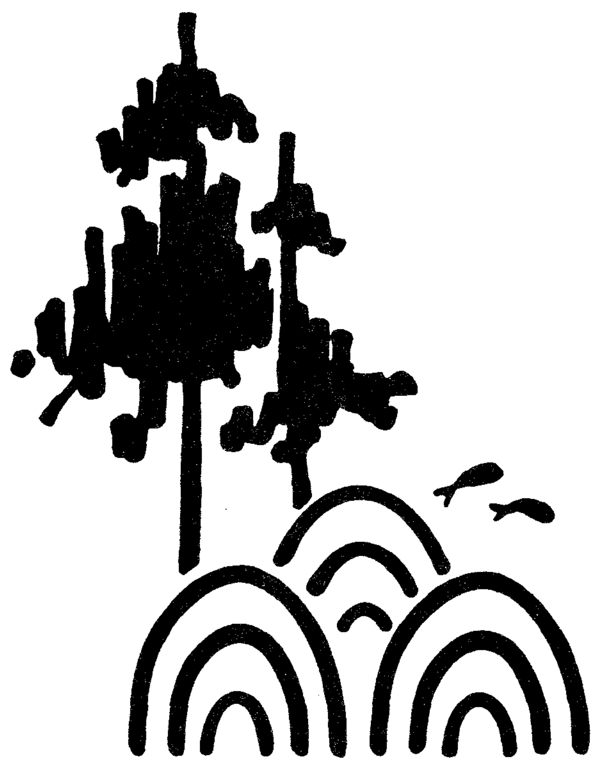
Pine Seedling Production in the South: A Problem Analysis



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by

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TABLE OF CONTENTS

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INTRODUCTION

Nearly one-half of the country's commercial forest land is located in the 13 southeastern states (Hammond, 1981). Of this 219 million acres extending from Virginia to Texas, one-half is composed of pine and mixed pine-hardwood forests (Anonymous, 1980). Presently, this region supplies 35 percent of the nation's annual softwood needs, second only to the Pacific Northwest which supplies 52 percent (Anonymous, 1980). Future projections indicate a reversal in the importance of these two regions with the southeastern states ultimately supplying 55 percent by the year 2030. Within this fifty year span the southern pine region will have to double its 1980 fiber production to meet this projected production level.

A key factor in forest production is rapid and adequate stand regeneration following harvest. The trend over the last two decades has been an increasing emphasis on artificial regeneration, specifically the planting of bare-root seedlings grown in nurseries. In 1979, ninety-six percent of the forest land in the south was artificially reforested by planting (USDA Forest Service, 1980). In the past ten years the number of acres planted annually in the south has increased from 1 million to 1.5 million (Williston, 1980). This represents, based on an average of 680 seedlings per acre, an increase from about 650 million to between 900 million and 1.2 billion pine seedlings planted annually. This number is expected to double to about 2.4 billion by 1985.

Associated with this trend of increasing seedling production has been a decline in seedling survival. In the last six years the south-wide average has dropped from 83% to 72% (Weaver, et al. 1980). During the last planting season 30 percent or about 350 million seedlings did not survive (Venator, 1981). The reasons for the increase in seedling mortality are many. One contributing factor is the shift from planting of abandoned agricultural land, i.e. old-field sites, to planting of converted hardwood or pine-hardwood sites which are typified by a large amount of competing vegetation.

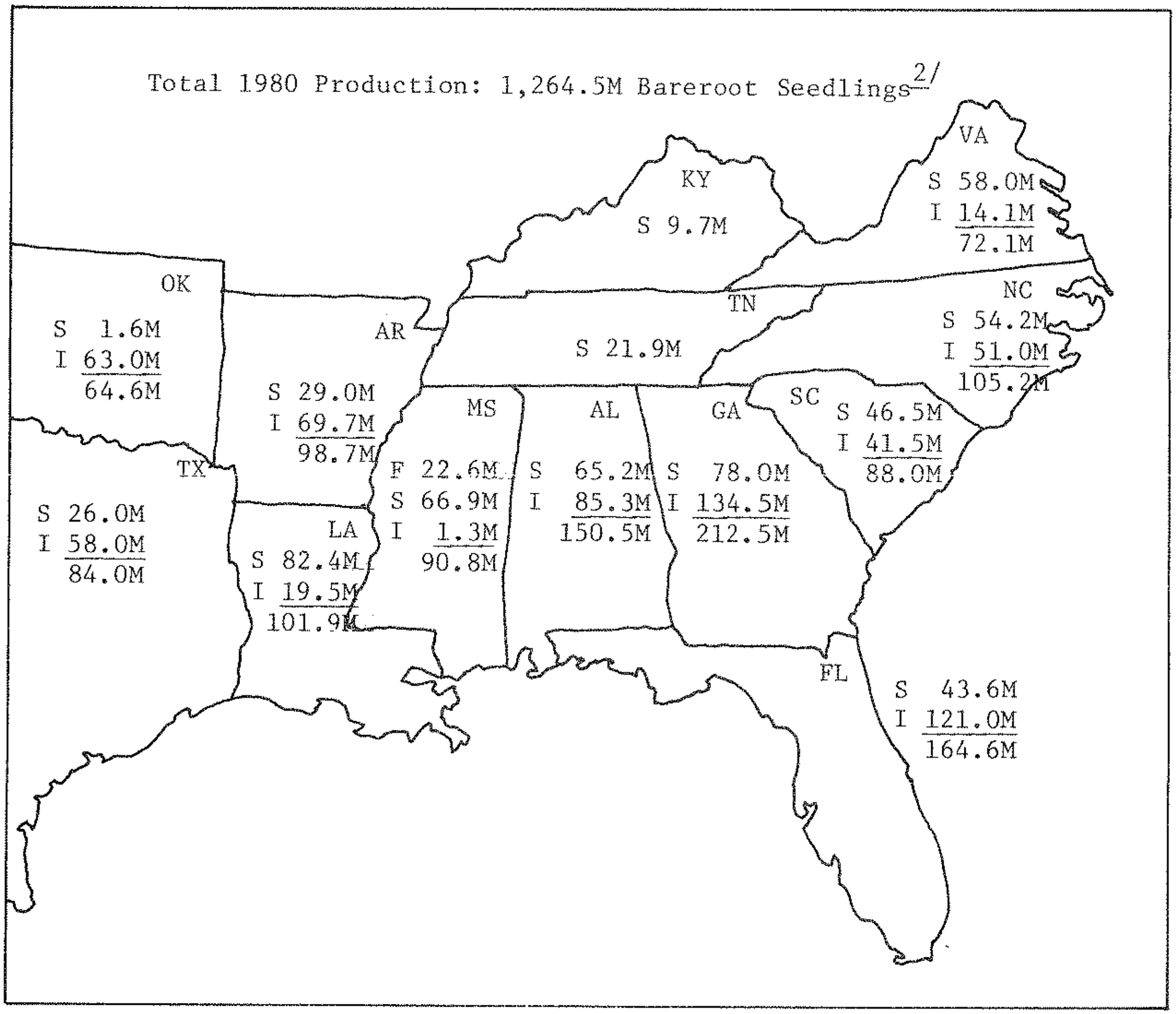
Another factor involved in the increased mortality is the change in nursery practices associated with the need to meet the increasing demand for seedlings. Many of the industrial nurseries have reduced or eliminated seedling grading (Weaver, et al. 1980). This results in a greater proportion of substandard or "cull" seedlings being sent to the field for planting. During this period of increase in demand and production of pine seedlings, the establishment of new nurseries has not increased proportionately, suggesting that the established nurseries are being overtaxed to meet required production levels. To meet the greater demand, some nurseries have gone from alternating nursery beds one year in production and one year in fallow to two or more years in production and one year in fallow. Although this does not seem too drastic, the resultant decrease in organic matter content of the soils during the second and subsequent production years may have detrimental effects on the seedlings.

Forest tree bare-root seedling production for the South was 1,264.5 million in 1980 (Figure 1; USDA Forest Service, 1981). This total included species other than pine, however. Pine seedling production was probably about one billion seedlings for 1980. Figure 1 shows the seedling production by state, for different ownership categories of nurseries.

The capacity of existing nurseries to produce seedlings is an important factor in meeting greater production demands in the short run. Since the lead time for establishing new bareroot nurseries is from two to five years, expanding production at existing nurseries is one way to meet present production demands. The amount of added production possible at a nursery depends on its capacity. As of 1980, 5383 acres were available for nursery production (Table 1). Total potential annual production was calculated to be 1,406.9 million seedlings, roughly equal to what was actually produced. Regional shortages and surpluses of seedlings undoubtedly occur due to varying nursery acreages among the states (Fig. 1). By changing rotation practice, the potential production could have been 2,813.7 million seedlings. These figures, however, represent the upper limit of seedling production and do not take into account other limitations such as equipment and manpower. In addition, one must be concerned with product quality as well as quantity. As this upper production limit is approached, it will probably be at the expense of seedling survival and field performance.

Improved nursery practices can increase forest production by reliably providing the required quantity of seedlings needed for complete reforestation and by improving survival and growth after planting. How a new nursery practice effects the latter is exemplified by three-dimensional root pruning technology, also known as box pruning, recently developed in New Zealand (Tinus, 1981). Box

Figure 1. Forest tree bareroot seedling production for 1980[1/] stratified by state and by nursery: State (S), industry (I), and federal (F). Values reported are in millions of seedlings.



1/ Data are from the 1981 Directory of Forest Tree Nurseries in the United States published by the American Association of Nurseryman in cooperation with the U.S.D.A. Forest Service.

2/ This value includes species other than pine.

Table 1. Forest Tree Bareroot Nursery Capacity (Pine and Hardwood) in the Southern United States and Their Potential Production Levels. 1/

State	Organization	Area Available for Production (acres)	Potential Annual Production 2/ 2y production 2y fallow (millions of seedlings)	2y production 1y fallow	Continuous production
Alabama	State	362	94.6M	126.1M	189.2M
	Industry	371	97.0M	129.3M	193.9M
Arkansas	State	155	40.5M	54.0M	81.0M
	Industry	234	61.2M	81.5M	122.3M
Florida	State	225	58.8M	78.4M	117.6M
	Industry	361	94.4M	125.8M	188.7M
Georgia	State	316	82.6M	110.1M	165.2M
	Industry	402	105.1M	140.1M	210.1M
Kentucky	State	105	27.4M	36.6M	54.9M
Louisiana	State	135	35.3M	47.0M	70.6M
	Industry	62	16.2M	21.6M	32.4M
Mississippi	Federal	82	21.4M	28.6M	42.9M
	State	252	65.9M	87.8M	131.7M
	Industry	50	13.1M	17.4M	26.1M
North Carolina	State	271	70.8M	94.4M	141.7M
	Industry	161	42.1M	56.1M	84.2M
Oklahoma	State	75	19.6M	26.1M	39.2M
	Industry	530	138.5M	184.7M	277.0M
South Carolina	State	224	58.5M	78.1M	117.1M
	Industry	299	78.1M	104.2M	156.3M
Tennessee	State	100	26.1M	34.8M	52.3M
Texas	State	127	33.2M	44.3M	66.4M
	Industry	225	58.8M	78.4M	117.6M
Virginia	State	204	53.3M	71.1M	106.6M
	Industry	55	14.4M	19.2M	28.7M
	Total	5383	1,406.9M 3/	1,875.4M 3/	2,813.7M 3/

1/ Data for this table was obtained for the 1981 Directory of Forest Tree Nurseries in the United States published by the American Association of Nurserymen in cooperation with the USDA Forest Service.

2/ Calculations were based upon utilization of only sixty percent of available area (four foot nurserybed with a two foot track) and a bed density of 20 viable seedlings per square foot. No allowances were made for cull seedlings.

3/ Potential production values do not include any other limitations such as equipment or man-power, and are based solely on the available acreage.

pruning has increased the survival and growth of planted Pinus radiata to the extent of decreasing the usual 27-year rotation by one year. This procedure, however, is not operational because seeder of required precision does not exist. Without the precision seeder vertical root pruning across the nursery bed must be done by hand. This is an example where the biological as well as the economical gain from a new cultural practice have been demonstrated but operationally it is not yet feasible.

SCOPE

The problem analysis concentrated primarily on the area of nursery operations, but also included was seed supply from seed orchards, seed biology, and the delivery of the seedling to the planting site. Hence, the entire process from seed collection as it pertained to nursery operation to seedling transport to the field was evaluated.

OBJECTIVE

The objective of this analysis is to identify southern pine seedling production problems that if alleviated would facilitate the increased production and "quality"[1] of seedlings needed to meet projected demand in the southeast.

APPROACH

The initial identification and delineation of problems was conducted by a six-member team selected to represent perspectives from State and Federal agencies, Forest Industry and University Researchers (Appendix 1). After two meetings and several drafts, 38 potential problem areas were incorporated into a questionnaire (Appendix 2). This survey was then distributed to 114 people associated with southern nursery operations and research. Representatives from various state and federal agencies as well as from forest industry were included (Appendix 3). The mailing list for the USDA Forest Service, State and Private Forestry, Southeastern Area was used to select individuals for the survey. These people were requested to add any problems that were omitted, to rank the problem in priority from very high to low, and to indicate known associated research presently being conducted in each area.

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[1]The word quality is in quotes because there are many different perceptions of what constitutes a "quality" seedling. Intuitively we all have an idea of what constitutes a "quality" seedling, but biologically we cannot define it.

Fifty-three surveys were returned (46.5 percent). The response by group was: Researcher/manager - 81%; Industry nursery - 45%; State and Federal nursery - 16%. The ratings were then assigned a numerical value (very high-4; high-3; moderate-2; low-1). The mean rating for each problem was calculated and then the problems were ranked numerically according to their mean rating (problems with the same mean rating were assigned the same numerical rank) (Appendix 4). The responses to the questionnaire were also assessed by grouping the problems into broad categories for the development of a general consensus. This is summarized in the recommendations found on pages 19, 20 and 21.

The results of asking respondents to indicate duplication of research effort were mixed; two problems emerged. In several instances people were identified as working on a specific problem, but when these same people returned their questionnaire, there was no indication that they were working on that problem. It is evident that many of the perceptions of who is doing what research is not accurate. Some research is being conducted by forest industry. There is a question of the availability of these results; such information may be considered proprietary. For this study the assumption was made that research being done by forest industry is proprietary and does not constitute duplication of effort.

RESULTS

The numerical ranking of the problems is attached in Appendix 4. For purposes of discussion the problems were divided into the broad categories: Basic Research Problems, Nursery Operation Problems, Equipment Development and Miscellaneous Problems.

After examining the questionnaire responses and comments a general consensus became evident. More information is needed on seedling physiology. Once this information is available cultural manipulations could be employed to achieve a given physiological state. The nursery environment is not a large concern; fertilization and irrigation problems consistently received low ratings. Some equipment needs are presently limiting advances in nursery operations and production. More research is needed in nearly all of the problem areas, even though some areas are now receiving attention.

Transportation to the planting site and subsequent handling in the field was determined not to be a biological problem, but a management problem. The technology involved in the process is adequate and mishandling of the seedlings can usually be rectified by proper supervision and management.

I. Basic Research Problems

Seedling Physiology

Ideotyping

Seedling Ideotype (5) - To assess the effect of nursery practices requires a physiological, morphological and anatomical description of the ideal seedling. This concept forms the basis of the morphological grades developed by Wakeley (1954) and the voluminous literature on shoot to root ratio. Morphological characteristics, however, constitute only a minor part of a seedling ideotype. Much more important are the physiological characteristics, but here again little information is available and measurement techniques are usually too involved and time consuming for routine analysis (Bunting, 1980). Jaramillo (1981) reviewed the techniques used to evaluate seedling "quality." She found that the physiological basis for some of the measurements is unknown and hence, one is left working with correlations between a meter reading and survival or performance. For example, in the case of water stress measurement, an absolute and fairly precise value can be obtained, but the difficulty lies in relating that value to seedling performance.

Other methods for determining physiological fitness of seedlings include root regenerating potential (also known as root growth capacity) (Burdett, 1979; Jenkinson, 1980; Stone, 1955) and root starch content (Barnard, et al. 1980; Gilmore, 1964; Jaramillo, 1981).

Early Physiological Indicators (6) - The development of indicators that would allow the prediction of seedling characteristics at lifting time would be beneficial to nursery operators. This area of research, however, depends on information that would be generated in the above problem and hence is further from operational implementation.

Cultural Manipulations

Many of the commonplace nursery practices are not founded on knowledge of their physiological effects on seedlings. This problem is especially important in the timing of nursery operations.

Cultural Manipulation (2) - Of the small amount of work that has been done on preconditioning or previous history effect on seedling physiology it is evident that any type of cultural manipulation will affect a seedling's response at a later time (Barnard et al. 1980; Bunting, 1980). Evidence for this is found in the differences of seedling survival and performance among various nurseries. This preconditioning is especially important in nursery operations where seedlings are grown for one year, uprooted and planted into a totally new environment. Are there cultural practices that will increase survival or field performance? Are some of the practices used today predisposing nursery-grown seedlings to poor performance or death? Ultimately, seedlings could be grown for different sites by using different cultural techniques to ensure maximum survival and good field performance across the entire array of planting sites.

Fertilizer Manipulation (2) - Although all nurseries apply fertilizer, the influence of this practice on seedling physiology is unclear. Traditionally, fertilization research has focused primarily on the rate of application by measuring seedling growth response. Timing of the fertilizer application, especially later in the growing season, is a critical factor and it may have an effect on seedling performance after outplanting. Late application of nitrogen is known to stimulate lammas growth in some pines and hence it can effect shoot elongation the following spring. Are seedlings that are grown under a highly favorable nutrient environment in the nursery less capable of adapting to lower nutrient levels in the field? How does this affect a seedling's ability to form mycorrhizal associations in the field?

Fall application of potassium has been reported to induce early dormancy (Insely, 1981). Are there other nutrients that if applied at the proper time would impart an ability to withstand cold storage or transplant shock?

Water Management (7) - Irrigation is a cultural practice that most nurseries employ, but it is undoubtedly overused, resulting in an overapplication of water (Day, 1980). The key factor here may not be the amount applied but its distribution, i.e. a gradient in the amount of irrigation water applied usually occurs from a low in the center of the nursery beds to a high along the irrigation lines. Development of better irrigation equipment would solve this problem. Another problem concerns irrigation scheduling. Several techniques have been developed to schedule irrigation, e.g. pan evaporation, but rule of thumb appears to be the prevailing technique. This is not only inaccurate, but it usually leads to over irrigation that results in a waste of water and energy.

Withholding irrigation in the early fall has been employed on the west coast to induce early dormancy and cold hardiness (Zaerr et al 1981). The latter may not be very critical for the South, but early dormancy induction is important (see Dormancy).

Root Morphology Manipulations (10) - Seedling root morphology and structure can be manipulated by using layers of different materials in the nursery bed. For example, a layer of organic material, e.g. peat moss, below the soil will tend to concentrate the roots in the soil. The roots will not grow through the organic layer due to poor percolation across the soil-organic layer interface. The implementation of layering will depend on its effect on seedling field performance. The cost alone may be prohibitive, especially if similar results can be achieved with a horizontal root pruning.

Cold Storage for Physiological Manipulations

Cold storage of lifted seedlings prior to planting is a ubiquitous nursery practice throughout the South. A portion of the bareroot seedlings produced pass through a cold storage facility (Miller, 1980). Early cold storage research focused on determining optimum temperature (Wakeley, 1954), but it is conceivable that imposing a decreasing thermoperiod associated with a decreasing photoperiod, seedlings lifted early in the fall could be induced into an early dormancy. This would allow for fall planting and an extension of the planting season.

The primary problem of cold storage is the maintenance of seedling vigor. The best vigor is usually attained by lifting dormant seedlings and planting immediately.

On the survey there were three questions relating to cold storage and they all were ranked about the same. Cold storage is one step in the process of seedling production that is usually taken for granted, but its research potential for immediate return appears high.

Photoperiod and CO_2 Enrichment (8) - Applying technology developed for post-harvest handling of fruits to seedling storage may have a dramatic and immediate impact on seedling performance. Imposing a photoperiod during cold storage has been reported to increase early growth and the number of expanding buds (Lavender, 1978). High CO_2 concentration would reduce respiration and may reduce the effects of ethylene (Barnett, 1980). Both photoperiod and CO_2 enrichment would tend to minimize respiration losses. These treatments may reduce the amount of storage carbohydrates that are respired and the seedlings may perform better in the field as a result (Barnard et al. 1980).

Immediate Planting Versus Cold Storage (8) - The key factor relating to this problem is one of dormancy. Cold storage of non-dormant seedlings lifted too early resulted in nearly 100 percent mortality (Dierauf, 1976a). Immediate planting of non-dormant seedlings resulted in about a 20 percent increase in mortality compared to fully dormant seedlings. Can cold storage practices be improved to handle non-dormant seedlings?

Cold Storage and Dormancy Induction (9) - Using specially equipped cold storage facilities, seedlings lifted early in the fall could possibly be induced into dormancy for fall planting. By daily decreasing the temperature and photoperiod in the storage facility dormancy induction may be accelerated in seedlings lifted in the early fall. This would allow fall planting and extend the planting season.

Dormancy

The physiological processes of dormancy are ill defined. The induction process, however, is known to involve decreasing day lengths and cooler temperatures. The time of dormancy induction is critical in scheduling when the seedlings are lifted from the nursery bed. Both field performance and storability are greatly decreased if seedlings are lifted too early (Dierauf, 1976; Garber and Mexal, 1980).

There is some question, however, of the exact state of dormancy in southern pines during the winter, especially at the lower latitudes, i.e., southern Georgia, Florida, and southern Alabama. Stem elongation may be inhibited by lower temperatures during winter, but a chilling requirement may be unnecessary unlike more northern species. A report of cambial activity during warm periods in the winter suggests that true dormancy doesn't occur, at least in the cambium. The diameters of outplanted seedlings were found to double from November to February in southern Georgia (Zimmerman and Brown, 1971).

Tinus (personal communication) is developing a differential thermal analysis (DTA) technique for measuring dormancy in northern species, Pseudotsuga and Picea. He has found that the technique does not work well on pines.

Dormancy Induction (4) - If the factors controlling the induction of dormancy were better understood, seedlings could be manipulated to induce dormancy earlier in the fall allowing for fall planting and thus extend the planting season.

Culturally-induced Dormancy (4) - Cultural manipulations could be employed to induce dormancy. Recent work on the west coast has experimented with the use of water stress to induce dormancy (Zaerr, et al, 1981). Proper timing of root pruning could elicit a similar response.

Introduction of Northern Provenances (8) - By employing northern provenances, early dormancy could be achieved. It is well known that northern provenances become dormant at longer photoperiods; thus by moving them south the seedlings would become dormant earlier in the fall. The growth potential of the seedlings after outplanting may be hindered by this practice if too northern a seed source is used.

Genetic Considerations

Many of the problems discussed above include to some degree a genetic component. There are several tree improvement cooperatives between universities, forest industry, and states that are functioning in the South. Considerable genetic gain in southern pines has been realized through the establishment of seed orchards of select trees. The genetic potential of the improved seed from these orchards is, in part, being lost due to antiquated nursery practices.

The problems related to genetics did not receive high rankings despite the large effect genetics have on seed and seedling response to the nursery environment. One explanation for this is the nature of the research cooperatives, in this case the tree improvement cooperatives. People perceive that all genetic questions are being researched by the tree improvement cooperatives and therefore genetics is a distinct and remote problem from nursery operations.

Family Segregation of Seed (9) - Genetic variation in seed size, germination rate and subsequent seedling growth results in heterogenous nursery beds, earlier competition among seedlings and a high number of cull seedlings. Top clipping is a technique to reduce this size difference and hence competition in the nursery bed. Some forest industries have begun to segregate their seeds by families as they are collected in seed orchards. The seeds are then planted by family in the nursery beds. The results of this practice is a more uniform product within families and fewer culls. This type of operation is the first step in customized seedling production, i.e. growing a particular genotype or family for a certain environment.

Screen Clones for Dormancy Induction (11) - Research in this area could result in immediate application for fall planting. By using inherent genetic variation, families could be screened for time of dormancy induction and those that induce dormancy early could be lifted and planted in the fall. This approach may be easier to implement than attempting to induce dormancy by manipulating seedling environment.

Physiological Testing in Seed Orchards(11) - Supplemental screening of seed orchard families could be facilitated by including physiological testing in seed orchards. This additional screening would provide a wider biological basis for selection and roguing. Of special interest is the determination of maternal effects induced by seed orchard practices and carried through into the nursery and the field (Perry and Hafley, 1981).

Miscellaneous

Root Growth Periodicity (4) - Root growth appears to be a cyclic process, alternating with shoot growth (Drew and Ledig, 1980). The time at which a seedling is lifted has been demonstrated to affect this periodicity (Garber and Mexal, 1980; Jenkinson, 1980; Stone, 1955). A number of researchers in both federal agencies and forest industry has been studying the root growth capacity (RGC) in southern pines, but little published information is available.

Much of the published research from the west coast has concentrated on showing different RGC among ecotypes (Jenkinson, 1980), but the key to this research especially for the southern pine species is the demonstration of the relationship between RGC and field performance. One major drawback to this research is that analysis takes at least one week or longer, and so the results always too late to determine when to lift. A technological breakthrough, however, may allow for the rapid determination of RGC or some related factor.

II. Nursery Operation Problems

The problems in this category are of a more applied nature and in some cases our knowledge of the effects of cultural practice are well documented. Research into these problems would probably be shorter term and the contributions to increased seedling production would be more immediate.

Cultural Practices

Root Pruning (3) - Vertical root pruning is a common practice in nurseries as is undercutting (horizontal root pruning). The former is accomplished by running tractor-mounted cutter discs along the seedling rows. Undercutting employs a tractor-drawn sharp blade which is pulled horizontally through the bed at a depth of between four and eight inches. These treatments result in a more compact, fibrous root system which helps to reduce shoot-root ratio by limiting height growth, induces dormancy and facilitates easier planting (Cleary et al, 1978).

Box pruning as discussed earlier is a three-dimensional pruning technique that has been proven in New Zealand to enhance seedling performance (Tinus, 1981).

Root Wrenching (3) - This technique is similar to undercutting, but an inclined, oscillating blade is used to disturb and aerate the soil and to trim off any new, deeply penetrating roots (Cleary et al, 1978). Wrenching is used to stimulate root growth and to induce dormancy, presumably through the induction of water stress.

Top Clipping (4) - This practice has been recently developed and its use is more widespread than undercutting. Top clipping essentially involves mowing of the seedling to a predetermined height, usually six to eight inches. The main advantage of top clipping is that it reduces the number of cull seedlings by allowing the smaller seedlings to keep pace with the larger ones.

Biologically, the soundness of this practice is unknown. Obviously, the growth potential of the fastest growing and hence tallest seedlings is retarded through the clipping of the terminal bud. One pass through the nursery bed in early fall, however, may affect photosynthate distribution resulting in transport to the root system rather than to an elongating stem. This higher carbohydrate reserve in the root system may decrease transplant shock, and enhance earlier and better growth in the field (Barnard et al, 1980; Dieruaf, 1976b). Top clipping may be unnecessary if other developments occur, i.e. planting by seed orchard families (see Genetic Consideration) and the development of a precision seeder (see Equipment Development).

Chemical Applications for Dormancy Induction (5) - The application of potassium salts in the fall has had mixed results for dormancy-induction. Dierauf (1978) found that potassium chloride when applied at two different rates to loblolly pine reduced survival. Insley (1981), on the other hand, reported good results with potassium iodide when applied to hardwood seedlings.

Nursery Soils

The importance of soil factors in nursery operation is becoming recognized, however, problems associated with soil management on the whole ranked quite low. The one area that did rank high suggests that the basic knowledge of nursery soil management is available, but the application of the knowledge is lacking. One of the more critical factors in southern nurseries is the maintenance of the organic matter content. Since most of the nurseries are on the coastal plain, the soils have a high proportion of sand and hence an inherently low cation exchange capacity. Organic matter provides nearly all of the exchange sites and yet organic matter content rarely exceeds two percent. As nurseries increase production the organic matter content tends to decrease, a one-half percent drop in content can have a considerable effect on the seedlings.

Other practices related to soil management such as fertilization and irrigation appeared to be of moderate concern. Soil-related pathogens also did not rank as severe problems.

Integrated Management of Beneficial Organisms (5) - A synthesis of present knowledge about soil fertility, its relation to soil organisms makes application to nursery soil management possible at this time. Several cultural practices now employed in nurseries are detrimental to soil organism, e.g. soil fumigation, herbicide and insecticide applications.

Of particular interest is the effect of these practices on mycorrhizal fungi. Mycorrhizae have been demonstrated to stimulate height growth and biomass production after outplanting on certain sites. Recent research has found that certain nursery practices significantly reduce fungal inoculation of hardwood seedlings (Kormanik, 1980). By manipulating the type of cover crops during following years, mycorrhizal inoculation was increased in hardwood nursery (Kormanik, 1980).

This illustrates one type of an integrated program that is needed. Other soil micro-organisms that are potentially beneficial and that could be manipulated are nitrogen-fixing bacteria.

Irrigation Scheduling (5) - Irrigation along with fertilizer application is the most widely practiced cultural technique in nurseries (Day, 1980). Irrigation is energy intensive and irrigation water is a limited resource. The development of a scheduling technique that would not hinder seedling growth would undoubtedly result in energy savings and better utilization of water, a limited commodity.

Fertilizer Application (8) - The application of fertilizers can be accomplished either by direct addition to the soil in a solid form or in solution through the irrigation lines. Each method has its advantages and disadvantages, but for ease of application and timing of application, fertilization through irrigation lines appears to be superior. This method also results in less disturbance of the nursery beds such as compaction by vehicles.

Irrigation Techniques (12) - Most nurseries now use some variation of an overhead irrigation system. New developments in irrigation includes both subsurface and trickle irrigation. The advantage of both of these techniques is that they use less water by virtually eliminating any evaporation during application. Difficulty of implementing these techniques, however, may occur especially if the irrigation lines are disturbed during root pruning or lifting.

Pest Management

There are a number of organisms that are detrimental to pine seeds and seedlings such as damping-off fungi, nematodes, fusiform rust and weeds. The control of these biological agents is necessary to the production of good seedling stock.

Weed Management (3) - Competition control is crucial to reducing the number of cull seedlings and maintaining good seedling growth in the nursery. The Auburn University Southern Forest Nursery Management Cooperative is conducting research aimed at chemical weed control. The use of herbicides, however, needs to be tempered until their entire impact on seedlings and soil organisms has been assessed (USDA Forest Service, 1981).

Soil Fumigation (8) - Nursery soils are annually or biennally fumigated with methylbromide prior to seeding to eliminate or reduce root pathogens and weed seeds. The fumigation procedure is not only costly in terms of both time and material, but it is also potentially hazardous. Fumigation has become a routine procedure in pine nurseries and as with any routine procedure, periodic re-evaluation is required to avoid needless applications (Rowan, 1981; South and Gjerstad, 1980; South et al, 1980).

Fusiform Rust Control (10) - The occurrence of fusiform rust is sporadic and in some areas of the South not present at all, e.g. areas of Virginia. Due to this spottiness, this problem was ranked low in priority. Additionally, the ability to control the rust with fungicides appears to be adequate (Rowan et al, 1980).

Nematode Control (12) - This problem was ranked low and probably for much the same reason fusiform rust control was not highly ranked. The occurrence of nematodes is sporadic and nematicides are available that appear to effectively control epidemic populations.

III. Equipment Development and Miscellaneous Problems

Equipment Development

The development of new equipment could have an immediate impact on seedling production. The example cited above pertaining to box pruning is a case in point. For that procedure to become operational it would require the development of a precision seeder and a root pruner capable of vertical pruning across the nursery bed.

As seedling demand increases, the need for equipment development will likewise increase as nurseries become more mechanized. The U.S. Forest Service has an equipment development center in Montana which could play an important role in the increased mechanization. The N.C.S.U. Forestry Equipment Cooperative could also contribute to this new development, especially for southern nurseries.

Precision Seeder (5) - The development of a precision seeder would greatly improve seedling production. The seeders presently on the market do not have the required precision for spacing seeds along a row nor sowing them at a uniform depth. The problem with present spacing is that areas are skipped and are not seeded or large number of seeds are dropped in a small area, resulting in extreme overcrowding. Seeds are also sown at variable depths accentuating any genetic variation in the rate of germination. Together these shortfalls result in a high number of culls.

Aside from the commercially available seeders, the development of a vacuum seeder has been undertaken by Weyerhaeuser and Dryden nursery in Ontario, Canada. Neither at the present are available commercially.

Lifting Machine (8) - From this survey it became evident that the present equipment used in lifting is not adequate. The performance of the lifters vary with soil type. They work best on light, sandy soil and become almost useless on wet, heavy clay soils. On one type the seedlings are transported up to the operator by a means of opposing wheels and belts which can damage their stems. The machines do not follow soil contours very well which can result in some seedlings being lifted by their foliage. Branches and needles can become crushed as they are transported betwen the moving belts.

Root Pruners (10) - The low priority of this problem should not detract from its importance. The development of a new root pruner has been discussed in relation to other problems above and the point will not be belabored. Before committing time and money into developing a new root pruner, however, some physiological research should be conducted to definitively determine the real biological value of root pruning. International Paper Company is in the process of developing a new root pruner.

Top Clippers (13) - Top clipping as it is practiced now involves the use of rotary blades. This can cause uneven clipping due to outward pressure from the rotating blades. Hammermill has a prototype top clipper that operates much like a reel-type lawnmower. This is an improvement over the rotary cutters now employed. The biological ramifications of top clipping is not known and requires research (see Nursery Operation Problems).

Development of Wider Implements (14) - Standard nursery implements are such that only about two-thirds of the area of a nursery is in production. Nursery beds are normally four feet wide with a two-foot wheel track. Developing implements to produce a six-foot nursery bed would result in seventy-five percent of the area in production, nearly a 10 percent increase. To achieve this increase, however, all of the equipment used in nursery operations would have to be widened and irrigation systems moved to get full rows between irrigation lines. Future equipment development should maintain flexibility in the widths of implements, especially as prime nursery land becomes scarcer.

Miscellaneous Problems

Cost-benefit Analysis (5) - An economic analysis of nursery production processes could provide useful information by identifying areas where new or additional money could be extended to produce a better product.

State-of-the-Art Nursery Manual (7) - The development of a new nursery manual will provide for the introduction of newly developed technology into seedling production as well as help standardize present practices. Jack May in cooperation with the USDA Forest Service, has writen a nursery manual, which will be available sometime in 1982.

A modular approach to the manual may in the long run allow for more rapid transfer and implementation of technology. As new technology is developed or changes made to old practices, an addendum could be published and circulated, rather than waiting ten years for an entire new manual to be written. To be successful this approach would require a continued research effort for the sustained development of new technology.

Systems Analysis of Nursery Production (7) - Applying systems analysis to seedling production could reveal additional information that could lead to the development of new nursery concepts and equipment. It could also identify barriers in the production process. A number of the respondents questioned the feasibility of using systems analysis on nursery production since it constitutes only a portion of a larger system. Hence, systems analysis of the entire reforestation process would be advisable.

Containerized Seedlings (12) - In spite of the large advances made with containerized seedlings elsewhere in this country, Canada, and Europe, this is an area that has not been fully accepted in the south (as indicated by its low priority). Some forest industries have containerized seedling operations in the south, however, they remain ancillary to bare-root nurseries for regeneration purposes. Containerized seedlings are also being used for specialty crops such as Christmas trees, and reforestation of refractory sites. Forest seedling research and progeny testing are often done with containerized seedlings due to the ease of handling the small number involved and the decreased environmental variation. The importance of containerization may increase as demand for seedlings begins to outstrip the supply and as nursery managers seek alternatives for additional production.

Greenhouse Nurseries (15) - In the ultimate application of seedling physiology knowledge a greenhouse nursery would allow for the total control of the seedling environment. Manipulation of seedling physiology and morphology could be achieved by varying radiation, water, temperature and nutrients. Seedlings could be tailored for specific planting sites.

RECOMMENDATIONS

I. Basic Research Problems

High Priority

- Effects of cultural manipulations on seedling survival and field performance. (1)

- Fertilizer manipulations to influence seedling physiology. (2)

- Determination of factors involved in dormancy induction for early lifting and fall planting. (4)

- Cultural manipulations to induce early dormancy. (4)

- Determination of the periodicity of root growth for southern pines, and identify optimum lifting data. (4)

Medium Priority

- Characterize the seedling "ideotype" morphologically, anatomically, and physiologically. From this "quality" seedling can be defined. (5)

- Early physiological indicators for predicting seedling characteristics at lifting time. (6)

- Water management to control irrigation for manipulating seedling physiology. (7)

- Determination of genetic control of dormancy induction; introduction of northern provenances. (8)

- Photoperiod and CO_2 enrichment during cold storage, and its effect on survival and field performance. (8)

- Short period of cold storage versus immediate planting. Use of cold storage to manipulate seedling physiology. (8)

Low Priority

- Separation of seed by family as it comes from the seed orchard. Seed sizing and family screening for germination rate. Sowing of seed by family in the nurserybed. (9)

- The use of cold storage for hardening off of seedlings lifted early. (9)

- Root morphology and structure manipulations by inorganic and organic layering in seedbed. (10)

I. Basic Problems, continued

Low Priority

- Screening of clones (half-sib families) for time of dormancy induction. "Early" families could be lifted early and planted in the fall. "Late" families may be better for cold storage and planting in late spring. (11)

- Introduction of physiological testing in seed orchards for supplemental screening of families. Determine the extent of the maternal effect in each family. (11)

II. Nursery Operation Problems

High Priority

- Root pruning effect on seedling survival and performance. (3)

- Root wrenching effect on seedling survival and performance. (3)

- Weed management. (3)

- Top clipping effect on seedling survival and performance. (4)

Medium Priority

- Development of an integrated management program for beneficial soil organisms. (5)

- Chemical applications to induce dormancy, e.g. potassium applications. (5)

- Irrigation scheduling for better water utilization, energy savings and frost hardiness in the fall. (5)

- Soil fumigation. (8)

- Determination of the best method for fertilizer application; in solution through irrigation system or in solid form added directly to soil. (8)

Low Priority

- Fusiform control in nurserybeds. (10)

- Nematode control in nurserybeds using biological and chemical agents. (12)

- Investigate the use of subsurface and trickle irrigation as alternatives jto overhead irrigation. (12)

III. Equipment Development and Miscellaneous Problems

High Priority

- Development of a precision seeder that will sow seeds in a uniform fashion (spacing and depth). (5)
- Economic (cost-benefits) analysis of nursery production, and the identification of areas where additional money can be expended to produce a better seedling. (5)
- Development of a "state-of-the-art" nursery manual. (7)
- Systems analysis of nursery production. Concentration on determining barriers in the production process and developing new nursery concepts and equipment. (7)

Medium Priority

- Development of new lifting machines. (8)
- Development of mechanical root pruners. (10)
- The use of containerized seedlings to accelerate production and extend planting season. (12)

Low Priority

- Development of mechanical top clippers. (13)
- Determination of the feasibility of using wider implements to bring more land into production in established nurseries. (14)
- Greenhouse nurseries for water and radiation control to alter seedling morphology and insure high germination. (15)

LITERATURE CITED

Anonymous. 1980. Forest Industries Council Forest Productivity Report. National Forest Products Assoc., Washington, D.C.

Barnard, E. L., C. A. Hollis and W. L. Pritchett. 1980. A comparative evaluation of seedling quality in commercial forest nurseries in Florida. Presented to the Southeastern Area Forest Tree Nursery Conf., Lake Barkley, Kentucky, 8 p.

Barnett, J. P. 1980. Ethylene absorbent increases storability of loblolly pine seedlings. In Proc. 1980 S. Nursery Conf., Lake Barkley, KY. 86-88.

Bunting, W. R. 1980. Seedling quality: Growth and development - soil relationships, seedling growth and development, density control relationships. In Proc. N. Am. For. Tree Nursery Soils Workshop. U.S.D.A. For. Serv., State and Private Forestry, 21-42.

Burdett, A. N. 1979. New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. Can. J. For. REs. 9: 63-67.

Cleary, B. D., R. D. Greaves and R. K. Hermann. 1978. Regenerating Oregon's Forests - A Guide for the Regeneration Forester. Oregon St. Univ. Exten. Serv. 287p.

Day, R. J. 1980. Effective nursery irrigation depends on regulation of soil moisture and aeration. In Proc. N. Am. For. Tree Nursery Soils Workshop, Syracuse, NY. 52-71.

Dierauf, T. A. 1976a. Fall planting and storage using non-dormant seedlings. In Proc. 1976 S.E. Area Nurserymen's Conf. 30-36.

Dierauf, T. A. 1976b. Top clipping in the nursery bed. In Proc. 1976 S.E. Area Nurserymen's Conf. 37-43.

Dierauf, T. A. 1978. Problems with seedling dormancy and freezing. In Proc. 1978 S.E. Area Nurserymen's Conf. 42-47.

Drew, A. P. and F. T. Ledig. 1980. Episodic growth and relative shoot: root balance in loblolly pine seedlings. Ann. Bot. 45: 143-148.

Garber, M. P. and J. G. Mexal. 1980. Lift and storage practices: Their impact on successful establishment of southern pine plantations. N.Z. J. For. Sci. 10: 72-82.

Gilmore, A. R. 1964. Food reserves of transplanted loblolly pine seedlings and root growth. Tree Planters Notes No. 66: 15-16.

Hammond, H. 1981. Forest economic data. USDA For. Serv. SA.

Insley, H. 1981. Chemical defoliation of hardy nursery stock. Arboriculture Res. Note, Dept. of Environ. UK No. 31, 3p.

Jaramillo, A. 1981. Review of techniques used to evaluate seedling quality. In Proc. of Intern. Nurs. Assoc. and W. For. Nurs. Assoc. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-109. 84-95.

Jenkinson, J. L. 1980. Improving plantation establishment of optimizing growth capacity and planting of western yellow pines. U.S.D.A. For. Serv. Res. Paper PSW-154, 22p.

Kormanik, P. P., W. C. Bryan and R. C. Schultz. 1980. Increasing endomycorrhizal fungus inoculum in forest nursery soil with cover crops. S. J. of Applied For. 4: 151-153.

Lavender, D. P. 1978. Bud activity of Douglas-fir seedlings receiving different photoperiods in cold storage. In C. A. Hollis, and A. E. Squillace (eds.) Proc.: 5th N. Am. For. Biol. Workshop, U. of Florida Press, Gainesville, Florida. 245-248.

Miller, A. E. 1980. Seedling storage, handling and planting procedures. In Proc. N. Am. For. Tree Nursery Soils Workshop, Syracuse, NY. 85-110.

Perry, T. O. and W. L. Hafley. 1981. Variation in seedling growth rates - their genetic and physiological bases. In P. P. Feret, ed. Proc. 16th S. For. Tree Impr. Conf., Blacksburg, VA.

Rowan, S. J. 1981. Soil fumigants and fungicide drenches for control of root rot of loblolly pine seedlings. Plant Disease 65: 53-55.

Rowan, S. J., C. E. Cordell and C. E. Affeltranger. 1980. Fusiform rust losses, control costs and relative hazard in southern forest tree nurseries. Tree Planters Notes 31: 3-8.

South, D. B. and D. H. Gjerstad. 1980. Nursery weed control with herbicides or fumigation - an economic evaluation. S. J. Appl. For. 4: 40-45.

South, D. B., D. H. Gjerstad and S. J. Campbell. 1980. Comparison of methyl bromide and herbicide effects on endomycorrhizal formation, seedling production, and weed control in sweetgum seedbeds. Eur. J. For. Path. 10: 371-380.

Stone, E. C. 1955. Poor survival and the physiological condition of planting stock. For. Sci. 1: 90-94.

Tinus, R. W. 1981. Concepts for seedling production and handling being developed in New Zealand. Forest Regeneration. The Proc. of the Symp. on Engineering Sys. for For. Regen. ASAE Publ. 10-81: 56-60.

U.S.D.A. Forest Service. 1980. Forest planting, seeding, and silvical treatments in the United States 1980 report. FS-368. 15p.

U.S.D.A. Forest Service. 1981. 1981 directory of forest tree nurseries in the United Staes. 40p.

U.S.D.A. Forest Service. 1981. Possible herbicide damage to conifer seedlings. Reply to 3400 Forest Pest Management distributed to S.E. For. Tree Nursery Managers. 2p.

Venator, C. R. 1981. Improved survival and growth justify planting only top quality seedlings. For. Farmer. 40: 6-7, 18.

Wakeley, P. C. 1954. Planting the southern pine. U.S.D.A. For. Serv. Agric. Monogr. No. 18, 233 p.

Weaver, G. H., B. Izlar, F. S. Broerman and K. Xydias. 1980. Preliminary report on the 1979 American Pulpwood Association pine plantation survival and nursery practices survey. Paper No. 4626, Mississippi Agric. and For. Expt. Sta. 7 p.

Williston, H. 1980. A statistical history of tree planting in the south, 1925-1979. U.S.D.A. For. Serv. Misc. Rep. SA-MR8. 37p.

Zaerr, J. B., B. D. Cleary and J. L. Jenkinson. 1981. Scheduling irrigation to induce seedling dormancy. In Proc. of Intermountain Nurseryman's Association and Western Forest Nursery Association. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-109, 74-79.

Zimmerman, M. H. and C. L. Brown. 1971. Trees: Structure and Function. Springe-Verlag. New York. 336p.

Appendix 1
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Appendix

Mean questionnaire response stratified by group: Combined groups-O; Researcher/manager-A; Industry nursery-I; and State nursery-S. Priority value: very high = 4; high = 3; medium = 2; and low = 1.

O	A	I	S	Item
				I. Genetic Considerations
				A. Applied
2.2	2.3	2.0	2.4	1. Separation of seed by family as it comes from the seed orchard. Seed sizing and family screening for germination rate. Sowing by family in the nurserybed may reduce the number of culls.
2.0	2.0	2.0	2.2	2. Screen clones (half-sib families) for time of dormancy induction. "Early" families could be lifted early and planted in the fall. "Late" families may be better for cold storage and planting in late spring.
				B. Basic
2.0	2.1	1.8	2.0	1. Introduce physiological testing in seed orchards for supplemental screening of families. Determine the extent of the maternal effect in each family.
				II. Seed Sowing
				A. Applied
2.7	2.6	3.0	2.0	1. A precision seeder needs to be developed that will plant seeds in a uniform fashion (spacing and depth). Further development of pneumatic seeder developed at N.C. State.
				III. Seedling Physiology
				A. Applied
2.8	2.8	2.9	2.6	1. Determine factors involved in dormancy induction for early lifting and fall planting.
2.3	2.6	1.9	2.2	a. Genetic control, introduction of northern provenances.
2.8	3.0	2.6	2.4	b. Cultural manipulations.
2.7	2.8	2.7	2.6	c. Chemical applications, e.g. potash application.
2.8	2.8	2.8	2.4	2. Determine the periodicity of root growth for southern pines, and the influence of lifting date and storage.
				3. The use of cold storage for physiological manipulations.
2.3	2.0	2.6	2.4	a. Short period of cold storage versus immediate planting.
2.3	2.3	2.1	2.8	b. Photoperiod and CO_2 enrichment during cold storage; and its affect on survival and field performance.

O	A	I	S	
2.2	1.9	2.5	2.6	c. The use of cold storage for hardening off of seedlings lifted early.
				B. Basic
2.7	2.8	2.7	2.2	1. Characterize the seedling "ideotype" morphologically, anatomically, and physiologically. From this "quality" seedling can be defined.
3.1	3.2	3.2	2.6	2. Effects of cultural manipulations on seedling survival and field performance. Some indication of the problem is evident in the differences of seedling "quality" among different nurseries.
2.6	2.8	2.4	2.4	3. Early physiological indicators for predicting seedling characteristics at lifting time.
				IV. Nursery Cultural Practices, Soil Management, and Their Effect on Seedling Physiology (Customized Seedling Production)
				A. Applied
				1. For the production of 'viable' seedlings and improving survival determine the role of:
2.9	2.9	3.1	2.2	a. Root wrenching
2.9	2.9	3.2	2.2	b. Root pruning
2.8	2.7	3.0	2.6	c. Top Clipping
2.7	2.6	3.0	2.2	2. Irrigation scheduling for better water utilization, energy savings and frost hardiness in the fall.
				3. Fertilization
2.3	2.0	2.7	2.4	a. Determine the best method for fertilizer application; in solution or solid form.
3.0	2.7	3.2	3.0	b. Fertilizer manipulations to influence seedling physiology.
				B. Basic
1.9	2.0	1.7	1.8	1. Investigate the use of subsurface and trickle irrigation as alternatives to overhead irrigation.
2.5	2.6	2.6	1.6	2. Water management to control irrigation for manipulating seedling physiology.
2.1	2.1	2.1	2.0	3. Root morphology and structure manipulations by inorganic and organic layering seedbed.
1.3	1.5	1.4	1.8	4. Greenhouse nurseries for water and radiation control to alter seedling morphology and insure high germination.

O	A	I	S	
1.9	2.0	1.6	3.0	5. The use of containerized seedling to accelerate production and extend planting season. Specialty crop production, e.g. Christmas trees or for regenerating mine spoils.
1.8	1.7	1.7	2.4	6. Development of mechanical top clippers.
2.1	2.0	2.2	2.0	7. Development of mechanical root pruners.
2.3	2.5	2.1	2.4	8. Development of new lifting machines.
1.7	1.7	1.6	2.0	9. Determine the feasibility of using wider implements to bring more land into production.
2.7	2.8	2.5	3.0	10. Development of an integrated management program for beneficial soil organisms.
				V. Pest Management
				A. Applied
2.1	2.4	1.9	1.8	1. Fusiform control in nurserybeds.
1.9	1.8	2.0	1.8	2. Nematode control in nurserybeds using biological and chemical agents.
2.9	2.8	2.8	3.8	3. Weed management.
2.3	2.4	2.1	3.0	4. Soil fumigation.
				VI. Miscellaneous
				A. Applied
2.5	2.5	2.5	3.0	1. Development of a "state-of-the-art" nursery manual.
				B. Basic
2.5	2.3	2.7	2.6	1. System analysis of nursery production. Concentration on determining barriers in the production process and developing new nursery concepts and equipment.
2.7	2.6	2.9	2.4	2. Economic (cost-benefit) analysis of nursery production, and the identification of areas where additional money can be expended to produce a better product.

Appendix 3

Survey Respondents

Nurseries

State/Federal

W. W. Ashe Nursery
USDA Forest Service
Brooklyn, MS

Augusta Forestry Center
Virginia Division of Forestry
Crimora, VA

Morgan County Tree Nursery
KDF
West Liberty, KY

Pennyrile State Nursery
Kentucky Division of Forestry
Dawson Springs, KY

Pinson Nursery
Tennessee Division of Forestry
Pinson, TN

John P. Rhody Nursery
KDF
Gilbertsville, KY

Industry

Champion International Corp.
Livingston, TX

Container Corporation of America
Brewton, AL

Continental Forest Industries
Hopewell, VA

Continental Group
Hodge LA

Gerogia-Pacific
Pooler, GA

Great Southern Paper
Cedar Springs, GA

Hammermill Paper Co.
Selma, AL

ITT Rayonier Inc.
Fernandina Beach, FL

MacMillian Bloedel Inc.
Pine Hill, AL

Manville Forest Products Corp.
Vivian, LA

Masonite Corp.
Shubuta, MS

St. Joe Paper Co.
Lamont, FL

St. Regis Paper Co.
Lee, FL

Tennessee River Pulp & Paper Co.
Counce, TN

Tennessee Valley Authority
Norris, TN

Weyerhaeuser Co.
Eutan, AL

Weyerhaeuser Co.
Hot Springs, AR

Weyerhaeuser Co.
George H. Weyerhaeuser Nursery
Washington, NC

Weyerhaeuser Co.
Fort Towson Nursery
Fort Towson, OK

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Westvaco
Wickliffe, KY

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University of Florida
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Ron Blackwelder
Champion International Corp.
Greenville, SC

Bud Broerman
Union Camp
Rincon, GA

Bill Carlson
Weyerhaeuser Co.
Hot Springs, AR

L. V. Collicott
Southwest Forest Industries
Panama City, FL

Chuck Davey
NCSU
Raleigh, NC

P. P. Feret
VPI & SU
Blacksburg, VA

Ray France
International Paper
Natchez, MS

Glen Hatchell
USFS SEFES
Athens, GA

Bill Isaac
International Forest Seed Co.
Birmingham, AL

Munroe Jones
Union Camp
Franklin, VA

S. B. Land
Mississippi State University
Mississippi State, MS

Clark Lantz
USFS SESPF
Atlanta, GA

Ed Manchester
USFS
Murphy, NC

Tom Marino
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Natchez, MS

Don Marx
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AThens, GA

John Mexal
Weyerhaeuser Co.
Hot Springs, AR

Ansel Miller
Clemson University
Clemson, SC

W. L. Pryor
Union Camp
Savannah, GA

Kurt Ray
Clemson University
Clemson, SC

Robin Rose
Westvaco
Summerville, SC

James Roebuck
Gilman Paper Co.
Day, FL

Mark Steigerwalt
Continental Forest Industries
Savannah, GA

Dave South
Auburn University
Auburn, AL

Charles Tauer
Oklahoma State University
Stillwater, OK

Dick Tinus
USFS RMFRES
Bottineau, Nd

John Toliver
Louisana State University
Baton Rouge, LA

C. P. Venator
USFS SOFES
Pineville, LA

Appendix 4

Priority of Pine Seedling Production Problem Ranked by Questionnaire Survey Response

Priority Ranking	Appendix 2 Cross Reference	Problem (Mean response from Appendix 2)
1	III. B.2.	Effects of cultural manipulations on seedling survival and field performance. Some indication of the problem is evident in the differences of seedling "quality" among different nurseries. (3.1)
2	IV. A. 3b	Fertilizer manipulations to influence seedling physiology. (3.0)
3	IV. A. 1b	Root pruning and its effect on survival and performance. (2.9)
3	IV. A. 1a	Root wrenching and its effect on survival and performance. (2.9)
3	V. A. 3	Weed management (2.9)
4	III. A.1	Determine factors involved in dormancy induction for early lifting and fall planting for dormancy induction. (2.8)
4	III. A. 1b	Cultural manipulations for induction of dormancy. (2.8)
4	III. A. 2	Determine the periodicity of root growth for southern pines, and the influence of lifting date and storage and its influence on survival. (2.8)
4	IV A. 1c	Top clipping and its effect on survival and performance. (2.8)
5	II. A. 1	A precision seeder needs to be developed that will plant seeds in a uniform fashion (spacing and depth). Further development of pneumatic seeder developed at N.C. State. (2.7)
5	III. A. 1c	Chemical applications, e.g. potash application, for dormancy induction. (2.7)
5	III B. 1	Characterize the seedling "ideotype" morphologically, anatomically, and physiologically. From this "quality" seedling can be defined. (2.7)
5	IV. A. 2	Irrigation scheduling for better water utilization and energy saving. (2.7)
5	IV. B. 10	Development of an integrated management program for beneficial soil organisms. (2.7)
5	VI. B. 2	Economic (cost-benefit) analysis of nursery production, and the identification of areas where additional money can be expended to rpoduce a better product. (2.7)
6	III. A. 3	Early physiological indicators for predicting seedling characteristics at lifting time. (2.6)
7	VI. A. 1	Development of a "state-of-the-art" nursery manual. (2.5)

Priority Ranking	Appendix 2 Cross Reference	Problem (Mean response from Appendix 2)
7	IV. B. 2	Water management to control irrigation for manipulation of seedlings. (2.5)
7	VI. B. 1	System analysis of nursery production. Concentration on determining barriers in the production process and developing new nursery concepts and equipment. (2.5)
8	IV. B. 8	Development of new lifting machines. (2.3)
8	V. A. 4	Soil fumigation. (2.3)
8	III. A. 1a	Genetic control, introduction of northern provenances for dormancy induction. (2.3)
8	III. A. 3b	Photoperiod and CO_2 enrichment during cold storage; and its affect on survival and field performance. (2.3)
8	IV. A. 3a	Determine the best method for fertilizer application; in solution through irrigation system or in solid form added directly to soil. (2.3)
8	III. A. 3a	Short period of cold storage versus immediate planting. (2.3)
9	I. A. 1	Separation of seed by family as it comes from the seed orchard. Seed sizing and family screening for germination rate. Sowing by family in the nurserybed may reduce the number of culls. (2.2)
9	III. A. 3c	The use of cold storage for hardening off of seedlings lifted early. (2.2)
10	V. A. 1	Fusiform control in nurserybeds. (2.1)
10	IV. B. 3	Root morphology and structure manipulations by inorganic and organic layering in seedbed. (2.1)
10	IV. B. 7	Development of mechanical root pruners. (2.1)
11	I. A. 2	Screen clones (half-sib families) for time of dormancy induction. "Early" families could be lifted early and planted in the fall. "Late" families may be better for cold storage and planting in late spring. (2.0)
11	I. B. 1	Introduce physiological testing in seed orchards for supplemental screening of families. Determine the extent of the maternal effect in each family. (2.0)
12	IV. B. 5	The use of containerized seedling to accelerate production and extend planting season. Specialty crop production, e.g. Christmas trees or for regenerating mine spoils. (1.9)
12	V. A. 2	Nematode control in nurserybeds using biological and chemical agents. (1.9)

Priority Ranking	Appendix 2 Cross Reference	Problem (Mean response from Appendix 2)
12	IV. B. 1	Investigate the use of subsurface and trickle irrigation as alternatives to overhead irrigation. (1.9)
13	IV. B. 6	Development of mechanical top clippers. (1.8)
14	IV. B. 9	Determine the feasibility of using wider implements to bring more land into production. (1.7)
15	IV. B. 4	Greenhouse nurseries for water and radiation control to alter seedling morphology and insure high germination. (1.3)