. The device was set such that the maximum and minimum acceptable seedling diameters were 0.291 and 0.236 in., respectively, which defined a very narrow acceptable window. The acceptance and rejection of a seedling was recorded. Optimum performance of the optical device requires a pass percentage of 100 in the acceptance window and zero percent elsewhere. If the seedling diameter was very close to the boundary, the pass percent was reduced. Other reasons for obtaining a pass percent between 1 and 100 might be nonuniformity of seedling stem diameters, presence of fusiform rust, nonuniform cross-sectional diameter, shadowing effect of bark, bumps on the stem, and mechanical problems associated with this device such as tape misalignment, speed fluctuation due to varied friction between feeding rollers, friction at ends of seedling spool, . . ., etc.

The circuit timers were set based on both seedling diameter range and feeding speed. Hence, the optical detection method is sensitive to speed variations. During the course of evaluation of this device, it was noted that the feeding speed was dependent on the friction between the taped seedlings and the feeding rollers which increased with the presence of the seedling between the rollers and resulted in speed fluctuations. Hence, this fluctuation is dependent on seedling spacings. The feeding speed was also affected by the friction between the taped seedling spool and its axis of rotation which varied with the loading scheme. In order to eliminate the problem of feeding speed fluctuation, a linear positive drive system is recommended.

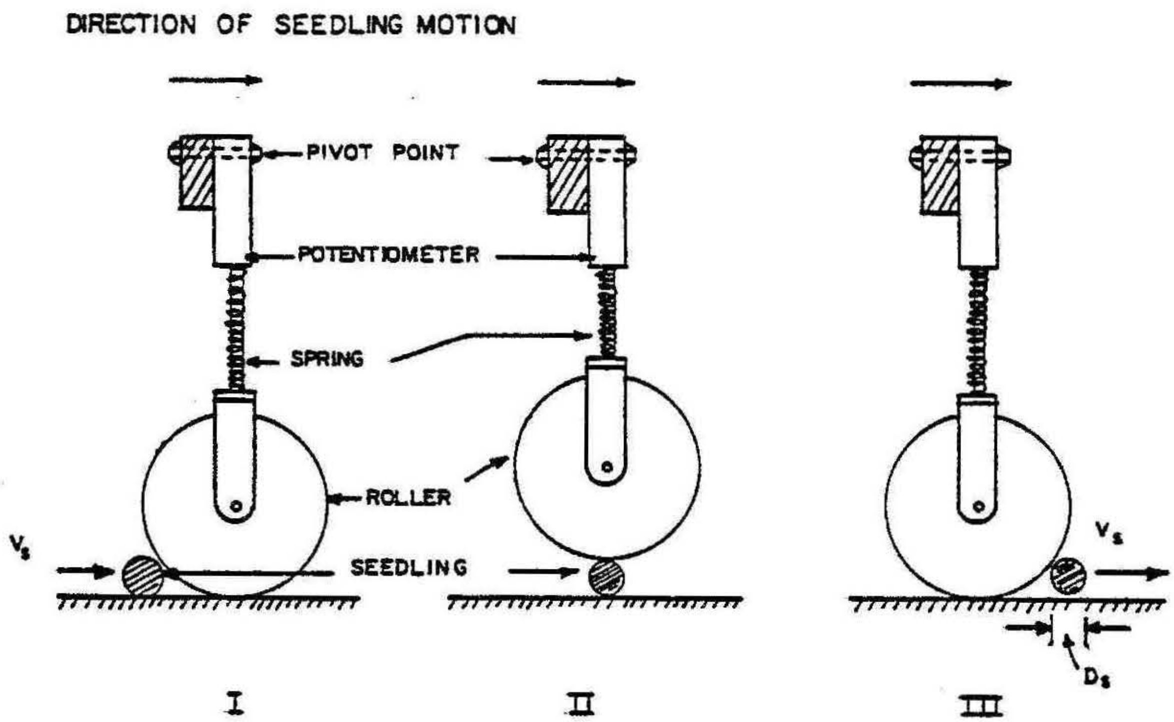


Figure 5.--Spring-loaded potentiometer for detecting and sorting seedlings.

Tape-II was used to study the effect of feeding speed and window on the seedling pass percentage. For the same window, (0.035"), a better performance of the device was achieved at high speed (10.4 in/s) where rejection of the seedlings outside the window was greatly pronounced. Similarly, increasing the acceptance window width for the same feeding speed resulted in a better performance of the optical detection device.

Linear displacement system.--The device evaluation was conducted using Tape-I with average seedling diameter of 0.27 in. Figure 6 illustrates one of the test runs recorded on the Hewlett-Packard strip chart recorder. In this test run (fig. 6), the acceptance window was set at $0.181'' < D_S < 0.343''$. The device performance was good as shown in the plot where seedlings within the acceptance window were selected and those outside the range were rejected (fig. 6). This device was not as sensitive to speed as the optical system and in general, its performance improved with the increase in the window width independent of the operating speeds.

Systems Comparison and Conclusions

The acceptance and rejection performance of the optical and linear displacement detection methods are shown graphically in fig. 7. The two seedlings "k" within the acceptance window were rejected by the optical system and accepted by the linear displacement system (fig. 7). These results should be interpreted carefully, however, as to the superiority of the linear displacement system over the optical system. Table 5 summarizes the performance of the optical and linear displacement detection systems. Future recommendations are also included in the table. It should be mentioned that the linear displacement device was simple and did not include seedling removal. However, all features of the optical system including time delay and tape cutting can be implemented in the linear displacement system.

Similar work has been done (Maw et al., 1980) in which the singularization and sorting was based on seedling length. The results indicated the difficulty involved in obtaining correct length measurements of seedlings for the purpose of detection. For example, using 8.98" long cards in place of seedlings, a standard deviation of 0.146" was achieved. However, when plants of the same length were used, a standard deviation of 1.673" was obtained which clearly shows the effect of plant variation and structure on device performance.

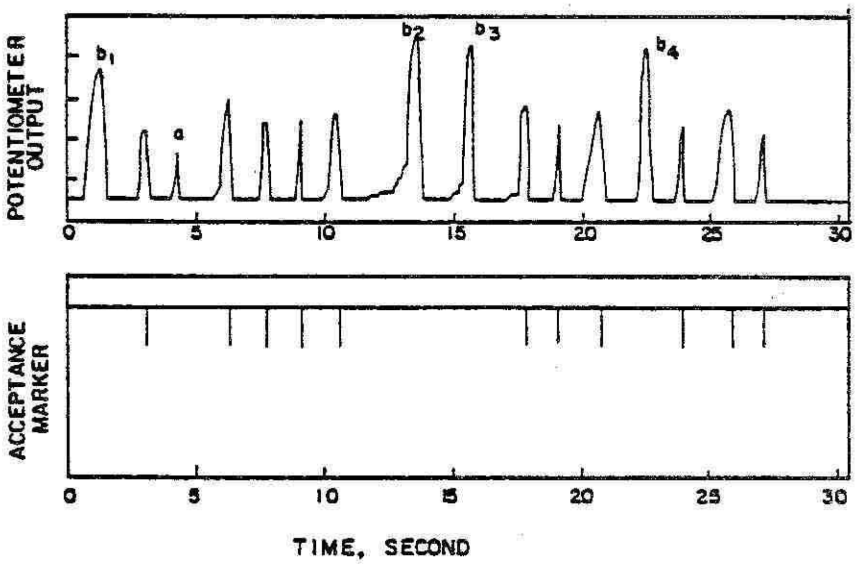


Figure 6.--Strip chart recorder output from the displacement detection device showing the acceptance markers for 16 seedlings fed at a speed of V_s= 1.5 in/s with D_{min} = 0.181 in. and D_{max} = 0.343 in. Diameter of the seedling "a" shown above was 0.138 in < D_{min} while diameters of seedlings b_1 to b_4 were greater than D_{max}.

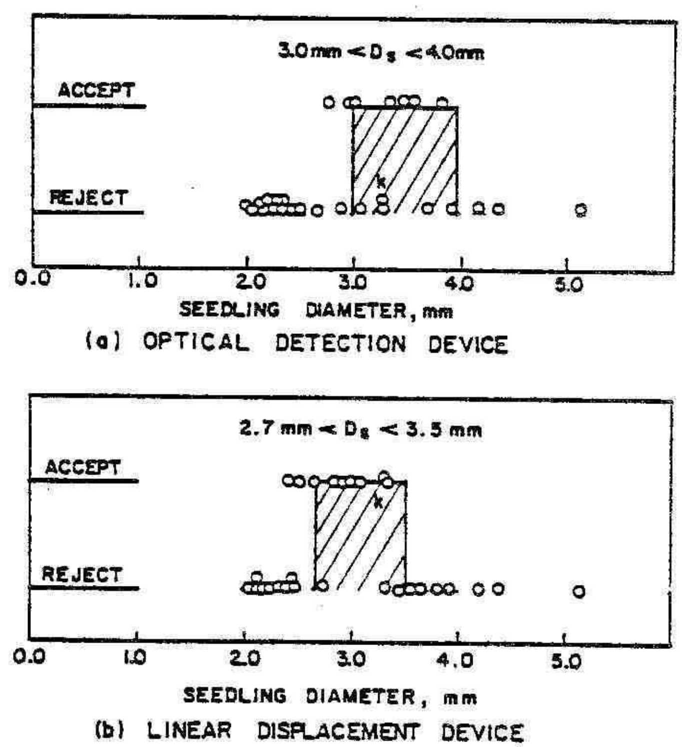


Figure 7.--Comparison between the optical detection and linear displacement methods using the same taped seedlings (Tape-II) and approximately the same acceptance window widths.

Table 5.--Comparison between the optical and linear displacement detection methods.

Parameter	Optical System	Linear Displacement System
1. Operational Speeds	Constant speed must be maintained throughout	Independent of speeds
2. Speed Sensitivity	Excellent performance at high speeds	Overshoot of potentiometer lever at high speeds
3. Sensing Method	No contact with seedlings	Direct contact with seedling
4. Life Expectancy of Sensing Device	Unlimited	Wear of displacement potentiometer after prolonged use
5. Seedling Effect	Shadowing effect of seedling bark	Sensitive to bends or curvature of the seedling stem
6. Seedling Damage	None	Might cause compression of cambium layer
7. Acceptance Window	Average performance	Better than average
8. Design recommendations	Positive drive to eliminate speed variations	Use of wheeled caliper for diameter detection
9. Future Adaptation on Tree Planters	Not affected by daylight, infrared modulated light used. Required frequent cleaning and dust removal.	System should be isolated from vibration transmittance. Not sensitive to dust contamination.

LITERATURE CITED

Ardalan, S., Hassan, A. E. 1982. Automatic feeding and sorting of bare root seedlings. Transactions of the ASAE 25(2):266-270.

Bowen, H. D. 1981. Useful concept for automatic tree planters. Proceedings of the Symposium on Engineering Systems for Forest Regeneration, ASAE Publication 10-81:162-170, American Society of Agric. Engineers, St. Joseph, MI.

Graham, L. F., Rohrbach, R. P. 1981. Mechanical singularization of bare root pine seedlings. Proceedings of the Symposium on Engineering Systems for Forest Regeneration, ASAE Publication 10-81:186-193, American Society of Agricultural Engineers, St. Joseph, MI.

Hassan, A. E. 1976. FECO First Annual Report, Unpublished, 57 p., School of Forest Resources, North Carolina State University, Raleigh, NC.

Hassan, A. E. 1977. FECO Second Annual Report, Unpublished, 93 p., School of Forest Resources, North Carolina State University, Raleigh, NC.

Hassan, A. E. 1981. Precision drum seeder for uniform spacing. Transactions of the ASAE 24(4):879-883.

Hassan, A. E. 1982. A new concept for growing bare root singularized seedlings. ASAE Paper No. 82-1073, American Society of Agricultural Engineers, St. Joseph, MI. 24 p.

Maw, B. W., and Suggs, C. W. 1981. Loading bare root plants onto a reel. ASAE Paper No. 81-9083, American Society of Agricultural Engineers, St. Joseph, MI. 10 p.

Maw, B. W., Suggs, C. W., and Harris, D. 1980. Progress in the mechanical singularization and sorting of seedlings. ASAE Paper No. 80-1055, American Society of Agricultural Engineers, St. Joseph, MI. 16 p.

A SYSTEMS APPROACH TO FOREST TREE SEEDLING PRODUCTION
A NEW CONCEPT

Charles R. Venator [1]

Abstract.-- A concept of an integrated systems approach to sowing and harvesting 50-foot-wide forest seedling nursery beds is presented. Basic nursery operations of bed preparation, sowing, bed tending, seedling care, and harvesting use a moveable carriage that operates on cogged tracks. The systems concept is based on a goal of harvesting 36 million seedlings within 10 work days. Time sharing of the harvesting equipment should be possible on a weather cline with a resultant large scale operating cost savings for forest industries.

Additional keywords: Nursery development, nursery production, nursery mechanization.

Forest tree seedling nurseries in the South are similar in operation and production techniques to those utilized 60 to 70 years ago. In most of the nurseries the seedlings are grown in 4-foot-wide mounded beds with 6-inch spacing between rows.

The 4-foot-wide bed poses a problem since only 8 rows of seedlings can be lifted simultaneously. In order to decrease harvest time, more machines must be used or machinery operation speed must be increased. However, it may not be possible to significantly increase the tractor speed down the nursery beds without damaging seedlings. Moreover, the 4-foot-wide bed is a limiting factor in that there is not enough room behind the lifter to handle the large volume of seedlings lifted. Consequently, seedlings are lifted en masse and transported to packing sheds where they are hand sorted, graded, and packed. In essence, the current harvesting and packing process is labor intensive and bottlenecks develop at various points in the system. A significant amount of soil is also removed in the process which must be returned to the nursery.

Aside from these problems, one of the major complaints against 4-foot-wide nursery beds is that only 67 percent of the available area is cultivated, with the remaining area used for tractor wheel paths and waterlines. Although there is talk of developing equipment to operate on 6-foot-wide nursery beds, this will not: (1) significantly increase bed cultivation space per acre; (2) increase the speed of harvesting operations; or (3) lower costs.

1/ Research Plant Physiologist, USDA--Forest Service, Southern Forest Experiment Station, Pineville, LA.

The problem is technological, but it appears that technological improvements of the current system result in smaller and smaller margins of productivity. Faced with the prospect of diminishing returns from increased mechanization efforts of the existing system, there is a need to radically redesign forest tree seedling operations so that improvements can be engineered over the next generation. This means that the next design in nursery operations should embody a concept that will permit large gains in productivity as new and more efficient machinery is developed. The overall objective is to develop not only a highly mechanized nursery system, but one which utilizes a low degree of complexity in equipment design. This is the basic concept of the proposed approach to nursery production.

Basic System Concept

The focal point of the new approach to nursery production described here is that all of the sowing, cultural harvesting, grading, and packing operations are done over the nursery beds. The key to the success of this new system is the operation of a wide span carriage on fixed, cogged rails. The carriage will provide sufficient work area so that the entire nursery operation, phase by phase, can be done directly over the seedling beds. Mechanical lifting, grading, and packing systems will be designed to lower operating costs.

The chart in figure 1 outlines the present stepwise process of nursery operations. These steps and a conceptual design for the equipment necessary to integrate them are discussed below.

Bed Preparation

Traditional nursery bed preparation practices include plowing, disking, harrowing, and mounding in addition to the application of fertilizers, fumigation, and herbicides. All of the processes are done on 4-foot-wide beds with standard equipment pulled by tractors.

In the proposed system, nursery bed preparation operations will be done from a carriage riding down fixed tracks. With fixed tracks, positive traction is the guiding force of the system. Thus, the entire operation can be done over a 50-foot and perhaps eventually a 200-foot-wide bed, cog by measured cog. Such a system can be speed graduated for any operation using synchromeshed electric motors on each wheel or each pair of wheels, or perhaps by a stationary diesel motor at the end of the bed with a cable hook-up to pull the carriage. Separate power sources for carriage movement and cultural operations will be employed.

Bed preparation and sowing would be integrated as follows. If necessary, at the leading edge of the carriage, rototillers would chop the soil. Immediately behind the rototiller (perhaps at 10 feet) a harrow operation follows. At the back edge of the carriage the bed would be sown

BED PREPARATION

1. Plowing, disking
2. Fumigation
3. Mounding
4. Pre-emergence herbicide

SOWING

1. Plant seed
2. Mulching
3. Post emergence herbicide
4. Fertilizers

BED TENDING

1. Insecticides
2. Herbicides/weeding
3. Watering
4. Fertilizers

SEEDLING CARE

1. Top pruning
2. Wrenching
3. Lateral pruning

HARVESTING OPERATIONS

1. Lifting
2. Grading
3. Packing

Figure 1.--Basic operations of a forest tree seedling nursery program.

and the drills covered by trailing rollers. All of the bed preparation equipment would be designed in 25-foot segments to fit exactly onto the carriage and to be operated by a single size power source. The development of tillers, harrows, and seeders for this phase of operation is not necessary. All that is needed is a technology transfer from existing equipment and an efficient connection to a power source.

Soil management techniques have been studied for years at the USDA National Tillage Laboratory in Auburn, Alabama, and operational procedures are well defined for raising crops in the soil bins of the type proposed. Cultivation of seedlings in bins, such as developed at the National Tillage Laboratory, would result in huge labor and energy savings since plowing, disking, and bed forming operations would not be done, making it unnecessary to purchase equipment for these operations. Since all of the operations are done from the carriage on the tracks, soil compaction will not be a problem. Consequently, because there is no soil compaction, tillage equipment, time, and energy requirements will be minimal. For example, after seedling harvest the only operation required to prepare the soil for sowing the next crop is to level the soil with a harrow.

The Carriage

The carriage would be designed to be lightweight in structure and form. The entire structure would be a lattice work with tubular metal used wherever possible. A sketch of the carriage design is shown in figure 2. The only purpose of the carriage is to hold equipment and people; it is a passive unit and is not subject to breakdown. Some of the cultural equipment such as the harrow, sprayer, and root pruners are passive and no breakdown is expected. Other equipment such as the beltlifters have moving parts and are subject to breakdown. This will require the development of highly reliable equipment.

Construction of Nursery Beds

A major concern of nurserymen is the condition of the nursery soil. Drainage and aeration are two of many important aspects of nursery soil management and are fully capable of being manipulated to specification. However, water management techniques in current forest tree nurseries are still primitive, consisting basically of aboveground delivery and runoff. Little can be done to improve aeration of the existing beds as long as heavy machinery operate in the nursery.

To achieve better soil and water management, about 30 inches of topsoil could be removed and replaced with a sand:perlite:loam mixture with a known drainage and aeration capacity. Since massive soil excavation and rearrangement is commonplace in nurseries now being constructed, an additional stage of mixing to known proportions should not be uneconomical considering the expected benefits.

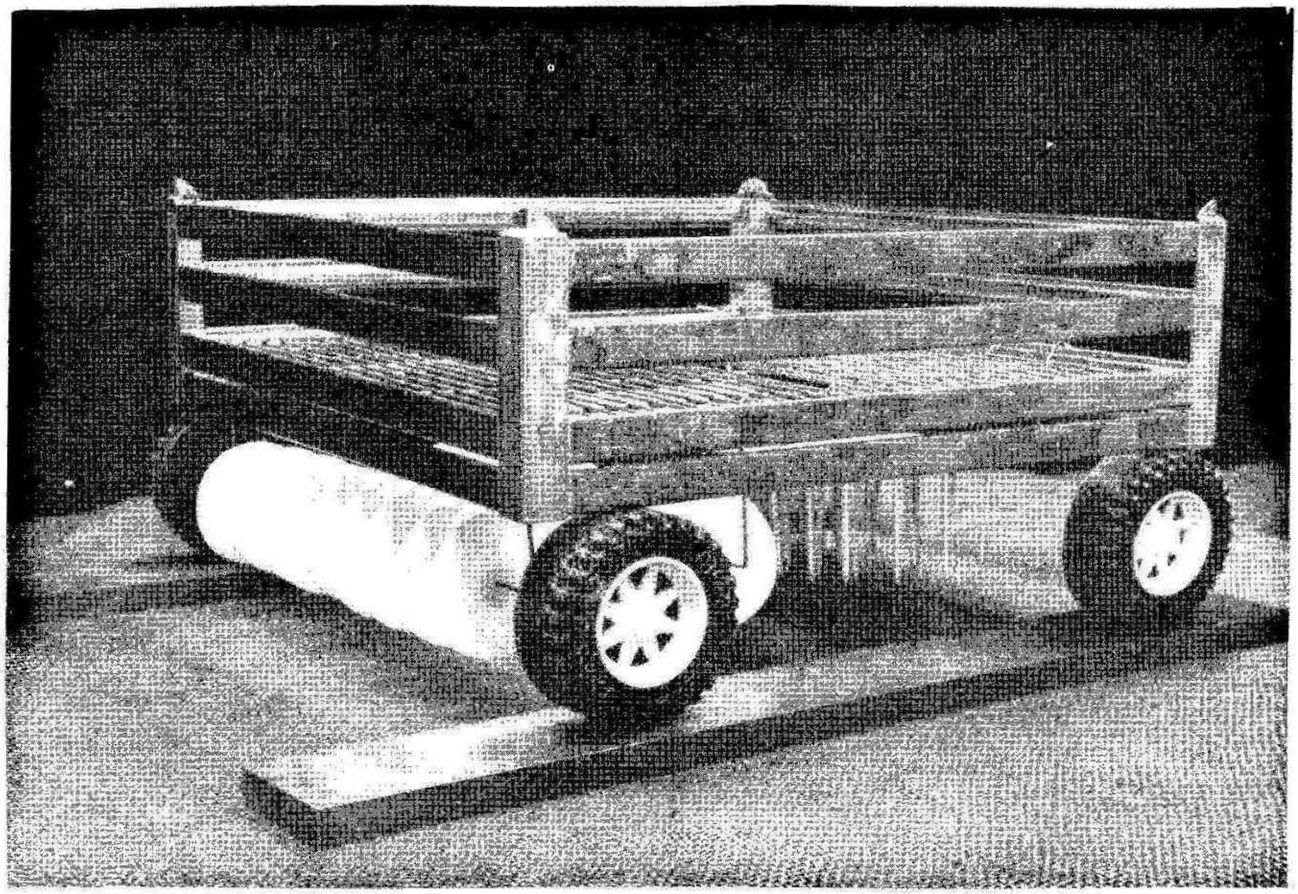


Figure 2.--Wide span nursery carriage. The carriage will travel over fixed tracks. All of the equipment needed for cultivation, sowing and harvesting will be accommodated on or under the carriage. In this view, disks and harrow operations are shown.

In the new generation nursery bed, the bottom and sides of the nursery pit could conceivably be lined with clay to hold water. Electronically operated moisture sensors and valves would monitor the level of moisture within the nursery pit to drain the pit if necessary. Among other benefits, this scheme would permit flushing of salts if necessary to avoid toxicity from salt imbalances.

Seedling Care

Another group of functions that could be integrated would involve insecticide, herbicide, and fertilizer application. Pesticides are currently applied with overhead sprayers which saturate the soil or foliage. This is wasteful in that tractor paths and waterlines are also sprayed. Precision sprayers are available which permit a directed application of pesticides to the target area if controlled tracking is used. The proposed system would result in very precise row spacing. Of even more importance, because of the fixed track nature of carriage travel, it is easy to adjust the spray nozzles either for precise, uniform application or for random application patterns. With precision application and a guaranteed repeatability it will be possible to reduce pesticide application rates by at least 60 percent and maybe more. Figure 3 illustrates the type of sprayers that would operate from the carriage. Little innovation would be required to position and adjust the sprayer angle, type of spray, and rate of delivery to reduce current costs. An alternate method is to lay a tape impregnated with fertilizers or pesticides between the seedling rows.

An additional benefit is that existing top pruning and lateral root pruning equipment can be easily adapted to operate on the carriage.

Lifting Operations

With the new method, lifting operations can be synchronized over the wide bed because the seedling beds have been sown with precision, the beds are level, and the rows perfectly spaced. In this integrated approach to nursery production, the most radical departure from existing technology will occur in the harvesting phase. A whole new method will be developed with the end result of total mechanization of the lifting, grading, and packing processes.

Figure 4 contrasts the structure of a traditional nursery bed with that of the new method. Lifting equipment on the proposed carriage will be sequential as follows: About 12 inches in front of each row lifter, a small trencher will operate. The function of this is to dig a trench between the seedling rows. Each trench will be about 2 inches wide and 7 inches deep. The seedlings will be left in 4-inch-wide mounds. Six inches behind the trencher, in a single row, a side to side reciprocating blade will undercut and guide each row of seedlings into the lifter belt where they will be transported up onto the carriage and enter into the root dipping trough and the mechanical grader. The advantage of having a lateral trencher

Figure 3.--Three types of precision sprayers for use in the proposed nursery system. Each of the sprayers in a), b), and c) are designed for directional application and to deliver either a mist/fog or a droplet/drench depending upon the required treatment.

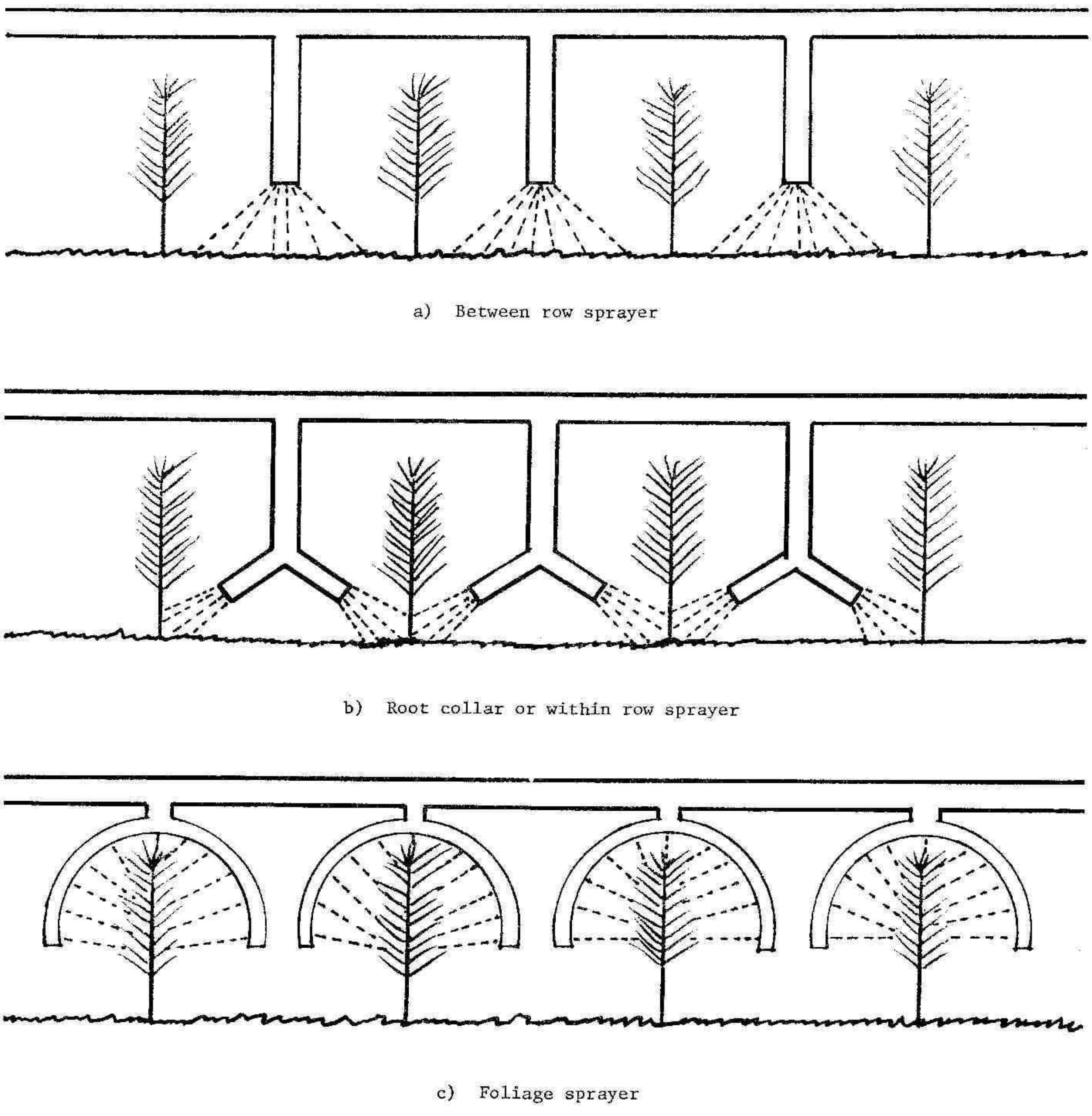


Figure 4a: Traditional seedling bed without trenches between the seedling rows. The lifting blade has a drag force along its entire width and has to be heavily built to avoid bowing along its front edge.

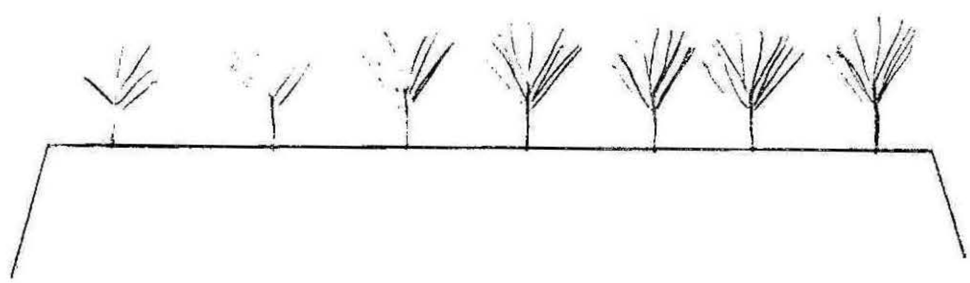
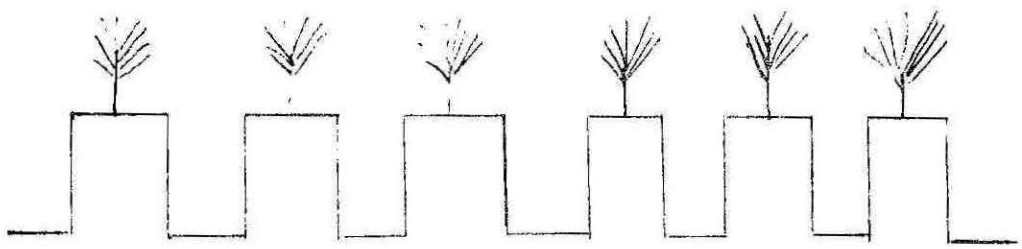


Figure 4b: The proposed bed with trenches between seedling rows. The lifting blade need only be about 6 inches wide to lift the 4-inch-wide columns with seedlings. The individual lifters could be lighter in design strength.



proceed the lifting operation is that the single row blade undercutter can be designed so that it is smaller, requiring less operating energy than a blade continuous across the entire bed. The open trench on each side of the seedling row will let the lifter operate freely. Only about 4 inches of drag will be placed on each lifter. The mechanics of a multiple row lifter working simultaneously with a lifter having a 4-inch drag will be simple; however, an estimate of the overall power required to operate the carriage forward during this process is not known. A prong about 12 inches long, parallel to the ground and about 2 inches wide, immediately proceeds the lifter. This will prevent the seedlings from falling over and guide them into the lifter.

The mechanics of developing a seedling lifter capable of simultaneous harvesting 50 to 200 feet of nursery bed should not be difficult. The hydraulic belt lifter currently used requires 1 hp to lift the 4-foot-wide bed. With slight modification this lifter unit would be mounted side by side on the carriage and run in series. The units would be small enough so that if one unit breaks down it could be removed and replaced by a spare. The damaged unit would be serviced off the carriage.

Seedlings from individual rows will be lifted by belt lifters and carried up about 6 inches into a trough full of water which runs parallel and then perpendicular to the seedling rows. As the individual seedling is carried along this trough its roots will be washed free of soil and the mud returned to the nursery bed. Somewhere along the path an electronic grader will react to each seedling and either cull it or let it pass to another trough containing clay slurry where the roots will be coated. The seedlings will then be packed and loaded into refrigerated trailers at the end of each bed. Culled seedlings will be transported to a central hopper on the carriage where they will be chopped and their remains blown back over the nursery bed.

The entire design for lifting, grading, and packing must be scaled to fit the carriage. Thus, a division of space must be allocated and developed into a workable model. Two important factors favor the development of a totally mechanized system: (1) the carriage has abundant space to work over the nursery beds, and (2) the slow rate of carriage travel over the bed. If need be, the carriage length can be expanded to the length necessary to accommodate the harvesting equipment.

The key to the success and flexibility of this concept is the rate of travel of the carriage. For example, a lifter designed to operate on a 4-foot-wide bed would have to lift 50, 4-foot-wide beds to cover the same area as the carriage lifting over the 200-foot-wide bed. With today's level of technology, the 200-foot-wide carriage only has to travel at 1/50 of the forward speed of a 4-foot-wide lifter to cover the same area. A slow forward speed would permit synchronized mechanical lifting and grading operations. The first designs will undoubtedly be relatively simple and slow, but as technology improves, lifting and grading speeds could be increased. Theoretically, if the forward speed of the carriage can be increased to 1/25 of the speed of a 4-foot-wide lifter, then the total time of lifting will be cut by 1/2. This ratio of forward speed of the carriage to total lifting time is the key to the long term viability of this nursery design. Improvements in lifting operations will result in direct reduction of labor costs. A totally mechanized nursery system such as described should not need over 3 to 5 people to operate it during the sowing and bed tending season. During the lifting season it would be necessary to employ between 10 to 15 people.

Time Sharing

With a concentrated effort the proposed nursery system could be workable within 3 to 5 years. Another notable feature of the system is that it may be possible for nurseries to cooperate or share equipment. For example, a crew could lift seedlings at one nursery for a 15-day period, dismantle the carriage harvesting equipment, and move it to another nursery where it would be installed on another carriage to lift seedlings at that site. This process could be repeated about 7 to 8 times on a north to south to north weather cline. Contract lifting could thus reduce substantially the carriage equipment capital investment for each nursery. The concept of shared use of the lifting equipment would easily fit into the framework of a large corporation that has several nurseries on such a weather cline. The corporation would purchase the carriage equipment but contract the operation to operators or assign a group of technicians to operate it during the lifting season.

Scale of Economy

Five basic phases of a typical bare-root nursery operation are outlined in figure 1. Current nursery operations are labor intensive for the bed preparation and harvesting operations, thus the greatest labor saving costs can be achieved by mechanizing these operations. Sowing, bed tending, and seedling care operations are less labor intensive and there is little room for lowering expenses by increased mechanization. The systems approach outlined in this paper suggests potentially large labor cost savings in the bed preparation and harvesting operation phases.

Data accumulated at the USDA National Tillage Laboratory in Auburn, Alabama, emphasize the potential of lowering labor costs by operating equipment on controlled traffic paths (Taylor 1981). Controlled traffic tillage has proven economic benefits; these are: less tillage energy required, improved tractive efficiency, and timeliness of operations. A controlled track system would eliminate the problems associated with soil compaction resulting from bed preparation, sowing, and tending operations. The major benefit would be a better soil structure resulting in increased air and water infiltration, decreased erosion by water runoff, decreased need for nitrogen fertilizer, and better root development.

The potential savings on nursery manual labor wages for the harvesting phase are substantial. The average southern nursery employs about 50 lifters, graders, and packers. If these work an average of 48 hours at \$4.50 per hour (a typical wage in the South) then the weekly payroll is \$10,800. In a 42-day lifting period the payroll is \$75,600. Each year (using constant dollars) 100 nurseries will pay out \$7,560,000 and in 10 years \$75,600,000. Under the proposed system, one harvesting crew will be able to work in several nurseries. If the average wage for the more skilled labor needed is \$9.00 per hour, the labor cost for the nursery harvest phase would be: 48-hour work week x 2 lifting weeks x 15 employees x \$9.00/hour = \$12,960, a savings of \$62,640 per year. The total cost of harvesting for 100 nurseries is \$1,296,000. Thus 100 nurseries could save \$6,264,000 per year. Over 10 years this would represent a savings of \$62,640,000.

Similar economics would result from a reduced need for total nursery tillage area. The average nursery utilizes approximately 5 acres for the packing shed, machine shed, etc. and about 41 acres to produce 36 million seedlings at 30 seedlings/ft^2 in 4-foot beds. In the proposed system, 36 million seedlings could be produced on 27.6 acres and less than 1 acre would be required for accessory area, since only an office and a small machinery building would be needed. Additional land for rotational/fallow schemes would follow the same ratio.

Additional savings would be realized from reduced costs by more precise, and consequently less, application of pesticides, fungicides and herbicides. It can be estimated that the rate of application of fungicides can be reduced by 80 percent and that of pesticides and herbicides by 60 percent. Currently, 70 southern nurseries spend approximately \$3 million each year for herbicides and fungicides. Consequently, there would be a yearly combined savings of about \$1.8 million for these nurseries or \$25,700 per nursery and about \$18 million over 10 years.

Very large savings would be realized from basic machine inventory costs. A modern nursery can easily carry an inventory of tractors, wagons, combines, etc. worth more than \$300 thousand. A machinery pool of this magnitude has a high yearly repair and maintenance expenditure, plus, it is depreciated at about 10 percent per year. Thus 100 nurseries collectively have about \$30 million worth of machinery and a yearly replacement cost of about \$3 million.

Development of the System

The nursery system described in this paper requires two radical changes from the traditional nursery operation. The first is the fixed track and soil bin. The technology of this system has been developed for 35-foot-wide bins at the National Tillage Laboratory. The second change is to develop a carriage to hold the sowing, tending, and harvesting equipment. The different equipment for different operations would be mounted on the carriage when needed. For example, when the seeder was not in use it would be removed and stored. The development of the carriage and power source to move it on a rail system is not a complex problem.

LITERATURE CITED

Taylor, James H. 1981. A controlled-traffic agriculture system using a wide-Frame carrier. In: 7th International Conference of the International Society of terrain-vehicle systems. p. 385-407. Calgary, Canada, August 16-20, 1981.

ELECTRONIC COUNTER USE IN FOREST TREE NURSERIES

James C. Wynens
Georgia Forestry Commission - Macon, Georgia

Since the Mid 1960's, forest tree nurseries have gradually shifted to less labor intensive harvesting and packing techniques. This mechanization trend has necessitated development of methods to ascertain quantities of seedlings being packaged for shipment. This is a critical factor with operations that sell to the public. Most nurseries not using the traditional grading table counting method uses the weight system of determining package quantity. Other systems use volume measurements, seedling bed count and the grab or number of handfuls per thousand method. At best, there can be wide deviations from the actual count using these systems. These deviations cause administrators of forestry programs considerable frustration on the producing as well as receiving end of transactions.

With the advent of miniaturization in the electronic industries, the Georgia Forestry Commission began in 1981 to adapt this technology to the seedling counting problem.

After reviewing responses from a number of manufacturers of sensing devices, field testing began on the pulsed infrared through beam system. This system is used extensively in applications of detecting a uniform sized, clean target moving at a controlled velocity such as on conveying systems. Seedling detection requires the opposite capability of a detection device. An off-the-shelf device loaned by Motion Technology, Lilburn, Georgia, on first trial gave mixed results indicating certain refinements were necessary. After collaboration with their engineers the various intricacies of optics and detection seemed to become more adaptable to seedling counting. By regulating beam width, intensity and belt speed, a consistent seedling count of 95% accuracy was achieved.

Highlights of the Georgia Forestry Commission initial attempt to use this system is as follows:

These specifications must be considered in selecting a unit:

1. Fast Response Time: This is the detection and recovery by the unit relative to the velocity or speed and diameter of the target. The frequency in Mhz of the light pulse may also be considered. This may necessitate merging components from different manufacturers depending on the accessories needed for an operation.
2. Optics: A fast response source and detector with .8 mil seconds response time. Beware of specification claims. Switch response times are at best ambiguous. A manufacturer is hard-pressed to describe the response times of his units. He will choose a unit with capabilities that fall within the customer's environmental conditions of use. There are varying capabilities within the same model. One may exceed the minimum-maximum specs of that model. Just because the counter will count 1,000 times per sec, doesn't mean it will count 40 seedlings per second traveling at 70" per second on a lifting machine's belt.
3. Predetermined Counter Capability. The unit is set for a predetermined amount and will reset back to zero at the completion of the amount.
4. Output for Direct Outside Relay Switching. This is necessary to provide a mechanical means of marking or separating the flow of seedlings when the amount counted is reached, thus identifying each amount.

5. The unit should be resistant to outside electrical interference.

After much analysis, it was concluded that a counter and optics were needed to detect and register an object 1/8" in diameter spaced at least 1/8" apart and traveling 70" to 75" per second in a dirty environment.

Trials suggested fast response optics (light source-detector) at .8 millisecond response might do the job. The halo or light bounce around the target (seedling) due to the focal distance of target from the lens of the detector was alleviated by covering the lens with a bottle cap with a round opening or aperture 2/32" less diameter than the smallest target to be detected. This aperture was 3/4" in front of the lens. This allowed the target to pass up to 3/4" in front of this aperture and break the light beam.

ALIGNMENT OF LIGHT SOURCE AND DETECTOR (OPTICS)

The optic holders were mounted using a round dowel or rod to line them up. The receiving optic should be placed so that the seedlings pass not over 3/4" in front of its cover. The lens of the light source optic should be 5-6" opposite. The demodulator or the counter should have a glow bulb for alignment. An audio and visual component is also available for this purpose. A 3/4" diameter lens will allow considerable vertical and lateral movement of the optics in seeking the center of the light beam. Since this unit is capable of detecting at a 40' range, the amount of light through the aperture to the detector is adequate when turned to full intensity. If intensity is turned too low or alignment is with the light on the edge of the beam, erratic counts result. Excessive vibration of the optic mounts will cause beam breaks resulting in overcounting.

RESULTS:

In most of the counts, a consistent ± 0 to 5% of actual seedling count has been achieved. Foreign material such as bermuda grass tends to give an undercount by blocking the beam and allowing seedlings to pass uncounted. A 2/32" aperture on the detector will let most seedlings less than 1/8" diameter pass undetected. The light will penetrate the needle cover on the stems. In fact, this light will penetrate paper and white plastic so lens covers should be of metal. The receiving optic can be mounted in a box like enclosure. A stem diameter less than 1/8" will be counted if the junction of suckers or limbs with the stem blocks the light beam. Buildup of splatter from mulch or sand on the stem will block the light and cause a count of the seedling when bed inventoring. Spacing between seedlings on the lifting belt is better if the belt runs faster than the forward motion of the lifter.

CONCLUSION:

Electronic counting has very good possibilities in seedling bed inventory, mechanical harvesting and in shed counting of seedlings for small packaging.

The Georgia Forestry Commission will endeavor to have operational counter use in seedbed inventoring and mechanical harvesting by the 1982-83 lifting season.

The mechanics of using the relay switching after each predetermined volume count is not yet resolved. It can be used to energize an audio signal such as a bell, activate a spacing device between each counted thousand or to shift catching containers as each amount is counted. Sowing in narrow drills with precise spacing of seed will greatly enhance counter use in bed inventoring as well as the counting of seedlings while mechanically harvesting.

The Georgia Forestry Commission will use the following components assembled by Southern Belting and Transmission Company.

Model CB2-514-AOP-CBB-10AR10 DYNAPAR
Reset Counter, 4 decade, 12 VDC
Input, Relay Output

8760A-6501 OPCON DEMODULATOR
11 to 15.5 VDC Input, Open Collector
OUTPUT, .8 MSEC. Switching Time

1261B-100 OPCON Fast Response
Detector .8 MSEC Response Time

1160A-100 OPCON SOURCE

8905A PLUG IN OPCON BASE

Shielded for outside interference

Cost - $540.00

CALCULATION OF COUNTER RESPONSE TIME

Detect Time - .8 MSEC Minimum

Calculation of Detect Time:

Target Width - Beam Width = $\frac{\text{Dark Width}}{\text{Belt Speed}}$ (in./MSEC) = Detect Time

	Minimum Target Width		Beam Width (Aperture)			Dark Width				Detect Time	Remarks
(1/8")	.125"	-	(3/32")	.094	=	.031	=	$\frac{.031}{.080}$	=	.387 M SEC	Too Fast Belt Speed
(1/8")	.125"	-	(1/16")	.063	=	.062	=	$\frac{.062}{.080}$	=	.775 M SEC	Questionable
(1/8")	.125"	-	(1/16")	.063"	=	.062	=	$\frac{.062}{.075}$	=	.826 M SEC	Acceptable
(1/8")	.125"	-	(1/16")	.063"	=	.062	=	$\frac{.062}{.070}$	=	.885 M SEC	Acceptable

Minimum seedling spacing should equal the above target width at the above acceptable speed and beam width. Slower belt speeds gives more favorable detect times.

FOR FURTHER INFORMATION CONTACT:

COMPANY	PRODUCTS
Opcon, Inc. 720 80th Street, S. W. Everett, Washington 98203 AC 800 426-9184	Optics & Counters
Southern Belting 472 Plaza Drive, Suite C College Park, Georgia 30349 AC 404 767-1581	Opcon & Dynapar Components, Harvester Belts
Motion Tech 4791 Gresham Circle Lilburn, Georgia 30247 AC 404 972-5050	Engineering Factory Representatives
Dynapar Corporation 1675 Delany Road Gurnee, Illinois 60031 AC 312 662-2666	Counter

NURSERY INVENTORY WORKSHOP

R. P. Karrfalt and O. Hall[1/]

Abstract.--This paper covers the contents of a one hour workshop presented at the nursery conference. The topics of the workshop were: graphic and statistical description of variability, confidence to be placed in the accuracy of inventory estimates, application procedures for systematic and random sampling, history plots, and, controlling nursery bed variation with management practices.

Additional keywords: Variation, history plot, nursery management, numbers of samples, random sampling, systematic sampling.

How many trees do we have in the nursery? This is an easy question to ask, but often a hard one to answer. To obtain the answer, a careful inventory needs to be conducted.

The most accurate way to inventory is to count all the trees. It goes without saying that this cannot be done because it is too time consuming. Therefore, we will count only some of the trees, or, in other words, we say we will count only samples of the trees.

There are many shapes our samples might have, such as circles, squares, or single rows of trees. A sample shape that is easy to use and avoids some theoretical problems is the 1 x 4 foot sample.

We must first discuss some basic statistical concepts which are very necessary to use if we are to understand our counts of seedlings. With these basic concepts, we can discuss the application of three types of inventory: systematic plots, random plots, and history plots. We will conclude our workshop by discussing the relationship between management practices and inventory data.

VARIABILITY

Variety might be the spice of life, but variability is the hard part about nursery inventory. However, it is from our understanding of variability that we will be able to understand the merits of the different sampling procedures and be able to conduct accurate inventories while keeping costs as low as possible.

In an ideal world, the nursery bed would have only plantable seedlings growing in it, and there would be the same desired number of seedlings per square foot. The nurseryman could plant 31 seeds, evenly spaced on each square foot of bed, and all 31 would germinate and give 31 plantable seedlings. In such a world, inventory might not even be necessary. But if we did do one, we

---

1/ Seed Processing Specialist and Seed Testing Specialist, National Tree Seed Laboratory, Region 8, USDA Forest Service, Dry Branch, GA

would only need to measure one square foot and then to multiply the number of seedlings counted by the number of square feet of bed. An ideal nursery bed would be diagramed as in figure 1. There is no variability in our ideal nursery.

31	31	31	31
31	31	31	31
31	31	31	31
31	31	31	31

Figure 1.--A diagram of an ideal nursery bed with no variability.

In real life, variability is everywhere. The normal distribution is often a useful and appropriate way of describing the variability found in biological systems. To understand the meaning of distribution, we will look at some simple examples where we will draw some bar graphs.

Figure 2 shows a diagram of an extremely uniform nursery bed. Each linear foot is marked in this diagram, and the number of seedlings per square foot is shown on each linear division. (The number of seedlings per bed foot can be used in place of the number of seedlings per square foot. However, in this workshop we will use the per square foot term.) In our diagram there are 20 plots with 28 seedlings per square foot (spsf), 9 plots with 27 spsf and 11 plots with spsf. A bar graph of these counts, or frequencies, is shown in figure 3.

28	28	27	31	27	28	28	28
27	28	31	28	28	31	28	27
28	31	28	27	31	31	28	31
31	31	28	27	28	27	27	28
31	27	28	28	28	31	28	28

Figure 2.--Diagram of a hypothetical nursery bed showing the number of seedlings per square foot for each linear foot of bed.

Figure 4 is a diagram of a 100 foot nursery bed like the diagram in figure 2. We can make a bar graph (figure 5) from these counts. By drawing a smooth line across the top of the bars in figure 5 we have an approximate shape of the normal distribution and its relative, the t distribution.

There are some useful calculations that can be made for the normal distribution that will guide us in determining the precision of our estimates of numbers of trees and also on how many sample plots we should take.

The first calculation is for determining the sample mean $\overline{X}$. This is commonly called the average.

$$\overline{X} = \frac{\Sigma X}{n}$$

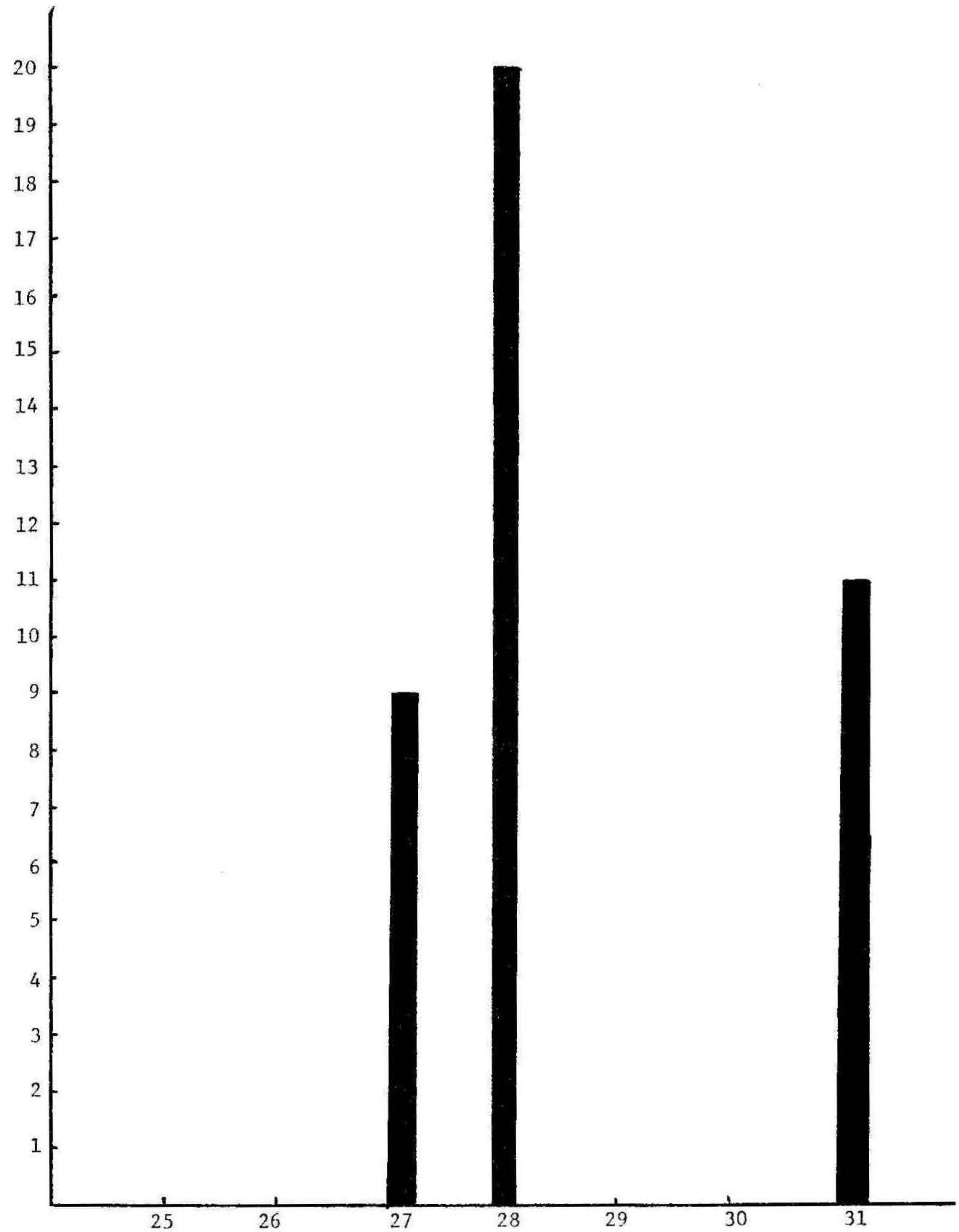


Figure 3.--Bar graph of frequencies of seedling densities in figure 2.

30	32	38	28	30
25	31	36	30	29
38	30	32	29	40
40	34	29	31	31
24	33	28	32	32
18	33	27	33	30
20	32	30	32	29
27	30	45	30	27
31	32	31	29	26
32	34	29	30	28
29	31	30	28	31
37	29	26	29	33
39	28	27	27	29
40	30	30	30	27
29	29	31	29	28
32	32	34	28	29
35	33	35	28	29
31	31	32	28	30
29	30	31	27	31
24	29	28	29	30

Figure 4.--A diagram of a hypothetical nursery bed, 100 feet long, with low variability, showing the number of seedlings per square foot for each linear foot. Called bed 1 in the text.

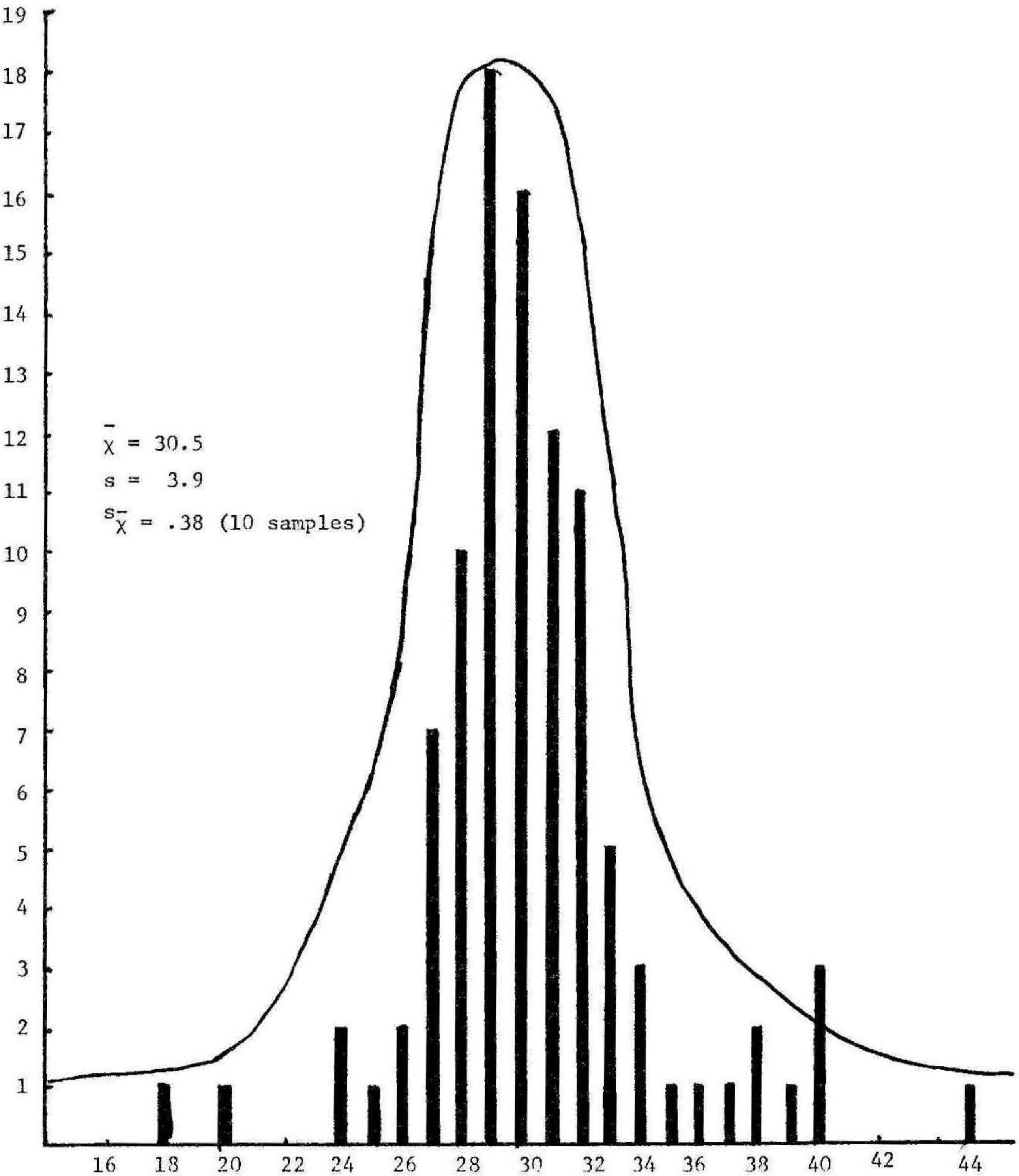


Figure 5.--Bar graph of frequencies of seedling densities in figure 4.

where Σ means to add together all the sample counts, x is a sample count, and n is the number of counts made. An example of a sample mean for 5 samples counts would be:

$$x = \frac{31+28+27+30+29}{5} = \frac{149}{5} = 29$$

The second calculation is for determining the sample standard deviation. This is a measure of the spread of the data or how variable it is. The sample standard deviation is computed as follows:

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n-1}}$$

This formula is most simply described by using the data from the example of the mean above.

$$s = \sqrt{\frac{(31)^2 + (28)^2 + (27)^2 + (30)^2 + (29)^2 - \frac{(145)^2}{5}}{5 - 1}}$$

$$s = \sqrt{\frac{961 + 784 + 729 + 900 + 841 - 4205}{4}}$$

$$s = \sqrt{\frac{4215 - 4205}{4}} = \sqrt{\frac{10}{4}} = \sqrt{2.5} = 1.58$$

Figure 6 shows how the s, sample standard deviation, describes how variable the counts are. Within one standard deviation above and below the mean ($\pm$ s) 68 percent of all other observations will fall; 95 percent are within $\pm$ 2s; and 99 percent are within $\pm$ 3s of the mean.

The hypothetical nursery beds diagramed in figures 4 and 7 give us some idea of how this relates to nursery inventory. For easier discussion we can call these bed 1 and bed 2 respectively. The seedling counts for bed 1 are graphed in figure 5 and the counts for bed 2 are graphed in figure 8. The mean value, $\bar{x}$, for these two beds are close, however, the standard deviation is twice as large in bed 2 as it is in bed 1. The importance of this difference in standard deviation is this. In bed 1 our random samples might be all from one side of the distribution, but because it is more compact, the estimate of the mean would not be too greatly in error. With bed 2 and its larger standard

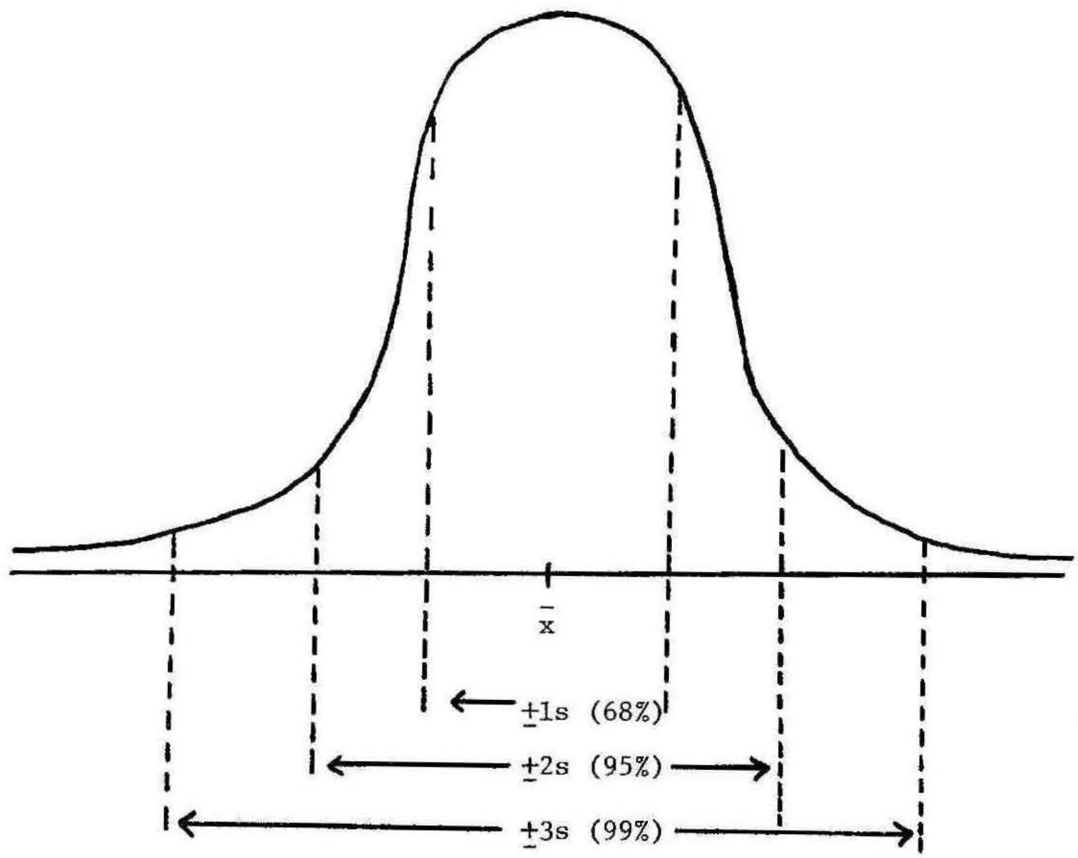


Figure 6.-- Structure of a standard normal distribution.

deviation we could be in greater error if our samples tended to come from mostly one side of the distribution. To compensate for this greater chance of error, we must take more samples. This at least reduces our chance for error.

The computation of the standard error of the mean, $s_{\bar{x}}$ is a way to describe with a number the effect we discussed in the last paragraph.

$$s = s/\sqrt{n}$$

where s is the sample standard error and n is the number of observations. For the example we used previously in this section we have that

$$s_{\bar{x}} = \frac{1.58}{\sqrt{n}} = \frac{1.58}{2.24} = .70$$

This s_x is some measure of how close a second measurement on the bed average would be if the boss were to check our work. For our simple example of five samples, we would expect that someone checking our work would have an $\bar{x}$ within 1.4 seedlings of our $\bar{x}$ of 29, 19 times of 20 checks.

10	38	45	28	30
20	25	40	29	29
30	27	28	30	35
28	32	30	32	15
29	15	31	31	19
32	18	32	27	23
35	20	28	29	29
60	29	28	30	40
55	32	29	32	42
40	34	30	32	35
35	40	40	31	32
31	50	32	30	33
29	60	18	27	18
32	53	19	28	22
34	40	15	31	27
40	32	31	29	32
48	29	29	33	37
31	31	32	40	31
32	40	30	41	29
28	30	29	35	28

Figure 7.--A diagram of a hypothetical nursery bed, with relatively high variability, showing the number of seedlings per square foot. Called bed 2 in the text.

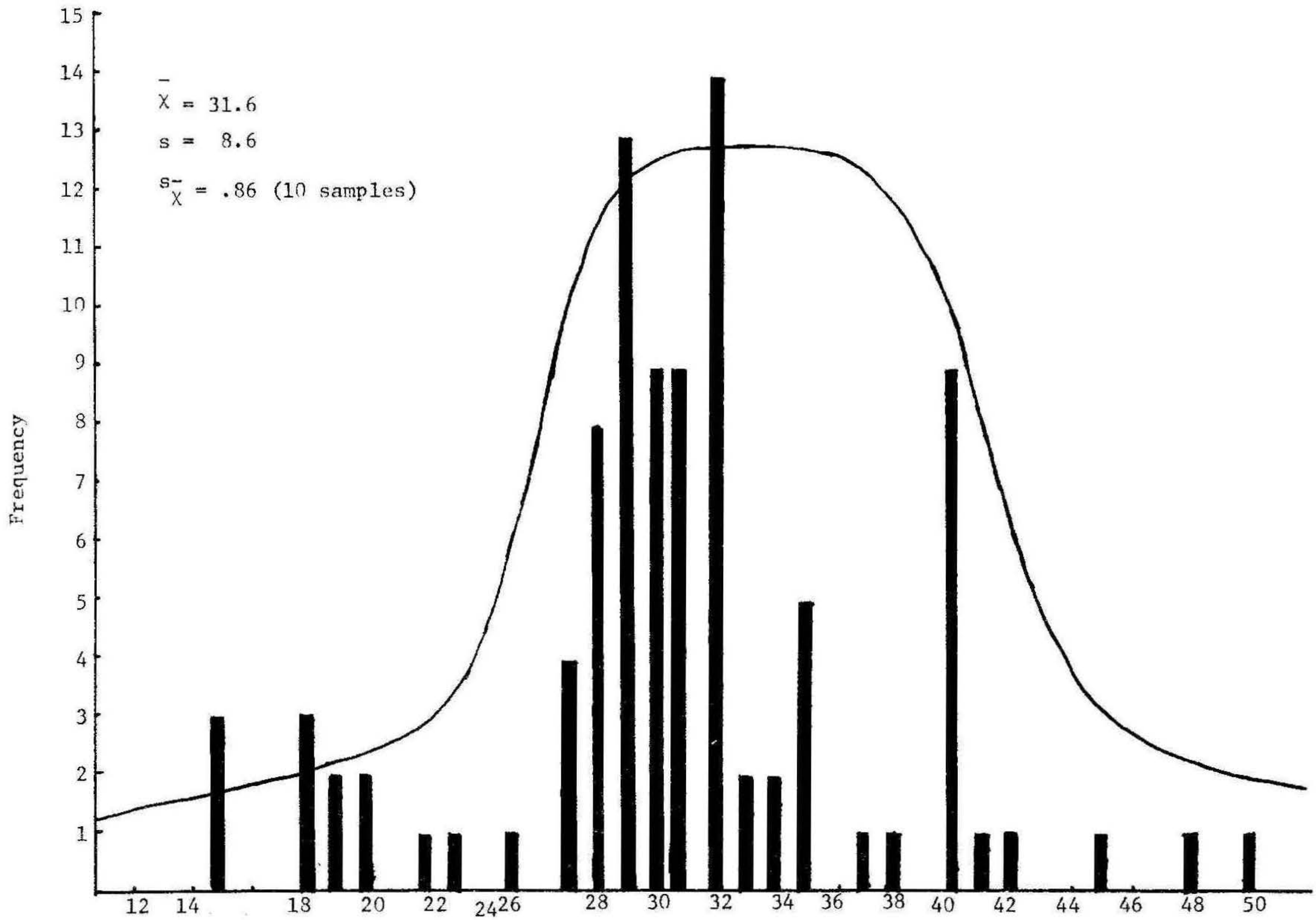


Figure 8.--Bar graph of frequencies of seedling densities in figure 4.

Our confidence that $\bar{x}$ is a precise estimate of the true average can be measured as follows:

$$\bar{x} \pm t_{.05,n} s_{\bar{x}} \quad .$$

Here $\bar{x}$,n and $s_{\bar{x}}$ are what we have already defined them as. The t is from a table of t values that can be found in most introductory statistic books. The .05 on the t is the error level. A .05 error level means that we will expect to be wrong only 1 time in 20 in the statements we make about what the average number of seedlings might actually be.

Continuing our simple example, our confidence interval will be as follows:

$$\bar{x} \pm t_{.05,4}\ s_{\bar{x}}$$

$$29 \pm 2.776\ (.70)$$

$$29 \pm 1.94$$

$$(27.1\ ,\ 30.9)$$

These computations lead us to say that we are wrong only 1 time in 20 when we say that the true average number of seedlings per square foot is between 27 and 31.

A simplified procedure for selecting a t value can be adopted if at least 10 samples are counted. This is because the change in the t value is relatively small when going from 10 samples to over 100 samples, especially when we consider how large the changes in standard error can be. Therefore, we can say that t will be 2.3 for an error level of 5 percent and will be 3.2 for an error level of 1 percent. Errors that result from using a constant t value are on the side of safety.

TYPES OF SAMPLING EXPLAINED

Systematic

Systematic sampling is the taking of a sample at fixed intervals, say every 20 feet, over the entire nursery bed. An example will be used to illustrate the procedure. We will adopt the sampling interval of every 20 feet. To start we randomly choose a number from 1 to 20. This can be done by drawing a number from a hat. Supposing the number is 7. Then we will measure in 7 feet from the end of the bed and make our count of seedlings on our 1 x 4 foot sample. The next sample will be taken at 27 from the end, the next at 47 and so forth. Choosing a number from the hat to tell us where to start is called making a random start. This is necessary if we want to use the statistics we discussed in the last chapter. The statistical calculations are very important because they are the only way to evaluate the precision of estimate, short of counting all seedlings.

Systematic sampling is somewhat easier to apply and relocate plots to verify previous counts. This is because of the regular intervals. However, we do not have the ability to improve the precision of our estimates as we have with random sampling.

Random Sampling

Plots are located by chance when sampling at random. Place 100 slips of paper, numbered 1 to 100, in a hat and thoroughly mix. Draw out as many slips of paper, one at a time, as there are samples to take. Supposing we desire to take 10 samples (this is a 10 percent sample) and the 10 slips of paper we draw have the numbers 8, 50, 3, 75, 42, 36, 19, 72, 56, 37. Then we measure in from the end of the bed 3, 8, 19, 36, 37, 42, 50, 72 and 75 feet and take a sample at each measured mark. Note that some plots are close together. This is to be expected because every lineal foot has an equal chance of being chosen. There is no problem in this unless the portion with more samples is noticeably different from the portion of the bed with few samples. In such cases we need to divide the bed into separate sampling units. More will be said about this in the last section. This system is a little more complicated to apply but offers the advantages of refining the estimate and minimizing the number of plots measured.

We will work through the application of random sampling on two hypothetical nursery beds. These two beds are diagramed in figures 4 and 7. Figure 9 is a data sheet that could be used to collect data and that we will use in our example. Figures 10 and 11 are worksheets that will be useful for computing and recording our estimates. In both figures 4 and 7 the circles indicate the first 10 samples taken, the squares the additional plots included to make the second estimate and the triangles the additional plots included to make the third estimate. The estimate number 1 for both beds in figures 10 and 11 was computed using the ten circled plots. Estimate 2 was then computed using the same 10 circled plots and the four plots marked with a square.

The mean and standard deviations in figure 10 were computed using a calculator with special functions to give the final answers directly without using the formulas of the previous section on variability. There are many relatively low cost machines that have these functions.

For estimate 1, bed 1, the mean number of seedlings per square foot is 31 or 12,400 seedlings in the whole bed. The standard error was 4.4 seedlings per square foot. The standard error of the mean is obtained by dividing the 4.4 by the square root of the number of samples which is 3.16. Therefore, the standard error of the mean is 1.39 seedlings per square foot. The 95 percent confidence interval for the mean is 31 ± 2.3 (1.39) or 31 ± 3.2. This confidence tells us that we are 95 percent certain in expecting the true average to be between 28 and 34 seedlings per square foot, or that the whole inventory in bed 1 is between 11,120 and 13,680 seedlings. If we are satisfied with being 95 percent sure we have between 11,120 and 13,680 seedlings we stop and go on to the next bed. By adding 4 more samples in making estimate 2 for bed 1, we narrowed the range in which the true average is expected to occur.

For bed 2, three estimates were made. With each estimate the average changed little. The standard error of the mean, however, dropped sharply by making the second estimate. The effect of this was to narrow the interval, by about one third, in which we expect to find the true average. In specific terms, our estimate of the number of trees in bed 2 can be expected to not be in error by more than 2,700 trees. And there is a 5 percent chance that this statement is incorrect. With estimate 2 we expect to be in error by no more than about 1,900

Bed 1			Bed 2		
Sample Number	Feet from end of bed	Seedlings per square foot	Sample Number	Feet from end of bed	Seedlings per square foot
1	3	38	1	3	30
2	10	32	2	15	34
3	33	28	3	29	32
4	43	32	4	33	60
5	51	30	5	36	32
6	73	27	6	50	30
7	83	40	7	64	32
8	93	29	8	67	29
9	95	28	9	76	29
10	98	30	10	90	35
11	24	34	11	16	40
12	27	32	12	44	30
13	68	30	13	46	32
14	79	27	14	97	37
15			15	9	55
16			16	54	19
17			17	69	32
18			18	78	40
19			19		
20			20		

Figure 9.--One possible worksheet for nursery inventory using random sampling.

Bed number	1		
Bed size	400		
Estimate number	1	2	
Number of samples (n)	10	14	
Mean($\bar{x}$) per sq. ft.	31	31	
Total	12,400	12,400	
Standard deviation (s)	4.4	3.9	
$s_{\bar{x}}$	1.39	1.05	
$2.3(s_{\bar{x}})$	3.2	2.4	
Confidence interval			
per sq. ft. low	27.8	28.6	
high	34.2	33.4	
Total bed low	11,120	11,440	
high	13,680	13,360	

Figure 10.--Worksheet for recording and computing estimates.

trees. The amount we can be off in our estimate has reduced because by using more samples the standard error of the mean was reduced. Estimate 3 failed to reduce the size of our confidence interval because the standard error increased slightly just by chance.

How many plots to count is an important question in random sampling. The cost of inventory is least when the fewest plots are counted, but this cost saving must be measured against the accuracy of the estimate. How accurate the estimate must be is the decision for the nurseryman.

Going back to figure 11, we see that our confidence interval for the mean for bed 2, estimate one, is from 10,880 seedlings to 16,320 seedlings.

Our estimate of the average, $\bar{x}$, is 13,600 seedlings. Therefore, if we promise this number of seedlings, we can be 95 percent sure that we would not be more than 2,720 seedlings short. In some cases there would be extra. In this case, we would not expect more than 2,720 extra seedlings. If we can live with

Bed number	2		
Bed size	400		
Estimate number	1	2	3
Number of samples (n)	10	14	18
Mean($\bar{x}$) per sq. ft.	34	34	35
total	13,600	13,600	14,000
Standard deviation (s)	9.3	8.0	9.5
$s_{\bar{x}}$	2.94	2.1	2.24
$2.3(s_{\bar{x}})$	6.8	4.8	5.2
Confidence interval per sq. ft. low	27.2	29.2	29.8
high	40.8	38.8	40.2
Total bed low	10,880	11,680	11,920
high	16,320	15,520	16,080

Figure 11.--Worksheet for recording and computing estimates.

the chance of being 2,720 seedlings short we can quit. If we have to be more certain, then we should take more samples as we did for estimate 2, bed 2. With this estimate, we are 95 percent certain that we will not be more than 1,920 short or over.

For bed two, we see that the confidence intervals on the average are smaller because of the lower variation in the bed. Therefore, the average estimate is used with greater confidence of being closer to the actual number of trees, the true average. A more uniform seedbed should be the aim of the nurseryman.

HISTORY PLOTS AND NURSERY INVENTORY

The primary purpose of history plots is for monitoring seedling growth and mortality. They are permanent sample plots located at random. What advantage do history plots offer over a general inspection of the seed beds? With a general inspection we can only make a guess of the amount of mortality and probably will not detect losses until an advanced stage. On a history plot, we know exactly how many trees are present, and can easily verify how many seedlings have died or are showing disease symptoms. In short, we can be more objective and specific in our determinations of crop survival or mortality. The early detection of mortality or above average survival can not be overemphasized if we consider how beneficial it will be to know that our survival is 10, 20 or even 30 percent below what we predicted. The advantage of history plots over spring inventory is that history plots represent less than 1 percent of the area, so they can be monitored rapidly.

History plots can also be used for inventory work. However, in this case extra random plots are taken in the general area of the history plot. The sample mean of these plots is calculated as well as the precision of the estimate of this mean. Enough extra samples need to be taken to give the desired precision just as we did in random sampling. Then for inventory purposes, we adjust the seedling count on the history plot up or down according to how it deviates from the mean of the extra plots. To this point, history plots are as much work as a random sampling inventory. The benefit will come in summer and fall inventory when only the history plots need to be measured.

A short example illustrates the procedure. The history plot has 30 seedlings per square foot and the extra plots 25 seedlings per square foot. For inventory purposes, then we will always reduce the count on the history plot by 1/6 or 17 percent. Adjustments are always made on a percentage basis.

To evaluate the percent cull factor, one half of the seedlings on the history plot is dug with a shovel and graded. The inventory count is reduced by the percent of culls. If there are 30 million seedlings and 10 percent culls, the plantable inventory would be 27 million.

CONTROLLING BED VARIATION AND MANAGEMENT OF THE NURSERY

Greater variation makes for greater problems in making accurate inventories and for keeping costs down. As we saw earlier, fewer samples were needed to obtain a desired confidence interval on the mean when the sample standard deviation was smaller. Fewer samples make for less work and, therefore, less cost. Therefore, controlling the variation is critical. One way to do this is to divide the nursery into parts that internally are uniform. Some examples of areas that would be internally uniform are areas of different soil types, areas prone to flooding, beds sown to one seed lot, and beds damaged by storms. These are types of variation which could be difficult or impossible to control. However, by recognizing where this variation exists, we can set boundary lines around the different areas and estimate a separate mean for each area.

There are practices that can reduce variation. These practices would include but not be limited to, working for uniform soil conditions, even water drainage, even application of pesticides, accurate seed sizing and sowing, use of high vigor seed and top pruning of seedlings. Because improved management gives lower variation, we can use our measures of variation as an objective way to evaluate our management practices. If variation is high we can expect that reducing variation will result in increased production and higher quality seedlings.

CONTROL OVER LIFTING AND PACKING

The purpose of a nursery inventory is to estimate the number of trees available for packing. Therefore, good control over the number of seedlings packed per bag or bundle is essential. A poor level of control at lifting can make even the most accurate of inventories meaningless. Whether seedlings are packed according to actual counts or by weight is not important. What is important is that someone has continuous responsibility to verify the counts and that a system exists to make corrections for errors.

Conducting an accurate inventory, controlling the variation, and maintaining control over packing require time, money and effort. Often it seems difficult to have enough of each to do all the jobs we are expected to do. Putting enough into inventory control is important to guide other practices and to maintain a good image for the nursery. In other words, a good inventory system can be indispensable in gaining maximum return from scarce resources and maintaining good relations with our customers and superiors who will supply resources to the nursery.

SUMMARY OF A WORKSHOP ON MANAGING NURSERY LABOR DURING LIFTING AND PACKING

John C. Brissette[1]

Abstract.--Three nursery managers presented brief descriptions of quite different methods of managing their temporary labor forces during lifting and packing. The audience discussed the ideas presented and other aspects of labor management and accountability. The variety of systems used for lifting and packing have a marked influence on the labor management styles of nursery managers.

INTRODUCTION

Two concurrent workshops were held at the Western Session of the Southern Nursery Conference to discuss management and accountability of temporary nursery labor during lifting and packing. The discussion was lead by 3 nursery managers: Chuck Gramling of the USDA Forest Service's W. W. Ashe Nursery in Brooklyn, Mississippi; Floyd Hickam of the Arkansas Forestry Commission's Baucum Nursery near North Little Rock; and Tony Simms of the Louisiana Office of Forestry's Columbia Nursery near Columbia. The objective of the workshops was to generate audience participation and interaction in a discussion about labor management at various nurseries.

PANEL DISCUSSION

At the Ashe Nursery, Chuck Gramling instituted a system of work standards and individual accountability for all workers on the grading and packing lines. Seedlings are culled to minimum standards and each grader is expected to accurately grade 200 seedlings each 5 minutes. The graders place a ticket on each batch of seedlings they pass down the table and a supervisor records each employee's production. The batches are also sampled randomly for accuracy of culling. The slurry sprayers initial each bag before it is strapped closed. For the 1981-82 season, 1.2 million seedlings could be packed on a good day while running 3 lines with about 10 graders each.

At the Baucum Nursery the packing shed is organized in stations. At each station the packer sprays clay slurry over a half barrel covered with expanded metal then packs the seedlings in a bag suspended from a scale. The bags are numbered by station for accountability. Two lines are set up with 4 such stations along a variable speed grading table controlled by the fastest packer. The best packers can process 200 bags per day. Last season up to 1 million seedlings were packed per day with 8 packers. Custom grading

---

1/ Nursery and Tree Improvement Specialist, Southern Region, USDA Forest Service, Jackson, MS.

requires additional people at the end of the table before the packing stations. The lifting crews are considered as work units rather than individuals. A total of 38 to 44 employees are used for lifting and packing.

The Columbia Nursery switched from shed packing to field packing for the 1981-82 season. Tony Simms has a paper elsewhere in these proceedings describing their field packing methods. At this workshop, however, he remarked that one of the unexpected benefits of field packing was reduced labor problems. Field packing not only lowered the required number of employees by nearly one half, it reduced dissention between inside and outside crews. All employees felt more a part of the team.

GROUP DISCUSSION

The workshops did generate some good discussion. An industry nursery manager talked about the value of developing a loyal and dependable work force by keeping fewer employees more of the year. The benefits of incentive pay and other kinds of rewards were debated. A philosophy of good communications and fair treatment of temporary labor came out as the most important factor in maintaining high employee morale and productivity. The problem women supervisors face with both male and female employees was also discussed.

Availability of labor and following traditional methods are important factors in determining what systems are used for lifting and packing, and therefore how crews are supervised. A method of evaluating the packing operation was suggested by one of the nursery managers in the audience. He said the ratio of packers to support workers; including supervisors, counters, strappers, forklift operators, and others, could be used as a measure of efficiency. The ratio will vary with the number of species and seedlots processed, the number of operations performed and other factors. However, the lower the ratio required to do the job, the greater the efficiency of operation.

SEEDLING QUALITY: SUMMARY OF A WORKSHOP

John C. Brissette and Clark W. Lantz[1/]

Abstract.--The results of discussion group presentations at a workshop on seedling quality are summarized. The concept of seedling quality held by most of the participants was based primarily on seedling morphological characteristics. The ideal loblolly pine (Pinus taeda L.) or slash pine (P. elliottii Engelm.) seedling is described based on the group presentations.

INTRODUCTION

In 1979, at a workshop on evaluating seedling quality, a world-wide group of scientists, nursery managers and foresters agreed on the following definition: "The quality of planting stock is the degree to which that stock realizes the objectives of management (to the end of the rotation or achievement of specified sought benefits) at minimum cost. Quality is fitness for purpose" (Willén and Sutton 1980). At the Eastern Session of the Southern Nursery Conference in Savannah, we assessed the participants' concept of seedling quality in two concurrent workshops. After a brief introduction in which morphological and physiological indicators of seedling quality were presented, the participants divided into discussion groups of about 10 people. Each group developed its own concept of seedling quality and then shared its views with the whole workshop. Each session of the workshop consisted of five groups. What follows is a summary of those 10 presentations.

RESULTS

The consensus of each workshop was quite different. The participants in the first session felt that seedling quality can only be assessed at the nursery. They reasoned that what happens to stock after it leaves the nursery may affect field performance, but does not reflect upon its quality. The participants in the second workshop session, however, argued that field performance is the ultimate indication of seedling quality.

The group presentations emphasized southern pine (Pinus spp. L.) planting stock. Some attempted to quantify loblolly pine (P. taeda L.) and slash pine (P. elliottii Engelm.) seedling quality. Nine of the groups discussed quality in terms of observable or measurable characteristics. The shoot to root ratio was the characteristic most often mentioned. Although 8 groups considered shoot-root ratio an indication of seedling quality, only 1 group quantified it by saying that a desirable ratio is 2:1, shoot to root.

The next most mentioned characteristic was the root system. Seven groups discussed the importance of root morphology to seedling quality. The

1/ Nursery and Tree Improvement Specialists, Southern Region, USDA Forest Service, Jackson, MS and Atlanta, GA.

need for a fibrous root system was often stated. Some groups quantified what they considered a good root system. The recommended overall length varied from 5 to 7 in. (13-18 cm). One group specified that the root system should be greater than 25 percent of the total seedling weight.

Root collar diameter, "dormancy", and absence of disease were each cited by 6 groups as important indicators of seedling quality. Some quantified desired root collar diameter, others did not. Two groups indicated that the caliper should be between 4/32 and ¼ in. (3-6 mm). One group specified 3/16 to 3/8 in. (5-10 mm) as the acceptable range of root collar diameters. While no attempt was made to physiologically define dormancy, it was specified that quality seedlings should be "dormant" (not actively growing) for outplanting. Freedom from disease was also specified by a majority of the groups.

Half of the groups said that seedling height and the presence of mycorrhizae were characteristics useful in evaluating planting stock quality. The range of heights mentioned varied from 7 to 12 in. (18-30 cm) with planting method a consideration. One group specified desired height by location. For Texas they recommended seedlings be 7 to 9 in. (18-23 cm), for North Carolina 10 in. (25 cm), and for Georgia 9 to 10 in. (23-25 cm). While mycorrhizae were recognized as being characteristic of quality seedlings, none of the groups quantified the amount of mycorrhizal roots desired.

Other morphological characteristics cited by 1 to 3 groups included bud condition, presence of secondary needles and woody bark, freedom from injury, and seedling form and vigor. Some groups discussed the importance of seed processing and nursery culture on seedling quality. Two groups suggested crop uniformity as an indication of quality. None of the groups mentioned the effects of lifting, handling and storing on the quality of planting stock.

Carbohydrate or starch reserves and root growth potential were cited by 3 and 2 groups respectively as important physiological characteristics of seedling quality. While the importance of such physiological indicators is recognized, the need for field applicable assessments was stressed.

Half of the groups mentioned the impact of genetic considerations on seedling quality. Selection of the best species and seed source for the intended planting site was emphasized. Two groups specified genetic improvement as a characteristic of quality planting stock. Including genetic implications in a discussion of seedling quality was controversial in one workshop session but no consensus was formed.

SUMMARY

We did not attempt to arrive at a definition of seedling quality at these workshop sessions. However, in assessing what was presented it must be concluded that the general concept of stock quality is based primarily on morphological characteristics of the seedlings. Based on the 10 group presentations the ideal loblolly or slash pine seedling could be described as follows:

1. -being of the appropriate species and seed source for the planting site

2. -having a balanced shoot-root ratio, perhaps approximately 2:1
3. -having a fibrous root system 5 to 7 in. (13-18 cm) long with abundant mycorrhizae
4. -the root collar diameter should be 4/32 to 3/8 in. (3-10 mm)
5. -having a good bud set indicating a low state of physiological activity in the stem
6. -being free from disease and injury
7. -being 7 to 12 in. (18-30 cm) tall, depending on the intended planting site and planting method
8. -having secondary needles and a woody stem
9. -having sufficient stored food reserves and the potential for rapid and prolific root growth after outplanting.

Evaluating seedling characteristics may allow us to predict field performance, but as one group pointed out; "Morphological and physiological characteristics are not 'quality' but are indicators of quality. We need to know how well these indicators tell us about quality."

LITERATURE CITED

Willēn, P. and R. F. Sutton. 1980. Evaluation of stock after planting. New Zealand J. of For. Sci. 10(1): 297-299.

SAVANNAH

S.E. FOREST NURSERY CONFERENCE

1982 Attendees

NAME	ORGANIZATION	ADDRESS
Dave Fisher	Kentucky Div of Forestry	Box 97, Gilbertsville, KY 42044
Newt Coop	Kentucky Div of Forestry	Rt 1, Box 854, W Liberty KY 41472
Jim Cook	GA Forestry Commission	Rt 2, Box 162, Washington, GA 30673
R. W. McPherson	R. W. McPherson & Assoc	Box 5011, Monroe, LA 71203
Simon Weng	"	"
John Vann	U. S. Forestry Service	1720 Peachtree Rd,N.W., Atlanta, GA
Clark Lantz	"	"
Wayne Barrick	Kirby Forest Ind., Inc.	Rt 2, Box 83-A-24, Winnsboro, TX 7549
Jerry Abbott	"	P. O. Box 577, Silsbee, TX 77656
Rhett Brooks	St. Joe Paper Company	Rt 1, Box 70, Lamont, FL 32336
John Brisette	USDA Forest Service	St 3260, 300 Woodrow Wilson,Jackson,M
Bill Rayfield	Kimberly Clark Corp.	PO Box 206, Harpersville, AL 35078
Howard Stanley	GFC Page-Walker	Reidsville, GA 30453
Don Stringfield	Westvaco Corp.	Greenville, SC
Kent W. Lewis	Reddick Fumigants	Williamston, NC 27892
Charlton McLeod	SC Forestry Commission	Wedgefield, SC
Tom Gilpin	GA Kraft Company	PO Box 149, Buena Vista, GA 31803
Manfred Mielke	USDA Forest Service	180 Canfield St, Morgantown,WVA 31803
Richard Jernigan	GA Forestry Commission	Box 819, Macon, GA
David B. Brown	SC Forestry Commission	Trenton, SC 29847
Helen M. Summer	"	"
Carl C. Durham	SC Forestry Commission	Salem, SC 29676
Carl D. Wood	Buckeye Cellulose Corp.	Rt 4, Box 178, Perry, FL
J. E. Alderman	ITT Grinnell	Rt 8, Canton, GA
Ray Eubanks, Sr.	Senninger Irrigation, Inc.	Orlando, FL
Paul Carson	SC Forestry Commission	Box 21707, Columbus, SC 29221
Richard Purvis	ITT Grinnell Corp	
Coy Womack	GA Forestry Commission	Davisboro, GA 31018
David Green	SC Forestry Commission	PO Box 766, St. George, SC
Jim Rowan	USFS	Athens, Georgia
Ed Barnard	FL Division of Forestry	PO Box 1269, Gainesville, FL 32602
Charlie Sears	FL Division of Forestry	Chiefland, FL 32626
Ken McNabb	U. of Florida	Gainesville, FL
H. Daniel Brown	USFS-Atlanta	1720 Peachtree, Atlanta, GA 30367
Frank VandeLinde	Brunswick Pulp Land Co.	Box 860, Brunswick, GA
Joe Douberly	Brunswick Pulp Land Co.	Jesup, GA
Leroy Mizell	Buckeye Cellulose Corp.	Rt. 3, Box 635, Perry, FL
Ron Blackwelder	Champion Intl. Corp.	37 Villa Rd.-Suite 319, Greenville,SC
James R. Whitfield	R.A. Whitfield Mfg. Co.	5431 Gordon Cir.SW, Mableton, GA
Evelyn Whitfield	" " " "	" " " " " "
Spencer R. Stone	Minn. DNR-Forestry	Gen. Andrews Nursery,Willow River, MINN 55795
Ronald L. Ramsey	Weyerhauser Co.	Rt. 2, Box 339, Washington NC 27889
Rick Brooks	Federal Paper Board Co.	P.O. Box 1001, Lumberton, NC 28958
George Michael Johnston	GFC	Route 2, Cochran, GA
Wayne Belflower	FFC	Route 1, Box 347, Byron, GA
John Ayton	Maryland-Dept. of Natural Resources	Harmans, MD 21077

S.E. FOREST NURSERY CONFERENCE

1982 Attendees

NAME	ORGANIZATION	ADDRESS
Kirk Hinson	Southern Seed Co.	Baldwin, GA
Stanley Hinson	Southern Seed Co.	Baldwin, GA
Mason C. Cloud	Texas Forest Svc.	Texas A&M Univ., College Sta., TEX
Ed Dennis	Container Corp. of Amer.	Brewton, AL
Barry Turpin	Champion Intl.	Rt. 1, Box 251, Verbena, AL
Lee Draper, Jr.	Container Corp. of Amer.	P.O. Box 626, Cullahan, FL
Jim Rakestraw	Union Camp	P.O. Box 216, Rincon, GA
Marvin Zoerb	" "	P.O. Box 216, Rincon, GA
W.L. Pryor	" "	P.O. Box 56, Bellville, GA
D.A. Banks	" "	P.O. Box 56, Bellville, GA
J.P. Riggs	" "	P.O. Box 56, Bellville, GA
Richard Thatcher	Lucky Peak Nursery,USFS	Boise, IDAHO
Ralph Gray	Grayco Harvesters	Heidelberg ONT Canada
Gray Zavitz	Grayco Harvesters	Heidelberg ONT Canada
Cliff Snyder	N.C. State Univ.	Raleigh, NC
Harry Vanderveer	N.C. State Univ.	Raleigh, NC
Russ Lea	N.C. State Univ.	Raleigh, NC
Alan L. Webb	St. Regis Paper Co.	Lee, FL
Jake Stone	Union Camp Corp.	Franklin, VA
John Hamner	Union Camp Corp.	Savannah, GA
John Godbee	Union Camp Corp.	Savannah, GA
Frank Bonner	U.S. Forest Svce	Starkville, MS
Bill Elam	Mississippi State UNIV.	Mississippi State, MS
Sam Campbell	Scott Paper	P.O. Box 5869, Saraland, AL
Ed Cordell	USFS	Box 5895, Asheville, NC
Clarence Lemons	Hendrix & Dial Inc.	P.O. Box 589, Oxford, NC
Tom Dierauf	VA Div. of Forestry	2514 Hillwood Pl., Charlottesvill VA
Mark Steigerwalt	Continental Forest Inc.	P.O. Box 6989, Savannah, GA
Dan L.nd	Auburn Univ.	Auburn University, AL
David South	Auburn Nursery Coop.	Auburn University, AL
Jim Boyer	Auburn Nursery Coop.	Auburn University, AL
Franklin A. Pokorny	Dept. Hort, Univ. GA	
R. Wayne Bell	Intl. Forest Seed Co.	Box 76008, Birmingham, AL
Walter D. Kelley	Botany, Plant Path Dept.	Auburn University, AL
Don & Selina Marx	USDA, Forest Service	IMRD, Athens, GA
Carlton Windsor	ITT Rayonier	Fernandina Bch, FLA
John J. Gill	Georgia Kraft Co.	Rome, GA
David G. Borem	Ga. Pacific Corp.	Savannah, GA
John D. Johnson	Virginia Tech	Blacksburg, VA
Oscar Hall	USDA Forest Service	Dry Branch, GA
Terrell Brooks	GA Forestry Commission	P. O. Box 819, Macon, GA 31298
William C. Harper	" " "	" " " "
Jim C. Wynens	" " "	" " " "
John W. Johnson	" " "	Glenwood, GA
Mike Young	" " "	Milledgeville, GA

Ken Jeffries	NC Forest Svce.	Raleigh, NC 27602
K.O. Summerville	NC Div. Forest Resources	Rt. 2, Box 206, Clayton, NC 27520
Frank Migacz	Jarke Corp	6333 W. Howard, Niles, IL 60648
G.W. Thompson	ITT Rayonier Inc.	Rt. 2, Box 18, Glennville, GA.
Dale Rye	Container Corp. of Amer.	P.O. Box 129, Archer, FL 32618
Bill Padgett	ALA Forestry Comm.	513 Madison Ave., Montgomery, ALA.
Charlie Rountree	SC Forestry	Box 2107, Columbia, SC 29221
Wilson Norris	NC Forest Ser.	Rt.B, Box 380, Goldsboro,NC
Leray Worley	NC Forest Svc.	Rt. 3, Box 203, Clayton, NC
John Conn	Champion Intl.	Rt. 1, Box 97A-1, Swansea, SC 29160
Jim Carter	Hammermill Paper Co.	417 Medical Center, Selma, ALA.
Robert Crum	Hammermill Paper Co.	417 Medical Center, Selma, ALA.
B.C. Rodrigo	Univ. of Ga.	Athens, GA 30602
Jim Barnett	U.S. Forest Svc.	2500 Shreveport Hwy, Pineville LA
Ron Hay	Univ. of Tennessee	P.O. Box 1071, Knoxville, TENN
Steve Oak	U.S. Forest Svce.	Box 5895, Asheville, NC
Carl A. Muller	Hammermill Paper Co.	417 Medical Center Pkwy
C. B. Davey	NC State Univ Forestry	Raleigh, NC 27650
Gary Cannon	Great Southern Paper Co	Cedar Springs, GA 31732
Paul Neal	Continental Forest Ind.	Statesboro, GA
Rob MacGregor	" " " "	Savannah, GA
R. D. Hendrix, Jr.	" " " "	Statesboro, GA
Olen Aycock	U.S. Forest Service	Atlanta, GA

1982 WESTERN SESSION, SOUTHERN NURSERY CONFERENCE

Dr. Larry Abrahamson
Dept. of Environmental & Forest Biology
SUNY College of Environmental Science & Forestry
Syracuse, NY 13210
(315) 470-6777

Charles Afieltranger
USDA Forest Service
2500 Shreveport Hwy
Pineville, LA 71360
(318) 473-7292

James Bright
Miss. Forestry Comm.
908 Robert E. Lee Bldg.
Jackson, MS 39201
(601) 354-7124

John Brissette
USDA Forest Service
Suite 3260,
200 Woodrow Wilson
Jackson, MS 39213
(601) 825-0240

Bonnie Appleton
Dept. of Horticulture & Landscape
  Architecture
Okla. State University
360 Agriculture Hall
Stillwater, Okla. 74078
(405) 624-5412

Kurt Atkinson
Dept. of Agriculture, Forestry Division
122 State Capitol
Okla. City, Okla. 73105
(405) 521-3886

John Baker
International Paper Co.
Rt. 1, Box 314-1
Bullard, TX 75757
(214) 894-6564

Rick Barham
#7 Lake View
Bullard, TX 75757
(214) 825-3848

Jim Barnett
U.S. Forest Service
2500 Shreveport Hwy.
Pineville, LA 71360
(318) 473-7216

Charles Berry
Southeastern Forest Experiment Station
Forestry Sciences Laboratory
Calton St.
Athens, GA 30602
(404) 549-8823

Bill Boechman
Weyerhaeuser Nursery
RR #2, Box 10A
Ft. Towson, Okla. 47435
(405) 873-2717

Darlene Bolser
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Leonard Bosch
Continental Forest Industries
Box 160
Hodge, LA 71247

James Boyer
Auburn University
510 E. University Dr.
Auburn, AL 36830
(205) 821-6208

Lee Carroll
Rt. 6, Box 491
Livingston, TX 77351
(713) 563-4797

Mason Cloud
Texas Forest Service
System Administration Building
College Station, TX 77843
(713) 779-6275

Norman Coleman
Masonite Corporation
Route 1, Box 25A
Shubuta, MS 39360
(601) 649-2721

Dr. Ed Cordell
USDA Forest Service, SA
P.O. Box 5895
Asheville, NC 28813
(704) 258-2850 Ext. 625

Max Craighead
Extension Forester
012 Ag. Hall
Okla. State University
Stillwater, Okla. 74074
(405) 624-5514

Robert Cross, Jr.
International Paper, Co.
Rt. 3, Box 312C
Natchez, MS 39120
(601) 446-6258

Roger Davis
Dept. of Agriculture, Okla. Forestry Division
122 State Capitol
Okla. City, Okla. 73105
(405) 521-3886

Michael Duplechian
Oberlin Nursery LA. Office of Forestry
P.O. Box N
Oberlin, La. 70655
(318) 639-2911

Robert Fewin
Texas Forest Service
Rt. 3, Box 216
Lubbock, TX 79401
(806) 746-5801

Raymond France
International Paper Co.
203 Hurricane Rd.
Natchez, MS 39120
(601) 442-7421

Chuck Gramling
U.S. Forest Service
WW Ashe Nursery
Box 8
Brooklyn, MS 39425
(601) 584-8488

Dr. Richard Guldin
Southern Forest Experiment Station
T-10210, US Postal Service Bldg.
701 Loyola Ave
New Orleans, LA 70113
(504) 589-6651

Andrea Hahm
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Floyd Hickam
Arkansas Forestry Commission
P.O. Box 4523, Asher Station
Little Rock, AR 72214
(501) 945-3345

Rick Horton
International Paper Co.
Box 23
Bluff City, Arkansas 71722
(501) 685-2562

Kent Howerton
Hendrix & Dail, Inc.
28631 Lochlevan Ct.
Huffman, TX 77336
(713) 324-3228

William Isaacs
International Forest Seed Co.
P.O. Box 76008
Birmingham, Al. 35253
(205) 591-1989

Robert Karrfalt
USDA Forest Service
National Tree Seed Lab.
Box 182B Rt. 1
Dry Branch, GA 31020
(912) 744-3311

Clarence Lemons
Hendrix & Dail, Inc.
P.O. Box 589
Oxford, N.C. 27565
(919) 693-4131

Harold Lovell
Texas Forest Service
P.O. Box 617
Alto, Texas
(713) 858-4202

Robert Major
U.S. Forest Service
1390 Ridgefield Dr.
Roswell, GA 30075
(404) 993-9630

Albert McCarty
Masonite
Rt. 5, Box 406
Waynesboro, Miss. 39367
(601) 735-9224

William McCullers
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Steve McDonald
USDA Forest Service
12th and Indep.
Washington, D.C.20013
(202) 382-8408

Pat McDowell
Dept. of Agriculture, Forestry Division
P.O. Box 3885
Enid, Okla. 73702
(405) 233-1194

Wilson McNeal
Mississippi Forestry Commission
903 Robert E. Lee Bldg.
Jackson, MS 39201
(601) 354-7124

Frank Migacz
Jarke Corp.
215 Applewood Ct.
Boling Brook, IL 60439
(312) 647-9633

Bart Mortensen
Colo-Hydro, Inc.
1561 Belmont Dr.
Longmont, CO.
(303) 823-6658

Ken Munson
University of Florida
3510 NW 22nd Dr.
Gainesville, FL 32605
(904) 378-4368

Tom Murray
Dept. of Agriculture, Forestry Division
P.O. Box 2023
Burns Flat, Okla. 73624
(405) 562-4884

Al Myatt
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Jay Odell
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Olon Ross
Miss. Forestry Comm.
Rt. 1, Box 130
Mt. Olive, Miss. 39119
(601) 797-3584

Jim Rowan
U.S.F.S. SE For Exp. Sta.
Carlton St.
Athens, GA 30602
(404) 546-2455

Gary Shoemake
Mississippi Forestry Commission
Route 4, Box 524
Waynesboro, MS 39367
(601) 435-9512

Dewey A. "Tony" Simms
Louisiana Office of Forestry
Columbia Nursery
Box 647
Columbia, LA 71418
(318) 649-7463

Gene A. Sirmon
U.S. Forest Service
132 Richmont Dr.
Brandon, MS
(601) 825-6073

Stuart Slayton
USDA Forest Service
Wind River Nursery
Star Route
Carson, WA 98610
(509) 427-5679

Ben Smith
OSU Forestry Research Station
RFD #1, Box 63
Idabel, Okla. 74745
(405) 286-5175

Norm Smola
Soil Conservation Service
402 N Manning
Stillwater, Okla.

David South
Dept. of Forestry
108 White Smith Hall
Auborn University, AL 36849
(203) 826-4050

Olin Stubbs
LA Office of Forestry
Box 1628
Baton Rouge, LA 70821
(504) 925-4507

Chuck Tauer
OSU University
012 Ag. Hall
Stillwater, Okla.
(405) 624-5462

John Vann
U.S. Forest Service
1720 Peachtree Rd.
Atlanta, GA
(404) 881-3551

Charles Venator
USFS
801 Pinelake Dr.
Pineville, LA 71360
(318) 448-3630

Jack Vozzo
Southern Forest Experiment Station
Forestry Sciences Laboratory
Box 906
Starkville, MS 39759
(601) 323-8162

Michael P. Vorwerk
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Carl Whitcomb
OSU, Dept. of Horticulture
360 Ag. Hall
Stillwater, Okla. 74074
(405) 624-6461

James Whitfield
R.A. Whitfield Mfg. Co.
6435 Gordon Cir. SW
Mableton, GA 30059
(404) 948-1212

Scott Williams
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Charlotte Willis
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

Denise Word
Texas Forest Service
Rt. 3, Box 216
Lubbock, TX 79401
(806) 746-5801

Dennis Young
Dept. of Agriculture, Forestry Division
C&W Area Headquarters & Nursery
Rt. 1, Box 44
Washington, Okla. 73093
(405) 288-2385

☆U.S. GOVERNMENT PRINTING OFFICE:1983 -651 -377/ 4924

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE