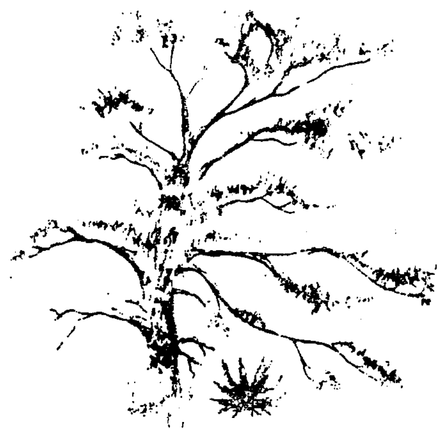
USDA Forest Service General Technical Report SE-2

Sand Pine Symposium



Proceedings

December 5–7, 1972
PANAMA CITY BEACH, FLORIDA

USDA Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina
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Sponsored by

Southeastern Forest Experiment Station, USDA Forest Service
Florida Division of Forestry
Florida Cooperative Extension Service

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FOREWORD

Sand pine, a species well suited to the excessively drained soils common to several million acres in the Southeast, was the subject of this well-attended 3 -day meeting. Papers presented included a review of the literature plus results of current research related to this species. Subjects covered ranged from seeds and seedlings to final harvest and conversion of the tree into various products.

It was pointed out that sand pine is not the "ugly duckling" it is thought to be. Its wood properties , especially those of the Choctawhatchee variety of sand pine, are similar to those of loblolly pine and adequate to meet the needs of many wood products. Deterrents to its use are factors other than basic wood characteristics. The se advantages and disadvantages should be a challenge to forest land managers. The potential of this species has been called to their attention. Perhaps we can expect sand pine to assume greater importance in the plans. for the South's Third Forest.

A number of people contributed to this symposium. Of course, without the enthusiastic support of the experts invited to present papers, and the session moderators, there could be no symposium. Members of the Planning Committee who worked to make this meeting a success deserve recognition:

Russell M. Burns, Program Chairman
Southeastern Forest Experiment Station, USDA Forest Service

Edwin A. Hebb, Field Tour Chairman
Southeastern Forest Experiment Station, USDA Forest Service

Thomas G. Herndon, Local Arrangement Chairman
University of Florida

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St. Joe Paper Company

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R. H. Brendemuehl, Chairman of Planning Committee
Southeastern Forest Experiment Station, USDA Forest Service

KEYNOTE ADDRESS

Honorable Robert L. F. Sikes
House of Representatives
Washington, D. C.
(1 st District--Florida)

I am very pleased to participate in this important symposium on sand pines, a program which commemorates the 20th anniversary of the Chipola Experimental Forest. We who are jointly interested in west Florida and in forestry are very proud of this facility. I was privileged to participate in its establishment. I have continued to support it, and I am happy to note that there has been sound recent expansion.

Experimentation is a very important key to sound and profitable forestry programs. It is important to realize that there is a continuing requirement for forestry research in many areas. We still have problems of insect and disease control. We need growth studies and genetic studies toward stronger and more productive strains in trees. New harvesting practices and improved marketing methods obviously are due more consideration. All of these can be as important in our time as tree planting programs. We need to become aware of the problems of visual impact on forest visitors, of wildlife habitat, and of other management considerations. The public will become more and more sensitive about the way we manage forests. It is better to do our research and come up with the right answers than have it done for us and to have the wrong answers inflicted upon us.

In the sand pine program, it is essential that we be certain we are making contributions which justify the cost and the effort. Is our research effort moving in the right direction? Just what is it that we have learned about sand pines ? Is sand pine truly an important economic asset? Some of the bloom may have departed from early hopes for sand pine. It is our business to learn whether its claim to fame is based on fact or fallacy.

That is what the Chipola Program is all about. There has been great enthusiasm for sand pine. Some of this undoubtedly has dimmed. Possibly, we expected too much. We need to know whether sand pine is truly a strong competitor for slash pine. Or, is it more realistically a substitute which is useful only in specific areas? I have seen exciting volunteer growths of sand pine in the deep sand forests of the Eglin Reservation, where , without help from man, sand pine has entered into competition and overcome scrub oaks; No other pine will do this.

This is, truly a time for evaluation of sand pine. Where does it grow best ? Under what circumstances is it economically a competitor? When and where is it preferable to slash pine or other species? In plain English, how can sand pines be used profitably in timber-growing programs?

Let me congratulate the participants who are here for the sand pine symposium. This is a very distinguished group. I am certain there has been no previous meeting which has gathered so much knowledge on this subject. We can all benefit from your contributions.

I realize that today 1 am preaching to the choir, but, where forestry is concerned, 1 am happy to do so. My work for forestry is not a new thing. It grew out of my boyhood days and my love for the outdoors. I feel at home where I can see growing trees and green shrubs and sparkling water. And I like to work for a better outdoors now and in the years ahead. The first large-scale tree planting project was begun in 1920. Legislation for systematic programs to control forest fires, for cooperative forest management, and for realistic research programs did not get underway until the late 1930's and the 1940's. Now, forestry practices are becoming the subject of a great deal of public interest.

1 have been happy to note that a great, new, nationwide tree planting program is in progress. It is proposed to plant 75 million acres of trees in the environmental 70's. That means planting 60 billion trees.

A long time ago, one of America's greatest conservationists, Gifford Pinchot, said, "Conservation means wise use of the earth and its resources." That is still the name of the game for those who believe in strong forestry practices. But we have a selling job to do. This job includes tree planting. And it is where conservation starts.

I am not at all certain that there are enough people in the land who understand the significance of forestry and its economic importance to the Nation. There is a requirement to educate the public so they may better understand the blessings which come to us simply because one-third of the Nation's area is forest land; they must understand that forest land provides a continuous flow of renewable wood fiber for housing construction, packaging, and paper, in addition to scenic, wildlife habitat, watershed, and recreational values. We must ensure that more people realize that productivity of the forest is essential to the economy in employment and community development. The public needs to understand better the Nation's need for wood, the A B C's of renewable resource management on forest lands. There are so many who have little or no contact with or knowledge of forest problems who could be easy game for special-interest groups, including ecologists, who want to place their stamp on all programs, forestry and otherwise, even to the point of stopping sound utilization of forests.

Consideration for the ecology, which was virtually an unknown thing just a few years ago, has in many areas become a major item. In particular, it has affected proposals for water use and waterway improvements. It also affects forest use considerations. It very definitely slows approval of developmental projects and, in some instances, blocks them completely.

Ecology is a new and exciting "catch phrase." It is something very important; also, it can be overdone. Admittedly, it is serving to force attention on the need for correction of abuses, particularly abuses which are associated with pollution. What has been done toward control generally has been needed.

There must be a balance between what people want and what is practical. We cannot close down this country's business and industry just for the sake of ecology. But it is very certain that we cannot allow the growing and steadily worsening pollution of our earth to continue.

Let us talk about forestry legislation. A forestry legislative package which I was privileged to sponsor contains some very important provisions. Approximately 100 Congressmen were cosponsors. They are scattered the length and breadth of the land, and it is hard to find 100 Congressmen nowadays who have an understanding of forestr'y. P. L. 92-288 is a multi-purpose bill which is designed to update the Nation's forestry programs to meet present-day needs. The bill was drafted with the help of Federal and State forestry agencies and industry representatives, and it is now law.

As you well know, most existing forestry legislation had been placed on the statute books in the late 1940's and early 1950's, and some of this carries my name. The new law updates the Clarke-McNary Act for fire protection by doubling the annual authorization for Federal funds from $20 million to $40 million; it provides increased authorization for Cooperative Forest Management by increasing the authorization for Federal participation from $5 million to $20 million annually; and it provides a new program for urban and environmental forestry management with an annual authorization of $5 million.

There is also before the Congress a Forestry Incentives Bill. This bill has passed the Senate, largely because of the strong efforts of Senator Stenni s , but it encountered very rough going in the House Committee, in part because of strong opposition of some Committee members to any type of subsidy program, and in part because of opposition by the Administration. A determined effort was made to get a bill reported and on the House Calendar. These efforts failed. I feel that we have made progress which can ensure a successful effort in the next Congress. We will not drop the fight until the job is done. There is very definitely a need for a forestry incentive program. It is intended to serve the forest landowner by encouraging sound forestry practices, just as agricultural programs have served the farmer by helping him take advantage of better farming practices.

Let us move slightly away from forestry. There are rural areas and small towns whose development has lagged, where too many young men and women must go elsewhere to make a living, where fertile fields and beautiful woodlands and streams are not fully utilized. One of the urgent needs in our Nation today is to reverse the flow of population from rural areas to city slums. Now Congress has enacted and the President has signed a rural development bill which can make the difference between today's rural problems and tomorrow's rural promise. The bill will stimulate small industry, including forest products, and, community improvements.

There is a recreational potential for west Florida which has barely been tapped. People are learning about our beaches, and well that they should, for they are the most beautiful in the world. But their utilization can be doubled and redoubled without damage to ecological value if we let more people know about them. Beyond that is a hunting, fishing, camping, and boating potential which is virtually unknown beyond our own boundaries, The rivers, forests, bays, and inlets which we possess can be among the most attractive in the world. But it is not enough that they be pretty to look upon; they must offer advantages which bring people to enjoy their potential. This means a revitalized hunting and fishing program which really offers game and fish. It means clean, attractive, and safe camping areas. It means recreational facilities. These are available now only in a limited way. That is not good enough.

I am happy to call attention to the fact that the Federal Government has released funds to begin the water management study which my legislation made possible for west Florida. This is the project which will have a far-reaching impact on flood control, navigation, water supply, and waste water management. These factors will be studied, and proper guidance will be developed to control these problems. The study will also include general recreational facilities, enhancement and control of water quality, and conservation of fish, wildlife, and other resources for environmental purposes and for human relations. West Florida is an area that has been richly endowed with water resources. Few areas can boast as much. This fact will become increasingly important as the years pass. Water is becoming scarce in many areas now, and water supply is becoming more and more a problem in many parts of the Nation. We have water for human consumption, for recreational purposes, and for industrial use. If we manage it wisely, it will be one of our greatest assets.

The return of peace, for which there are very good prospects, emphasizes the need to focus on other activities, on the development of your resources, and on sound programs to ensure a healthy economy,

For years, America's defense industry has been a major factor in the economy. Now, there will inevitably be an increase in the demands for cuts in the U. S. Defense budgets. The pressures for more money for nondefense programs have been mounting even during the war. Percentage - wise, we have been spending less in recent years for defense and much more for other purposes in constant dollars. Defense budgets are lower now than they were even in 1962, which was a year of comparative peace.

There are always those who profess to see no dangers abroad and who will question the necessity for continued, large military expenditures. These people will add strength to the demands for more domestic spending. The Administration is not immune to these pressures, and already the Administration is seeking places to cut the defense dollars more. Among other proposals will be one on the closing of additional bases. No area is immune to this threat. The message should be very clear to us. It is important that our bases keep their best foot forward; that base personnel at all levels re-examine their sense of mission and their accomplishments and make certain that theirs is a base which is genuinely needed in the inventory. It is equally important that our local people show full support for the military bases in their area and a special degree of cooperation toward military personnel and their families. These are requirements in which we must all share.

We should seek the retention of a strong military presence for America because we live in a dangerous world. We have seen the effects of aggression by one small country of 20 million people in Indochina. For a generation, they have successfully defied efforts to bring peace to an entire area, and through some strange zeal, they have harnessed their people for the conquest of half of the area. This peace, which we so eagerly await, may leave them in possession of most of their ill-gotten gains because they probably will not move out of captured territory, regardless of agreements which may be reached.

If a pigmy among nations can create such havoc, we certainly cannot overlook the power which can be wielded by Russia and Red China in a world which now seeks to accommodate itself to threat rather than to resist threat. These countries embrace a philosophy of government which is alien to ours, and they seek world domination. Their entire national structure and all of their assets can be directed toward their aims. They have no labor problems, no minority problems, and only minimal demands for domestic improvements.

In other words, America still has formidable foes in the World--foes that respect only armed might. It would be extreme folly for this country to weaken itself to the point where our enemies know we dare not accept a confrontation on issues affecting world peace. For the foreseeable future, we must maintain a strong America.

There will be growing recognition for other considerations, hopefully worldwide. Of necessity, there must be such recognition here at home. There is a need now for west Florida to move as a single unit toward a better tomorrow. Regrettably, we have done this only in a very limited way. Each community, or each county, has in the main fought its own battles and sought its own objectives. That is not good enough in today's highly competitive world. We need to plan as one integral area for roads, waterways, airports, for industrial expansion, and for the redevelopment of the rural areas which have not held their own in progress. Always, there must be added concern for the ecology. We live in an age where the ecology is something of extreme importance. It is certain we cannot allow the growing arid worsening pollution of our country to continue.

SAND PINE: DISTINGUISHING CHARACTERISTICS AND DISTRIBUTION

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Abstract. --Sand pine is endemic to the droughty, infertile soils of the sandhills where little other than scrub hardwoods, wiregrass, and scattered longleaf pines are able to survive and grow well. Other southern pines have been introduced into the sandhills, and several share features similar to those of sand pine. Morphological characteristics that differentiate sand pine from other southern pines and distinguishing features of the two recognized varieties of sand pine are discussed.

BACKGROUND

Sand pine (*Pinus clausa* (Chapm.) Vasey) is endemic to the sandhills. It seems appropriate, therefore, to first present some background information about the sandhills, i. e. , to answer such questions as what and where the sandhills are and why they are in their present condition.

The sandhills are an important physiographic feature of the southeastern United States. They comprise about 30 percent of the land in Florida and extend in a narrow hand through Georgia and South Carolina into North Carolina. South of St. Augustine and Ocala in peninsular Florida, they are used to grow citrus. North of the citrus zone, the soil and climate are well suited for melon production? but a rapid buildup of pathogens endemic in the soil makes cropping for more than 1 year in 7 a risky or expensive undertaking. Irrigated and fertilized, the soil will support a variety of other crops.

Sandhill soils developed from marine and fluvial deposits of sand which, either before or during deposition, were depleted of virtually all major and minor elements essential for plant growth. As the name sandhills implies, soils are mostly quartz sand ranging in depth from a few to more than 20 feet. Most contain only 1 to 2 percent organic matter in surface horizons and 10 percent or less silt plus clay in underlying profiles. Their relatively coarse texture and the paucity of organic and mineral exchange surfaces make them inherently droughty and infertile.

Moisture is relatively abundant and summertime temperatures are quite high throughout the sandhills. Average annual rainfall ranges from about 60 inches near the coast in northwest Florida to about 45 inches in South Carolina. Rainfall is fairly well-distributed throughout the year but, in general. is heaviest during June, July, and August. Despite the generous supply. water retention after only 1 day of drainage ranges from 5 to 8 percent on an ovendry-weight basis.. Because of rapid to excessive internal soil drainage, most water percolates to depths below feeder roots. Surface soil temperatures of 135° F. are not uncommon, and they sometimes exceed 160° F. on exposed surfaces during the summer.

Longleaf pines (*Pinus palustris* Mill.) that occupied the, sandhills during colonial times were worked for naval stores. The land was burned periodically to facilitate the operation and to improve forage for cattle and hogs. The pines were harvested progressively from north to south. Lumbermen finished harvesting most of the native longleaf pine in the early 1900's, but the burning continued. Some sandhill land was cleared and cropped to meet homestead requirements., but much was soon abandoned after the timber was harvested. Scrub hardwoods[1/] and wiregrass (*Aristida stricta* Michx.), both native to most sandhill soils, ultimately occupied the area, almost to the exclusion of other plants. Conditions remain essentially the same today.

1/ Principally turkey oak (*Quercus laevis* Walt.), bluejack oak (*Q. incana* Bartr.), common persimmon (*Diospyros virginiana* L.), and sand post oak (*Q. stellata* var. *margaretta* (Ashe) Sarg.).

Competition for available moisture and nutrients is intense. Roots of established woody and herbaceous plants fully occupy surface soils and rapidly deplete them. During periods of active plant growth, drought conditions can develop within days of a soaking rain. High temperature, abundant rainfall, and a coarsely textured soil with rapid internal drainage combine to oxidize litter and leach the nutritive products of its decomposition to depths plants are unable to tap. It is not surprising, therefore, that most introduced trees fail to survive an unaltered sandhill environment.

Contrary to popular impression, sandhill soils are not uniform. Sometimes the sand is underlain with one or more horizons of finely textured soil or with organic-coated sand. These impede internal soil drainage and, when they are within 12 to as much as 16 feet of the soil surface, may influence tree growth. 2/ More often than not, the horizons are at depths greater than 80 inches and so are not reflected in the present system of soil classification used in the United States. Therefore, the way a sandhill soil is classified does not necessarily suggest true soil depth or potential for tree growth. Occasionally, soil types are encountered when such horizons occur near the surface. When these occur, retentionof soil moisture is improved and the soils are capable of supporting a broader spectrum of vegetation. Slash pine (*Pinus elliottii* Engelm.), loblolly pine (*P. taeda* L.), or even pond pine (*P. serotina* Michx.) and spruce pine (*P. glabra* Walt.) may survive and grow well in such areas. When these horizons are absent or below a depth where they can significantly affect the quantity of moisture available for tree growth, all but longleaf and the sand pines are growing offsite.

DISTINGUISHING CHARACTERISTICS OF SAND PINE

In the past, managers of sandhill land in Florida found longleaf pine difficult to regenerate and were reluctant to plant native, scrubby sand pine as long as other southern or exotic pines held promise of adaptability. In other Southern States, few were truly aware of the pine whose botanical range was confined almost solely to the State of Florida or of its potential for sandhill land. Most introduced pines failed to adapt to refractory conditions in the sandhills, but some of these plantings remain. The seven species other than sand pine most likely to be found are longleaf, slash, loblolly, shortleaf (*P. echinata* Mill.), pond, spruce, and Virginia (*P. virginiana* Mill.) pines.

The problem, therefore, is. to distinguish sand pine from other southern pines and to differentiate between the two recognized varieties. Features recognizable in the field without aids have been used here to distinguish among the pines at any season of the year. Other features apparent only seasonally are listed as additional aids.

2/ Hebb, E. A., and Burns, R. M. Slash pine productivity on Florida sandhills sites. (Manuscript in preparation.)

There would be little likelihood of confusing sand pine with other southern pines if all grew, or were planted, onsite. Sand pine is a tree for well- to excessively drained, infertile sand where little other than longleaf pine, scrub hardwoods, and wiregrass are able to survive and grow well.

Only rapid growth under sandhill conditions and flushes of growth during most seasons of the year serve to distinguish sand pine from the seven other pines. All other features are shared by one or more of these pines (table 1). However, if gross morphological characteristics possessed either by sand pines or by the other pines are used, differentiation between sand pine and each of the others is not difficult.

Sand pines have a reputation for poor form, rapid growth, and limbiness. The twisting trees have a tendency to retain their branches, cones, and needles. Branches or branch stubs may be found over the entire length of the bole. The condition gradually diminishes with age, especially in heavily stocked stands, but branch stubs are evident over a large portion of the bole even in some old trees. Sometimes cones are found embedded in branches or the bole as diameter growth envelops them (fig. 1). Needles normally are cast after the second growing season, but dry, gray remnants are occasionally found affixed to the bark of young trees after 5 or 6 years.

Needles range from 4 to 11 cm (1.75 to 4. 25 inches) and average 6.5 cm. (about 2. 5 inches) in length. With the possible exception of spruce pine, needles of sand pine are finer and have a softer texture than those of other southern pines. Most authorities list the sand pines as having needles in fascicles of two. Although this is the most common number, fascicles containing three needles are frequently found near the terminus of growth flushes, especially on young, planted trees. On rare occasion, a fascicle with four needles may be found.

Cones vary somewhat in size in the recognized varieties of sand pine, but, in general, they average 6 to 9 cm. (2.5 to 3.5 inches) long. Buds are relatively small and reddish-brown in color.

Sand vs. Longleaf Pines

Both longleaf and sand pines are indigenous to sandhill soils, but here any similarity ends. Needle length alone is sufficient to differentiate between the two. However, the familiar form of seedlings and trees, color and size of buds, and size of cones might serve as well.

Table 1. --Features distinguishing sand pine from other southern pines in the sandhills of northern Florida

Pine	Needles/fascicle	Needle length	Characteristic bark[a]	Cone length	Cone morphology
	Number	Cm.		Cm.	
Sand	Mostly 2, sometimes 3, rarely 4	4-11	Conspicuous, yellow phellogen	6-9	Stalked (mature may appear sessile)
Longleaf	3	20-45	Conspicuous, yellow phellogen	13-25	Stalked
Slash	2 and 3	15-30	Conspicuous, yellow phellogen	8-15	Stalked
Loblolly	3	12-25	Inconspicuous, gray phellogen	10-13	Sessile
Shortleaf	2 and 3	4-9	Conspicuous, yellow phellogen, Gummy resin pits	4-8	Sessile (deciduous spines)
Pond	3 and 4	7-22	Inconspicuous, gray phellogen	5-7	Stalked (mature may appear sessile)
Spruce	2	4-10	Conspicuous, yellow phellogen Small plates resemble hardwood bark	5-10	Stalked
Virginia	2 (twisted)	2-5	Conspicuous, yellow phellogen	4-6	Stalked

a/ Phellogen is visible as the light-colored streaks in a cross-section of the bark.

Sand vs. Slash Pines

Needles and cones of slash pine are larger than those of sand pine. However, few slash pines older than 8 years retain many second-year needles on droughty, sandhill soils. For this reason, both needles and cones should be examined.

Sand vs. Loblolly and Pond Pines

Conspicuous, yellow phellogen serves to distinguish sand pine from loblolly and pond pines (fig. 2). Bark of sand pine and of most other southern pines contains conspicuous layers of ivory-white to yellow phellogen. Phellogen of the bark of loblolly and pond pines is an inconspicuous, slate -gray color (2).

Sand vs. Shortleaf Pines

Probably the best gross feature differentiating shortleaf pine from sand pine and from every other southern pine is the presence of small, isolated pits within the bark, many of which contain a gummy, resinous substance (4). They are most easily observed in the reddish-brown, corky phellem when large plates of shortleaf pint, bark are removed (fig. 3). Once observed, evidence of the pits can be found on the surfaces of bark exfoliated with age. However, no gummy resin is present in pits on weathered surfaces. The bark of several other southern pines contains pits or shotholes of similar size, such as those made by'bark beetles, but none are isolated nor are they as likely to contain gummy resin.

Sand vs. Virginia Pine s

Lack of vigor, small cones, and short, twisted needles differentiate Virginia pine grown under sandhill conditions from sand pine. Virginia pine is in fact closely related to sand pine (6, 7). The two species share characteristics of branch and cone retention, and both have needles in fascicles of two. However, the botanical range of Virginia pine does not extend south of central Alabama and Georgia. It will not be encountered in the sandhills except in plantations, and here Virginia pine appears as a scrubby tree exhibiting lack of vigor and poor growth. Branches are not pruned naturally, and cones are retained on the tree for 5 to 15 years.

Sand vs. Spruce Pines

Aside from the rapid growth of sand pine, differences between sand and spruce pines in the sandhills are subtle. Young spruce pine has a light-gray bark as compared to the brownish-gray of sand pine bark. Older trees are more easily differentiated, not only by differences in bark coloration but also by the size and pattern of bark plates (fig. 4). Spruce pine has many bark fissures and small, tight plates that resemble hardwood bark, particularly that of some oaks and gums. The bark of sand pine has fewer fissure6 and larger and darker plates that cannot be confused with those of any hardwood.

Actually, spruce pine is a name occasionally ascribed to sand and Virginia pines (3), whereas in reality it is a separate species with many features resembling both. Spruce pines in the sandhills are characterized by needles 4 to 10 cm. (about 1. 5 to 4. 0 inches) long in fascicles of two stalked cones 5 to 10 cm. (about 2 to 4 inches) long that open when mature, and by a scrubby appearance and slow growth.

VARIETIES OF SAND PINE

Two varieties of sand pine are currently recognized. Before their value for reforesting the sandhills was exploited, they were all but separated geographically. Ocala sand pine (*Pinus clausa* var. *clausa* Ward) grew only in peninsular Florida, and Choctawhatchee sand pine (*P. clausa* var. *immuginata* Ward) grew principally in northwestern Florida. Now that both varieties have been planted extensively throughout their native sandhilis, geographic location alone no longer is a reliable means of identification, except in natural stands of old trees.

The cone-opening feature reported by Little and Dorman (5) remains the most widely used means for differentiating Choctawhatchee sand pine (CSP) from Ocala sand pine (OSP). Cones of CSP open when mature, whereas those of OSP remain closed. Because young planted trees of both varieties are precocious, bear mature cones as early as plantation age 5, and retain their cones for many years, this one feature usually can be used for identification year-round.

Although reasonably reliable, cone -opening characteristics are not infallible for differentiating CSP from OSP. Both open and closed cones may be found on the same tree. Diseased, injured, or wet CSP cones remain closed or close'temporarily. Some OSP cones open naturally when the resinous adhesive that seals them softens. The 125° F. temperature required for OSP cones to open (1) may come from direct sunlight or result from the combined effect of direct and reflected sunlight. For this reason, open OSP cones are found more frequently on exposed surfaces of upper crowns in dense stands and on lower branches in comparatively sparse stands. These atypical cones constitute a relatively small proportion of the total crop. The one exception occurs when humidity is high during or immediately following rain: at this time, virtually all CSP cones will be closed.

Stands of "open-coned" OSP have been found in peninsular Florida, principally in Pasco County and on and around the Withlacoochee State Forest in Hernando County. Virtually all of these cones open when mature. Presumably, these "open-coned" OSP are the CSP reported by Ward (8) in northwestern Marion County and in a few scattered locations elsewhere on the peninsula. Examination of the pines in Pasco and Hernando Counties showed that they possess some gross and microscopic features common to both CSP and OSP. To date, no taxonomic status has been assigned to the "open-coned" OSP. However, to differentiate these pines from CSP and OSP, local foresters refer to them as Withlacoochee sand pine (WSP).

Another group of OSP exists, differentiated from typical OSP and WSP by the proportion of mature cones that open. As many as one-half of these cones open without regard to their position in the crown or exposure to the sun. Several large groups of these OSP have been observed in Volusia and Flagler Counties. Others of this kind may exist elsewhere on the peninsula.

Coastal portions of Gulf and Franklin Counties in northwestern Florida contain stands of sand pine that are geographically isolated from contiguous regions of CSP and OSP. Although an open-cone variety predominates and is presumed to be CSP, a few small groves of sand pines with closed cones can be found between East Bay and Ochlockonee Bay. As yet, no definitive work has been done to identify the sand pines of this area.

Seasonal Difference Between CSP and OSP

Incidence of winter growth flushes, color of foliage of dormant seedlings, and the period during which staminate flowers shed their pollen can also be used to differentiate CSP from OSP. The paper "Temperature effects on growth, assimilation, and bud development of sand pine" will elaborate upon flushes of winter growth. Suffice it to say here that OSP flushes more readily than CSP.

Color differences between seedling foliage of CSP and OSP are almost undetectible during summer months. Although CSP may have a slightly darker hue, needles of both varieties are yellow-green. Cold winter weather brings out color differences (fig. 5). Yellow-green OSP becomes darker green but remains essentially the same color. In contrast, foliage of CSP seedlings changes first to blue-green and then, after a mid- or late-winter cold snap, to blue-green tinged with purple-red.

Time of ripening of staminate flowers, as evidenced by pollen release, is probably one of the most reliable phenological events distinguishing CSP from OSP. Five years of records from throughout the State show that, although mediated somewhat by weather and climate, time of pollen release is predictable within a comparatively short time span. CSP, for example, occurs naturally only in northwestern Florida, essentially within 1 degree of latitude. Pollen dissemination may start as early as the last week in December and end as late as the second week in March. However, the event most frequently occurs from late January through the end of February. OSP, in contrast, grows between latitudes 26° and 30° North, throughout most of the peninsula. At the southern extreme of its range, OSP may start shedding pollen as early as mid-November, whereas it may start a month or more later in northern Florida. In the sandhills of north Florida, OSP generally sheds its pollen from the last weeks of December through mid-January. Little, if any, overlap exists in the periods during which the two varieties disseminate pollen.

SUMMARY

Sand pine can be differentiated from other southern pines in the sandhills of northern Florida by one or more easily discernible characteristics of the needles, cones, or bark. The most significant of these, for year-round use, are listed in table 1.

The most widely used feature in distinguishing Choctawhatchee sand pine from Ocala sand pine is the open cones on CSP and the closed cones on OSP. Natural stands also can be identified by their geographic location. OSP is found in peninsular Florida, whereas CSP grows principally in northwest Florida. "Open-coned" OSP that may be confused with CSP is found in scattered locations on the peninsula. Such trees are known locally as Withlacoochee sand pine, but they do not have formal taxonomic status. During winter months, CSP seedlings have blue-green foliage that may have a purplish-red hue, whereas OSP needles remain yellow-green. OSP also flushes more readily than CSP when stimulated by warm weather during winter months. Probably the most reliable, easily recognized difference between the two varieties of sand pine is the period during which staminate flowers ripen. In north Florida, OSP sheds its pollen from mid-December through mid-January, whereas the flowers of CSP ripen from late January through the month of February.

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Figure 1.--Partially overgrown cones of Ocala sand pine. Only on rare occasions are cones completely engulfed by diameter growth of the tree.

Figure 2. --The phellogen (streaks) of shortleaf pine bark (left), sand pine, and most other southern pines is more conspicuous than that of loblolly pine (right) or pond pine.

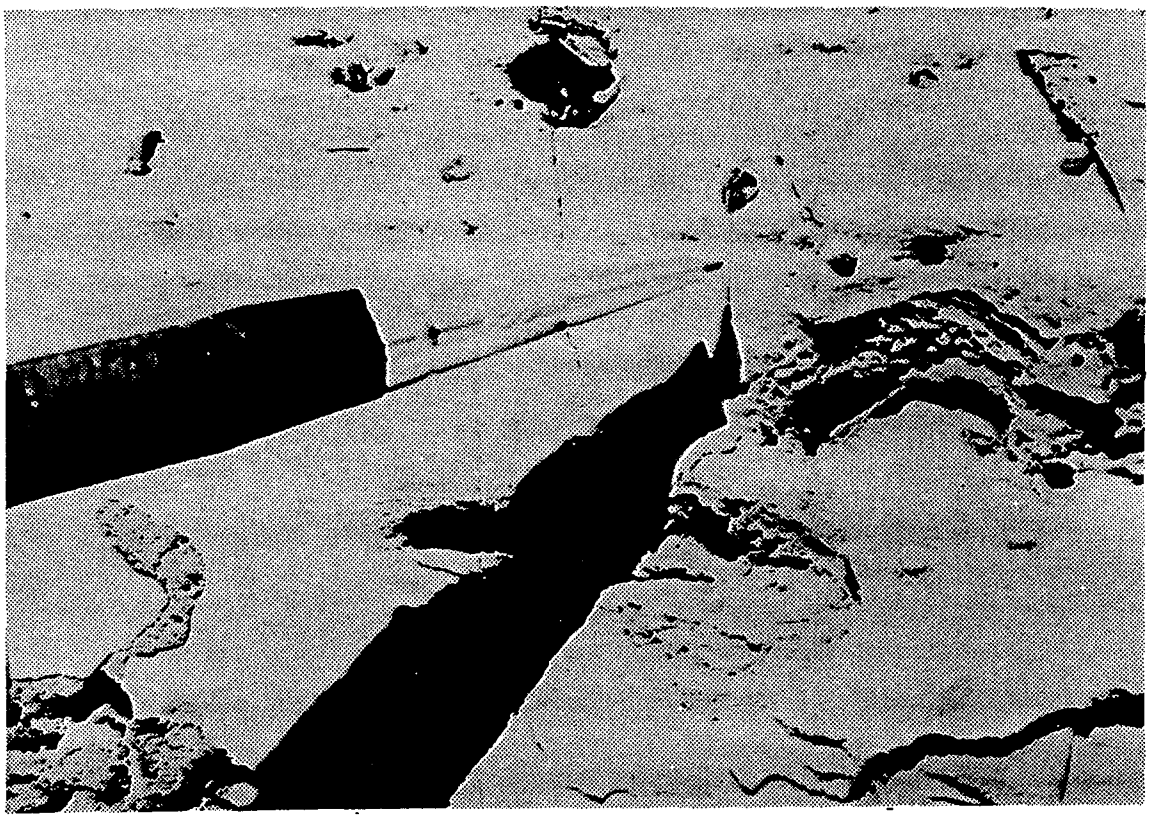

Figure 3. --The pencil shadow shows a strand of gummy substance extending from a small resin pit in shortleaf pine bark to the tip of the lead. Resin pits characterize the bark of this species.

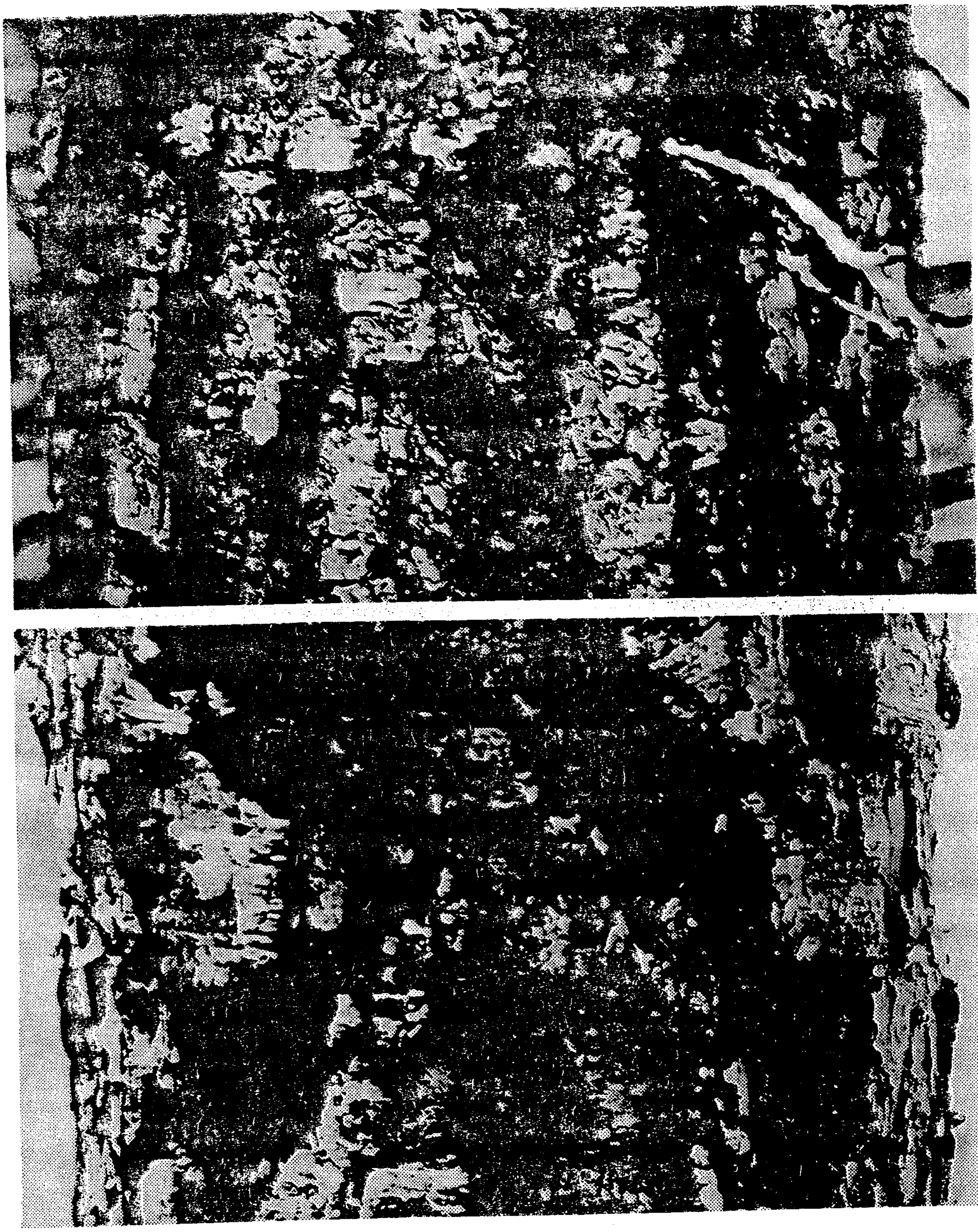

Figure 4. -- The bark of spruce pine (top) with its small, light-gray plates resembles hardwood bark. The bark of sand pine (bottom) has larger and darker plates.

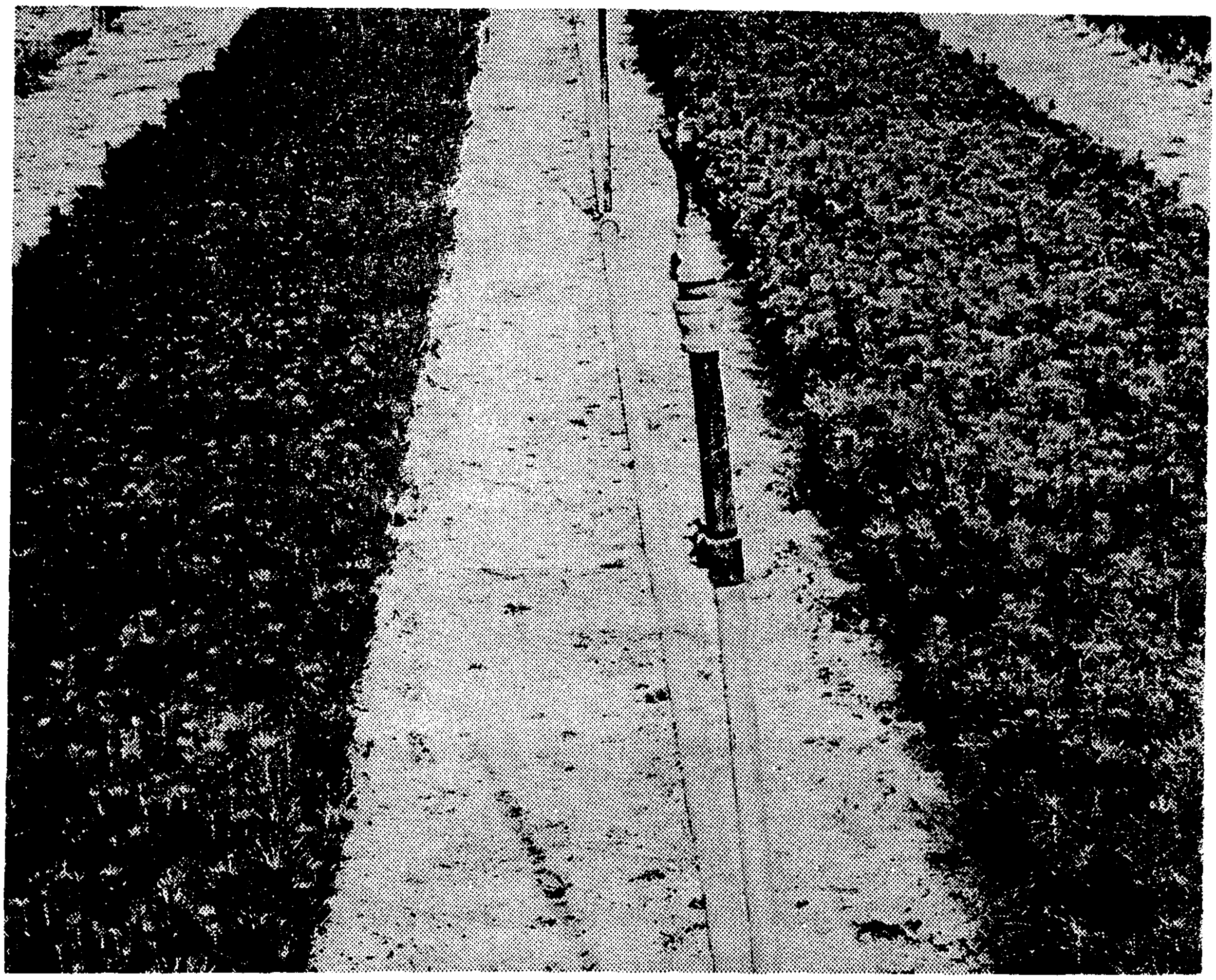

Figure 5. --CSP (left bed) and OSP (right bed). The darker hue of CSP is readily apparent even in this black and white photograph taken during the winter of 197 1.

PROPERTIES, USES, AND POTENTIAL MARKET OF SAND PINE

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Abstract. --The anatomical features, chemical, mechanical, and physical properties, and wood quality characteristics of both varieties of sand pine are discussed in relation to end use. Current uses of sand pine are limited primarily to the pulp and paper industry, with a small volume being used for structural lumber. Investigations indicate that sand pine can be pulped under the same conditions as slash and longleaf pines with little sacrifice in pulp yield and that it can be readily mixed with these species without seriously affecting paper properties. There are future potential markets for sand pine in the veneer-plywood and particle-board industries.

INTRODUCTION

Sand pine (*Pinus clausa* (Chapm.) Vasey), one of the six minor species of yellow pines in the eastern United States, has received limited attention by wood technologists and other wood products researchers since it was first classified in 1880. The small, limby, generally crooked tree with a lacy, light-green crown presents a rather uninspiring sight, not only to people that are knowledgeable about trees but also to those who are not.

In addition to its generally poor appearance and small size, the fact that its range and total volume are relatively small are perhaps further reasons for the limited attention given it over the past 90 years. In the past, many people who saw sand pine for the first time asked, "What is it good for?" I am sure there are still many people asking the same question today. I hope to answer that question to some extent.

This paper will be limited to a review and interpretation of the literature available on the anatomical, mechanical, and physical properties, wood quality, paper-making characteristics, and the uses of the Ocala variety of sand pine (*Pinus clausa* var. *clausa* Ward) and the Choctawhatchee variety (*P. clausa* var. *immuginata* Ward). In the interest of brevity, these will be referred to as OSP and CSP.

WOOD PROPERTIES

Anatomical Characteristics

The anatomical characteristics of sand pine are identical to those of all the other species of yellow pines in the United States, making it impossible to distinguish it from other yellow pines on the basis of its anatomical features alone. The only true method of so distinguishing it is by examination of the fruit, flowers, and needles. The wood is tasteless and has a slight resinous odor typical of pines. The sapwood is white to buff, and the heartwood is a very light tan to a pinkish brown. In cross section, the annual rings are very distinct and readily visible to the naked eye because transition between earlywood (springwood) and latewood (summerwood) within an annual ring is abrupt.' The resin canals are small and barely visible to the naked eye as fine, white dots on the end grain. In radial view, the resin canals appear as fine, light-brown, vertical and horizontal scratches. The wood rays are relatively small and inconspicuous in radial view. The pith is extremely small--generally less than 1 / 16 inch in diameter.

The wood is composed of six basic cell forms: (a) longitudinal tracheids, typical of gymnosperms, which make up the largest proportion of the woody tissue, (b) strand tracheids in limited quantity occurring along the vertical resin canals, (c) ray parenchyma, which makes up part of the ray tissue, (d) longitudinal parenchyma associated with vertical resin canals, (e) dentate ray tracheids, which make up the remainder of the rays, and (f) epithelial cells which line the vertical and horizontal intercellular spaces called resin ducts (10).

The bark of sand pine is similar in anatomical structure to that of the other species of yellow pines in the eastern United States (9). Like the wood, it is virtually impossible to distinguish from that of other yellow pines on the basis of bark anatomy. The inner bark (phloem) is made up primarily of longitudinal, thin-walled, sieve cells; albuminous ray cells; ray parenchyma; epithelial cells (only in the horizontal resin canals of fusiform rays); and dispersed, longitudinal parenchyma. The outer bark or periderm is made up of three general zones: a meristemic region of parenchymatous -type cells called the phellogen (cork cambium); an inner layer of parenchymatous tissue in various stages of expansion and varying wall thickness, called the phelloderm; and an outer layer, the phellum or corky portion of the bark made up primarily of thick-walled stone cells and thin-walled cork cells generally arranged in bands. All yellow pines contain the same types of periderm cells but considerable variation occurs in the arrangement of these cells. This is a feature that may have some diagnostic value, but it requires further research. In both varieties of sand pine, the thin-walled cork cells constantly form on the outer margin (9). The phellogen lines produced behind each layer of corky tissue are reported by DeVall (8) to be ivory white in sand pine as well as in five other yellow pines, and, although the lines are not in themselves sufficient for species identification, they are helpful in supplementing other means of recognizing the species.

Physical and Mechanical Properties

The physical and mechanical properties of sand pine are important from the standpoint of its use as a building or structural material. Information on these properties is limited to data developed by Markwardt and Wilson (13) in 1935 on five OSP trees collected in Marion County, Florida. The values based on this five-tree sample are shown in table 1, together with the properties of five other yellow pines that grow within the same geographical range. These species (loblolly, longleaf, slash, pond, and spruce pines) are listed for comparative purposes because sand pine lumber is mixed with that of the others and all are sold commercially under the same common name --southern yellow pine.

The data on physical properties in table 1 show that OSP has the lowest volumetric shrinkage (10.0 percent) and radial shrinkage (3.9 percent) of the species listed. Tangential shrinkage is also slightly lower (7.3 percent) than in all the species shown except pond pine. The lower shrinkage indicate: that OSP is slightly more dimensionally stable than the other pine species. High dimensional stability is desirable in most wood products, especially in such items as paneling and siding.

Table 1 also shows the mean values of the various mechanical properties of sand pine and some associated pine species in the green condition and at 12 percent moisture content. These values, which were developed on

Table 1. --Physical and mechanical properties of sand pine (OSP) and other pine species within its range[a]

Pine species	Trees tested	Moisture content	Specific gravity at test	Wt. / cu. ft.	Shrinkage from green to ovendry, based on green dimension: Volumetric	Radial	Tangential	Static bending: Fiber stress at proportional limit	Modulus of-- Rupture	Elasticity	Work to-- Proportional limit	Maximum limit	Total
	No.	Percent		Lb.	- - - Percent - - -			Lb. /sq. in. -		1,000 lb. / sq. in.	- In. -lb. /cu. in. -		
Sand (OSP)	5	36	0.45	38	10.0	3.9	7.3	4,100	7.500	1.020	0.95	9.6	20.6
		12	.48	34				6.700	11.600	1.410	1.83	9.6	17.4
Loblolly	56	81	.47	53	12.3	4.0	7.4	4,100	7.300	1,410	.68	a. 2	24.2
		12	.51	36				7.800	12,800	1.800	1. 92	10.4	17.5
Longleaf 4	4	63	.54	55	12.2	5.1	7.5	5,200	8, 700	1,600	.95	a. 9	32.4
		12	.58	41				9,300	14,700	1,990	2.44	11.8	21.9
Pond	5	56	.50	49	11.2	5. 1	7.1	4,500	7,400	1.280	.93	7.5	26.8
		12	.54	38				a, 300	11,600	1,750	2.21	8.6	16.0
Slash	30	66	.56	58	12.2	5.5	7.8	5,100	a. 900	1,580	1.02	9.5	30.6
		12	.61	43				9,800	15,900	2,060	2.76	12.6	20.8
Spruce[b] 3	5	(c/)	.41	--	--	--	--	2.900	6,000	1,000	.51	--	--
		12	.44	--	--	--	--	5.100	10,400	1,230	1.22	--	--

a/ Data from Markwardt and Wilson (13) except where otherwise indicated.

b/ Data from Bendtsen (1).

c/ Green.

Table 1. --Physical and mechanical properties of sand pine (OSP) and other pine species within its range[a/] (continued)

Pine species	Trees tested	Moisture content	Specific gravity at test	Wt./cu. ft.	Impact bending: Stress at proportional limit	Impact bending: Work at proportional limit	Impact bending: Height of drop causing complete failure (SO-lb. hammer)	Compression parallel to grain: Stress at proportional limit	Compression parallel to grain: Maximum crushing strength	Compression perpendicular to grain, stress at proportional limit	Shear parallel to grain, maximum shearing strength	Tension perpendicular to grain, maximum tensile strength	Hardness (Load required to embed a 0.444-in. ball to 1/2 its diameter): End	Hardness: Side
	No.	Percent		Lb.	Lb./sq. in.	Lb./cu. in.	In.	Lb./sq. in.					Lb.	
Sand (OSP)	5	36	0.45	38	9,800	4.6	25	2. 670	3,440	560	1,140	380	460	480
		12	.48	34	12,400	5.4	19	3. 90.0	6.920	1,030	1,100	300	950	730
Loblolly	56	81	.47	53	8,900	3.0	30	2,550	3.490	480	850	260	420	450
		12	.51	36	12,100	4.2	30'	4,820	7.080	980	1.370	470	750	690
Longleaf 4	4	63	.58 54	41 55	10,100 15,400	3.26.1	34 35	3.430	4,300	590	1,040	330	550	590
		12						6,150	8,440	1.190	1,500	470	920	870
Pond	5	56	.50	49	9.400	3.2	33	2.940	3.660	540	940	280	460	510
		12	.54	38	13,200	5.0	28	6,300	7.540	1,120	1,380	360	780	740
Slash	30	66	.56	58	10,800	3.9	36	3,040	4,340	680	1,000	400	600	630
		12	.61	43	15,800	8	36	6.280	9,100	1,390	1,730	570	1.080	1,010
Spruce[b/] 3	5	(c/)	.41	--	--	--	--	--	2.840	280	900	--	480	450
		12	.44	--	--	--	--	--	5,650	730	1,490	--	.820	660

a/ Data from Markwardt and Wilson (13) except where otherwise indicated.

b/ Data from Bendtsen (1).

c/ Green.

small, clear test specimens, are indicative of the strength and structural properties of the wood and are the basic values used to compute working stresses for the design of wooden structures. Specific gravity is correlated with strength. and, as can be seen in table 1, is quite variable among species. In order to put the more important strength properties on a comparative basis, ratios of strength to specific gravity were developed by taking the strength values in table 1 at 12 percent moisture content and dividing them by the specific gravity at the 12 percent level. The ratios of strength to specific gravity shown in table 2 indicate that sand pine is about equal to or better than the other species listed in breaking strength (modulus of rupture), crushing strength parallel to the grain, and compression perpendicular to the grain and that it can therefore be put to some of the same- construction uses as the other yellow pines. It is, however, lower in stiffness (modulus of elasticity) than all species listed except spruce pine and is lowest in shear parallel to the grain. These characteristics limit the spans over which sand pine could be used. Because of its lower stiffness, it would have to be used over shorter spans; otherwise, it would exceed deflection limitations before reaching its load limitations.

Hardness is an indicator of ease of nailability as well as resistance to wear than the average of the other five yellow pines.' OSP is higher in end-grain hardness and about equal in side hardness. It should, therefore, have about the same nailing and wearing characteristics as the other pines listed.

Chemical Composition

The chemical composition of the wood of the two varieties of sand pine is important in the pulping and chemical industries. Table 3 lists the basic chemical composition of both varieties, together with that of slash and longleaf pines --two species with which they are mixed in the manufacture of pulp. It appears from the limited analysis made in table 3 that both varieties of sand pine have a slightly lower lignin content than do longleaf and slash pines . Low lignin content is, of course, desirable because lignin has little use; thus, a low lignin content helps reduce the pulp industry's problems of disposal and pollution.

The holocellulose content, is an indicator of the total non-lignin fraction of the wood. Table 3 shows that OSP has about 11 percent less holocellulose than do CSP and longleaf pine and about 3 percent more than slash pine.

Of primary significance are the yields'of alpha-cellulose and pentosans. According to the analyses summarized in table 3, CSP has a higher alpha-cellulose content (8.6 percent more) and pentosans content (7.5 percent more) than OSP. This higher alpha-cellulose content of CSP would make it more desirable than OSP for the dissolving pulp industry in the manufacture

Table 2.--Ratios of strength to specific gravity for sand pine and several yellow pines within its range[a]

Pine species	Static bending		Maximum crushing strength parallel to grain	Compression perpendicular to grain, stress at proportional limit	Maximum shearing stress parallel to grain	Hardness	
	Modulus of rupture	Modulus of elasticity				End	Side
	Lb./sq.in.	1,000 lb./sq.in.	Lb./sq.in.	Lb./sq.in.	Lb./sq.in.	Lb.	Lb.
Sand (OSP	24,200	2,900	14,400	2,150	2,290	1,980	1,520
Loblolly	25,100	3,500	13,900	1,960	2,690	1,470	1,350
Longleaf	25,300	3,400	14,600	2,050	2,590	1,590	1,500
Pond	21,500	3,200	14,000	2,070	2,560	1,440	1,370
Slash	26,100	3,400	14,900	2,280	2,840	1,770	1,660
Spruce	23,600	2,800	12,800	1,660	3,390	1,860	1,500

[a] Values in this table were computed by dividing the respective strength values at 12 percent moisture content in table 1 by their specific gravity at 12 percent moisture content.

Table 3. --Chemical composition of both varieties of sand pine and of longleaf and slash pines

Item	OSP [a]	CSP [b]	Longleaf pine [b]	Slash pine [c]
	Percent			
Lignin	27.2	28.4	29.2	28.5
Holo-cellulose	61.0	72.2	72.1	57.7
Alpha-cellulose	42.9	51.5	55.9	45.0
Pentosans	6.9	i4.4	12.7	7.6
Alcohol-benzene	2.2	3.1	2.3	2.8
1 percent sodium hydroxide	1.1.8	11.4	11.0	10.8
Hot water	2.5	2.2	1.2	1.8
Ether	1.1.			2.2
Ash		.4	.3	.3

a/ From Bray and Martin (2).

b/ From Martin (14).

c/ From USDA Forest Products Laboratory (21).

of rayon and nitrocellulose. The higher pentosans content makes it more desirable than OSP for the manufacture of furfural, a compound used to manufacture furan and phenolic resins. CSP is only 4.4 percent lower in alpha-cellulose and slightly higher in pentosans (1.7 percent) than longleaf pine. CSP has higher alpha-cellulose and pentosans contents than slash pine. OSP, on the other hand, has lower alpha-cellulose and pentosans contents than longleaf and slash pines. It appears from these data that CSP could be mixed with longleaf pine in the production of alpha-cellulose without seriously affecting the yield and that it would also contribute to a high yield of pentosans for furfural production.

WOOD QUALITY

Specific Gravity

Evaluation of the wood quality of sand pine has been centered around the development of information on wood specific gravity. This property has been given considerable attention because it has been found to be correlated with other wood properties and is relatively easy to determine.

Early determinations of the specific gravity of this species were made on a relatively small number of samples, from different parts of the stem as well as by different techniques. Because of these differences, considerable variation in the specific gravity of OSP was reported: Markwardt and Wilson (13) reported a specific gravity of 0.45, Bray and Martin (2) 0.46, McGovern and Keller (12) 0.51, Saucier and Taras (16) 0.48. CSP, which did not receive any attention until 1962, showed similar variations in specific gravity: Martin (14) reported 0.46 and Burns and Brendemuehl (3) 0.51.

The most comprehensive study of the specific gravity of sand pine was conducted by Clark and Taras (5) in 1969. As part of a wood density survey of the minor species of yellow pine in the eastern United States, both varieties of sand pine were sampled in 35 different locations over their entire ranges. Average specific gravity of increment cores was 0.439 for OSP and 0.485 for CSP. When increment cores were extracted with benzene and alcohol to remove the turpentine, gums, and resin acids (thereby leaving only the wood substance), the specific gravity of increment cores of OSP dropped to 0.407, a difference of 7.86 percent. In CSP, solvent extraction reduced specific gravity to 0.442, a reduction of 9.73 percent.

Estimates of average tree specific gravity of OSP and CSP as determined by this study are shown in table 4; these estimates are broken down by diameter classes and by Forest Survey Units in Florida and Alabama. Estimated tree specific gravity for all diameter classes averaged 0.419 for OSP and 0.482 for CSP. Examination of the data collected over the entire range of the two varieties indicated that there were no geographic trends from north to south or east to west, except for the major difference in specific

Table 4. --Specific gravity of OSP and CSP by diameter classes and by Forest Survey Units in Florida and Alabama[a/]

OCALA SAND PINE

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Specific gravity of unextracted increment cores: Mean and standard error	Specific gravity of unextracted increment cores: Standard deviation	Estimated tree specific gravity,[b/] mean and standard error	Approx. timber volume[c/]
	No.	In.	No.				Million cu. ft.
Florida							
Northeast (1)	19	5.0- 8.9	254	0.438 (.005)	0,034	0.437 (.003)	42.4
		9.0-14.9	136	.441 (.006)	.043	.418 (.005)	18.0
		15.0+	10	.449 (.018)	.065	.379 (.017)	.9
Central (3)	6	5.0- 8.9	68	.425 (.008)	.048	.397 (.008)	13.0
		9.0-14.9	44	.452 (.008)	.041	.385 (.010)	5.1
		15.0+	11	.465 (.003)	.054	(d/)	.1
State total	25	5.0- 8.9	322	.435 (.004)	.035	.433 (.003)	55.4
		9.0-14.9	180	.444 (.005)	.041	.403 (.006)	23.1
		15.0+	21	.458 (.003)	.056	(d/)	1.0
Total all classes	25		523	.439 (.004)	.037	.419 (.004)	79.5

Table 4. --Specific gravity of OSP and CSP by diameter classes and by Forest Survey Units in Florida and Alabama[a] (continued)

CHOCTAWHATCHEE SAND PINE

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Specific gravity of unextracted increment cores: Mean and standard error	Specific gravity of unextracted increment cores: Standard deviation	Estimated tree specific gravity,[b] mean and standard error	Approx. timber volume[c]
	No.	In.	No.				Million cu. ft.
Alabama							
Southwest (1)	1	5.0- 8.9	9	.501 (.019)	.057	.497 (.012)	--
		9.0-14.9	11	.515 (.017)	.056	.502 (.011)	--
		15.0+	0	0	0	0	--
Florida							
Northwest (2)	9	5.0- 8.9	90	.480 (.020)	.053	.480 (.004)	8.8
		9.0-14.9	72	.484 (.006)	.037	.478 (.005)	1.1
		15.0+	11	.489 (.009)	.057	.472 (.012)	--
Total both states	10	5.0- 8.9	99	.482 (.018)	.053	.482 (.004)	8.8
		9.0-14.9	83	.488 (.005)	.056	.481 (.005)	1.1
		15.0+	11	.489 (.009)	.057	.472 (.012)	--
Total all classes	10		193	.485 (.003)	.045	.482 (.003)	9.9

a/ Adapted from Clark and Taras (5).

b/ Estimates were made from the following equations:

OSP: Tree sp. gr. (Y) = 0.26222 + 0.56947 (sp. gr., 2 extracted cores) - 0.19747 (d. b. h./age).

CSP: Tree sp. gr. (Y) = 0.14879 + 0.78915 (sp. gr., 2 extracted cores) - 0.05552 (d. b. h./age).

c/ From Forest Survey data of the Southern and Southeastern Stations.

d/ The ratio of mean d. b. h. to age for the 15.0+ inch diameter class lies outside the range for which the OSP equation can be used with confidence to estimate tree specific gravity.

gravity between CSP in western Florida and OSP in eastern Florida. One factor which may have contributed to some of the varietal differences in specific gravity could be the difference in age of the sample trees.

When these values for tree specific gravity are compared with those developed by the other investigators mentioned previously, it can readily be seen that the early investigators tended to overestimate the specific gravity of both varieties.

Values for tree specific gravity of the sand pine varieties are compared with those of the other yellow pines in the Southeast in the following tabulation:

Pine species or variety	Tree specific gravity	Source
Slash (var. densa)	0.58	Clark and Taras (6)
Slash	.53	USDA Forest Products Laboratory (22)
Longleaf	.53	USDA Forest Products Laboratory (22)
Table -Mountain	.49	Clark and Saucier (4)
CSP	.48	Clark and Taras (5)
Loblolly	.47	USDA Forest Products Laboratory (22)
Shortleaf	.47	USDA Forest Products Laboratory (22)
Pond	.47	Taras and Saucier (18)
Pitch	.47	Saucier and Clark (15)
Virginia	.45	Clark and Wahlgren (7)
Spruce	.43	Taras and Saucier (17)
OSP	.42	Clark and Taras (5)

These data show the tree specific gravity of CSP to be slightly higher than that of loblolly and shortleaf pines, two species that represent a major portion of yellow pine volume in the East. CSP is, however, lower in specific gravity than slash pine, its variety densa, longleaf pine, and Table -Mountain 'pine. The OSP variety, on the other hand, has the lowest specific gravity of all the yellow pines listed.

What does this difference in specific gravity mean in terms of utilization? From the pulping standpoint, both varieties will produce less pulp than slash and longleaf pines from the same volume of raw material. The difference in yields should not be as great for the CSP variety as it will be for the OSP variety. In the area of plywood and construction, it would be reasonable to assume that the CSP variety could be used for the same purposes as shortleaf and loblolly pines. Although the specific gravity of OSP is relatively low, this variety could still be used in plywood production. However, because of its low specific gravity, its use would be limited to the inner-ply portion of the plywood. In construction lumber, its lower specific gravity would indicate lower stiffness and its use would therefore be restricted to shorter spans than those used for other yellow pines of the same dimensions.

Tracheid Length

A wood property of considerable importance in papermaking is tracheid (or fiber) length because it is highly correlated with the tear, burst, and tensile strengths of paper. As can be seen in table 5, rather limited data are available regarding this property. In his book on the southern pines, Koch (11) shows on the basis of a survey of the literature that sand pine has an average fiber length of 3.5 mm. This is 0. 5 mm. shorter than the length reported for the four major species of yellow pines (loblolly, slash, longleaf, and shortleaf). This small difference in fiber length is not a limiting factor in the manufacture of pulp and paper from sand pine.

Koch (11) developed data on fiber length from one tree of each variety. His data show that OSP has a higher average fiber length (4.4 mm.) than CSP (3.64 mm.). Because of the limited sample, these data should be considered as only indicative of fiber length.

The USDA Forest Products Laboratory (19) reported the average fiber length of sand pine to be 2. 85 mm. --which appears to be rather low. This discrepancy has perhaps resulted because pulp and paper manufacturers generally report measurements made on all cellular elements and broken fibers rather than on the fibers alone.

Tracheid Dimension

Tracheid dimensions are properties of wood that are avoided by most researchers because of the difficulty, tediousness, and time consumption involved in gathering the data. Consequently, the information available on cell wall thickness and diameter is very limited. Such data are important in the pulp and paper field because they reflect the ease of collapsibility of the fiber as well as its flexibility, both of which play an important role in paper properties and characteristics.

Table 5.--Tracheid length for both varieties of sand pine

Pine species or variety	Tracheid length	Range SD	Trees sampled	Comments on samples	Source
	---- Mm. ----		No.		
Sand	2.85	--	--	--	USDA Forest Products Laboratory (19)
OSP	4.40	0.76	1	Mean for one 58-yr. -old tree, range was 2.8 to 6.5 mm.	Koch (11)
CSP	3.64	.67	1	Mean for one 57 -yr. -old tree, range was 2.2 to 5.1 mm.	Koch (11)
CSP	3.6	--	--	Range was 1.5 to 5.5 mm.	Buckeye Cellulose Corporation[a]

[a] Buckeye Cellulose Corporation. Sand pine properties and uses. Personal correspondence, April 20, 1972.

Single-wall thickness and tangential and radial diameters of early-wood and latewood cells are shown for both varieties of sand pine in table 6. The data in this table are limited to Koch's (11) observations made on one tree of each variety and should be considered as only weak indicators of the various parameters measured. On the basis of these data, radial and tangential wall thicknesses of the earlywood cells of both varieties are the same--about 3.7 microns. In latewood, the radial walls appear to be slightly thicker (1 to 2 microns more) than the tangential walls in both varieties. The latewood of OSP has slightly thicker cell walls (1 to 2 microns more) than CSP.

In the earlywood, radial diameter 'is larger by 2 to 4 microns than the tangential diameter in both varieties. In the latewood cells, the tangential diameter is 5 to 6 microns larger than the radial diameter. In both the early-wood and the latewood, CSP has cells of smaller diameter than OSP.

When the cell dimensions of both varieties are compared with those of slash and longleaf pines, it appears that the wall thickness of the earlywood of both varieties is about equal to that of longleaf pine and greater than that of slash pine. The cell wall thickness of the latewood of OSP is equal to that of slash and longleaf pines, but CSP has slightly thinner walls than the two major yellow pines. The diameters of the earlywood cells of both varieties are smaller (by 10 to 12 microns) than those of longleaf and slash pines.

In the latewood, slash and longleaf pines both have larger cell diameters than sand pine. In a study made by the Buckeye Cellulose Corporation,[1/] wall thickness of CSP was reported to be 7.7 microns, which is slightly higher than that reported by Koch (11). Cell diameter, however, was reported as 34 microns, which is equivalent to that reported by Koch for the average of springwood and summerwood tracheids.

Heartwood and Sapwood

The amounts of heartwood and sapwood contained in a tree are important in wood preservation because they are directly related to wood durability and penetrability of preservatives. Large proportions of sapwood are desirable because of the ease of penetration of preservative into this type of tissue. Heartwood is virtually impenetrable but slightly more durable than sapwood.

A study of the percentage of heartwood and the depth of sapwood in both varieties of sand pine indicated that heartwood in trees of both varieties

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1/ Buckeye Cellulose Corporation. Sand pine properties and uses. Personal correspondence, April 20, 1972.

Table 6. --Tracheid dimensions for both varieties of sand pine and for longleaf and slash pines as based on single-tree samples[a/]

EARLY WOOD

Pine species or variety	Cells measured	Single-wall thickness: Tangential	SD	Radial	SD	Cell diameter: Tangential	SD	Radial	SD
	No.	Microns							
OSP	104	3.7	0.8	3.7	0.9	36.9	5.6	39.4	5.5
CSP	296	3.7	.9	3.6	.8	34.6	5.8	38.7	6.2
Longleaf	384	4.0	1.1	3.8	1.1	47.7	7.2	49.2	7.9
Slash	216	3.2	.3	3.2	.3	45.1	8.4	52.1	9.3

LATEWOOD

Pine species or variety	Cells measured	Single-wall thickness: Tangential	SD	Radial	SD	Cell diameter: Tangential	SD	Radial	SD
OSP	52	9.8	1.9	11.7	1.8	34.7	5.3	28.8	4.2
CSP	164	8.7	1.5	9.9	1.8	32.6	5.2	26.9	4.3
Longleaf	300	9.9	1.9	12.0	2.7	38.8	7.0	31.1	5.3
Slash	124	9.0	1.4	12.9	2.8	39.1	7.0	27.1	3.9

ALL WOOD

Pine species or variety	Cells measured	Single-wall thickness: Tangential	SD	Radial	SD	Cell diameter: Tangential	SD	Radial	SD
OSP	156	5.7	3.2	6.3	4.0	36.2	5.6	35.8	7.2
CSP	460	5.5	2.7	5.8	3.3	33.0	5.7	34.5	8.0
Longleaf	684	6.6	3.3	7.4	4.5	41.0	7.4	41.3	11.3
Slash	340	5.3	2.9	6.8	5.0	42.9	8.4	43.0	14.3

[a/] Data from Koch (11). OSP was 58 years old, 10.3 in. d. b. h., and 58.0 ft. high. CSP was 57 years old, 18.2 in. d. b. h., and 69.0 ft. high. Longleaf pine was 60 years old, 16.7 in. d. b. h., and 91.5 ft. high. Slash pine was 39 years old, 14.8 in. d. b. h., and 74.5 ft. high.

averages about 2'7 percent.[2/] This study was conducted on 84 OSP and 50 CSP trees that ranged in age from 12 to 72 years and in d. b.h. from 5.1 to 17.1 inches. Prediction equations have been developed for estimating percentage of heartwood with either age or age and d. b. h. as independent variables; these equations are shown in table 7, together with equations for estimating depth of sapwood. According to the USDA Forest Products Laboratory (20), depth of sapwood in southern yellow pines ranges from 3 to 6 inches, especially in second-growth trees. Taras' unpublished study shows the average depth of sapwood to be 1.79 inches for OSP trees 42 years of age and 2.01 inches for CSP trees 44 years of age.

Percentage of Summerwood

Percentage of summerwood is an expression of the proportion of the denser, smaller-celled part of a growth ring. It is a property correlated with specific gravity and is sometimes used as a rough indicator of it. Growth rings vary considerably in this property from the pith to the bark within a tree and from the bottom of the tree to the top within a given growth sheath. Proportions of summerwood above 30 percent are generally associated with relatively high specific gravity. No information exists on the relative amount of summerwood contained within either variety of sand pine on a total-tree basis. In 1943, McGovern and Keller (12) indicated the summerwood on a small sample of OSP pulpwood to be 32.5 percent. In 1962, Martin (14) showed the summerwood of some CSP pulpwood to be 28 percent. The relative value of this particular property is difficult to assess.

PULP AND PAPER QUALITIES

Pulping Characteristics

Sand pine was first evaluated as a potential pulp and paper species in 192'7 by Wells and Rue (23). Although their first tests were limited, they stated that, under the sulfite process, sand pine has uniform digestion qualities and yields pulp of very fair quality, capable of bleaching with reasonable quantities of chemical (10 to 20 percent), and suitable for wrapping and printing papers. Yields were between 25 and 35 percent. Sand pine was also found to reduce readily by the sulfate process and to produce unbleached pulp of fair strength, suitable for high-grade kraft wrapping papers and fiberboards. Yields were reported to be between 40 and 45 percent.

[2/] Taras, Michael A. 1972. (Unpublished data, Work Unit on Grade and Quality of Southern Timber, Southeast. For. Exp. Stn., For. Sci. Lab,, Athens, Ga.)

Table 7. --Prediction equations for estimating the percentage of heartwood and the depth of sapwood in trees of both varieties of sand pine[a/]

PERCENTAGE OF HEARTWOOD

Variety	Average-- Sample trees	Age	D.b.h.	Ht.	Correlation coefficient	Coefficient of determination	Regression equations	SE associated w/regression
	No.	Yr.	In.	Ft.				
OSP	a4	42	8.7	51.3	0.685	0.470	Y = 1.4191 t 0.6169 (age)	9.01
					.709	.504	Y = -4.2017 t 0.5733 (age) + 0.8545 (d. b. h.)	8.88
CSP	54	44	10.8	54.4	.685	.469	Y = -5.9556 + 0.7616 (age)	7.67
					.756	.498	Y = -6.9423 t 0.6435 (age) t 0.5746 (d. b. h.)	7.68
Both	138	43	9.6	52.9	.681	.464	Y = -0.2768 t 0.6474 (age)	8.56

Table 7. --Prediction equations for estimating the percentage of heartwood and the depth of sapwood in trees of both varieties of sand pine[a] (continued)

DEPTH OF SAPWOOD

Variety	Average-- Sample trees	Age	D.b.h.	Ht.	Correlation coefficient	Coefficient of determination	Regression equations	SE associated w/regression
	No.	Yr.	In.	Ft.				
OSP	84	42	8.7	51.3	.628	.395	$Y = 0.9352 + 3.5454 \left(\frac{d.b.h.}{age}\right)$	.528
					.695	.483	$Y = 1.2871 + 0.1622\,(d.b.h.) - 0.0220\,(age)$	.497
CSP	54	44	10.8	54.4	.792	.627	$Y = 0.5155 + 6.1026 \left(\frac{d.b.h.}{age}\right)$	.333
					.768	.591	$Y = 1.5982 + 0.1339\,(d.b.h.) - 0.0232\,(age)$	.359
Both	138	43	9.6	52.9	.654	.428	$Y = 0.8983 + 4.0380 \left(\frac{d.b.h.}{age}\right)$	.484

[a] Adapted from: Taras, Michael A. 1972. (Unpublished data, Work Unit on Grade and Quality of Southern Timber, Southeast. For. Exp. Stn., For. Sci. Lab., Athens, Ga.)

In 1942, Bray and Martin (2) reported on a sample of OSP on which pulping tests were made by the soda, sulfate, and neutral sulfite semi-chemical processes. They concluded that OSP is suitable for the production of strong kraft and bleachable pulps with the sulfate process. The unbleached sulfate pulps were found to be suitable for wrapping papers, the semi-bleached pulps for newsprint, and the fully bleached pulps for high-grade papers. OSP was also readily reduced by the soda and soda-sulfur processes, but the pulps did not possess the softness, opacity, and bulk common to bleached hardwood pulps. The neutral sulfite semi-chemical pulps were somewhat brash, dark-colored, and much weaker than the kraft pulps and were therefore suitable for lower grades of wrapping paper stock and corrugating board. McGovern and Keller (12) found the paper-making qualities of pulps produced by the sulfite process from a sample of OSP to be decidedly inferior to those of sulfite pulps from other southern pines.

Pulping tests conducted on CSP by Martin (14) with the kraft sulfate process showed that pulps from this variety were higher in overall strength and brightness than kraft pulps made from longleaf pine under the same cooking conditions and bleaching requirements. Tests indicated CSP pulps to be suitable for unbleached and bleached kraft papers of high strength.

In 1957, the Hudson Pulp & Paper Corporation conducted a series of tests on OSP with the kraft sulfate process and compared its pulp properties to those of slash pine. 3/ OSP was found to pulp satisfactorily under the same conditions as slash pine. The OSP pulp was stronger than slash pine pulp in burst factor (15 percent higher) and tensile strength (14 percent higher). It also produced a denser sheet of about the same softness as slash pine. Tear factor of the OSP pulps, however, was about 19 percent lower than that of slash pine. St. Regis Paper Company in 1956 produced OSP pulps with similar properties. 4/ These studies also showed that, in some cases, OSP pulps can be satisfactorily mixed in various proportions with slash pine pulp to produce combination pulps with slightly improved properties over those of slash pine pulps alone.

Pulp Yields

In addition to a species' pulping characteristics, its pulp yields are of prime importance to the pulp and paper industry. How do the pulp yields

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3/ Hudson Pulp & Paper Corp. Comparison of strength and softness of regular pine and sand pine kraft pulps. 1957. (Internal office report, Woodlands Division, Palatka, Fla.)

4/ St. Regis Paper Company. Evaluation of sand pine (*Pinus clausa*). 1956. (Internal office report, Pensacola, Fla.)

for sand pine compare with those for other species? This question is answered in part in table 8, which shows the pulp yields for the two varieties of sand pine as well as for longleaf and slash pines. The yields shown in table 8 are computed on the basis of input of ovendry wood chips. On this basis, it can readily be seen that pulp yields for both varieties of sand pine under a variety of cooking conditions are equal to the yields obtained for longleaf and. slash pines when cooked under the same conditions.

Pulp yields may also be computed with volume (cord) or green weight as a basis for computation. On this basis, the yield obtained from a given volume of sand pine will be less than that obtained from the same volume of slash or longleaf pine. This difference in yield is attributable to the differences in the relative density or the specific gravity of the wood. On an ovendry basis, a cubic foot of OSP weighs about 26 pounds, whereas slash and longleaf pines average about 33 pounds. If the same cord-weight equivalent used for slash and longleaf pines (about 5, 500 pounds) is also used for OSP, the yield difference would nearly disappear. This method would involve increasing the cord weight or volume by 500 pounds because a cord of OSP weighs about 5,000 pounds. In view of this difference in cord weight, pulping sand pine alone would require greater digester capacity in order to meet the same production level as that reached in the pulping of slash and longleaf pines.

USES AND MARKETS

Early investigations as well as the more recent ones in the late 1960's show that both varieties of sand pine are suitable for pulping by several processes. The kraft sulfate process, however, appears to be the one best suited to the reduction of sand pine to pulp because of the high yields and superior -quality pulp obtained. The pulp and paper industry, which currently uses the greatest volume of sand pine, will continue to use it in increasing volumes in the future.

The amount of sand pine going into the manufacture of yard and structural lumber for the construction industry is not known. I personally estimate it to be an extremely small amount. Most of the sales of sand pine timber are currently being made to the pulp and paper industry from the National Forests, where the bulk of the volume is located. The construction lumber market is a good potential outlet for some of the volume of sand pine. Tree size and, perhaps, form have been the main deterrents to the use of sand pine for the manufacture of structural lumber. Size, however, need not be a deterrent any longer because of the changes taking place in utilization and logging practices. Sawmills are now using chipper headrigs or are supporting their large mills with small chipper-canters so that they can handle large volumes of small logs 6 to 10 inches d.i. b. A chipper-headrig operation set up for small timber can produce large volumes of lumber suitable for construction purposes. Both varieties definitely have sufficient density for this use.

Table 8. --Pulp yields for both varieties of sand pine and associated yellow pines with the kraft sulfate process

OCALA SAND PINE

Source	Cooking condition: Active alkali added	Cooking condition: Permanganate No.	Pulp yield: Screened pulp by weight	Pulp yield: Screening	Total crude pulp
	Percent		Percent	Percent	Percent
Wells and Rue (23)	20.0	--	40.1	1.0	41.1
Bray and Martin (2)	13.3	--	47.0	3.4	50.4
	13.3	--	42.8	1.7	44.5
	20.0	--	43.8	.1	43.9
Hudson Pulp & Paper Corp.[a]	18.6	18.5	43.8	.7	44.5
	20.5	23.0	44.8	.5	45.3
Hudson Pulp & Paper Corp.[b]	--	28.5	43.5	3.0	46.6
St. Regis Paper Company[c]	16.8	33.4	45.6	4.5	50.1
	16.8	33.4	45.4	4.1	49.5

CHOCTAWHATCHEE SAND PINE

Source	Active alkali added	Permanganate No.	Screened pulp by weight	Screening	Total crude pulp
Martin (14)	14.0	32.8	47.6	3.3	50.9
	18.0	19.4	45.1	.3	45.4
	20.0	16.6	43.9	.1	44.0

LONGLEAF PINE

Source	Active alkali added	Permanganate No.	Screened pulp by weight	Screening	Total crude pulp
Martin (14)	14.0	31.5	48.4	2.7	51.1
	18.0	19.2	46.0	.2	46.2
	20.0	16.8	44.7	.1	44.8

Table 8. --Pulp yields for both varieties of sand pine and associated yellow pines with the kraft sulfate process (continued)

SLASH PINE

Source	Cooking condition		Pulp yield		Total crude pulp
	Active alkali added	Permanganate No.	Screened pulp by weight	Screening	
	Percent		----- Percent -----		
Hudson Pulp & Paper Corp.[a]	18.6	18.3	43.7	0.7	44.4
	20.5	22.9	47.9	1.0	48.9
Hudson Pulp & Paper Corp.[b]	--	28.2	44.5	3.0	47.0
St. Regis Paper Company[c]	16.8	33.4	48.1	3.8	51.9
	16.8	31.5	47.2	2.4	49.6

[a] Hudson Pulp & Paper Corp. Comparison of strength and softness of regular pine and sand pine kraft pulps. 1957. (Internal office report, Woodlands Division, Palatka, Fla.)

[b] Hudson. Pulp & Paper Corp. Pulp yields from slash and sand pine. 1964. (Internal office report, Woodlands Division, Palatka, Fla.)

[c] St. Regis Paper Company. Evaluation of sand pine (<u>Pinus clausa</u>). 1956. (Internal office report, Pensacola, Fla.)

Although OSP is somewhat low in specific gravity for construction purposes, it can still be used for beams on limited spans. Its low density is not altogether disadvantageous. Low density also means that the wood is lighter and therefore easier to handle, to saw, and to nail without splitting. It would be excluded from areas requiring dense, structural-grade material; however, there are numerous places where it could be used without problems. CSP, whose density is somewhat higher than that of OSP, could be put to structural uses similar to those of loblolly and shortleaf pines because the specific gravity of all three is in the same range.

The rapid expansion of the southern pine plywood industry is placing increasing demands on our forest resources. Although size of raw material is a major factor to this industry, plywood manufacturers are considering using some 4-foot lathes with small spindles in order to cut small-sized material down to a core diameter of less than 3 inches. Veneer made from OSP could be used for the inner plies of a plywood panel. Because of its higher density, CSP could possibly meet the plywood standards and be used for face as well as inner-core plies. When the properties of sand pine and its relatively low density are considered, there is no reason why it cannot be made into veneer without difficulty.

The particle -board industry, which started as a secondary industry that utilized the residue of other industries as its main source of raw material, is now using roundwood as its prime source of such material. Timber size or quality is not important in this industry because the wood is reduced to small particles or flakes and then glued back together. Because of its low density, OSP would be very useful in the manufacture of particle boards of relatively low to medium density.

The "ugly duckling," as this species has been referred to in the literature, has adequate wood properties to meet the requirements for many wood products --the deterrents to its use are factors other than basic wood characteristics.

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SAND PINE: CONE AND SEED TRAITS

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Abstract.--Trees of the Choctawhatchee variety of sand pine in western Florida average 1,010 cones per bushel and 56,100 seeds per pound. The Ocala variety in peninsular Florida averages 830 cones per bushel and 47,200 seeds per pound. Cones of the Choctawhatchee variety open readily at 105° F.; cones of the Ocala variety will open if dipped in boiling water and then dried at 105°. The latter, if 2 or more years old, yield seeds of decreased viability, but seeds from both varieties store well at 10-percent moisture content and 25° F. Seeds of the Choctawhatchee variety require stratification for 14 days, but seeds of the Ocala variety, if from new or 1-year-old cones, are nondormant.

The two varieties of sand pine (*Pinus clausa* (Chapm.) Vasey) differ in their cone characteristics. Variety *clausa,* often referred to as Ocala sand pine, has persistent, serotinous cones that normally open only after fire. Cones of variety *immuginata,* or Choctawhatchee sand pine, open on the tree as do those of most other southern pine species.

About 10 years ago, studies were started at Alexandria, Louisiana, to obtain information about collecting and processing cones and treating and storing seeds of both varieties. Many of the findings were published as U. S. Forest Service Research Paper SO-19 (3). The present summary is based on this paper but includes some data acquired later.

For the Alexandria studies, cones from the Choctawhatchee variety were collected on the Eglin Air Force Base Reservation, Walton County, Florida, in mid-September 1962. Collections from the Ocala variety were made in Marion County during early November. For each variety, 15 to 20 trees of uniform size and age were felled to obtain seed. Cones from individual trees were kept separate, and those of the Ocala variety were also segregated by age, i.e., new cones, l-year-old cones, and cones 2 or more years old. Further segregation by age would have been difficult, because sand pine often forms two or three whorls of cones a year (9). Additional collections in the same year were used to evaluate the effects of cone specific gravity on opening characteristics and seed viability.

CONE SPECIFIC GRAVITY

Cones from 20 trees of the Choctawhatchee variety opened within 48 hours at kiln temperatures of 105° F. , despite a range in specific gravity of 0.85 to 1.11. Germination of the seeds from these cones ranged from 80 to 93 percent, except that seeds from one tree averaged 47 percent. Specific gravity and viability were uncorrelated ($r = -0.055$).

The cones from the Ocala variety, which were collected nearly 2 months later than those from the Choctawhatchee variety, ranged from 0. 63 to 0.90 in specific gravity. They opened completely after treatments that released the scales. Viability was uniformly high and was unrelated to specific gravity; the lowest germination of any seed lot was 86 percent.

Cones of most southern pines do not open fully if collected at specific gravities above 0.89 (13). In longleaf pine (*Pinus palustris* Mill.), seeds from cones of the higher specific gravities germinate less well than seeds from mature cones (10).

EXTRACTION

The cones of the Choctawhatchee variety opened within 48 hours in kilns heated to about 105° F.

Cones of the Ocala variety resemble those of other serotinous species in that a resinous substance seals the tips of the scales. Cooper et al. (7) reported that kiln temperatures of 140° to 150° F. opened cones of this variety in 4 hours and that temperatures up to 170° for 2 hours had little effect on seed viability. Temperatures this high are difficult to obtain in commercial practice ; most cone kilns in the South are designed to operate at 100° to 105° F. Little and Dorman (9) reported that immersion in boiling water for a few seconds loosened the scales sufficiently to allow seed release after drying.

Several extraction methods were tested on cones of the Ocala variety: (a) kilning, (b) applying a flame directly to the cones, (c) soaking in a solvent, and (d) immersing in boiling water. Kiln temperatures of 130° to 140° F. were required to break the resinous seal, and even then many of the cones opened only partially. Directing a flame on the cones in a wire basket broke the seal in about 5 seconds, but 'the danger of cone ignition appears to be too great for this technique to have commercial application. A 1:2 mixture of ethanol and benzene, which Roe (11) found to be effective for jack pine (*P. banksiana* Lamb.); freed the scales in 12 to 18 hours. However, this process is too slow and expensive for practical purposes.

Immersion of Ocala sand pine cones in boiling water was fast and efficient. Scales separated in 5 to 15 seconds, and the cones then opened completely during 24 hours of normal kilning at 100° to 105° F. By placing the cones in water and gradually raising the temperature, it was found that the resinous seal breaks at 125° F., which is near the 122° value that Cameron (5) reported as the melting point of the bonding substance in cones of lodgepole pine (*P. contorta* Dougl.) and jack pine.

Except for the controls, in which some seeds were damaged when the scales were pried apart with a knife, none of the opening treatments affected germination significantly:

Treatment	Germination (Percent)
Control (scales pried apart)	78
Boiled for 15 seconds	85
Alcohol-benzene soak	86
Direct flame	92
Kilned at 140° F.	91

Because immersion in boiling water appeared to be the most satisfactory means of opening cones of the Ocala variety, a test was run to determine how long cones could be immersed without injury to the seeds. The controls were opened by direct flame instead of by prying the scales apart. Immersion for 0.5 minute reduced germination by 6 percentage points, and viability declined significantly with each increase beyond 0.5 minute:

Immersion (Minutes)	Germination (Percent)
0.0	90
.5	84
1.0	77
2.0	15
5.0	0

Thus, cones of this variety should be kept in the water only until the scales separate--usually within 15 seconds.

In recent years, Ocala sand pine cones have been processed commercially by submerging 1-bushel lots, held in burlap bags, in vats of boiling water. Although the scales will separate when the temperature of the water is as low as 125° F., boiling water separates them much faster and also provides a wide margin to offset cooling when the bags are immersed.

PROCESSING

Commercial techniques for processing cones and seeds of sand pine are identical to those for other southern pine species. Consideration should be given to factors known to reduce storability, such as damage to seedcoats in dewinging and long-term kilning at high temperatures (4).

Liquids of varying specific gravities were tried for separating full and empty seeds for research purposes. Absolute or 95-percent ethanol gave almost perfect results, with full seeds sinking and empty seeds floating. Soaks for as long as 5 minutes in ethanol did not lessen viability; in fact, seed thus treated germinated faster and more completely than the controls.

Recent results have shown, however, that when seeds of slash pine (*P. elliottii* Engelm.) and spruce pine (*P. glabra* Walt.) are soaked in ethanol, they lose viability during storage (2). The alcohol apparently becomes toxic to the seed after lengthy contact. Drying for extended periods after soaking alleviates some of this effect, but flotation should be' delayed until just before the seeds are used.

SEED YIELDS

In all determinations, the Choctawhatchee variety averaged 1, 010 cones per bushel and ranged from 630 to 1,310. Cones of the Ocala variety, which *are* larger, averaged 830' per bushel and ranged from 450 to 1, 100. Although the trees selected for collection were relatively fruitful, most yielded less than 1 bushel of cones, and many yielded less than 0.5 bushel.

Seed yields *were* determined for five cones from each of 18 Choctawhatchee sand pines. The average yield was 42 seeds per cone--28 sound and 14 empty. No comparable measurements were made for the Ocala variety, but the average yield from 25 new cones from each of three trees was 37 sound seeds per cone.

After the seeds were cleaned of wings and trash and dried to about IO-percent moisture content, yields for both varieties averaged 0.62 pound per bushel of cones. Yields per bushel of cones from individual Ocala sand pines ranged from 0.3 to slightly over 1 pound. The 1961 (l-year-old) cones consistently yielded more seed than did the new, 1962 cones --0.77 as compared to 0.58 pound. Such year-to-year variations are common in pines (13).

Seeds of the Ocala variety averaged 47,200 per pound, with a range from 26,000 to 67,800. Seeds of the Choctawhatchee variety were generally smaller, averaging 56,100 per pound and varying between 40,800 and 58,900. These determinations were made with seeds that were 100 percent sound. The Woody-Plant Seed Manual (12) reports 75,000 seeds per pound, with a range from 65, 000 to 85, 000, but it does not distinguish between *varieties.* The values reported were probably derived from samples with high proportions of empty seed.

VIABILITY BY CONE AGE

Cooper and Schopmeyer (6) found a strong relationship between age of Ocala sand pine cones and seed viability. They reported germination of 76 'percent for seeds from new cones and 27 percent'for seeds from 5-year-old cones.

To evaluate this relationship further, Barnett and McLemore (3) tested the viability of seeds from cones of three age classes from 15 Ocala sand pines. A breakdown into more than three age groups was impractical because of multiple whorls and similar coloration of old cones.

Viability decreased with each increase in age of cones (table 1). The difference of 7 percentage points--93 versus 86 percent--between new and 1-year-old cones was relatively small compared to the drop of 37 percentage points for seeds 2 or more years old.

Table 1.--Germination of seeds of Ocala sand pine, by cone age and individual tree[a/]

Tree number	Seed extracted from-- New cones	1-year-old cones	2-year-old and older cones
	---------- Percent ----------		
1	90	87	70
2	94	84	65
3	93	87	67
4	94	88	72
5	95	84	68
6	86	72	22
7	92	94	60
8	92	76	34
9	93	95	8
10	89	88	84
11	100	95	48
12	90	95	82
13	85	69	14
14	98	92	66
15	98	90	74
Average	93	86	56

a/ Adapted from tabular data in Barnett and McLemore (3).

Germination of both new and 1-year-old seeds was fairly uniform among individual trees. Older seeds varied widely, ranging from 8 to 84 percent. This variation probably was due to differences in individual trees and in cone age. To assure high-quality seeds from the Ocala variety, collections should be limited to new and 1-year-old cones. New cones are readily distinguished by their light brown color, whereas 1-year-old cones are dark brown. Older cones are a weathered gray, are often covered with lichens, and occur in the interior portion of the crown.

The effects of cone storage on viability were evaluated by storing, three individual-tree lots of Ocala sand pine cones at a constant-temperature of 72° F. Seeds were obtained by immersing the cones in boiling water and then drying at 100° F. Viability tests were conducted initially and after 3, 6, and 9 years.

Germination of seeds from Ocala sand pine after 9 years of cone storage averaged 26 percent, as compared to 93 percent initially and 90 and 54 percent after 3 and 6 years (table 2). Viability varied markedly among trees. These tests show that serotinous cones provide a suitable environment for maintenance of viability for several years.

Table 2. --Germination of Ocala sand pine seeds initially and after cone storage for 3, 6, and 9 years at 72° F.

Tree number	Germination when tested after --			
	0 years	3 years	6 years	9 years
	------------ Percent ------------			
3	93	87	48	16
4	94	92	42	12
7	92	91	73	49
Average	93	90	54	26

PREGERMINATION TREATMENTS

Seed dormancy and methods of speeding germination were studied with lots from 10 trees of both varieties. Seeds of the Ocala variety were further subdivided into those from cones of three ages for each tree. Four treatments plus a control were evaluated for the Choctawhatchee variety and two plus a control for the Ocala variety (table 3).

Seeds of the Choctawhatchee variety were mildly dormant. Stratification on a peat-sand medium for 14 days boosted both rate and total amount of germination, but increasing the length to 28 days gave little added response. Soaking in water at 34° F. was better than soaking in l-percent hydrogen peroxide.

Table 3. --Germination of Choctawhatchee and Ocala varieties of sand pine seed subjected to various pregermination treatments[a/]

CHOCTAWHATCHEE VARIETY

Pregermination treatment	Peak germination	Germination value[b/]	Final germination[c/]
	Day		Percent
None	17	15.4	88
14 -day stratification	11	26. 3	93
28 -day stratification	10	27.9	94
24 -hour soak in water	13	20.7	92
24 -hour soak in H2 02	14	18. 1	89

OCALA VARIETY

Pregermination treatment	Peak germination	Germination value[b/]	Final germination[c/]
New cones			
None	10	32.0	94
14-day stratification	9	34.3	96
28-day stratification	8	35.9	93
1 -year-old cones			
None	10	24.1	89
14 -day stratification	10	26.6	90’
28 -day stratification	10	25.3	84
‘L-year-old and older cones			
None	15	10.9	70
14-day stratification	14	8.2	54
28-day stratification	11	5.7	43

a/ Adapted from tabular data in Barnett and McLemore (3).

b/ Czabator's (8) germination values, which take into account both speed and completeness of germination, are presented so that treatments can be compared.

c/ Germination tests conducted with loo-percent sound seed from 10 trees of each variety.

Dormancy of Ocala sand pine seeds varied with cone age. Seeds from new and 1 -year-old cones germinated promptly without presowing treatment, and none of the treatments stimulated germination significantly. Older seeds were slightly dormant. Stratification speeded germination but'decreased total viability substantially; thus it is not recommended for Ocala sand pine seeds.

A comparison of treatments common to both'varieties indicates that fresh Ocala sand pine seeds performed slightly better than Choctawhatchee sand pine seeds stratified for 28 days.

STORAGE

Sand pine seeds are easily stored (1). When held in sealed containers at all possible combinations of 6-, 9-, 12-, and 15-percent moisture contents and 0°, 25°, and 34° F. temperatures, Ocala sand pine seeds from new and l-year-old cones remained almost uniform in viability over a 5-year period. Even after 5 years, germination of seeds from new cones exceeded 95 percent and that of l-year-old cones exceeded 84 percent. With other southern pines, germination declines fastest when seeds are stored at high temperatures and moisture contents.

Seeds of the Choctawhatchee variety apparently are more sensitive to storage conditions than are those of the Ocala variety. Although there were no losses in viability after 1 or 3 years (table 4), germination after 5 years averaged 75 percent for storage at 0° F., 70 percent for storage at 25°, and 61 percent for storage at 34° F. Even seeds held under the most ideal conditions for 5 years germinated less than the initial 86 percent, but storage at 0° and 25° F. was significantly better than at 34° F. Moisture contents, ranging from 6 to 15 percent, had no effect on storability. Apparently, temperature is more important than moisture content in preserving viability of the se seeds.

The sand pine seeds in this study kept well under a wide range of conditions, but moisture contents of 10 percent or less and subfreezing temperatures are recommended for long-term storage. These conditions will allow a margin of safety for seed lots weaker than those tested.

Table 4. --Viability of Choctawhatchee sand pine seeds after 1, 3, and 5 years of storage[a]

Storage conditions[b]		Viability after storage for--		
Temperature (° F.)	Moisture content (percent)	1 year	3 years	5 years
		- - - - Percent - - - -		
0	6	86	92	72
	9	92	94	78
	12	87	95	69
	15	86	94	81
25	6	86	94	76
	9	84	94	72
	12	83	93	64
	15	86	90	68
34	6	85	91	60
	9	87	93	58
	12	84	90	67
	15	85	89	59
Average		86	92	69

a/ Adapted from tabular data in Barnett (1).

b/ Initial viability was 86 percent.

CONCLUSIONS

The findings of these studies have practical applications:

1. Choctawhatchee sand pine cones collected after September 15 open readily at a kiln temperature of 105° F. even though their specific gravities may range from 0.85 to 1.11. No relationship has been established between specific gravity and viability. The serotinous cones of the Ocala variety may be collected at any time after they have turned brown, as maturity is then assured.

2. Immersion in boiling water for 15 seconds followed by 24 hours of kilning at 100 to 1 10° F. efficiently opens cones of the Ocala variety.

3. Both cones and seeds are larger in the Ocala variety. Cones of the Choctawhatchee variety average 1,010 per bushel whereas those of the Ocala variety average 830. The Choctawhatchee variety averages 56, 100 seeds per pound, and the Ocala variety averages 47,200.

4. Flotation in 95-percent ethanol is an effective means of sorting empty seeds from full ones. Soaking for as long as 5 minutes does not harm viability, but flotation should be done just before the seeds are used.

5. Commercial collections of Ocala sand pine cones should exclude those 2 or more years old, because seeds from such cones will be less viable than those from newer cones.

6. Seeds of the Choctawhatchee variety are mildly dormant, and stratification for 14 days increases both speed and completeness of germination. Cold stratification is superior to soaking in water or ‘hydrogen peroxide.

7. Stratification is not recommended for seeds of the Ocala variety. Seeds from new and l-year-old cones are nondormant. Seeds from cones 2 or more years old are apt to be dormant, but their germination will be low at best and stratification will reduce it further.

8. Seeds of the Ocala variety store well under a variety of conditions for periods up to 5 years. Seeds of the Choctawhatchee variety are more sensitive to storage conditions, and temperature apparently is more important than moisture content in preserving viability. All seeds should be dried to IO-percent moisture content and placed at subfreezing temperatures for long-‘term storage. These conditions will allow a margin of safety for weaker seed lots.

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NURSERY PRACTICES USED FOR SAND PINE

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Abstract. --Nursery practices used for sand pine by the Florida Division of Forestry are summarized. These include site selection, soil management and fumigation, seed treatment and sowing, seedbed mulching and weeding, insect and disease control, and the growth, lifting, grading, packaging, and shipping of seedlings.

The species of seedlings produced in forest tree nurseries in the South have for the most part been determined by commercial wood value. Interest in nursery production of sand pine started through the efforts of Armstrong Cork Corporation, which provided 1 pound of seeds to the Florida Division of Forestry's Munson Nursery in west Florida in 1956. These seeds were planted, and nursery practices commonly used for slash pine were applied. In December of 1956, 8,000 sand pine seedlings were ready for outplanting.

Since 1956, over 60 million sand pine have been produced in the Florida Division of Forestry nurseries. The results of the 1956 nursery planting revealed that not all of the nursery practices used for slash pine are successful with sand pine, but in general many of the same practices applied.

This paper will summarize each phase of the nursery operations and practices that are currently being applied to sand pine.

SITE SELECTION

The selection of the site within the nursery may mean the difference between success or failure.' This is especially true when soil types in the nursery vary. Our experience has taught us to avoid poorly drained soils and, most especially, heavily textured clays. Well-drained sandy loams are best suited for growing sand pine. Heavily textured, poorly drained soils appear to encourage root pathogens; most often, seedling growth and development are poor. When heavily textured nursery soils are sown to sand pine, irrigation should be watched closely and limited to that necessary to produce a crop. Should the season be unusually wet, the seedling crop growing on heavily textured clay soils could be a complete failure.

SOIL MANAGEMENT

Soil management procedures for growing sand pine in the nursery are basically the same as those used for the major southern pines. A soil pH of 5.5 to 6.0 is acceptable. Because this species does best on well-drained, sandy loams, soil organic matter may be less than the 3 percent most nurserymen like to maintain.

Nursery soils are sampled and tested annually. All Division of Forestry nursery soils are tested by the University of Florida Soils Testing Laboratory. The fertilizer recommendations are made by Dr. W. R. Pritchett and Extension Forester Tom Herndon. It should be pointed out for the benefit of those from other states that the ammonium acetate method of determining available phosphorus is used by the University of Florida Soils Laboratory. This method may differ from the method used in other testing facilities . We like to maintain our potassium level at 250 pounds per acre and our phosphorus level at 100.

When phosphorus is needed, it is applied in the form of superphosphate before planting in early April. All mixed fertilizers are also applied at this time. Nitrogen and potassium are most often applied as a top dressing after the seedlings are 3 weeks old. In cases where nitrogen and potassium are extremely low, we may make pre -plant applications. The first top dressing with nitrogen is most often made in mid-June and should not exceed 50 pounds per acre. Additional applications of ammonium nitrate are made in July and early August, when additional height growth is desired.

Potassium is applied in the form of muriate of potash or sulfate of potash. We favor the sulfate of potash in areas where the pH value may be 6.0 or above. The potash is applied as a top dressing in July. The total amount needed will determine whether we make split applications or only one application. Chlorosis, a nutrient deficiency, is not uncommon in nursery beds of sand pine. It is more often found in the areas of heavy soil but may show up when nitrogen is deficient. We normally apply 50 pounds of ammonium nitrate. If this application does not correct the condition, we apply iron chelate or iron sulfate.

SOIL FUMIGATION

The Florida Division of Forestry nurseries apply 68-percent methyl bromide at a rate of 600 pounds per acre 2 weeks before the seeds are sown. Fumigated soils are cropped 2 years in succession before rotation with a cover crop for 2 years.

SEED TREATMENT

Seeds are removed from cold storage and treated with Arasan® s-42 and aluminum flakes before sowing. Stratification has not been revealed to produce any increase in germination; therefore, the seeds are not stratified. Seed treatment is accomplished through the use of a small cement mixer. After treatment, the seeds *are* dried *on* a concrete floor by constant rotation with a rake.

SEED SOWING

The established rates of sowing seeds are designed to produce 27 to 30 plantable seedlings per square foot of seedbed. Current seed tests are used in computing the sowing rates. The seed lots sown by the nurseries usually, average 78- to 82-percent germination and a purity of 97 to 99 percent. 'Past experience has dictated that we figure our nursery survival at 60 percent in order to produce the desired number of plantable seedlings per square foot. It is evident that 60-percent *nursery* survival is low, and we are seeking methods to attain better survival.

Seed is sown with the conventional Whitfield® seeder. This seeder is not designed for seeds as small as those of sand pine, and we experience difficulty in regulating it to our desired densities of seed sowing. For this reason, we are considering the purchase of a Stan Hay@ seeder for use in sowing both slash and sand pine seedbeds. The latter seeder is designed for vegetable crops and has the flexibility required for precise placement of most conifer seeds on nursery beds. Nursery sowing of sand pine seed is done in late April and coincides with the spring sowing of other conifer species in the Southeast.

SEEDBED MULCHING

After seeding, the seedbeds are mulched with chopped pine straw. The pine straw is not treated for control of weed seeds because the use of herbicides directly over the seedbeds after mulching appears to be more economical. The chopped straw does not require removal after the seedlings have germinated. It is applied with a modified manure spreader, and we try to mulch the beds to a depth of 1/4 to 1/2 inch. A number of nurseries in the Southeast have used the Hydro Seeder@ and wood fiber mulch for seedbed mulching. Our results with this seeder on sand pine have not been acceptable. Because considerable time is required for nursery personnel to rake, haul, and chop, we shall continue to make trial applications with the Hydro Seeder@ on sand pine in an effort to reduce the amount of pine straw needed for mulching.

IRRIGATION

Irrigation is applied immediately after sowing, and all seedbeds receive approximately 1/4 inch of water daily until germination is complete (which usually requires from 7 to 10 days). The decision onwhether to irrigate after germination is usually left to the nurseryman and depends upon rainfall and the nurseryman's ability to determine soil moisture requirements. Tensiometers have proved successful in determining when irrigation is needed and are now being purchased for the future production of crops. After the seedlings attain a height of 7 inches, irrigation rates are decreased and limited to the amounts necessary to ensure healthy seedlings. We strive to reach this point by September in order to begin the conditioning period before lifting in December. In order to condition the seedlings to withstand the shock of lifting, shipment, and transplanting, they receive no fertilization and a minimum of irrigation from September to December.

INSECT AND DISEASE CONTROL

Insect damage to sand pine seedlings has been almost nonexistent. The red spider is the only insect *for* which control measures have been used: when this insect is present, usually one spray with malathion is applied in late August.

Our program of soil fumigation gives adequate disease control, and I am not aware of any problems in the nursery with black root rot.

Sand pine appears to be resistant to fusiform rust and may not need ferbam sprays for *control* of this rust. In the past, we have applied ferbam at the rate of 4 pounds per acre as a preventative measure because we were not sure about sand pine's resistance to fusiform rust.

SEEDBED WEEDING

All efforts are made in the fumigation program to control the seeds of noxious weeds and grasses and thereby reduce the amount of hand weeding necessary to promote seedling growth'. Through the trial and error process, it was found that sand pine could withstand sprays of mineral spirits of the same volume and number of applications as those withstood by slash pine. Sprays of mineral spirits amounting to 15 gallons per acre 2 weeks after germination and progressing up to 35 gallons per acre in July are not uncommon with this species; such sprays never exceed two applications per week. I must emphasize that close field observations should accompany the spray, program with mineral spirits in order to detect any foliage burn that might result from the mineral spirits. A spray repeated too closely after such a burn can cause severe injury to small seedlings. Pressure of the spray rig should *never* exceed 50 pounds, and a pressure of 30 pounds is most desirable.

GROWTH OF NURSERY SEEDLINGS

In general, the growth of sand pine in the nursery can be compared with that of loblolly pine. Sand pine's first flush of growth occurs after that of slash pine by a 2-week margin, generally in late June. The second flush should begin in late July or early August, terminating in late September or mid-October with a winter bud set. The desirable top growth from the root collar appears to be 8 inches. Root development is normally commensurate with height growth. Small seedlings often have a very fibrous root system and appear to survive well after outplanting.

LIFTING, GRADING, PACKAGING, AND SHIPPING OF SEEDLINGS

The lifting of seedlings from the nursery beds begins in early December. To date, we have not been able to lift sand pine with the mechanical lifter. The high resin content of the needles causes a buildup of resin on the lifter belts, and the seedlings do not release from the belts as well as do those of slash pine. This problem may be partly due to late growth of the seedlings and to succulent foliage. For the past 2 years, seedlings in the nursery have not been as large as those of slash pine. Average top heights have been about 5 inches; this diminished size has also contributed to the failure in mechanical lifting of these seedlings. Consequently, the lifting of sand pine is done by hand. The lifting blade is used to undercut the beds before lifting is begun. This blade utilizes an agitating mechanism which loosens the soil and allows the seedlings to be lifted with most of the root system intact.

The seedlings are placed in metal tubs in the field as they are lifted and are then transported to the packing shed on a field trailer. Lifting is mainly governed by the existing orders to be filled; when possible, the lifting and packing are done on the same day that the seedlings are to be shipped. We do not like to hold sand pine in storage for more than 24 hours under any conditions.

Grading of seedlings on the conventional grading table in the nursery has been discontinued as of the 1971-72 crop. This procedure is used only in extreme circumstances when field grading is less economical. By more precise rates of sowing, lower densities in the seedbed, and careful sizing of the seeds, we have attempted to deliver to the landowner a seedling which equals those from our conventional grading belt. When grading is necessary, we grade in the field before lifting begins. Crews weed the beds of cull seedlings before December.

Seedlings are sold on an estimated per-thousand basis. The estimated count is made by weighing the seedlings. All seedling weights are derived by a continuing counted sample. Weights are recorded and averaged at the end of each day. This process has proved to be sufficiently accurate for purposes of distribution. Most seedling bales will be within plus or minus 10 percent.

Seedlings are packaged in the conventional Forest Service bales. Kim Pac® fiber is used as the moisture -holding medium in the bales. Normal bales contain 2,000 seedlings. The bales contain a $1\frac{1}{4}$- by $1\frac{1}{4}$- by 28-inch wooden stake which gives rigidity for handling purposes. All bales are strapped about 5 inches from each end with a band of steel.

Most sand pine seedlings are picked up at the nursery by the landowner or contractor who will be planting the seedlings. Small orders are often delivered by the nursery's truck to the various headquarters of the Division of Forestry throughout the state. All persons who request delivery by nursery truck are notified as to the approximate time the seedlings will arrive at District headquarters.

Purchasers of sand pine seedlings are requested to plant the seedlings as soon after receiving them as possible. Past experience of storing sand pine in the seedling bale indicates that extended storage will decrease planting survival beyond that of seedlings planted within 48 hours of lifting from the nursery beds.

TEMPERATURE EFFECTS ON GROWTH, ASSIMILATION, AND BUD DEVELOPMENT OF SAND PINE [1/]

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Abstract. --The Choctawhatchee and Ocala varieties of sand pine differ in their reaction to temperature; Both dry matter accumulation during the first vegetative season and bud development during the second varied according to variety. Choctawhatchee sand pine, the more northern variety, was more tolerant of low temperature but showed slightly lower dry matter accumulation at higher temperatures than did the Ocala variety. Also, more warmth is required for breaking dormancy in the northern variety. The net assimilation rate of sand pine and its dependence on temperature regimes are comparable to those of other species of conifers.

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INTRODUCTION

The two sand pine (Pinus clausa (Chapm.) Vasey) varieties exist almost exclusively in deep sands of coastal and peninsular Florida: Choctawhatchee sand pine (Pinus clausa var. immuginata Ward) in northwest Florida and Ocala sand pine (Pinus clausa var. clausa Ward) in the peninsular area. A number of isolated stands appear in areas other than the two major centers, but there are extensive zones where the species does not occur because of a lack of suitable habitat. Inundation of most of Florida following the last ice age, leaving several isolated islands, is probably a main contributing factor to observed variation.

The two major regions of the sand pine range differ slightly in climate, especially in winter temperature. The purpose of this study was to determine the effect of temperature on seedling growth characteristics of the species. The response of young seedlings to greenhouse conditions and to various temperature regimes in controlled environment chambers was studied.

MATERIALS AND METHODS

Seed used in this study were from broad-base collections made on the Ocala National Forest (Ocala variety) and the Eglin Air Force Base Reservation (Choctawhatchee variety) during the fall of 1968. Seed were sown in flats during mid-December and placed in the greehouse; germination took place in about 2-1/2 weeks. Newly germinated seedlings, their cotyledons still encased in the seedcoat, were transplanted to a sand media in peat pots, placed in flats, and immediately transferred to three temperature regimes in controlled environment chambers.' These plants *were* sampled for dry matter determinations and growth analyses after 8 week6 and 11 weeks. Except for the Ocala variety in the hot chamber, harvests consisted of from 100 to 120 seedlings from each variety at each temperature condition, Because of early mortality (damping off), harvests Of the Ocala variety in the hot chamber consisted of only 20 seedlings.' All samples were dried at 105° C. to a constant weight.

One-year-old nursery grown seedlings were used for the study of dormancy and bud *development . One group was lifted bare root, trimsplanted into pots, and placed *in* a heated greenhouse under favorable conditions during DecembeEhese seedlings were observed over a period of 2 months. During February, another two groups from two different nurseries were lifted, soil intact, planted directly in pots with a transplant tool, and placed in the three temperature regimes in the growth chamber.

Soils in the two major regions of the sand pine range are similar. Also, there is little difference in precipitation, the Ocala region being slightly drier during winter. However, meteorological records indicate some differences occur in winter minimum, maximum, and mean temperatures. Therefore, it was decided to adjust the temperatures of the three growth chambers to represent average winter, spring, and summer conditions in the north-central Florida region.

Average summer temperature of both regions is about 27° C., but average winter temperatures of the two regions differ by about 3° C.: the average winter temperature is 12° C. in the Choctawhatchee region and 15° C. in the Ocala region. There is a fairly constant, about. 12° C., monthly amplitude between mean maximum and minimum temperature for both regions throughout the year. Kramer (7) showed that large differences between day and night temperatures stimulated growth of loblolly pine seedlings. Therefore, the three growth chambers were adjusted to approximately cover the entire range of average temperature variations in the sand pine range:

Hot chamber	32° C. day - 21° C. night
Medium' chamber	24° C. day - 13° C. night
Cool chamber	15° C. day - 4° C. night

Relative humidity ranged from 60 to 90 percent. A 12-hour photoperiod was maintained with a mixture of incandescent and fluorescent lamps at 2,000 ft.-c. At every cycle, dawn and dusk were imitated by 15 minutes of incandescent light alone.

RESULTS.

In the experiment with seedlings germinated from seed, almost the same pattern of ecotypic differentiation was observed at both sampling dates (fig. 1). The Choctawhatchee variety had higher dry matter accumulation in the cold chamber,' but the Ocala variety had higher accumulation in medium and hot chambers. At the first sampling, there was a highly significant interaction between seed sources and temperatures. The same trends were present at the second sampling, but they were not statistically significant.

Student's t tests between races within chambers showed, for both sampling dates, significant differences at low temperature but not at medium temperature. The Ocala data were insufficient to make comparisons at high temperature. Significant differences in total dry matter accumulation resulted mainly from stem and needle differences whereas root dry matter was usually within the error limits.

Within the investigated range of temperatures, dry matter accumulation by sand pine seedlings was almost directly proportional to' the average temperature of the growth conditions. However, this pattern is only valid for the aboveground portion of the seedling; growth of root systems was distinctly reduced in the hot chamber.

Net assimilation rates (expressed as mg. of dry matter increase per g. of dry needle matter per day) for the five fully representative groups of data are presented in table 1. Net assimilation rates of both varieties decreased with increasing temperature, but varietal trends were not quite the same.

Table 1. --Net assimilation rate in mg. of dry matter per g. of dry needle matter per day calculated according to the formula

$$NAR = \frac{(W_2 - W_1) \times 2}{(A_1 + A_2)(t_2 - t_1)}$$

Seed source	Temperature conditions °C. (day/night)		
	Cool 15/4	Medium 24/13	Hot 32/21
Ocala	61.9	30.1	--
Choctawhatchee	59.2	35.1	32.6

W_1, W_2 - total dry matter at the first and second harvest

A_1, A_2 - dry weight of needles

$(t_2 - t_1)$ - time interval in days between the two samplings.

Bud development of one-year-old, seedlings was determined at several day intervals (fig. 2). Appearance of new needles from bud scales was the criterion assumed for bud breaking. Data were expressed as percentage of the total number of plants examined that broke dormancy at each time interval. The Ocala variety broke dormancy before the Choctawhatchee variety under all temperature conditions in the greenhouse and in the three temperature regimes in the growth chamber. Seedlings placed in the greenhouse during December broke dormancy more slowly than those placed in growth chambers during February. In the greenhouse, the varietal difference exceeded 2 weeks, but in all temperature regimes in the growth chamber the differences averaged 7 to 10 days. There was no difference in the reaction of plants from two different nurseries.

DISCUSSION

Considerable information indicates that temperature is an important factor in ecotypic differentiation of plants (2, 5, 11).

The sand pine experiments reported here clearly showed a variety-temperature interaction, Although analysis of meteorological data did not indicate a great diversity between the conditions of northwestern and central Florida, slight differences in climate apparently influenced varietal differentiation of sand pine. Dry matter accumulation and net assimilation rates of the two races were different, as was the period of spring development of apical buds. Again, it must be stressed that both main regions of sand pine differ mainly in winter temperatures; in the north, mean winter temperature is lower and the number of frost days is considerably higher. Citrus, for example, grows well in the Ocala region but does not occur in the Choctawhatchee region or even 25 miles north of the Ocala National Forest.

Differences in bud development in the greenhouse and in the growth chamber (fig. 2) indicate both varieties may differ not only in requirement of temperature increase during the spring period; but also possibly in their characteristics of dormancy. Perhaps Ocala sand pine has no typical winter dormancy because such a short period of favorable conditions promotes flushing considerably in advance of Choctawhatchee sand pine. Difference in time of bud development could account for the different flowering dates which make gene exchange between the two varieties even more difficult. Also, difficulty in establishing Ocala sand pine plantations is probably due to the absence of a winter-type dormancy in this variety. Harms (4) observed relatively better survival of Choctawhatchee compared with Ocala sand pine plantings in Georgia and South Carolina. He attributed the poorer survival of Ocala sand pine to freezing soon after plantation establishment. Several attempts to establish seed orchards of Ocala sand pine seedlings in the north-central Florida area by the University of Florida Tree Improvement Cooperative failed for apparently similar reasons. That is one factor that prompted this study, for it was generally known that better survival was obtained with the Choctawhatchee variety. Goddard and Strickland (3) report similar observations in a sand pine provenance trial.

In general, data presented in this work contribute. to our knowledge of plant-temperature relationships. In our experiments, as in those of Brix (1) with Douglas-fir seedlings, a decrease in net assimilation rate occurred at higher temperatures. The decrease could be attributed to increased respiration. Pharis and Woods (8) found the maximum rate of photosynthesis of Choctawhatchee sand pine occurred at 23° C., but respiration increased even above 48° C. However; it is also possible that decreased net assimilation with increased temperature is also due to differences in the seedlings' developmental stages in the different temperature regimes. It is well known that photosynthesis per unit of foliage weight decreases as development stage advances.

Comparison of these sand pine data with some other authors' data on northern conifers (Brix (1) and Sorensen (10), with Pseudotsuga menziesii; and Kramer (7), with Pinus taeda) indicates sand pine is more tolerant to higher temperatures than more northern species.

The net assimilation rates reported here, 30 to 60 mg. per g. of dry needle matter per day, are comparable with those reported by Rutter (9) and Jarvis and Jarvis (6) for Scots pine (Pinus silvestris L.) seedlings.

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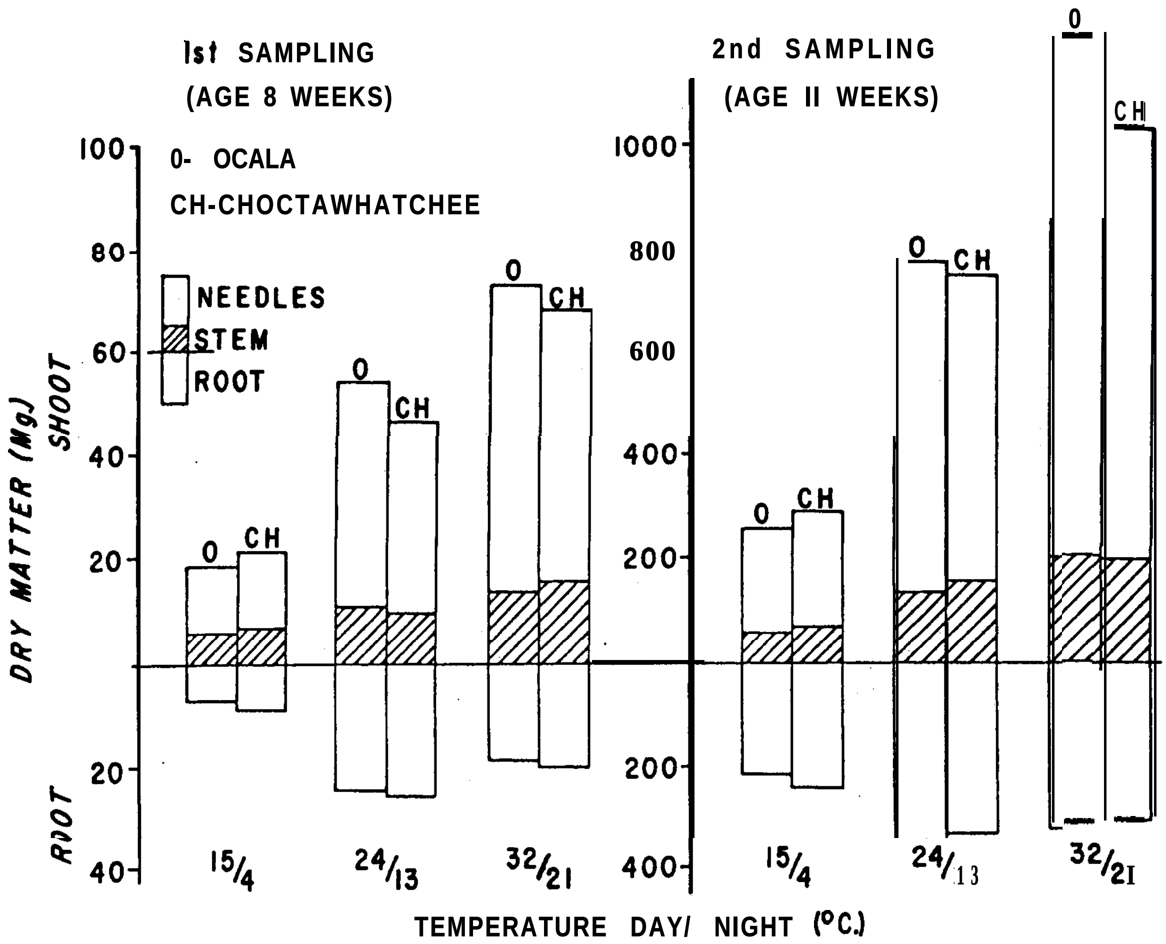

Figure 1. --Comparison of dry matter accumulation between varieties under different temperature regimes.

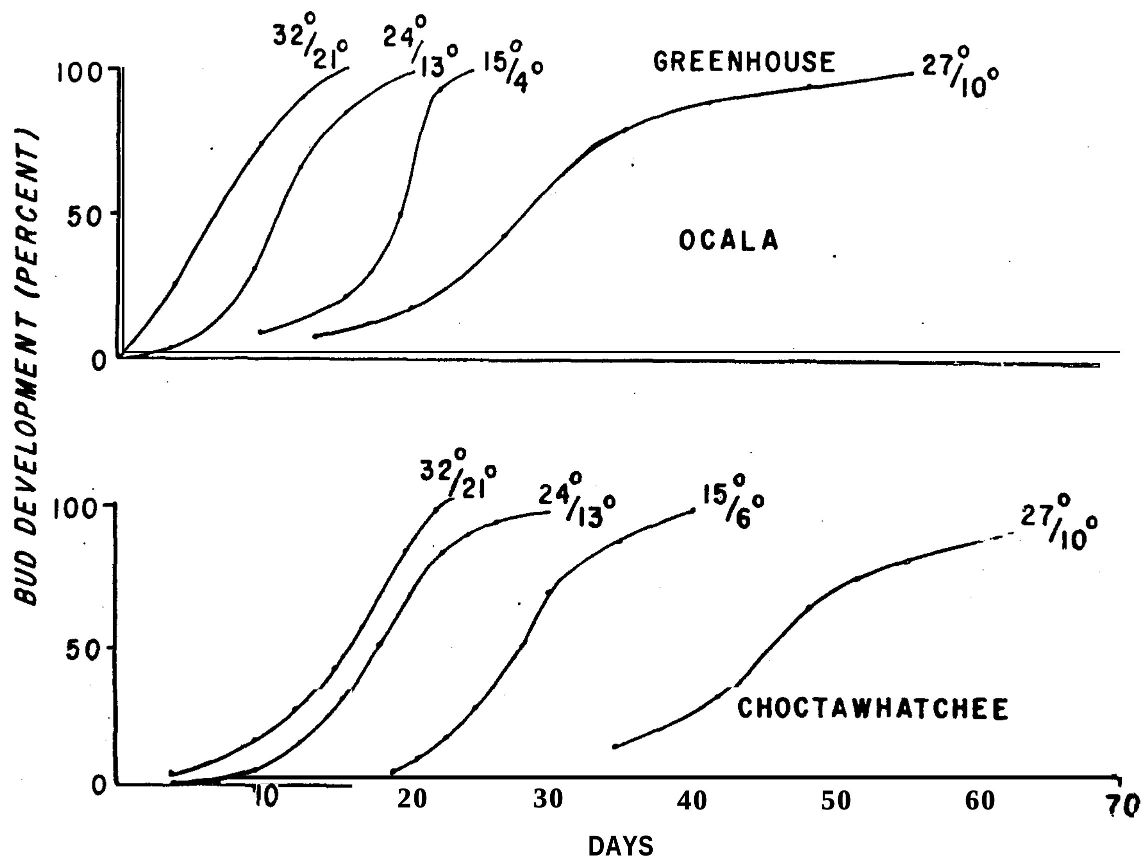

Figure 2. --Bud development under different temperature regimes.

METHODS AND GOALS IN PREPARING SAND PINE SITES

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Abstract; --Alternative methods of preparing sandhill land for sand pine are compared. Chopping, a method that conserves topsoil essential for plant growth in the sandhills, proved the most efficient of the mechanical methods and better than the chemical method considered. Because of inherently low site productivity, practical methods must be relatively inexpensive. If public pressures for environmental preservation and 'improved wildlife habitat are to be met, the natural landscape should be disturbed as iittle as possible during the conversion from scrub hardwoods to pine. Strip site preparation that conserves topsoil promises to meet these requirements. Choctawhatchee sand pine appears best suited for planting on partially prepared sandhill sites.

Mechanical site preparation is the most effective, hence the principal, method of site preparation used in the sandhills. Burning alone does not help seedlings survive and grow, and successive burns are difficult because fuels in the sandhills accumulate slowly and in patches. Chemicals are expensive, and until recently, did not.result in satisfactory survival and growth of planted seedlings (3).

All methods of mechanical site preparation destroy the vegetation by cutting or displacing it. These processes destroy the aboveground portions of hardwoods and sever subsequent sprouts, thereby depleting food reserves stored in the roots. Roots may also be torn out of the soil or destroyed in the soil by being cut, chopped, moved, or exposed. Mechanical site preparation is most commonly done with choppers, rakes, disks, and rotary tillers--sometimes in combination.

The purpose of this paper is to review alternative methods of site preparation that have been used to establish pines in the sandhills, to compare results obtained with the various methods, and to explain why differences in survival and height of pines planted on variously prepared sites probably occur.

METHODS FOR ESTABLISHING SAND PINE PLANTATIONS

Underplanting and Release

All the southern pines planted in the sandhills with the exception of sand pine (*Pinus clausa* (Chapm.) Vasey) require intensive site preparation to ensure adequate survival. This preparation involves reducing the number and vigor of the scrub oaks (principally turkey oak, *Quercus laevis* Walt., and bluejack oak, *Q. incana* Bartr.) and wiregrass (*Aristida stricta* Michx.). Release from overtopping scrub hardwoods after underplanting is not enough for pines other than sand pine, as illustrated by the results of the following test.

Seedlings (1-O stock) of five pine species were hand-planted 6 feet apart in 8-foot rows amid scrub hardwoods on a sandhill site. Some seedlings of each species were released from overtopping trees. at the time of planting, some were never released, and the remainder were scheduled for release at 2-year intervals through age 5. By age 4, the planting of longleaf pine (*P. palustris* Mill.) was a complete failure and the performance of loblolly (*P. taeda* L.) and shortleaf (*P. echinata* Mill.) pines was so poor that these plantings were abandoned. At plantation age 5, the slash pine (*P. elliottii* Engelm.) did not look as if it would survive, so the release scheduled forge 5 was applied only to Ocala sand pine (*P. clausa* var. *clausa* Ward).

At plantation age 12 years, the sand pines released at planting averaged 33 feet tall and those released 1, 3, and 5 years after planting were 28 to 29 feet tall (table 1). Varying the time of release did not have an appreciable effect on growth among trees not released at the time of planting. Despite the competing hardwoods, unreleased Ocala sand pine averaged 26 feet tall--fully twice as tall as the slash pine released at the time of planting.

Table 1. --Average survival and growth of Ocala sand pines and slash pines at plantation age 12 years, according to time of 'release from scrub hardwoods

Pine species or variety and time of release	Survival	Growing space	Height	D. b. h.
	Percent	Sq. ft.	Ft.	In.
Ocala sand				
Released at:				
Planting	61.1	78.6	32.8	5.1
1 year	55.6	86.3	29.3	4.1
3 years	52.8	90.9	27.8	3.8
5 years	62.5	76.8	28.6	4.0
No release	59.7	80.4	26.0	3.6
Average	58.3	80.3	28.9	4.1
Slash				
Released at:				
Planting	43.1	111.4	12.9	2.0
1 year	52.8	90.9	10.9	1.5
3 years	39.6	121.2	8.9	1.2
No release	60.0	80.0	6.7	.6
Average	48.9	100.9	9.8	1.3

At about age 17, unreleased Ocala sand pine overtopped the hardwoods; within 3 years these pines showed signs of a height-growth response. At age 20, unreleased slash pine still had not overtopped its hardwood competitors.

This comparison clearly demonstrates that sand pine is superior to the other southern pines in its ability to survive and grow in a sandhill rough, even without release from overtopping hardwoods. Release applied within 5 years after planting was better than none at all, but it was not as beneficial as a release applied immediately after the sand pine was planted. Slash pines were able to survive underplanting and respond to release, but they were unable to develop to a merchantable pulpwood size even when released from overtopping hardwoods: at 20 years, height of the slash pines released at planting averaged barely 20 feet. The deeper sands (which comprise the more droughty sites) are better suited to sand pine than slash pine. If the sand overlies a layer of clay, thus making soil moisture levels more favorable, slash pine will reach merchantable size.

Mechanical Site Preparation

Rootraking. --A second study was installed on a site where the preparation was intensive. The results indicate the importance of thorough site preparation prior to planting southern pines.

Choctawhatchee sand pine (*Pinus clausa* var. *immuginata* Ward), longleaf, shortleaf, loblolly, slash, and Ocala sand pines were hand- and machine -planted at a 7 - by 7-foot spacing on a sandhill site which had been cleared with a rootrake, then disk harrowed and leveled with a roadgrader. Most of the organic matter and topsoil was removed. Data collected at plantation ages 5 and 12 are summarized in table 2. Because no lasting significant differences attributable to method of planting were found, results from machine- and hand-plantings are combined.

Table 2. --Average survival and growth of pines planted on a sandhill site intensively prepared with a rootrake, disk harrow, and roadgrader

PLANTATION AGE 5 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
	Percent	Sq. ft.	Feet	In.
Ocala sand	60.9	80.5	9.3	--
sand	88.4	55.4	8.4	--
Choctawhatchee	27.6	177.5	2.0	--
Slash a/	90.9	53.9	7.2	--
Loblolly	88.4	55.4	4.8	--
Shortleaf	87.8	55.8	4.0	--

PLANTATION AGE 12 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
Ocala sand.	55.4	88.5	29.8	4.0
sand	87.1	56.2	27.5	3.8
Choctawhatchee	13.9	352.5	14.4	3.2
Slash a/	86.5	56.6	16.1	2.5
Loblolly	81.5	60.1	9.4	1.5
Shortleaf	83.0	59.0	7.8	1.4

a/ Brown spot needle blight was not controlled.

First-year survival averaged 90 percent for all but longleaf and Ocala sand pines. Brown spot needle blight (Scirrhia acicola (Dearn.) Siggers), and presumably improper planting depth, contributed to the 45 percent survival of longleaf pine. An unknown disease, later identified as mushroom root rot (Clitocybe tabescens (Fr.) Bres.), probably contributed to the relatively low first-year survival (65 percent) of Ocala sand pine and to subsequent mortality (5). This endemic fungus, which spreads from infection centers via root contact, is known to be responsible for mortality averaging about 3/4 or 1 percent per year over the past years. The planting of Choctawhatchee sand pine, which averages only 2 feet shorter and 0.2 inch d. b. h. smaller than that of the Ocala variety, remains disease -free although within 25 feet of the infected Ocala variety. Despite the root rot, and quite possibly because of the additional growing space provided by mortality, Ocala sand pine has grown to be the largest of all the pines by plantation age 12.

Survival of slash, loblolly, and shortleaf pines declined less than 7 percent between plantation ages 5 and 12; however, their height and diameter growth does not compare with that of sand pine, although all have had a similar amount of growing space available to them. Similarly, growth of Ocala and Choctawhatchee sand pines exceeds that of longleaf pine even though the sand pines had less than one-third as much available growing space over the last 7 years.

These tests confirm that slash, loblolly, and shortleaf pines require intensive site preparation when planted in the sandhills. On the intensively prepared site, fifth-year survival of the three pines averaged approximately 90 percent. When underplanted and immediately released, survival of slash pine averaged 43 percent (table 1) and that of loblolly and shortleaf pines (not included in the table) averaged 39 percent. Release from overtopping woody competition was not sufficient. Survival of sand pine was not as poor as that of the others, and sand pine grew well whether released or not. A comparison of 12-year-old sand pine' in tables 1 and 2 shows that they grew taller when underplanted and released (32.8 feet) than when planted on the rootraked site (29.8 feet) where much of the topsoil had been *removed.*

A characteristic effect of rootraking is evident in this study. When the site is prepared with a rootrake, all standing vegetation is removed from the planting site and deposited in windrows, but so is much of the topsoil. Consequently, trees near the windrows grow taller than those in the center of the rootraked area and the plantation develops a saucer-shaped crown profile. The importance of topsoil for the growth of slash pine has been demonstrated by Brendemuehl (2) in a pot test. The saucer-shaped crown profile is apparent in sand pine as well as slash pine, but not to as great a degree.

Chopping. --Tests with site -preparation equipment have shown that slash pine, and presumably other pines, grow faster on sandhill sites prepared with a duplex brush cutter (chopper) than with other equipment. The chopper leaves the topsoil in place, thereby **conserving it, and** incorporates the herbaceous and all but the largest woody vegetation **into** the surface soil, thereby increasing its organic content (virtually the only source of nutrients in sandhill soils).

In a third study involving intensive site preparation, we compared the performance of slash, longleaf, loblolly, and Choctawhatchee sand pines machine-planted 6 feet by 8 feet on a sandhill site prepared by double chopping To obtain a truer measure of its potential, seedlings of longleaf pine were sprayed four times in the first 2 years after planting to control brown spot needle blight. Measurements taken at plantation ages 5 and 12 are summarized in table 3.

Table 3. --Average survival and growth of pines on a site prepared by double chopping

PLANTATION AGE 5 YEARS

Pine species or variety	Survival	Growing space	Height	D. b. h.
	Percent	Sq. ft.	Feet	In.
Choctawhatchee sand	98.7	48.6	11.2	--
Longleaf[a/]	72.7	66.0	3.0	--
Slash	65.0	73.8	6.9	--
Loblolly	74.6	64.3	5.7	--

PLANTATION AGE 12 YEARS

Pine species or variety	Survival	Growing space	Height	D. b. h.
Choctawhatchee sand	98.7	48.6	32.4	4.4
Longleaf[a/]	55.0	87.3	16.0	2.8
Slash	63.32'	75.8	19.6	3.1
Loblolly	67.8[b/]	70.8	11.7	2.0

a/Sprayed with Zinc Coposil (4 lb. per 50 gal. of water) to control brown spot needle blight (four semiannual sprayings at ages 1 and 2).

b/ Best estimate of survival: based upon survival before a' fire and subsequent rate of mortality of unburned plots.

The performance of sand pine was exceptional. First-year survival averaged 98.7 percent, and no trees died over the subsequent 11 years. Choctawhatchee sand pine, with an average growing space of less than 49 square feet per tree, grew to a height of 32 feet and a diameter of 4.4 inches by plantation age 12.

It appears that the amount of topsoil left on a site after preparation affects pine growth more than it does survival, at least for slash and loblolly pines. For Choctawhatchee sand pine, the additional topsoil on the chopped site seems to have improved survival as well. However, the comparison is not entirely legitimate. The soils were similar, but the chopped and rootraked sites were 20 miles apart.. However, comparable results were obtained in another test installed in a relatively small area where loblolly, shortleaf, and Choctawhatchee sand pines were hand-planted at a 7- by 9-foot spacing on both chopped and rootraked sites (table 4).

Table 4. --Average survival and growth of pines at plantation age 10 years on a site prepared by either a rootrake or a chopper

Pine species or variety and preparation	Survival	Growing space	Height	D.b.h.
	Percent	sq. ft.	Feet	In.
Choctawhatchee sand				
Chopped	76.0	82.9	27.7	4.1
Rootraked	68.0	92.6	29.0	4.7
Loblolly				
Chopped	96.0	65.6	16.9	2.7
Rootraked	80.0	78.8	14.1	2.2
Shortleaf				
Chopped	96.0	65.6	14.6	2.8
Rootraked	92.0	68.5	12.1	2.2

Results varied with species and method of site preparation. At age 5, average survival for all pines was lower on rootraked than on chopped sites, yet height differences were negligible for all but Choctawhatchee sand pine, which was taller on the rootraked site. Although sand pine continued to grow at a faster rate there through age 10, loblolly and shortleaf pines grew faster on the chopped sites. Results from comparative plantings on chopped and rootraked sites suggest that the field performance of Choctawhatchee sand pine planted in the sandhills of northwest Florida may be affected considerably less than the other southern pines by method of site preparation or soil fertility as measured by quantity of topsoil.

Rotary tilling, --Rotary tillage was another type of mechanical site preparation tested in northwest Florida. Because the tiller is not as rugged as the rootrake or chopper, large obstacles must be avoided. It does a thorough job of digging up and chopping roots; no second treatment is needed; and small tracts can easily be prepared. Its very thoroughness may be a disadvantage. Rotary tilling reduces the organic matter to small-sized particles and fluffs up the soil, aerating it excessively. This aeration encourages the oxidation of the organic matter, thereby reducing the amount of this valuable soil component.

Strip tillage with the rotary tiller might have special use in preparing land for sand pine because partial preparation appears to be sufficient for this species. The machine can be maneuvered through the woods to avoid large trees, stumps, and clumps of smaller trees. Sand pine planted on such strips has no primary competition, and, because of sand pine's ability to tolerate shade and drought, it will overtop residual competition and maintain a relatively uniform rate of growth.

Chemical Methods

Hundreds of chemicals were tested for control of scrub hardwoods without success until the soil sterilant monuron (3-(p-chlorophenyl)-1,1-dimethylurea) was used (7). High dosages killed all competing vegetation but were expensive and left a residue in the soil that lasted for several years. Pines planted 9 months after 20 pounds per acre of the active ingredient were applied suffered a mortality of 85 percent (6).

More recently developed chemicals are as effective in killing oaks and are not persistent. One of these is fenuron (3-phenyl-1,1-dimethylurea), a chemical related to monuron. It is applied in the form of pellets containing 25 percent active ingredient. We applied 10, 20, and 30 pounds of fenuron pellets per acre in June, planted Choctawhatchee sand pine the following January, and 4 years later found that growth on the untreated plots was about half that on areas that received the heaviest treatment:

Treatment per acre (Lb.)	Height after 4 years (Ft.)
0	2.7
10	3.6
20	4.2
30	5.4

Fenuron is no longer available, but a successor, bromacil (5-bromo-3-sec-butyl-6-methyluracil), appears to be as effective (4). Tests of this chemical are planned.

Age 4 may be too early to draw firm conclusions, but a comparison of heights at this age among the sites prepared by the various methods may indicate potential differences. The following tabulation compares studies involving herbicides, chopping, rootraking, rotary tilling (4 by 40 inches), and release. Both varieties of sand pine are included so that a rough comparison with underplanting and release (used only with the Ocala variety) can be made:

	Fenuron	Chopping	Rootraking	Rotary tilling	Release
			(Height in feet at 4 years)		
Choctawhatchee	5.4	7.6	6.2	5.8	--
Ocala	--	--	6.8	5.9	4.3

Trees grew less on chemically than on mechanically treated sites. And for Ocala sand pine, and possibly for the Choctawhatchee variety, growth was better on the plots treated mechanically than on the released plots.

Chemical methods may be especially suitable for the establishment of sand pine plantations because this species can be established on sites from which only the hardwoods have been removed. This type of site preparation leaves lesser vegetation untouched, and, because the hardwoods are 'eliminated, there is a surge of growth of the herbaceous plants. The increase of competition from this source may account for differences between the chemical and mechanical treatments, but it. is not as great a deterrent to sand pine as it would be to other southern pines.

Although growth is not as great on chemically controlled sites as on chopped or rootraked sites, even though chemical control is fully as expensive, there are advantages to this method. Growth on the fenuron-treated plots was twice that on the check plots. The site was not disturbed (topsoil and organic matter were left in place), and a large investment in heavy equipment was not required. For this reason, pelleted herbicides provide an alternative method for preparing farm woodlands and odd blocks of land for sand pine.

GOALS IN SITE PREPARATION

It may seem peculiar to devote part of this paper to goals; we know what we want--the establishment of a desirable species. Until recently, such silvicultural and economic requirements have been setting the pace in regeneration. Now, the enhancement of wildlife habitat and amenity values has begun to assume increasing prominence.

One way in which the needs of wildlife and its enthusiasts can be favored is by the alternation of planted land with strips of wild land (1). The "edge" thus created stimulates production of a variety of food and cover. Strip site preparation appears to be a promising way of creating the same effect, especially if we use methods less harmful to the organic components of the soil than rotary tilling.

Sand pine plantations may already offer more wildlife food than those of other southern pines. We have noticed quite a number of fox squirrel nests in our older plantings. The seed-storing habit of Ocala sand pine makes food available year-round. Both Ocala and Choctawhatchee sand pines offer dense foliage and limbiness that provide more cover and avenues of escape than are available in the rough and in stands of other pines.

When sand pine is planted, it is not necessary to remove all competing vegetation. Consequently, roadsides need not- be completely, prepared. Narrow strips parallel to the road can be prepared and planted, or sand pine can be planted directly in the scrub oaks, leaving them as a screen along the 'right-of -way. The ability of sand pine to grow in such a habitat means that a managed forest can be established without the blemish of thorough site preparation.

Uniform spacing' in pine plantations is an effective means of producing equal growing space for each tree, but the uniformity of mechanical spacing is unnatural and offends an eye sensitive to natural beauty. The alternation of planted, prepared stripe with strips of wild land will create a woodland more satiefying in this respect. The natural alternation of sites--creeks, branches, flatwoods, uplands--can be accentuated by restricting sand pine and strip site preparation for sand pine to only the most adverse sandhill sites.

CONCLUSIONS AND RECOMMENDATIONS

From the foregoing data and discussion, we conclude that a minimum investment should be made on the deep sands, the sites with the lowest potential. Strip site preparation recommends itself because it costs less than root-raking or chopping an entire area. Moreover, strips can be prepared by 'methods that will conserve the organic matter in the sand and preserve the natural diversity of hardwoods and pines.

Where small tracts or limited accessibility make machine work overly expensive and where there is no danger of contamination, herbicide pellets will do a good job of preparing a rough for sand pine. Because the major part of the cost of chemical control of vegetation is for the material, this method will become especially attractive if the price of the chemical drops.

Where appearances are especially critical, as along highways and in or near scenic areas, relatively narrow strips can be prepared parallel to the right-of -way and planted with sand pine. . Where gradual conversion to a managed forest without violent modification of the present vegetation is desirable, sand pine can be planted in the rough and either not released at all or released only to that degree *most* suited to the overall objective,

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WINTER AND SUMMER PLANTING OF SAND PINE

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Abstract. --Present knowledge indicates that 1-O sand pine seedlings are the best stock for field planting. They should be planted deeper than the root collar, preferably during the months of January or February. Dibble and machine planting are almost equally successful. Infertile, excessively drained areas within the sandhills region of Florida and Georgia are the recommended planting sites. Some information suggests that sand pine should not be planted in the Carolina sandhills, but a final decision cannot yet be made, Because high densities of Choctawhatchee sand pine result in reduced height growth, only 500 seedling6 per acre are recommended for planting if a single-harvest cut is planned and 750 if a commercial thinning is planned. Because survival of Ocala sand pine is generally lower and less consistent, about 900 seedling6 per acre should be planted and the decision about thinning should be delayed until the trees reach merchantability.

INTRODUCTION

The establishment of stands of sand pine (*Pinus clausa* (Chapm.) Vasey) by planting is a relatively new venture. The oldest known plantation is on the Eglin Air Force Reservation in northwest Florida (2). It was planted in 1938 with wilding stock of Choctawhatchee sand pine (CSP).

Cooper et al. (4) experimentally planted Ocala sand pine (OSP on the Ocala National Forest in central Florida during the early 1950's. They mentioned that OSP had been planted occasionally prior to 1950, but with little success.

These early plantings, plus the few others from about the same period, received little attention for many years. Now, however, the superiority of sand pine over other southern pines in producing pulpwood on droughty, infertile sites has been recognized (3). Consequently, over 6 million nursery seedlings of sand pine are being produced annually for planting on the sandhills of Florida and Georgia.

This paper presents the best information now available on how to plant sand pine during the normal winter planting season plus a report on summer planting trials. It does not cover nursery practices, storage of planting bales, site preparation, or choice of variety to plant on various sites, for these topics are discussed in other papers in this Symposium.

SELECTION OF PLANTING SITES

Sand pine occurs naturally on infertile, excessively drained sandy soils. To date, most plantings have been made on such soils: the Lakeland, Kershaw, and Lakewood soil series in northwest Florida; their hyperthermic counterparts Lake, Astatula, and Paola in central Florida; the Alaga series in Georgia; and Troup in South Carolina.

These sandhill soils severely test newly planted pines. Such sites can revert to drought conditions 2 weeks after a heavy rain, and, on cleared land, surface temperatures sometimes exceed 160° F. (1). Nevertheless, these are the recommended sites --in Florida, at least--for planting sand pine because it outperforms other southern pines on such sites. Early results of studies in the Georgia sandhills indicate sand pine may also be the preferred species for excessively drained sites there. Not enough plantings of sand pine have been made in South Carolina to make recommendations for that state. Cold damage to Ocala seedlings (6) and ice damage to trees of both varieties of sand pine (7) may be problems there.

Occasionally, both OSP and CSP can be found on relatively wet sites, but their fields on such sites are lower than those of other southern pines. Moreover, mortality and foliar discoloration of sand pine have been observed on normally well-drained sites that become saturated from abnormally heavy rainfall (Russell M. Burns, personal communication).

AGE AND SIZE OF PLANTING STOCK

One-year-old planting stock of sand pine is usually smaller than that of loblolly (*Pinus taeda* L.) or slash (*P. elliottii* Engelm.) pines. This relatively small size prompted Cooper et al. (4) to compare survival of standard 1-O stock with that of $1\frac{1}{2}$-0 and 2-O stock planted on the Ocala National Forest in December 1955. Six months after planting, the 1-O stock with 71 percent survival war far superior to the $1\frac{1}{2}$-0 with 20 percent and to the 2-O with 5 percent. Cooper et al. suggested that survival of planted seedlings was closely related to their ratios of top length to root length. At lifting, root length was equal to or greater than top length for the 1-O seedlings but was less than two-third8 top length for the $1\frac{1}{2}$-0 and 2-O seedlings. During the study, care was taken to retain as much of the root system a8 possible during lifting.

This study indicates that standard 1-O stock is better than older stock. Perhaps increasing the size of planting stock could be beneficial, but attaining this increase by simply leaving seedlings in the nursery bed for more than 1 year is not the right approach.

OPTIMUM PLANTING SEASON

In another planting trial conducted by Cooper et al. (4) on the Ocala National Forest, about 7,500 OSP seedlings were planted in both November and December of 1953. Six months later, the November plantings averaged 44 percent survival and the December plantings averaged 55 percent--a statistically significant difference.

Burn8 (unpublished data) lifted CSP and OSP seedlings in early January, late January, and early February of 1969 and stored them 1, 3, 5, and 8 days before machine planting them on unprepared and on double-chopped sandhill sites. At the end of the first growing season, there was little difference in survival among seedlings planted at different dates (table 1).

These two studies indicate that December planting is better than November planting and that early February planting is a8 good as January planting, but the results are not definitive in determining the optimum planting season. What other information is available that might be helpful?

Table 1. --Average survival one growing season after storing seedlings 1, 3, 5, or 8 days and then machine planting them in northwest Florida

Lifting date	Choctawhatchee sand pine		Ocala sand pine		Average
	Unprepared site	Chopped site	Unprepared site	Chopped site	
	----w-w----------	---	Percent	------------------	
January 8	93	96	79	84	88
January 22	93	[illegible]	84	94	92
February 5	89	96	87	96	92
Average	91	96	83	91	91

Within the range of sand pine, commercial tree planting is ueually started when the winter rains begin in late November or early December and is stopped before vigorous top growth begins, usually sometime in March. Thus, the optimum season must lie within this period.

Cool temperatures and ample moisture increase the chances of survival for newly planted seedlings. Long-term averages from the U. S. Weather Bureau Stations within the sandhill regions show that December and January are the coolest months of the year, that average temperatures and average precipitation for these two months are nearly the same and that February is the third coolest month and has higher rainfall than December or January (tables 2 and 3). These data suggest that all three months are good for planting. December may be the poorest of the three, however, because soil moisture may be deficient as a result of low rainfall in November.

Another reason for not planting in December may be that nursery seedlings are not at their physiological best for planting until January. No data are available for sand pine, but Huberman (8) discovered that seedlings of loblolly, slash, longleaf (Pinus palustris Mill.), and shortleaf (P. echinata Mill.) pines continue to increase in dry weight in the nursery beds between the first week in December and the first week in January. He attributed much of that weight gain to accumulated food reserves and suggested that these reserves have an important favorable effect upon survival after planting.

Thus, present information suggests that January and February are the best months for planting sand pine.

SPACING OF PLANTINGS

In discussing the spacing of plantings, we need some information that will be discussed more thoroughly later in this Symposium; i. e. , the desired number of trees to carry through the rotation. In order not to take too much from a later paper, we shall simply say that, if no thinning is planned, about 400 trees per acre at the end of the rotation are recommended and, if a thinning is planned, about 600 trees per acre should be present at age 20.

What initial spacings should result in these desired densities at harvest ages? According to Burns and Hebb (3), CSP will average about 85 percent survival 1 year after planting and about 80 percent survival 20 to 30 years later . Thus, they recommend an 8- by 11 -foot spacing (495 seedlings per acre) when a single harvest is planned but a 7- by 8-foot spacing (778 seedlings. per acre) when one commercial thinning is planned. Spacings need not be exactly these dimensions, but extreme rectangularity should be avoided so that trees are not crowded within rows while growing space between rows is not being utilized.

Table 2.--Long-term mean monthly temperatures in eandhill regions as averaged from data from a series of U. S. Weather Bureau Stations within that region

Sandhill region	Stations	November	December	January	February	March
	Number	- - - - - - - - - -	- - - - - - - - - -	°F . - - - - - -	- - - - - - - - - -	- - - - - - - - - -
Central Florida	15	66.5	61.9	61.1	62.7	66.3
Northwest Florida	5	59.7	54.7	54.3	56.4	61.0
Georgia	5	54.3	47.6	47.9	49.7	55; 3
South Carolina	6	53.7	46.3	46.7	48.0	54.0

Table 3.--Long-term mean monthly precipitation in sandhill regions as averaged from data from a series of U. S. Weather Bureau Stations within that region

Sandhill region	Stations	November	December	January	February	March
	Number	Inches				
Central Florida	18	1.69	2.03	2.11	2.77	3.91
Northwest Florida	7	3.10	4.02	4.06	4.15	5.55
Georgia	8	2.51	4.01	3.68	4.27	4.99
South Carolina	6	2.65	-3.38	3.15	4.60	4.14

Table 4.--Planting densities for sand pine as based upon plans for thinning and upon expected survival

CHOCTAWHATCHEE SAND PINE

Commercial thinning	Survival expected at age 20	Spacing of planting	Stems per acre at planting	Stems per acre at age 20		
				Surviving	Cut	Remaining
	Percent	Feet	------------- Number ----------			
No	80	8 x 11	495	400	0	400
Probably	80	7 x 8	778	600	200-300	300-400

OCALA SAND PINE

Possibly	45-67	7 x 7	889	400-600	0-200	400

Should not initial densities be higher in order to offset the possibility of low survival? Burns and Hebb (3) think not. They state that the chances of unacceptable survival with CSP are slight and that planting more trees per acre would necessitate expensive precommercial thinning when survival is average or above. As evidence, they report that CSP planted at 5- by 5-foot spacing began to grow more slowly in height between plantation ages 5 and 8 than those in wider spacings and that those planted at 7- by 7 -foot spacing began slower height growth between ages 12 and 15.

Ocala sand pine usually has poorer first-year survival than CSP, and because of its susceptibility to mushroom root rot (*Clytocybe tabescens* (Fr.) Bres.), it also has poorer subsequent survival (3). Because OSP is planted on the same or similar sites as CSP, it might also suffer growth decline at about the densities and ages as does CSP. These considerations indicate that OSP should be planted at about 900 seedlings per acre (5- by 10-, 7- by 7-, or 6- by 8-foot spacing). With such initial spacings, subsequent survival should be neither so high that precommercial thinning is necessary nor so low that a single-harvest rotation would be seriously understocked (table 4).

MACHINE PLANT OR DIBBLE PLANT?

Machine planting of sand pine can give acceptable survival (table 1). So can dibble planting (3) (table 5). In the one comparison of type of planting found in the literature (4), there was no significant difference in survival between machine -planted and dibble -planted OSP.

Table 5. --Survival of sand pine 5 years after dibble planting on sandhill sites in Florida, Georgia, and South Carolina[a]

Variety of sand pine	Northwest Florida	Central Georgia	South Carolina
		Percent	
Choctawhatchee	87	75	81
Ocala	61	34	60

[a] Extracted from tabular data in Burns and Hebb (3).

Perhaps some unprepared sites could be too rough for proper planting by machine. With that exception, machine and dibble plantings probably result in similar survival and growth of sand pine seedlings.

DEPTH OF PLANTING

No reports on comparisons of depth of planting for sand pine could be found in the literature, but studies with slash and loblolly pines show that either their survival or their growth is increased by deep planting on well-drained soils (5, 10, 12). These results do not necessarily mean that sand pine will benefit from deep planting, but they do suggest that sand pine should be deep-planted until studies prove otherwise.

Burns (personal correspondence) recommends planting sand pine deep enough to cover the hypocotyl and reports excellent survival and growth after sand pines were machine-planted so that only the bud and a few green needles protruded above the soil. He also points out that machine planters usually throw mini-ridges against each side of the planted seedlings and that these ridges eventually are blown or washed away, re-exposing much of the stem and needles.

SUMMER PLANTING TRIALS

In an effort to supplement the winter planting season in Florida, McGregor (9) and Schultz and Wilhite (11) lifted and planted actively growing, bare-rooted seedlings of slash pine during several summer rainy seasons. Survivals ranged from excellent to less than acceptable. In the summers of 1966 and 1967, the planting trials were expanded to include OSP (14). All sand pine seedlings were raised at the Florida Division of Forestry Nursery in Chiefland, Florida. With the exception of early sowing and summer lifting, standard nursery and baling procedures were followed.

For the first summer's trials, OSP seed were sown in nursery beds in November 1965. (A normal April sowing would not have produced seedlings large enough for summer lifting.) By late June of 1966, the seedlings were only about 4 inches tall, but, because with care they could be handled with little stem breakage, a series of 10 weekly plantings was begun.

For each planting, 2, 500 seedlings were lifted, baled, and transported 80 miles to the Withlacoochee State Forest in central Florida on one day and machine-planted the next. The planting site was a double-chopped ridge of longleaf pine and scrub oaks on Lakeland sand. The seedlings were set at the root collar or slightly below it. (Deeper planting would have buried many seedlings, for they still averaged less than 6 inches tall at the final planting in late August.) The seedlings in all plantings began wilting a few minutes after planting, and considerable mortality was apparent a few weeks after planting. By January, survival was less than 5 percent for each planting.

Rainfall for the lo-week planting period averaged 2.7 inches per week, about 0.6 inch above normal, and was well distributed--the lowest weekly total being 1. 1 inches. Thus, the seedlings should not have suffered from inadequate soil moisture. Sand pine is intolerant of excessive soil moisture, but it seems unlikely that soil moisture was excessive on this deep-sand ridge with a water table several feet below the surface. That excessive moisture was not the problem was further evidenced by the very low survival of the longleaf pine seedlings planted alongside the sand pine, even though longleaf pine is apparently more tolerant of excessive moisture than sand pine.

Thus, soil moisture did not seem to be the problem. Furthermore, the seedlings were handled with care, and the time between lifting and planting was about as short as practicable. Finally, the choices of site and of site preparation were apparently satisfactory, because the ridge was successfully replanted to sand and longleaf pines the following winter without additional site preparation. This process of elimination indicated that the seedlings themselves were not suitable for summer planting and that their small size was a likely cause of planting failure.

Consequently, in preparation for the second summer's trials in 1967, OSP seed was again sown in November (1966), but the first of the 10 weekly plantings was in mid-July rather than in late. June. Also, some OSP seedlings from an April 1966 sowing were left in the nursery beds to furnish $1\frac{1}{2}$-0 stock for the 1967 summer plantings.

Another double-chopped ridge of longleaf pine and scrub oako on Lakeland sand--this one near Ocala, Florida--was chosen for the 1967 plantings. Part of this ridge had been successfully planted to sand pine a few winters previously. As before, seedlings were lifted, baled, and transported (this time about 50 miles) on one day and planted the next. One thousand seedlings of each age group were dibble -planted on each of the ten planting dates. The younger. seedlings were less than 6 inches tall throughout all lifting dates. The older seedlings averaged about 12 inches tall at the first lifting and 20 inches at the last lifting, and they appeared to have much larger tops in relation to their roots than did the younger seedlings. The younger eeedlings were planted deep enough to cover the hypocotyl; the older seedlings were set 1 to 2 inches deeper than that.

As in the previous summer, the seedlings began wilting a few minutes after planting. The last survival count was made in late September--less than 2 weeks after. the final plantjng date. Survival of the seedlings planted on the 10 dates ranged from 0 to 2 percent for the older stock and from 2 to 9 percent for the younge'r stock. Soil moisture seemed ample, . just as it did in the first summer's trial. The area received, 9.20 inches of rainfall in July, $\frac{1}{2}$ inch below normal, and. 10.75 inches in August,. 2 inches above normal. Only 2.62 inches fell in September, 6 inches below normal. The latter drought was of little consequence, however, for the earlier plantings were failures before September 1.

The results of these studies indicate that the low survival of summer-planted OSP cannot be attributed to lifting, storing or planting techniques, or to rainfall. Perhaps newly planted OSP seedlings cannot survive the high summer temperatures of the surface soil on cleared sandhill sites; however, slash pine seedlings survived summer planting in scalped strips on a ridge of Lakeland sand which also supported native OSP (13).

The OSP seedlings in the summer planting trials were not graded (except that the very small ones were thrown out), and measurements to determine average heights were the only morphological measurements taken. However, the seedlings were lifted and planted weekly for 10 weeks, beginning with 7-, 8-, and 15 -month-old stock. If there is a morphological grade that has acceptable survival in the field, it would seem that one of the 30 plantings would have contained enough seedlings of that grade to give a survival percentage greater than 9.

We have no further plans for summer planting trials of any species. Should someone else wish to try summer planting of sand pine, here are a few possible approaches:

1. Try CSP.
2. Try container planting.
3. Attempt to increase the size of seedling roots in relation to that of the tops by modified nursery techniques. Wrenching might be a possibility.
4. To avoid the extremely high surface temperatures of prepared sites, try planting under scrub oaks and then releasing the pines after they have become established.

RECOMMENDATIONS

Recommendations on nursery practices, bale storage, site preparation, and the choice of variety of sand pine to plant on various sites are presented in other papers of this Symposium. Recommendations on planting as condensed from the discussion in this paper are as follows:

1. Plant only on sandhills or other infertile, excessively drained sites where sand pine can be expected to outperform other southern pines.
2. Plant in January or February.

3. Plant about 750 seedlings of Choctawhatchee sand pine per acre if a thinning is planned and about 500 seedlings if no thinning is planned.

4, Plant about 900 seedlings of Ocala sand pine per acre because this variety has poorer survival than the Choctawhatchee variety.

5. Bury hypocotyl and possibly most of the epicotyl during plantin'g .

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DIRECT SEEDING SAND PINES IN THE SANDHILLS OF NORTHWEST FLORIDA

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Abstract. --Choctawhatchee and Ocala sand pines were seeded biweekly during 1966 and 1967 on a sandhill rite 'in northwest Florida. The eeed were repellent-coated and covered with ¼ inch of roil. Some reed and seedlings were lort to predotorr, especially mice and mtr. The highest proportion of sound reed germinated and developed into seedlings when sowing war done during Novimber, December, and the firrt half of January. Temperatures during the IO-week period immediately qfter planting appeared to govern germination and, ultimately, the success or failure of the reeding operation.

INTRODUCTION

Sand pines (Pinur clausa (Chapm.) Vasey) can be established on sandhill sites by row reeding or by broadcasting reed and covering them with soil, as with a cultipacker. Success requires that reeding be done during months of the year that promise the best chance for stand establishment. Cooper ♏♦ ♋●✍ (2) ● owed reed of Ocala sand pine (Pinus clausa var. clausa Ward) in April, but germination was delayed until October.

objective of the present otudy was to determine which month8 of the year are beet for direct seeding sand pines and to ascertain some of the factors affecting seedling establishment of soil-covered eeedr in the sandhills of northwest Florida.

METHODS

The study was established in a randomized complete-block design on a typical sandhill site prepared by double chopping and harrowing. Each variety of sand pine was assigned six blocks, and each block contained 26 plots. At biweekly interval8 during 1966, one plot in each of three blocks was sown to each variety of sand pine. The procedure was repeated on the remaining three blocks in 1967. This work was part of a larger study which included slash and longleaf pinee; the complete study will be reported elsewhere. No statistical comparison was made between varieties of pines.

Seed of the Ocala variety were collected on the Ocala National Forest in 1963 and, because of Ocala sand pine'8 closed-cone characteristic, included some seed from the 1963,. 1962, and 1961 seed years. Seed of Choctawhatchee sand pine (Pinus clause var. immuginata Ward) were harvested in 1963 and 1964 on the Eglin Air Force Reservation in Okaloora County, Florida. Seed of both varieties were stored at 20° F. until sown. None were stratified.

Both seed lots were winnowed until cutting tests revealed 95 percent filled seed. Each lot was then thoroughly mixed, divided into 54 portions of approximately 500 seed each, and stored in numbered packets until randomly chosen for planting at biweekly interval8 during 1966 and 1967. Each packet of seed was coated with a formulation to repei oeed predatorr just before sowing. The extra two packet8 of seed were used in germination tests conducted in the laboratory before planting started in i966 and again after it was completed in 1968.

Each plot was split to afford two levels of protection from large predator8. One-half had no protective cover, and the other half was covered with a wire cone made of hardware cloth with a q-inch mesh. All seed were planted $\frac{1}{4}$ inch deep in a grid pattern of approximately 1 -inch spacing. The unprotected spots were planted with 100 seed each, but the protected spots were planted with only 37 seed because of limited space under the protective cone s.

A count of newly germinated and established seedlings waa made on each seed spot at interval8 of 4, 6; 8, 10, 12, and 52 weeks after planting. . Sign8 of activity by predators of seed and seedling8 were noted at there times. Rainfall data were read from a gauge located on the rtudy area. Air temperatures *were* recorded at the Chipola Experimental Forert Headquartera approximately 3 mile8 away.

RESULTS AND DISCUSSION

Field data were converted to tree percents to facilitate comparison of results from unprotected seed spots and spots protected with wire cones:

$$\text{Tree percent} = \frac{\text{No. seedlings alive}}{\text{No. of seed planted}} \times 100$$

Tree percent for each seed spot 52 weeks after eeeding is shown in figures 1 and 2. The 52-week seedling counts integrate germination, mortality, and loss to predators occurring in the first year after eeeding.

Most germination occurred in the first 3 months after seeding. However, many recently germinated seedlings were counted in the 52-week tally, especially *among* the Choctawhatchee sand pines. These seedlings grew from seed which had lain in the soil 8 to 10 months before germinating.

. The germination tests in the laboratory ehowed no loss in germinability attributable to 2 years of cold storage. At both the beginning and end of this Z-year period, germination of reed of Ocala sand pine was 85 percent and that of seed of Choctawhatchee eand pine was 83 percent.

On one occasion, a 4-inch rain uncovered some recently sown seed.

The mort succearful seedings were those made in fall and winter. Seedling eetablirhment of both varieties war depressed during spring and • uxnmer. Depreseion of eeedling establishment during the *warm* season was evident from March through September of 1966 and 1967 and even during unseasonably warm weather in late January and February of 1967. Correlations were highly significant between tree percents and the daily highs *for* air temperatures as averaged *over* the lo-week period after each seeding. As temperatures increased from 65° to 90° F., tree percents decrearsd sharply (figures 3 and 4).

Light shade cast by the wire cones on seedlings in the protected spots may have had a beneficial effect, especially among the Ocala sand pines. During the summers of both 1966 and 1967, consistently more seedlings of the Ocala variety became, established under cones than outride. Such consistency wae lacking among the Choctawhatchee sand pines.

Droughts had less effect 'on seedling eetablirhment than did temperatures. There were three droughts during the 2 year8 of seeding. The first, in the spring of 1966, lasted almost 7 weeks (March 15 through May 1). There were only five showers during thir drought, totaling less than.1 inch of rain. Eetablishment *from seedingr* during the summer after this drought was no *better* than establishment from seedings during the drought., The second drought, in the' epring of 1967, lasted 13 weeks (February 22 through May 22). Ten shower8 during this drought yielded less than 3 inches of rain.

Again, establishment was no better after the drought. The third drought came in the fall of 1967 (November 3 through December 10). During this $5\frac{1}{2}$-week drought, only 0.23 inch of rain fell from two showers. This fall drought failed to depress establishment during a season of favorable temperatures.

In the course of planting the seed and counting the seedlings, the activities of a number of predators of seed and seedlings were observed. Three oldfield mice (Peromyscus polionotus) were seen on the plots at the beginning of the study. Many small mouse diggings were seen, and seed integuments were occasionally found nearby in almost every month of the year. The little excavations left by mice indicated that they sensed exactly where to dig for each seed. Mice in this study consumed some seed before being deterred by the repellent coating. Birds left no signs but probably accounted for additional losses, especially during periods of migration.

As would be expected, loss of seed and seedlings to mice and birds was less on spots protected by wire cones than on open spots. The protective cones appeared to have been effective in preventing losses to mice and birds but not to ants. Several species of ants *were* active on the plots. Florida harvester ants (Pogonomyrmex badius Latreille) were observed cutting off and carrying away cotyledons of sand pine in March 1966, and there was evidence of missing cotyledons even in December. Seedlings usually survived the loss of a few cotyledons, but seedlings died when all their cotyledons we're removed. Ants were never seen cutting off primary or secondary needles.

Eastern moles (Scalopus aquaticus) and southeastern pocket gophers (Geomys pinetis) were occasionally active throughout the year. n -neled directly under a number of seed spots. It was not determined if their burrowing activity caused seedling losses. While seed spots *were* being prepared, pocket gopher tunnels were encountered almost anywhere one chose to dig. Pocket gophers pile considerable quantities 'of sand on the surface when tunneling, and a few seed spots were partly buried under such piles, causing the loss of some seedlings.

Choctawhatchee sand pine seed is mildly dormant (1). Becaure'of this dormancy, it was not surprising to find many recently germinated seedlings of Choctawhatchee sand pine at the time of the 52-week tally, as well as seedlings 9 or 10 months old. Two weeks of cold stratification are recommended (1) for seed of Choctawhatchee sand pine.

The sharp drop in seedling establishment for the seeding conducted *on December 20,* 1966, on unprotected spots may have been due to heavy predation. The difference in establishment of Ocala sand pines on protected and unprotected spots for this date appears larger than any difference that might be attributable to possible benefits of shading alone. This explanation is supported by the fact that the Choctawhatchee variety, which did not seem to derive as much benefit from shading by the wire cones, also suffered a sharp drop in establishment on this seeding date.

Temperatures, though unanticipated, proved to be a more controlling influence on the establishment of sand pine than were moisture conditions on the study plots. Consequently, fall and winter seedings were more successful than spring and summer seedings.

The most active predators of seed and seedlings were the oldfield mice and Florida harvester ants. Despite predation, 40 to 60 percent or more of the seeds sown from November through mid-January produced seedlings.

CONCLUSIONS

The best time to seed sand pine in the sandhills of northwest Florida is during November, December, and the first half of January. Fully 40 percent of planted seed can be expected to produce seedlings within 1 year under conditions similar to those encountered in the 2 years of testing. Extending the planting season for seed to include October or February is a gamble; chances for failure are about equal to those for success. Soil moisture, as measured by rainfall, is adequate for seedling establishment throughout most of the year, but the high temperatures normally experienced between March and September depress germination.

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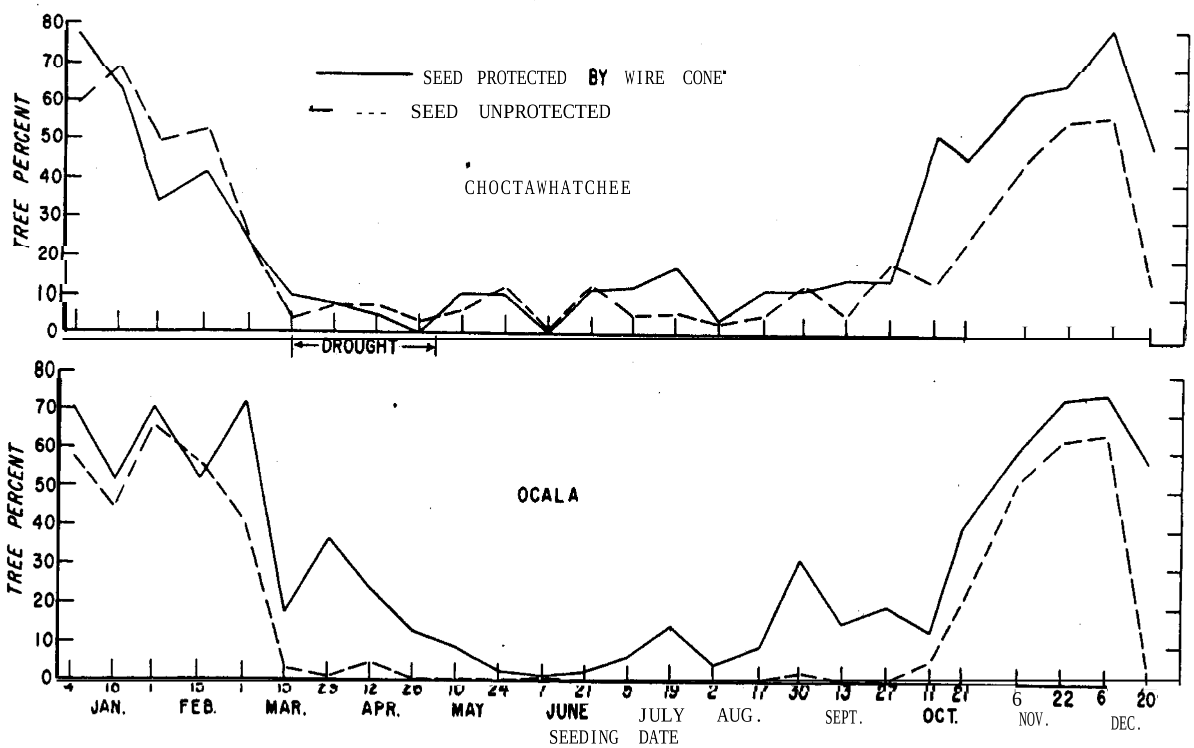

Figure 1. --Tree percents 52 weeks after the 1966 seedings of Choctawhatchee and Ocala sand pines.

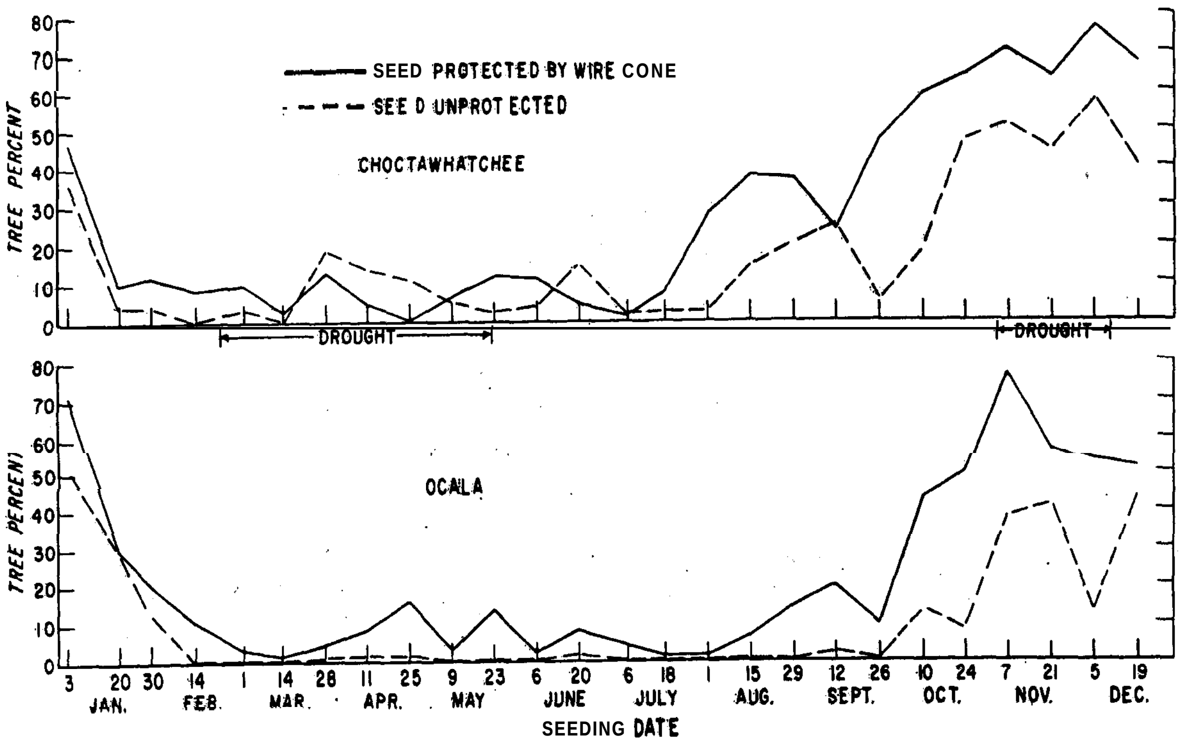

Figure 2. --Tree percents 52 weeks after the 1967 seedings of Choctawhatchee and Ocala sand pines.

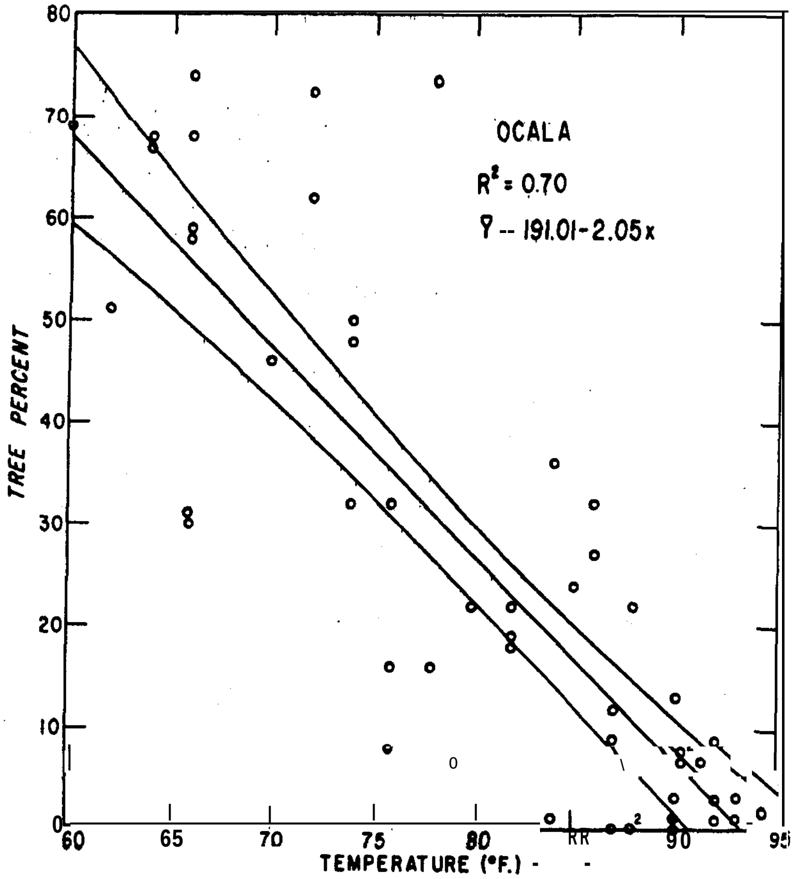

Figure 3. --Tree percents for Ocala sand pine at 10 weeks and average daily maximum temperatures during the 10 weeks after seeding.

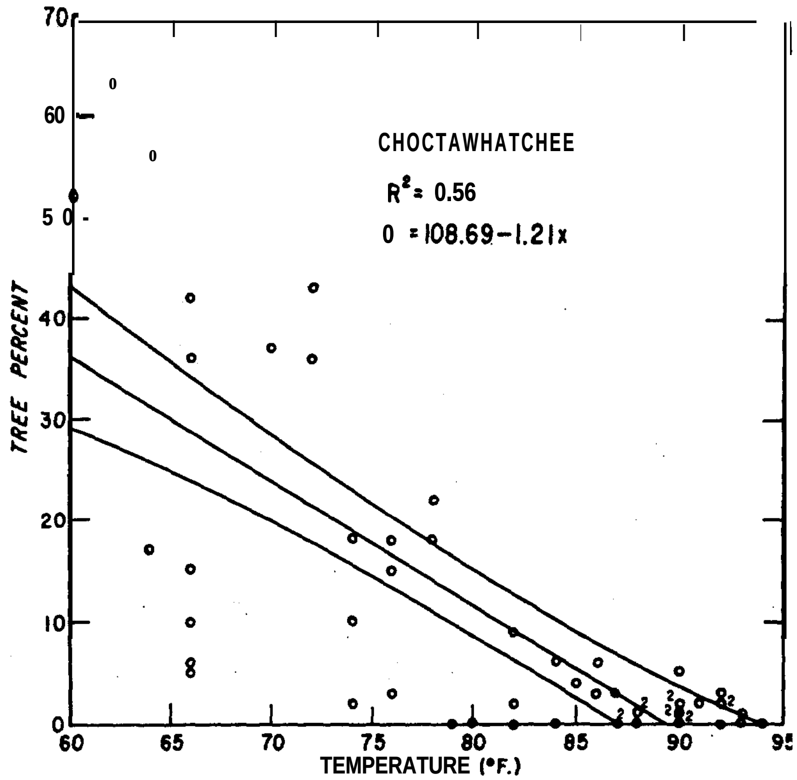

Figure 4. --Tree percents for Cho ctawhatchee sand pine at 10 weeks and average daily maximum temperatures during the 10 weeks after seeding.

COMPARATIVE GROWTH OF PLANTED AND SEEDED CHOCTAWHATCHEE SAND PINE

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Abstract. --Growth of 1-0 nursery stock of Choctawhatchee sand pine (*Pinus clausa* var. *immuginata* Ward) was hindered when planted amid year-old sand pines that had been direct-seeded, scrub hardwood sprouts, and vegetation that had invaded the previously prepared site. On newly prepared land, however, nursery stock initially grew faster than direct-seeded seedlings, though both were the same age from seed. During the ninth growing season, seeded pines grew slightly faster than planted nursery stock. Possible explanations are discussed.

INTRODUCTION

In the South, direct seeding and planting are commonly used methods of artificially regenerating pines. Sowing seeds directly in the field is cheaper than planting nursery-grown seedlings, but planted seedlings produce more uniformly stocked stands because planting is usually a more reliable method of reforestation. New and better seeding techniques and equipment are expected to correct many shortcomings of direct seeding. Whether diredt-seeded pines, with the advantage of naturally developed root systems, grow as rapidly as planted nursery stock of good quality is not known. Experiments conducted in Okaloosa and Calhoun 'Counties, Florida, with Choctawhatchee sand pine (*Pinus clausa* var. *immu-ginata* Ward) were aimed at answering this question.

METHODS

Okaloosa County Planting

The study area was typical of many sandhill sites. Soils were well- to excessively drained sand underlain at depths of 84 to 108 inches with sandy loam material. The site was cleared of scrub hardwoods--mostly turkey oak (*Quercus laevis* Walt.) and bluejack oak (*Quercus incana* Bartr.)--and wiregrass--pineland threeawn (*Aristida stricta* Michx.)--by double chopping with an 8-ton duplex brush cutter. The first chopping was done early in October and the second in mid-November 1959. About 3 weeks later, repellent-coated seeds of Choctawhatchee sand pine collected in Walton County, Florida, in 1959 were either broadcast or row-seeded in plots established on the prepared site. Moderately dense to sparse seedling stands developed.

Seed from the same lot *were* sown in the Chipola Experimental Forest nursery in March 1960, 3 months after seeding the field plots. One year later, the 1-O seedlings were lifted from the nursery bed and hand-planted among the year-old, direct-seeded seedlings. By this time, many of the scrub hardwoods had resprouted, and herbaceous weeds were invading the plots. Thirty to 40 planted seedlings and an equal number of the largest direct-seeded'seedlings were identified with painted wire pins on each of six plots. Density on the plots averaged between 550 and 650 seedlings per acre. The height of these seedlings, approximately the same age from seed, was measured annually for 3 years and again at 5 years.

Calhoun County Plantings

The study in Calhoun County was on soil similar to that in Okaloosa County, i. e. , sand underlain by a water-impeding layer of sandy loam or organic-coated sand at depths greater than 80 inches.

The study area was cleared of scrub hardwoods and wiregrass by burning in May and chopping twice with an 11 -ton duplex brush cutter in early July and again in late August 1958. After chopping, the area lay fallow 4 years. In November 1962, one-half of the area was disked in preparation for seeding and planting in 1963. The remaining half was disked during November 1963 for a replicate installation in 1964.

Seed of Choctawhatchee sand pine were spot-seeded and seedlings were hand-planted in mid-February 1963 and in mid-February 1964. Seed for nursery sowing and direct seeding were from a composite seed lot collected in west Florida in 1961. Seedlings were 1-O stock grown in the Chipola Experimental Forest nursery and were outplanted 1 day after lifting. Two rows, totaling 50 seed spots or seedlings, constituted a plot. Rows were 8 feet apart, and seedlings or seed spots within rows were at 8-foot intervals . At each seed spot, 12 repellent-coated seeds were planted $\frac{1}{4}$ inch deep and covered with'a protective cone of hardware cloth. Seedlings were thinned to one per spot, and covers were removed after 1 year. Height of all seedlings was measured annually.

RESULTS

Okaloosa County Planting

In the Okaloosa County study, direct-seeded seedlings grew faster and were almost 2 feet taller than nursery transplants when both were 5 years old from seed (fig. 1, bars 1 and 2). The nursery seedlings grew faster only during the first year while they were in the nursery bed with the advantages of cultivation, fertilization, and irrigation. For the first 2 years after transplanting, seeded pines grew more than twice as much as the planted pine s , and, although differences in growth rate decreased with time, the seeded pines continued to grow almost 25 percent more than planted pines during the fourth and fifth growing seasons.

Calhoun County Plantings

In the Calhoun County test, planted nursery stock grew faster; thus, these results were opposite from those obtained in Okaloosa County. Nursery stock in Calhoun County was 1.4 feet taller than direct-seeded pines when both were 5 years old from seed (fig. 1, bars 4 and 5). At 9 year6 from seed, the height differences had increased to 2.2 feet.

The amount by which nursery stock in Calhoun County outgrew direct-seeded pines the same age from seed increased each year to age 4 and declined after age 6. During the fourth, fifth, and sixth growing seasons, nursery stock grew 0.4 foot per year more than seeded pines the same age from seed. The difference decreased to 0.3 foot during the seventh and eighth growing seasons. During the ninth growing season, the trend reversed and direct-seeded pines grew 0.2 foot more than planted nursery stock.

Comparison of pines planted and direct-seeded the 'same year (i.e., nursery stock 1 year older than seeded pines but both having the same plantation age) is of interest from a practical standpoint. After 9 years in the field, nursery stock planted in 1963 averaged 6.6 feet taller than.pines direct-seeded in 1963 (fig. 1, bars 3 and 4). Similarly, after 8 years, *nurs* - ery stock planted in 3964 averaged 7.6 feet taller than pines direct-seeded *in* 1964 (fig. 1, bars 5 and 6). Clearly, through plantation age 9, planted sand pines in the Calhoun County study grew more than sand pines established by direct seeding.

When this comparison between nursery stock and seeded pines of the same plantation age is made, annual growth differences appear even greater than when pines the same age from seed are compared. The differences increased the first few years, peaked during the fourth and fifth years, and declined after that. In the 1963 installation, planted pines grew 1.6 feet more than direct-seeded pines during the fourth'plantation year. During the ninth plantation year of the 1963 installation, both planted and direct-seeded pines grew at the same rate. In the 1964 installation, planted pines grew 1.5 feet more than direct-seeded pines during both the fourth and fifth plantation years . During the eighth plantation year, planted pines grew only 0.5 foot more than direct-seeded pines.

DISCUSSION

The direct-seeded seedlings outgrew the nursery transplants in Okaloosa County but did not in Calhoun County. The reason for this difference probably lies in part with the established vegetation on the ground in the Okaloosa County test at the time the nursery seedlings were 'transplanted. The newly transplanted 1-O nursery seedlings had to compete with established year-old seedlings that had been direct-seeded, resprouting scrub hardwoods,. and he rbaceous regrowth. In contrast, direct seeding was done 3 weeks after the last chopping treatment so that most seeded seedlings had little vegetative competition.

The Okaloosa and the Calhoun County studies also differed *in* the season in which pine seeds were *sown*. Seeding in Okaloosa County was in early December, whereas the two seedings in Calhoun County were delayed until March. Fall germination of pine seed often occurs in nature and may have given the seeded seedlings in Okaloosa County a chance to establish deeper root systems than the seeded seedlings in Calhoun County. Well-rooted seedlings are better able to survive the severe moisture stress associated with spring droughts common to this area.

Still another difference between the Okaloosa and Calhoun studies was in the weight of choppers used for site preparation. The area in Calhoun County was chopped twice with an 11 -ton brush cutter; hardwood sprouts and herbaceous vegetation were then disked just 3 months prior to planting and seeding. The area in Okaloosa County was chopped twice with an 8-ton brush cutter before direct seeding, but the seedlings were not planted until 1 year later. No additional site preparation was done in Okaloosa County in the interim. This delay permitted direct-seeded pines, invading herbaceous vegetation, and hardwood sprouts to become established. Comparative tests have shown that more and larger hardwood sprouts develop after chopping with an 8-ton brush cutter than with an 11 -ton cutter.[1] Seedlings planted amid established competition rarely grow as rapidly as those introduced to a prepared site. The more intensive site preparation in Calhoun County provided less competition from herbaceous and woody vegetation than did the Okaloosa site. The fact that nursery stock in Calhoun County attained no more height in 5 years than nursery stock planted amid more competition in Okaloosa County indicates that either site or weather conditions were more favorable to pine growth in the Okaloosa County study.

In Calhoun County, nursery transplants outgrew direct-seeded pines in both the 1963 and 1964 installations. Vegetative competition was reduced equally for both sown and planted seedlings in this study. There is a biological explanation for this superior performance of the nursery transplants in the Calhoun County plots: they were fertilized and cultivated in the nursery for 1 year prior to outplanting. Nutrients incorporated in the seedling stimulate growth for several years after transplanting (1). With increasing age and mass, however, these nutrients are lost or are diluted so that they no longer stimulate growth. When this dilution occurs, the growth rate of planted seedlings approximates that of unfertilized direct-seeded seedlings. In the 1963 installation of the Calhoun County study, stimulating effects of nursery fertilization were no longer apparent after plantation age 8.

Direct-seeded trees retain a rooting advantage over transplanted trees, although this advantage may not become apparent for several years. Roots of planted stock are oriented in one plane by the planting slit and may develop abnormally when forced into a small hole (fig. 2, top). Improper planting may influence both survival and growth in later years. In contrast, roots of direct-seeded pines (fig. 2, bottom) are well distributed throughout the rooting zone, tap more of the soil's nutritive reserves, provide better support, and might be expected to develop more rapidly than root systems poorly planted in the same environment. Furthermore, planted seedlings initially have to recover from transplanting shock, whereas seeded seedlings do not. It takes time for the root system of a transplanted seedling to re-establish itself.

1/ Burns, Russell M., and McReynolds, Robert D. Heavy vs. medium choppers for preparing sandhill sites for pine. (Submitted to USDA For. Serv. Tree Plant. Notes.)

CONCLUSIONS

When interplanted among year-old, direct-seeded seedlings and herbaceous regrowth, 1-O seedlings of Choctawhatchee sand pine failed to grow as rapidly as their direct-seeded counterparts. When planted on newly cleared soils of deep sand, however, nursery transplants grew faster than direct-seeded seedlings, at least through plantation age 8. Differences in rates of height growth appear to decline with age, presumably because nutrients provided in the nursery are lost or diluted by tree volume. Indications are that the advantages of a well-distributed, naturally developed root system eventually may overbalance advantages of nursery care and fertilization, especially when roots of planted stock are poorly placed in the planting slit.

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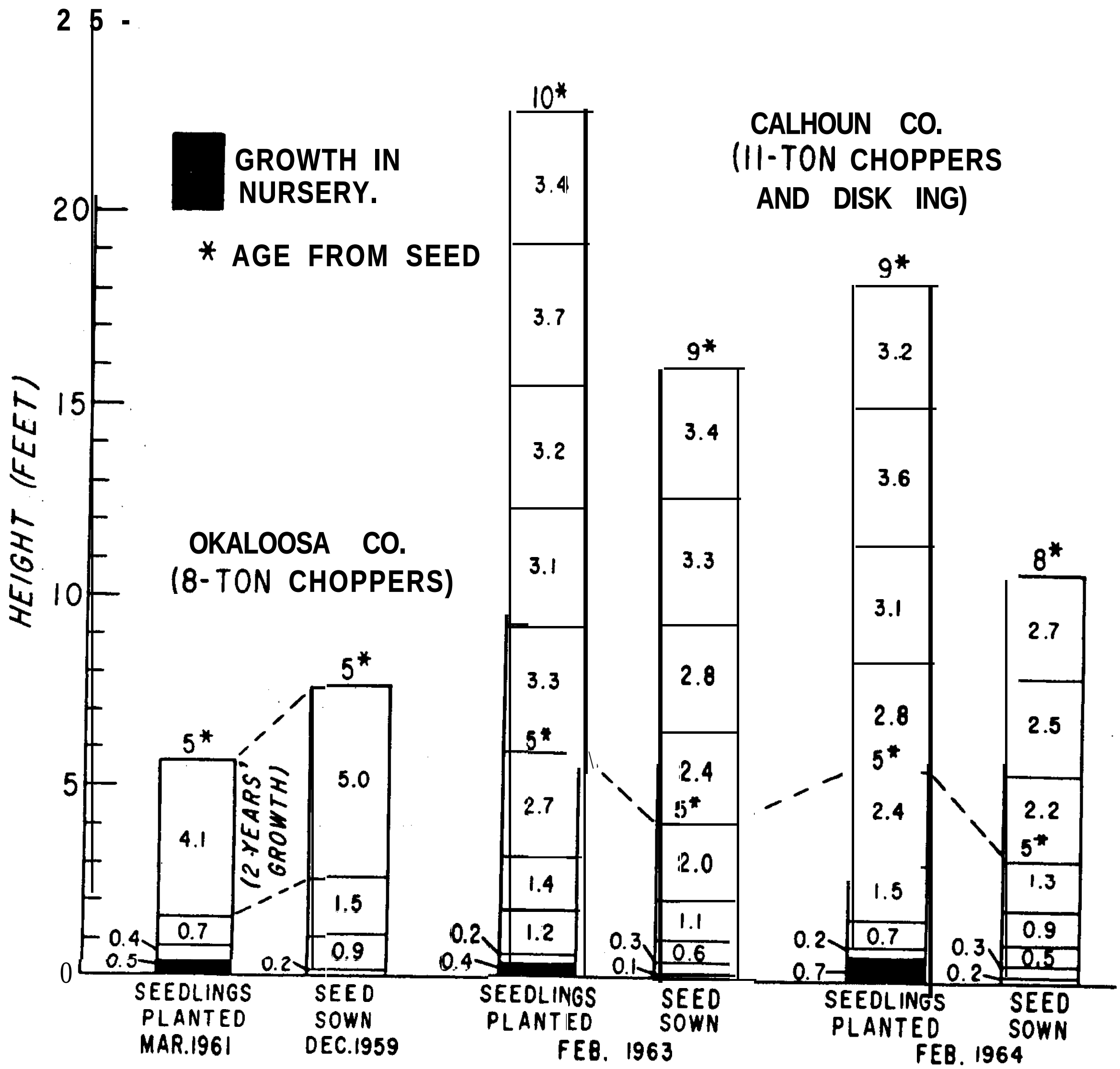

Figure 1. --Total and annual growth in feet of planted 1-0 seedling and direct-seeded Choctawhatchee sand pines. Bars 1 and 2 and bars 4 and 5 compare trees of equal age from seed. Bars 3 and 4 and bars 5 and 6 compare trees of equal plantation age.

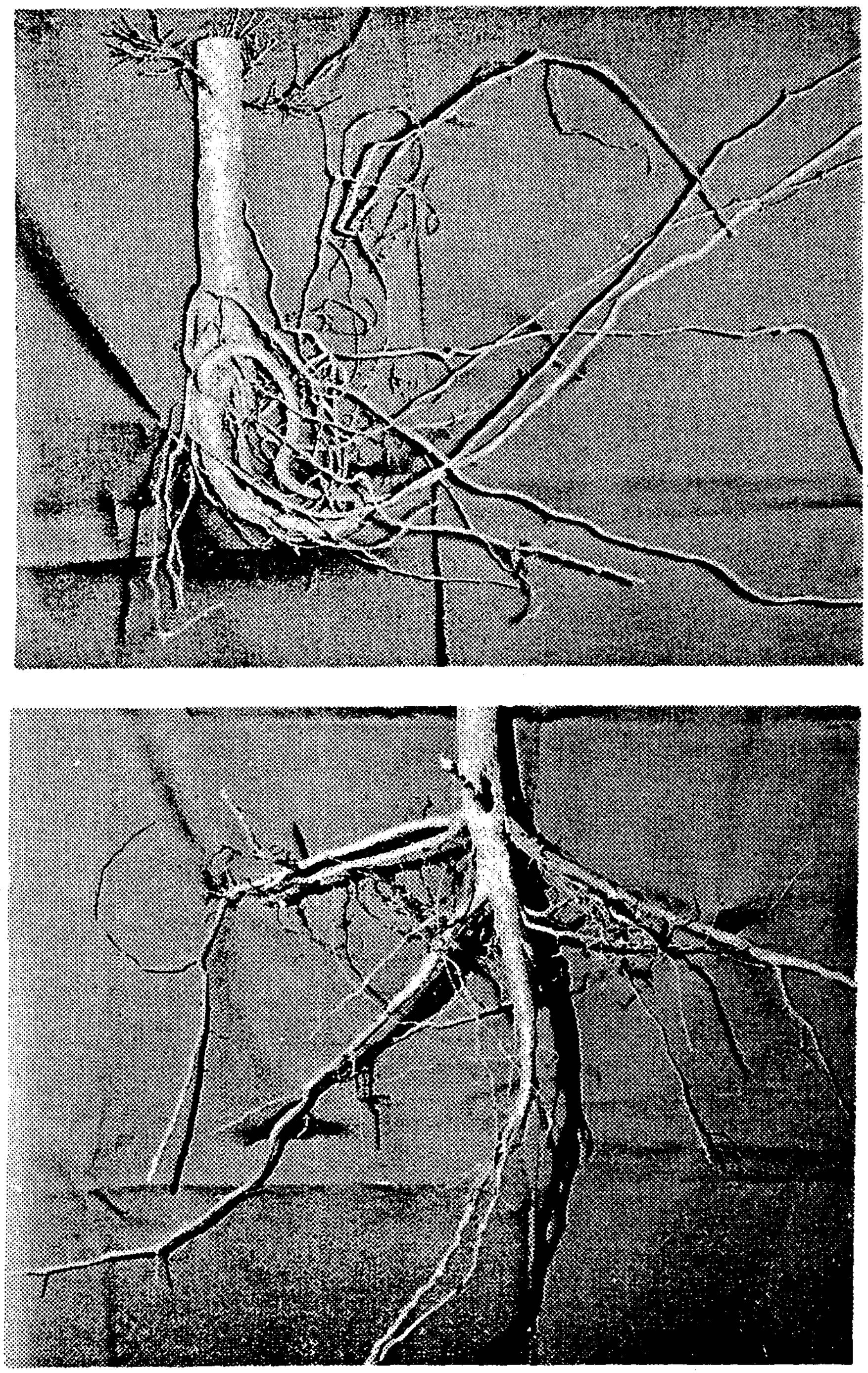

Figure 2. --(Top) Poorly planted seedling of sand pine. Because the roots were forced into a narrow planting slit, growth of the root system and of the entire tree may be retarded and the tree may not stand firm against the wind. (Bottom) Well-distributed root system of a direct-seeded sand pine. These roots will develop naturally and tap a larger volume of soil and its nutritive reserves.

COMPARATIVE GROWTH OF PLANTED PINES IN THE SANDHILLS OF FLORIDA, GEORGIA, AND SOUTH CAROLINA

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Abstract. --The performance of longleaf, slash, loblolly, shortleaf, and Ocala and Choctawhatchee sand pines was compared on several soils in the sandhiils. Choctawhatchee sand pine appears best suited for planting on excessively drained sands in the Florida and Georgia sandhills and a good prospect for the Carolina sandhills.

This paper summarizes past and current research comparing the performance of native and exotic pines planted in the sandhills. Although data for several pines will be presented, particular emphasis has been placed on performance of sand pine (*Pinus clausa* (Chapm.) Vasey). Formal work with this species was initiated in Florida almost a decade before it was started elsewhere in the sandhills, and for this reason, most of the results presented here are from northwest Florida.

The adaptability of more than 40 conifers and several hardwoods from around the globe has been tested since formal research on regeneration started in the sandhills shortly before World War I. The majority failed. Some did not survive the nursery phase of the work. Others were not able to compete with established herbaceous and woody plants, to withstand the climate or, *having* survived planting, to sustain themselves in an alien and hortils environment.

Only five of the species tested show any promise. All are southern piner. All are well adapted to the climate, as evidenced by their performance on less refractory sites throughout the South. They are longleaf pine (*Pinus palustris* Mill.), slash pine (*P. elliottii* Engelm.), loblolly pine (*P. taeda* L.), shortleaf pine (*P. echinata* Mill.), and both the Ocala and Choctawhatchee varieties of sand pine (*P. clausa* var. *clausa* Ward and *P. clausa* var. *immuginata* Ward). Of these, only longleaf and sand pines are native on well- to excessively drained, infertile sandhill soils.

To obtain a clearer picture of comparative growth among species in the following tests, volume has been computed for both the average-size tree and for an acre.

The oldest comparative test of species on the Chipola Experimental Forest involved underplanting slash (SL), longleaf (LL), loblolly (LOB), shortleaf (SHTLF) and Ocala sand pines (OSP) at a density of 908 trees per acre and releasing them from overtopping hardwoods at various intervals following planting. Survival and height data were reported previously in this rymposium by Hebb in a paper on site preparation. Reported here is a comparison of wood volume production for surviving SL and OSP at plantation ages 12 and 20 (table 1). Plantings of the other three pines failed.

When measured at age 12, the average OSP was 20 feet taller and 2¾ inches larger at d. b. h. than the average SL and had produced about 25 times as much wood. Unreleased OSP and SL growing at the same stocking level provided the most critical comparison. In this treatment, OSP were 19 feet taller and 3 inches larger at d. b. h. than SL and had produced more than 100 timer as much wood per acre. Neither pine had as yet overtopped itr hardwood competitors.

At age 20, the OSP plantings produced an average of 1,400 cubic feet of wood per acre. Trees released when planted produced at least half again as much wood (2, 100 cubic feet per acre) as any of the other release treatments, and almost twice as much as unreleased OSP. By contrast, SL produced an average of only 64.4 cubic feet of wood per acre. Even the unreleased OSP produced almost 10 times the volume of wood produced by SL released at the time of planting. In every treatment, OSP. attained a larger rite than SL while growing with less available growing space per tree.

Differences in survival and, therefore, differences in stocking levels make a comparison of wood production *on* an average tree basis even more meaningful. In every release treatment, the *average* OSP produced from about 13 to 23 times more wood than the average SL. Unreleased OSP

. Table 1. --Comparison of performance of slash and Ocala sand pine when underplanted and released

PLANTATION AGE 12 YEARS

Treatment	Survival	Average height	Average d.b.h.	Volume [a]	
	Trees/ acre	Feet	Xncht s	cu. ft. / tree	cu. ft. / acre
Ocala sand pint:					
Released at planting	554	32.8	5.1	1.5646	866.8
Released at 1 year	505	29.3	4.1	.8905	449.7
Released at 3 years	516	27.8	3.8	.7463	385.1
No release	542	26.0	3.6	.6292	341.1
Average	529	29.0	4.2	.9649	510.7
Slash pint:					
Released at planting	391	12.9	2.0	.0948	37.1
Released at 1 year	479	10.9	1.5	.0469	22.4
Released at 3 years	479	8.9	1.2	.0250	12.0
No release	544	6.7	.6	.0048	2.6
Average	473	8.9	1.4	.0391	18.5
PLANTATION AGE 20 YEARS					
Ocala sand pine:					
Releas td at planting	542	45.8	6.9	3.9175	2123.3
Released at 1 year	505	40.8	6.0	2.6766	1351.7
Released at 3 years	516	40.5	5.6	2.2931	1183.2
No release	541	38.7	5.5	2.0953	1133.5
Avt rage	526	41.5	6.0	2.7527	1447.9
Slash pint:					
Released at planting	391	19.7	2.9.	.2953	115.5
Released at 1 year	466	17.0	2.4	.1725	80.4
Released at 3 years	479	14.9	1.9	.0990	47.4
No release	428	11.5	1.3	.0337	14.4
Avt rage	441	14.8	1.9	.1461	64.4

[a] Total tree volume' (conical volume) = 0.001818 x d. b. h. ^{2} x htight = cubic feet.

overtopped their hardwood *competitors* at about age 17, but SL had not done so by age 20. For this reason it is not too surprising that unreleased OSP produced more than 60 times as much wood on an individual *tree* basis a6 unreleased SL, and seven times more than SL released at the time of planting.

This comparison shows that both SL and OSP can survive underplanting with or without release from overtopping hardwoods, but that of the two, only sand pine will grow at an acceptable rate when underplanted in the sandhills.

Comparable results were obtained *on* intensively prepared sites. In one test, SL, LL, LOB, SHTLF, OSP, and Choctawhatchee sand pine (CSP) were planted at a density of 889 trees per acre. Re sults , summarized at plantation age 15 (table 2), show that the sand pines produced far more wood than other southern pines, and because of difference6 in survival, CSP produced more wood per acre than OSP. They also emphasize the influence that diseases have *on* pine survival and growth, and the importance of site preparation for pines other than sand pine planted in the sandhills.

The sand pines produced more than twice the volume of wood on an average tree basis a6 did any of the other southern pines. Of the sand pines, OSP produced about 1/8 cubic foot more wood than CSP. Volume production, however, is a function of the number of trees per acre a6 well as individual tree size: in plantation6 established at comparable spacings, factors affecting survival and growth influence wood production. Diseases play such a role in droughty, infertile sandhill soils.

Table 2. --Comparison of pine performance at plantation age, 15 years on an intensively prepared sandhill site

Pine	Survival	Average height	Average d.b.h.	Volume[a]	
	Trees/ acre	Feet	Inches	cu. ft./ tree	cu. ft./ acre
Ocala sand	481	36.5	4.4	1.2861	618.6
Choctawhatchee sand	771	34.6	4.2	1.1352	875.0
Longle af	119	18.0	3.7	.4502	53.6
Slash	760	17.7	2.6	.2240	170.3
Loblolly	677	10.5	1.6	.0515	34.8
Shortleaf	706	8.5	1.6	.0379	26.8

[a]/Total tree volume (conical volume) = 0.001818 x d. b. h. ^{2} x height = cubic feet.

The incidence of disease and pine survival and growth in this test were fairly typical for plantings on prepared sandhill sites in northwest Florida. Because of high planting density, stocking levels for most pines were higher than the 400 to 450 trees per acre believed to be optimum for pulpwood in the sandhills. CSP, growing under relatively crowded conditions, were almoet a8 large as OSP. The difference in stocking levels resulted from the loss of OSP to mushroom root rot (Clitocybe tabescens (Fr.) Bres.). This loss enabled 771 CSP per acre to produce about 40 percent more wood than the 481 OSP. Slash pine growing at about the same density as CSP (760 per acre) produced only one-sixth as much wood.

The importance of site preparation for pines other than sand pine is demonstrated by a comparison of volume production for OSP and SL at age 15 in both tests. Interpolation of data in the first test indicates that 528 OSP per acre were alive at age 15, and that they averaged 34.2 feet tall and 4.81 inches in diameter. Similar computations show that about 454 SL per acre were alive and that they averaged 11.1 feet tall and 1.58 inches at d. b. h. Thus, 528 underplanted OSP produced 1.44 cubic feet of wood per tree and 760 cubic feet per acre, while 481 OSP planted on an intensively prepared site produced 1.29 cubic feet of wood per tree and 619 cubic feet per acre--a like amount on both sites. In contrast, 454 SL produced an average of 0.05 cubic foot of wood per tree and 23 cubic feet per acre when underplanted, while 760 SL produced an average of 0.22 cubic foot of wood per tree and 170 cubic feet per acre after 15 years of growth on the intensively prepared area. Clearly, OSP does not require intensive site preparation but benefits from release from overtopping competition, whereas SL needs intensive site preparation in order to survive and grow in the sandhills, albeit at a less than satisfactory rate. Supplementary informal tests conducted elsewhere in the sandhills show that CSP also survives underplanting and will overtop a scrub hardwood canopy at about the same age as OSP.

The second comparison on an intensively prepared sandhill site involved CSP, SL, LL, and LOB planted at a density of 908 trees per acre. In this test, brown spot needle blight (Scirrhia acicola (Dearn.) Siggers) on LL was controlled for 2 years following planting to obtain a measure of the species potential in the sandhills. Measurements taken at plantation age 10 (table 3) confirm results of the previous test on a prepared site and show that, even with some control of brown spot, growth of LL falls far short of CSP.

The effects of brown spot control for even 2 years are readily apparent. At age 5, almost three-fourths of the planted trees were alive and many had started height growth. About 14 percent of the LL died between ages 5 and 10. However, most of these trees were infected with brown spot and failed to escape' the grass stage. Some of these trees probably could have been saved by prescribed burning because, by age 5, sufficient fuel had accumulated on the chopped site to sustain a fire. Fire was not used, however, so by age 10 LL stocking dropped to about 530 trees per acre. By sandhill standards, the site planted to LL may have been overstocked at age 10.

Table 3. --Comparison of pine performance at plantation age 10 years on an intensively prepared site in the west Florida sandhills

Pine	Survival	Average height	Average d.b.h.	Volume[a/]	
	Trees/acre	Feet	Inches	cu. ft./tree	cu. ft./acre
Choctawhatchee sand	896	26.2	3.8	0.6959	62-3.3
Longleaf[b/]	529	11.4	2.3	.1137	60.2
Slash	555	15.9	2.6	.2032	112.7
Loblolly	625	10.2	1.6	.0500	31.3

a/ Total tree volume (conical volume) = 0.001818 x d. b. h.^{2} x height = cubic feet.

b/ Sprayed with Zinc Coposil to control brown spot needle blight (four semiannual treatments at ages 1 and 2).

CSP produced twice as much wood on an average tree basis and three times as much wood on an acre basis at age 10 as LL, SL, and LOB combined. SL, growing at about the same stocking level as LL, produced twice as much wood .as LL. However, if performance on the older test reported previously can be used as a guide, growth of LL will surpass that of SL within the next few years and may eventually produce a comparable amount of wood. Growth of neither SL nor LL is expected to approximate that of CSP within a 25- to 40 -year pulpwood rotation. LOB appears to be a poor choice for Florida sandhills.

Species comparisons that include sand pine are quite rare in the sandhills of Georgia and the Carolinas. McGee (5) reported results of a test on Lakeland soil in South Carolina in which survival of planted CSP was 71 percent, but tree height averaged only 1. 9 feet at age 5. Improper planting is suspected as a possible cause of the poor growth. Sand pines planted in the sandhills at the conventional root-collar depth, or shallower, seldom survive and grow as well as those planted deep enough to insure that the lowest whorl of green branches remains covered with soil.

The poor height growth cited by McGee should have been sufficient to discourage further testing of sand pine so far north of its natural range, but fortunately it was not. That year, comparative plantings including both varieties of sand pine were installed on an Alaga loamy sand in Georgia and on a Troup loamy sand in South Carolina (2). Results of the test indicate that sand pine will survive climatic extremes not normally encountered within its native range, and that relatively slight differences in fertility and depth of sandhill soils can markedly influence the field performance of planted pines.

The test site in Georgia was prepared with a bulldozer with the blade set at the soil surface. In South Carolina the site was root-raked, disked, and cropped for watermelons the year prior to planting. OSP, CSP, LL, SL, and LOB seedlings were planted at a density of 1,210 trees per acre on both areas. No attempt was made to control brown spot needle blight. When the plantations were 5 years old, a severe ice storm struck the South Carolina planting (3). During their seventh growing season, trees on both sites were thinned to standardize stocking levels among pines: the Georgia plantings to 463 and the South Carolina plantings to 649 trees per acre. Diseased, damaged, and poorly formed trees were preferentially removed to meet required stocking levels and to obtain uniform distribution of residual trees. 0 riginal stocking levels were high enough for all but LL in Georgia so that only the best trees were left. Measurements taken at plantation ages 5 and 7 are summarized in tables 4 and 5.

Few trees died after the first year. Wilted planting stock was blamed for low LL survival, and a freezing temperature shortly after planting was blamed for OSP mortality (2). Survival of CSP averaged 76 percent in Georgia and 82 percent in South Carolina at age 3. Survival of SL and LOB averaged 85 to 97 percent on both sites.

The paucity of nutrients in sandhill soils usually is reflected in the growth of planted pines within 3 to 6 years. Differences manifest themselves earliest on the poorest sites and among the most poorly adapted species. In these tests, CSP was slightly taller than SL or LOB at age 3 in Georgia and by age 5 in South Carolina. By age 7, following the thinning, CSP was clearly taller and larger than any of the other pines in Georgia and South Carolina.

All pines survived and grew better on Troup loamy sand in South Carolina than on Alaga loamy sand in Georgia. Differences were attributed to a greater store of moisture available for tree growth and to fertilizer residues from the watermelon crop previously grown on the South Carolina site (1).

In the Troup loamy sand, an argillic horizon at about 4 feet retained moisture at a depth inhabited by pine roots. In comparison, the fine -textured horizon in the Alaga loamy sand in Georgia was at too great a depth to materially ‘influence survival and growth of the young pines. Chemical analyses of the two soils also revealed evidence of calcium and phosphorus at the 4- to 12-inch depth in Troup loamy sand where the watermelons had been grown. In most sandhill soils, pines do not respond to other nutrients until a phosphorus deficiency is satisfied.

All pines in the South Carolina test were damaged by ice to some degree, but damage appeared to be greatest in sparsely stocked stands of tall trees. OSP suffered most (37 percent damaged), LOB least (13 percent damaged), and SL, CSP, and LL suffered an intermediate amount: 27, 25, and 23 percent, respectively. Because the CSP planting was taller and more widely spaced than the SL planting yet suffered no more damage, CSP appears to be better suited for planting in the sandhills of South Carolina than SL. Both were planted north of their natural ranges.

Table 4. --Pine performance in Georgia

Pine	Survival	Average height	Average d. b. h.	Volume[a]	
	Trees/ acre	Feet	Inches	cu. ft. / tree	cu. ft. / acre
PLANTATION AGE 5 YEARS					
Ocala sand	417	7.8	1.0	0.0134	5.6
Choctawhatchee sand	905	8.3	1.0	.0148	13.4
Longleaf	195	1.5	1.1	.0036	.7
Slash	1015	5.1	.8	.0064	6.5
Loblolly	1061	5.4	.7	.0054	5.7
PLANTATION AGE 7 YEARS[b]					
Ocala. sand	415	13.9	2.2	.1176	48.8
Choctawhatchee sand	357	14.5	2.2	.1278	45.6
Longleaf	312	4.8	1.5	.0195	6.1
'Slash	460	9.6	1.6	.0418	19.2
Loblolly	415	9.7	1.4	.0365	15.2

[a] Total tree volume (conical volume) = 0.001818 x d. b. h. ^{2} x height = cubic feet.

[b] Sample sise increased, and trees thinned to leave 463 per acre. (Longleaf was the only pine that did not meet this minimum stocking level.)

Table 5. --Pine performance in South Carolina

PLANTATION AGE 5 YEARS

Pine	Survival	Average height	Average d. b. h.	Volume[a/]	
	Trees/ acre	Feet	Inches	cu. ft./ tree	cu. ft./ acre
Ocala sand	.724	9.7	1.2	0.0262	19.0
Choctawhatchee sand	980	10.6	1.4	.0357	35.0
Longleaf	713	'5.8	1.3	.0184	13.1
Slash	1108	8.8	1.5	.0363	40.2
Loblolly	1158	10.0	1.5	.0386	44.7
PLANTATION AGE 7 YEARS[b/]					
Ocala sand	649	15.0	2.4	.1555	100.8
Choctawhatchee sand	563	15.8	2.5	.1814	102.0
Longleaf	649	10.3	2.1	.0805	5.2. 2
Slash	649	13.2	2.3	1317	85.4
Loblolly	645	13.5	2.2	: 1164	75.0

[a/] Total tree volume (conical volume) = 0.001818 x d. b. h.^{2} x height = cubic feet.

[b/] Sample size increased, and trees thinned to leave 649 per acre.

The thinning was scheduled for the hottest summer month to reduce the likelihood of infection by Fomes root rot (Fomes annosus (Fr.) Karst.). No evidence of annosus was found, but bark beetles (Ips spp.) attracted by the thinnings attacked all pines. However, their attack seemed directed at CSP.

Interpretation of results of these tests is confounded by differences in stocking levels through age 6, the ice damage in South Carolina, and the preferential insect attack following the summer thinning. Prior to thinning in Georgia, the average sand pine tree had produced about twice. as much wood as other species, .and CSP had produced twice as much wood per acre as other pines. Following the thinning and the insect attack, the remaining 357 CSP and 415 OSP had produced from about 2½ to 9 times more wood per acre than 312 LL, 460 SL, or 415 LOB. The average CSP manufactured slightly more 'wood during the 7 years than OSP. before the ice storm, LOB and SL growing at a higher stocking level were shorter but larger in diameter than CSP. They also produced more wood. After the ice storm, thinning, and insect attack, the 563 CSP remaining at age 7 had produced more wood on an average-size-tree basis and on an acre basis than other pines growing at a density of at least 80 stems more per acre.

The performance of sand pine in another comparison in the Georgia sandhills elicited a recommendation from Keider (4) for planting sand pine rather than slash pine on deep sandy soils of the Fall Line. Measurements taken during the thirteenth growing season showed that slash pines at a density of about 400 trees per acre had attained a size of 17 feet and 2.8 inches d. b. h. In contrast, Ocala sand pine growing at a density of 310 trees per acre were 29 feet tall and 5.1 inches d. b. h. Implications from Keider's report and results from plantings installed by Harms suggest that CSP is a safe choice for the Georgia sandhills and a good prospect for the Carolina sandhills.

SUMMARY AND RECOMMENDATIONS

Sand pine will produce more wood in a shorter time than other pines planted on droughty sandhill soils. The species is tolerant of underplanting and responds to release. Neither intensive site preparation nor fertilization is required, but sand pine benefits from both. CSP is preferred over OSP because of its higher planting survival, apparent resistance to mushroom root rot, superior form, and greater tolerance to freezing temperatures.

Shallow planting is believed responsible *for* poor survival and growth occasionally reported for CSP in the sandhills. Seedlings should be planted deep enough to insure that the entire hypocotyl remains underground after the soil settles--at least the lowest whorl of green branches should be planted.

Summer thinning of CSP should be avoided. In Georgia and Soutb Carolina, bark beetles preferred CSP over other pines planted. Planting at a spacing to obviate the need for any thinning, or thinning more closely planted trees during winter, seems a prudent alternative to thinning during the summer.

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MANAGEMENT OF NATURAL STANDS OF CHOCTAWHATCHEE SAND PINE

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Abstract.--This paper describes the important factors that have influenced the formation of stands of Choctawhatchee sand pine, discusses the characteristics of the species, and explores some management dynamics and techniques used for natural stands of this species at Eglin Air Force Base in Florida. Opportunities for using Choctawhatchee sand pine for small-diameter forest products are compared with those for other southern pines.

The management of natural stands of Choctawhatchee sand pine is not a new topic for foresters--it has been around for quite ***some*** time. But there has been a change. The tone of discussion is now directed toward the question, "What are the opportunities ahead for sand pine?" This change has resulted because of ***one*** reason: the present and future ***concern*** for timber.

I will briefly describe the important factors that influenced the formation of stands of Choctawhatchee sand pine, discuss the characteristics of the species, and explore some management dynamics and techniques in natural stands.

For a quick review of the subject of managing natural stands of Choctawhatchee sand pine, we should look at the background. Back in the "good old days" when Eglin Air Force Base--a large 464,000-acre military base in northwest Florida--was known as the Choctawhatchee National Forest, sand pine was discussed in most meetings where management decisions were being made. The Forest Rangers of that day believed that "a stand of timber is only as good as the trees in it." Consequently, the discussions of managing sand pine usually ended in a gruff and nasty fashion. To put it simply, sand pine was considered to be worse than Bermuda grass in a cornfield--it was a weed! It grew and spread like a weed. Sand pine sprang up everywhere it was not wanted, particularly wherever a beautiful, tall, stately longleaf pine was cut and where it was expected to be replaced by another vigorous, shapely, young longleaf pine. The management of sand pine was simple: a crew of CCC boys were dispatched with sharp axes to do a "weeding" in accordance with the prescription-of-the-day. And that was the genesis of our present system of managing natural stands of Choctawhatchee sand pine.

DESCRIPTION OF THE TYPE

Now let us assess some of the factors that have influenced the formation of the natural stands of Choctawhatchee sand pine around Eglin Air Force Base. How did this. forest develop? We cannot be sure, but observation provides some clues for an educated guess.

Eglin's forest lands are dominated by the longleaf-slash type. However, the virgin longleaf-slash pines that once were so abundant have gradually disappeared. Man has profoundly affected this plant community by his timber cutting, naval stores operations, and grazing practices. Yet man's greatest influence has been through the use of or exclusion of fire, These four practices have greatly affected the spread of Choctawhatchee sand pine into areas that it once did not occupy. Even though this spread has taken place in a relatively short period, it has resulted in Choctawhatchee sand pine's becoming the dominant species on about 100, 000 acres of our cutover longleaf-slash land. To be more descriptive, this is a very large "land grab" and represents almost 20 percent of our land holdings.

Most of the soils are deep sands of the Lakeland soil series, The soils tend to be infertile and low in organic matter. Altitude varies from sea level to 295 feet above sea level, and gentle hills characterize the terrain. The average site index is between 60 and 70 feet for sand pine. More than 25 percent of Eglin's soils is classified as being well-suited for growing sand pine, whereas 37 percent is classified for growing slash pine and 32 percent for growing longleaf pine. The rest is designated for hardwoods.

The sand pine type occurs over a wide variety of sites, from white beach sands to the best loamy sands. It tends to occupy the sandiest soils because its capacity to extract moisture and nutrients from these soils is superior to that of other southern pines. Of course, the best soils produce the faster growing, larger sized sand pines, whereas the white beach sands produce the "runts," the picturesque trees with the artistic, windswept crooks.

Sand pine usually grows in pure stands with heavy densities and is essentially single -storied. Frequently, the open-grown stands of sand pine are layered and multi-aged, with seedlings and saplings beneath the parent trees giving a multi-storied appearance.

The best development of sand pine takes place in stands with 1,000 to 1,500 stems per acre. Open-grown trees develop poor forms with large orchard-shaped crowns and many branches and often with crooked stems. On the poor sites, sand pine tends to form dense stands in which growth is slow and trees are spindly.

CHARACTERISTICS OF CHOCTAWHATCHEE SAND PINE

Choctawhatchee sand pine is often described as "scrub pine" by most of the local residents, particularly by those who have been in the "log-woods" all of their lives. It is with this description in mind that I want to show a different side of Choctawhatchee sand pine, a view that will become clearer as I expound upon the best characteristics of the tree and its potential.

The species has several distinct advantages that are important to recognize. One advantage has already been mentioned: its superior ability to extract moisture and nutrients from sandy soils.

Let me explore this advantage a little further by asking this question: "What would sand pine do with adequate moisture and nutrients?" or "What will it do on a good site?" Mentally compare these measurements with measurements of other pines that grow under natural conditions:

	Best sites	Good sites	Average sites
Diameter	24 inches	18 inches	14 inches
Height	80 feet	75 feet	60 feet

These are actual measurements of some individual trees of the same age class at Eglin. They are not the ordinary trees that are seen when one looks at sand pines, but they do represent a potential. Furthermore, figures such as these will lead us to certain questions concerning management decisions. For instance, could this species be suitable for plywood? or for saw-timber? These are distinct possibilities.

The second advantage of sand pine is its ability to put on an early growth spurt in the spring, as well as to have winter flushes of growth. These may amount to about 6 inches of height for each spurt.' The first growth spurt takes place in March with the earliest warm days. Sand pine is the first tree to start the height-growth process in the spring. It has been rated as moderately intolerant, but in its early establishment it is rather tolerant of shade and competition. You may ask, "What advantage is this ?" For one thing, it gets a jump on its neighbors, the hardwoods. Also, it is the first tree to draw upon the water that is stored in the soil during the winter. Both of these are big advantages from a management standpoint, especially when rain is deficient in the spring.

The second spurt takes place during the summer with the coming of thundershowers. Height growth varies considerably at this time, but another few inches are formed. It is important to remember that this is the period when summerwood is being added to the diameter of the tree. Total height growth averages as much as 2 feet annually, and some genetically superior trees may average 3 feet in height annually.

Diameter growth on some of the open-grown sand pines with orchard-shaped crowns will average about one-half to three-fourths of an inch in a year. Diameter growth on an average tree in a natural stand is similar to that of other pines; also, it varies considerably from site to site. In contrast to the major southern pines, actual growth data for sand pine are relatively scarce, but yields of 40 cords to the acre may be expected on good sites at age 40 in well-stocked stands. This yield equals the 1-cord-to-the-acre growth concept which is the forester's rule of thumb in gauging good production.

MANAGEMENT DYNAMICS AND TECHNIQUES

Many people do not realize that Choctawhatchee sand pine has some very fine qualities. Not only does it have the previously mentioned advantages, but it can also be managed to produce a variety of commercial products--provided that this is the objective.

To emphasize this ability, let me point out some examples that nature has produced. Throughout Eglin, more than 100 superior sand pines have been identified for tree improvement purposes. There are many more which have not been selected, but they are equally as spectacular. One such tree is over 20 inches in diameter, 80 feet tall, and limbless for at least 2½ logs.

From a management concept, it is important to reproduce this quality in trees, not only in individual members, but also in stands of trees over a wide area. I am speaking of developing this quality in natural stands--stands that we now have to work with--rather than in cultured plantations. On

Eglin, there are now some stands which have this characteristic of fast growth, good comparable height, and potential quality. However, there are relatively few. I suspect that some of our past management procedures, such as fire and grazing practices, have not helped the situation.

We are now at the point where we can explore some management dynamics as well as management techniques for developing cultural treatments for natural stands of Choctawhatchee sand pine. The whole idea is to give the forest manager an alternative to his present concept of managing his stands on short rotations with clearcutting and planting. The actual choice represents a compromise between economic, technical, and silvicultural factors. Ultimately, the forest manager may have to recognize that even-aged crops of trees cannot be grown continuously on short rotations without taking into account the biotic factors and the problem of maintenance of soil fertility (as affected by intensive site preparations and so forth).

The discussion of management dynamics is founded on two basic premises. The first concerns the goal of growing the highest-valued product, or products, that the site will produce in the shortest period of time. The second concerns the role that techniques play in developing a major commercial product while also considering the environmental aspects of other uses, such as recreation, wildlife habitat, and aesthetics.

Generally, we think of sand pine as a pulpwood tree growing on a site with low potential for productivity. As such, our management is limited--this is understood. But let us move forward for a moment and consider two distinct prospects. The first regards the growing of sand pine on sites other than poor ones, and the second points to the fact that new markets are opening up in the South. Both of these prospects are quite real.

To explore these prospects, we must change our management directive from the production of pulpwood to that of the alternatives of multiple - products. A shift of emphasis is apparent --from quantity production to quality production. For Choctawhatchee sand pine, quality is defined as that ability to produce a product of greater value than pulpwood, such as short saw logs for studs or short bolts for plywood..

We know that a mature stand of Choctawhatchee sand pine at age 50 can contain as much as 15 thousand boardfeet of merchantable sawtimber, with 10 cords of pulpwood per acre on a good site. Furthermore, we know that sand pine sawtimber is usually knotty and small in size. Yet we know also that, on the average, second-growth southern pine also produces lumber which is lower in quality than is desirable. So what are we looking for in Choctawhatchee sand pine ? Maybe we should lower our sights somewhat and look at the market place to see what it will accept in 10 or 20 years, or perhape 50 years from today.

By the year 2000, the U. S. population will climb to nearly 290 million, if Federal Government projections are correct. This is nearly 80 million more people in this country than we now have. It is the pressure of this added population requiring more timber--in the form of new homes, schools, shopping centers, recreation areas, and the like--that will be the main thrust behind rising timber values in the future.

Not only is the population going to increase by the year 2000, but our timber supply is going to be greatly affected. For one thing, the quality of products that come from the woods is going to be less than what is now being produced.

Until recent years, the local lumber industry has been operating its plants on a supply of timber from the major southern pines. A steady market has been provided with these species, and the result has been a decline in the average tree size. It is in this climate where small-diameter trees are acceptable that an avenue will open for Choctawhatchee sand pine to enter the market. I am convinced that in the near future sand pine will successfully blend with other pines (much of which are already grown in short-rotation, second-growth plantations) in the small-diameter market and possibly in other markets where stud mills and plywood plants compete with the pulpwood companies for the smaller pine trees.

To illustrate how the economics of the small-diameter market might work, let me use part of a table that Jiles (1) developed for natural stands of shortleaf and Virginia pines and for planted stands of loblolly pines in east Tennessee:

D.b.h.	Pulpwood stumpage price per standard cord (dollars)				
(inches)	$1	$3	$5	$7	$9
	Equivalent sawtimber stumpage price per Mbf (dollars)*				
7	4.08	12.24	20.40	28.56	36.72
9	3.28	9.84	16.40	22.96	29.52
11	2.82	8.46	14.10	19.74	25.38
13	2.45	7.35	12.25	17.15	22.05

*Based on International ¼ Inch Log Rule.

The table shows price equivalents for small-diameter trees when used for pulpwood or sawtimber. The price equivalents are based on the number of standard cords required for each diameter class to produce 1,000 boardfeet by the International ¼ Inch Log Rule. For example, the column for

$1 pulpwood stumpage shows that, for the 9-inch diameter class, 3.28 cords is equivalent to 1,000 boardfeet. It also shows that the $1 pulpwood stumpage price is equivalent to $3.28 for sawtimber and that $9 in pulpwood stumpage is equivalent to $29. 52 for sawtimber.

The table gives a good dollar-value comparison for small-diameter products. It appears from the table that pulpwood might be competitively pushed if sawtimber stumpage continues to rise as it is now rising in our "seller's market."

Of course, all of this is speculative. But it represents a potential, and it is on this potential that we are gauging our present and future management of natural stands of Choctawhatchee sand pine.

Let me show you what we are thinking about for the future in regard to the 100,000 acres of sand pine that we have at Eglin.

At present, our rotation age for sand pine is 40 years. This is the age at which we believe we can best accomplish our management objectives. We also believe that manipulations of quality are within the scope of the forest manager and that we will develop the intensive cultural practices needed to obtain our multiple-use goals.

Even-aged management will be practiced, with intermediate cuts at 10 -year intervals for internal maintenance when needed and harvest cutting at the rotation age. This technique will be applied to good sites first, then to medium sites, and possibly to poor sites if it is economically justified.

Thinning is a cultural tool that we plan to use in its traditional role as a growth regulator and developer of products. It will be applied in the life of a stand on good and medium sites as an improvement operation. Normally, a stocking level of 70 to 90 square feet of basal area per acre will be maintained. The cutting operation will be a conservative one and will remove 5 to 10 cords in the first thinning. The aim is to leave those trees which are vigorous and dominant and which have the best chance for quality growth.

Regeneration is not a problem with Choctawhatchee sand pine. Trees are relatively fruitful at an early age, and usually they have a good cone crop at 4- to 6-year intervals and light crops in intervening years. Cones reach mature size by late summer, and seed dispersal takes place in late October.

At the rotation's end, natural stands of sand pine can be regenerated successfully by either the clearcut or shelterwood method. Both techniques are used at Eglin, but we prefer the shelterwood system.

Our future logging units will be about 50 acres in size at harvest time. The final cut under the shelterwood system will be made as soon as regeneration is adequate . There are some risks with this system, such as an influx of Ips beetles after a cutting, Fomes annosus root rot, and damage to young seedlings. However, it must be remembered that, over large areas in any type of regeneration, complete stocking seldom occurs. As a rule, a young, understocked stand becomes relatively more fully stocked with age. On the other hand, an abnormally dense stand is likely to decline in stocking as it grows older.

One other aspect of management that is available to us as a cultural tool is prescribed burning. We have successfully applied this technique for a number of years in our sand pine areas, but it has been for purposes other than fore s t management. Sand pine stands are burned in the same manner in which we burn the other pine species. However, there are some minor differences in the results. For one thing, not much fuel accumulates under sand pines; consequently, the fire is not as hot and the scorch line usually is not as apparent.

Over the past 10 years, we have repeatedly burned several young stands of sand pine under "normal" burning conditions. Usually, there have been winter burns which were applied several days after a rain. The result of our burning of sand pine is almost the same as it is with the burning of longleaf and slash pines: it is an effective tool in pruning the lower limbs, and it provides a cleaner ground area for cultural operations.

CONCLUSIONS

What are some of the conclusions to be drawn from this discussion on managing natural stands of Choctawhatchee sand pine? Perhaps one of the most significant is that Choctawhatchee sand pine has several natural characteristics that will allow us to manage it for small-diameter timber products other than pulpwood. As to the market value, I believe our future trees will have a considerably greater earning capacity than the average tree managed to date.

Intensive management of sand pine is just beginning, and markets are developing around this new emphasis on the species. Because of these two bright prospects, I am convinced that sand pine will benefit from the favorable opportunities that the future will present..

Another conclusion that can be drawn is that we should "make the moot of what we have." Even at this moment, we possess the necessary tools that will successfully develop natural stands of Choctawhatchee sand pine: our "standard forestry practices." All that we need to do is patiently apply them to this minor species that we have underrated and bypassed for so many years. If this application is made, then Choctawhatchee sand pine will find its place among the other southern pines in meeting the anticipated demands of the future.

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MANAGEMENT OF NATURAL STANDS OF OCALA SAND PINE

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Abstract. --After World War II, tremendous acreages of Ocala sand pine reverted to scrub vegetation as a result of the exclusion of fire, natural deterioration of old stands, clearcutting, and the lack of natural and artificial regeneration. Recent research plus on-the-ground practices' of the Forest Service show that direct seeding on adequately prepared sites is the best method of reconverting scrub vegetation or cutover areas to Ocala sand pine. Planting has not proved satisfactory. The Seminole Seeder, developed on the Ocala National Forest, allows direct seeding at the time of site preparation and also covers the seeds with soil, thereby improving chances of germination. Once established, little management other than fire protection is practiced.

Ocala sand pine (*Pinus clausa* var. *clausa* Ward), also known as "scrub pine" or "spruce pine," is limited in range to peninsular Florida. Prior to World War II, there was little commercial interest in sand pine forests (or the "Big Scrub," as it was known to the early settlers in central

Florida). It was only after the war that the first extensive cutting of Ocala sand pine for pulpwood took place. Because of the difficulties of regeneration, many cutover, fire-killed, or age-deteriorated stands were left to revert to scrub oaks and other species.

This paper presents information on establishing, growing, and managing the Ocala variety of sand pine under the standard practices of timber management used by the USDA Forest Service on the Ocala National Forest. It is a collection of published knowledge on the subject supplemented by current research and practices used in managing Ocala sand pine.

DISTRIBUTION AND ASSOCIATION

The range of Ocala sand pine is confined to about 32 counties in central Florida. The heaviest concentration is on the Ocala National Forest (more than 200,000 acres) in Lake, -Marion, and Putnam Counties. It is also found in a narrow strip along the east coast from St. John's County south into Palm Beach and Broward Counties.' On the west coast of the peninsula, it is limited to Hernando and Lee Counties.

Ocala sand pine is also found in longleaf-scrub oak forest types and is rarely associated with other forest types. Associated or understory plants include sand live oak (Quercus virginiana var. maritima (Michx.) Sarg.), myrtle oak (Quercus myrtifolia Willd.), turkey oak (Quercus laevis Walt.), live oak (Quercus virginiana Mill.), sandheath (Ceratiola ericoides Michx.), saw-palmetto (Serenoa repens (Bartr.) Small), and etonia palmetto (Sabal etonia Swingle).

REQUIREMENTS FOR OCALA SAND PINE

Ocala sand pine grows in an area of rolling sandhills varying in elevation from less than 40 feet to about 200 feet above sea level. Numerous lakes and sinkholes are found throughout its range. Astatula and Paola are the major soils supporting Ocala sand pine on the Ocala National Forest (1). These are dry, infertile, acidic soils derived from deep deposits of marine sand and clay. Ocala sand pine sites change rapidly in central Florida because of changes in soil types or moisture conditions. In many instances, roads along type lines separate sand pine from other species.

NATURAL REGENERATION

Factors directly affecting natural regeneration of Ocala sand pine after seedfall include time of year, temperature of the soil surface, soil moisture, and predator populations. Records show that the period between

October and January is most conducive to natural establishment of seedlings (3). Temperature of the soil surface at other times of the year can prohibit satisfactory establishment of Ocala sand pine, especially when it exceeds 130° F. Soil moisture must be in adequate supply for both germination of seeds and establishment of seedlings.

The principal predators of seeds of Ocala sand pine include many species of birds, the Florida deer mouse (Peromyscus floridanus), the old-field mouse (Peromyscus polinotus), and the Florida harvester ant (Pogonomyrmex badius Latreille). Any of these factors can contribute to erratic germination of seeds and poor survival of seedlings.

Before the days of cutting and fire protection, unmanaged forests of Ocala sand pine regenerated naturally as a result of fire. Wildfires moved through large acreages, burning and destroying the forest. But it was only through this means that the serotinous cones of Ocala sand pine would open and release their seed on a fresh seedbed. Cooper et al. (3) reported collecting samples comprised of more than 1,000,000 seed per acre in dense stands and about 420, 000 seed per acre in open stands 3 weeks after a fire. Forty percent of these seed were viable, and early examinations showed high seedling counts per acre. Dense, even-aged forests resulted when weather and site conditions allowed germination and establishment of seedlings.

Some natural regeneration also occurs after clearcutting operations, Forest Service personnel on the Lake George Ranger District of the Ocala National Forest have reported satisfactory regeneration after cutting a dense stand. This regeneration probably occurred when sunlight opened the cones on downed tops and the seeds reached mineral soil. Such cases are the exception rather than the rule. Adequate distribution of seeds from tops is not predictable. The result is often poorly regenerated stands. A large portion of the seeds are also consumed by predators, who have unrestricted access to them as they are released.

Harrington and Riebold (4) reported that the shelterwood method holds promise as a means of natural regeneration on the Ocala National Forest. Their study indicated that seedling counts were significantly higher with this method than with clearcutting but were still less than acceptable minimum stocking (280 seedlings per acre on National Forest lands). The shelterwood method permits sunlight to open cones on logging slash, while the remaining trees provide sufficient shade to protect newly germinated seedlings.

ARTIFICIAL REGENERATION

During the years following World War II, about 30,000 acres of land on the Ocala National Forest reverted to scrub vegetation as a result of extensive cutting, a high incidence of wildfires, deterioration of old stands , and a lack of natural regeneration. This area needed conversion to sand pine by artificial means.

In the sand pine types of central Florida, some form of site preparation or scarification is a prerequisite to artificial regeneration. Site preparation, whether by disking, chopping with brush cutters, or prescribed fire, helps to eliminate or reduce the brush or logging slash and exposes mineral soil needed for a satisfactory seedbed or planting area. Disking is an effective means of site preparation when brush or logging debris does not prohibit the blades from reaching and effectively disturbing the soil. Prescribed fire has also been used successfully to reduce or eliminate surface cover and prepare seedbeds. Predicting suitable conditions for burning is not always possible, and many backfires change into hot head fires with unpredicted and sudden changes in windspeed and direction. Prescribed burning involves a risk not present with other methods of site preparation.

In the Ocala sand pine forest, chopping with brush cutters is probably the best and most widely used means of obtaining both good brush reduction and exposed mineral soil. All brush and logging debris, as well as unwanted residual vegetation up to 4 inches in diameter, can be incorporated into the soil with the se machines. The large-diameter material is not easily chopped or broken, but single or scattered individuals can be pushed down with the heavier tractors and later burned. Depending upon the amount and size of the material, a second or double chop may be necessary in order to obtain adequate site preparation. If sufficient cured vegetation remains after chopping, the sites can be burned to further eliminate surface litter. It is presently the policy of the Forest Service on the Ocala National Forest to specify Marden® brush cutters (11 -ton, B-7 model) because this cutter gives better cutting and rough reduction plus adequate soil disturbance.

Most early attempts at planting Ocala sand pine resulted in failure. Sand pine seedlings are apparently extremely sensitive to shock from transplanting. Root disturbance also has resulted in the death of otherwise healthy, mature trees (3).

Direct seeding at a rate of 0.5 to 1 pound of seed per acre after some form of site preparation has been the most practical and successful means of regenerating Ocala sand pine to date. Direct seeding usually is done during the 4-month period from October to January in order to ensure satisfactory establishment of seedlings.

On the Ocala National Forest, many methods of direct seeding sand pine have been used--with varying degrees of success. Tractor seeding, aerial seeding, and some hand seeding have been done. Up to the present time, most regeneration has been obtained by chopping, burning, and aerial seeding.

Many problems became important and had to be solved with the available methods of artificial regeneration. Among the problems encountered were increasing pressure from the public sector regarding cutting and regeneration on the Ocala National Forest, the apparent high number of failures in aerial seeding, the elimination of endrin-treated seed on National Forest lands, concern for wildfires and smoke pollution by neighboring landowners during site-preparation burns and increasing costs as a result of recent changes in the size and shape of regeneration areas.

To solve these problems and to ease some of the public's concern, a seeder was needed that could be used for direct seeding of Ocala sand pine at the time of mechanical site preparation. Such a seeder would eliminate the separate operations of burning and aerial seeding and would also incorporate the seeds into mineral soil. Hodges and Scheer (5) found that sand pine seeds covered with a thin layer of soil (0. 25 to 0.75 inch) germinated better than those lying on the surface. Because endrin-treated seeds could no longer be used on National Forest lands, a soil cover to reduce predator losses became even more important.

The Seminole Seeder (fig. 1), developed on the Ocala National Forest, has proven satisfactory and makes it possible to combine site preparation, seeding, and covering of seeds into a single operation. This seeder is a durable, self-contained, gas -powered machine that can be mounted on almost any type of ground carrier (crawler or wheeled tractor). With the Seminole Seeder, it is possible to reduce the regeneration of Ocala sand pine from a 6- to 8-month operation to a single operation combining site preparation **and** seeding. In heavy brush, seeding is combined with the required second chop.

Four areas seeded with the Seminole Seeder at the rate of 1 pound of seed per acre gave satisfactory results on three of four areas (between 480 and 670 seedlings per acre with 280 per acre necessary for success). Areas seeded from the air under similar conditions were below the minimum requirements for stocking. In future years, this seeder will play an important part in artificial regeneration of sand pine on the Ocala National Forest.

RECOMMENDATIONS FOR ARTIFICIAL REGENERATION

Although satisfactory artificial regeneration of Ocala sand pine is pos sible, it presents unique and complex problems. Following are some recommendations to improve chances of a successful first-year seed catch:

1. Do not skimp on site preparation. Apply a second chop when it is required. Areas of heavy brush, even when chopped once and burned, can still have a thick layer of surface or organic litter, quick-sprouting scrub species, and unburned spots that prevent seeds from reaching'mineral soil and becoming established.

2. Do not mechanically prepare and burn too far in advance of seeding if seeding at the time of site preparation is not anticipated. Fresh site preparation provides less chance for a sand crust to form or for excessive sprouting of scrub species. The crust and hardwood sprouts make it difficult for germinating seeds to become established.

3. Seed Ocala sand pine during October and November. Seeding in the fall allows extra time for seedling establishment and cuts losses during the following spring and summer months.

4. Direct seeding should be done at the rate of 0. 5 to 1 pound of seed per acre. The 1 -pound rate is particularly important when effective controls of predators are not available or cannot be used or when no covering of seeds is planned. If treated seeds can be safely used to cut losses from predators or if covering of seeds is planned, the 0.5-pound rate should be sufficient.

5. Whenever possible, cover the seeds after seeding or, better yet, seed and cover in a single operation. A farm tractor equipped with a drag will cover the seeds and thereby reduce seed losses to predators while improving chances of a successful catch.

6. Seek means of combining site preparation, seeding, and covering of seeds in one operation. Seeding in front of a Marden® brush cutter has proven successful on the Seminole Ranger District.

PROTECTION

Once established, Ocala sand pine is capable of surviving high temperatures, periods of drought, insects, and disease. Cooper (2) reports that gall rust (*Cronartium quercuum* (Berk.) Miy.) is common but not serious. However, he reports that red heart (*Fomes pini* (Thore) Lloyd) is frequently present in older trees. The black turpentine beetle (*Dendroctonus terebrans* Oliv.), southern pine beetle (*Dendroctonus frontalis* Zimm.), and Ips engraver beetles (*Ips* spp.) kill sand, pine, particularly those injured or weakened by fire.

Fire is the most serious enemy of Ocala sand pine, even though this species probably owes its very existence to fire. Ocala sand pines are easily killed by fire. The settlers' cry of "Fire in the Scrub" usually meant thousands of burned acres. Wildfires in stands of Ocala sand pine are difficult to control. Crown fires can race uncontrolled for miles, killing trees and cone-stored seeds alike.

GROWTH AND YIELD

Cooper (2) reports that root growth and development is rapid (up to 2 inches in 10 days) if the radicles can survive extreme temperatures and soil moistures. Later growth usually occurs in two spurts each year. Height growth varies considerably, but it has been reported to be as much as 24 inches annually. A 3 -year-old seedling will average about 3 feet in height. Ocala sand pine exhibits remarkable tolerance to competition and shade immediately after establishment. Little dominance is expressed in its usual growth patterns (6, pp. 447 -450).

On the best sites (index 70), mature sand pines should average 16 to 18 inches 'in diameter and 70 feet in height (6, pp. 447-450). On average sites (index 60), average diameter at maturity should be 12 to 13 inches and height should be 60 feet. On the poorer sites (index 50), mature trees should average 8 to 10 inches in diameter and 50 feet in height. Pulpwood yields vary from 8 to 20 cords per acre, depending on site index and age when cut. Quality yields tend to fall off with age because of red heart.

MANAGEMENT AND MARKETING

From sapling stage to maturity, little actual management other than fire protection is practiced on Ocala sand pine. At present, Forest Service practices do not include precommercial thinnings, intermediate cuttings, or fertilization. In time, research may tell whether these or other practices are necessary and economical in the sand pine types.

Because of its poor form and appearance, Ocala sand pine is used almost totally for pulpwood. From age 4 to 10, most of these trees have an excellent conical shape, making them good prospects for Christmas trees in and around central Florida. At present, a relatively small number are sold each year by the Forest Service for this purpose. Although the production of Christmas trees is not a part of our management practice, it should not be overlooked by either the National Forest or private land managers.

The actual input, of Ocala sand pine into Florida's wood-using industry is small (less than 5 percent of total consumption), but it is especially important in times of prolonged rains (7). Most of the sales made on the Ocala National Forest are area-estimate sales in which pulpwood volumes are determined on an acreage basis. All merchantable material is then offered on a lump-sum basis to prospective buyers. Under normal sale conditions, no marking is practiced. Prices for pulpwood of Ocala sand pine currently run between $8 and $10 per cord. Most sales, especially those of sizable volume, are readily purchased.

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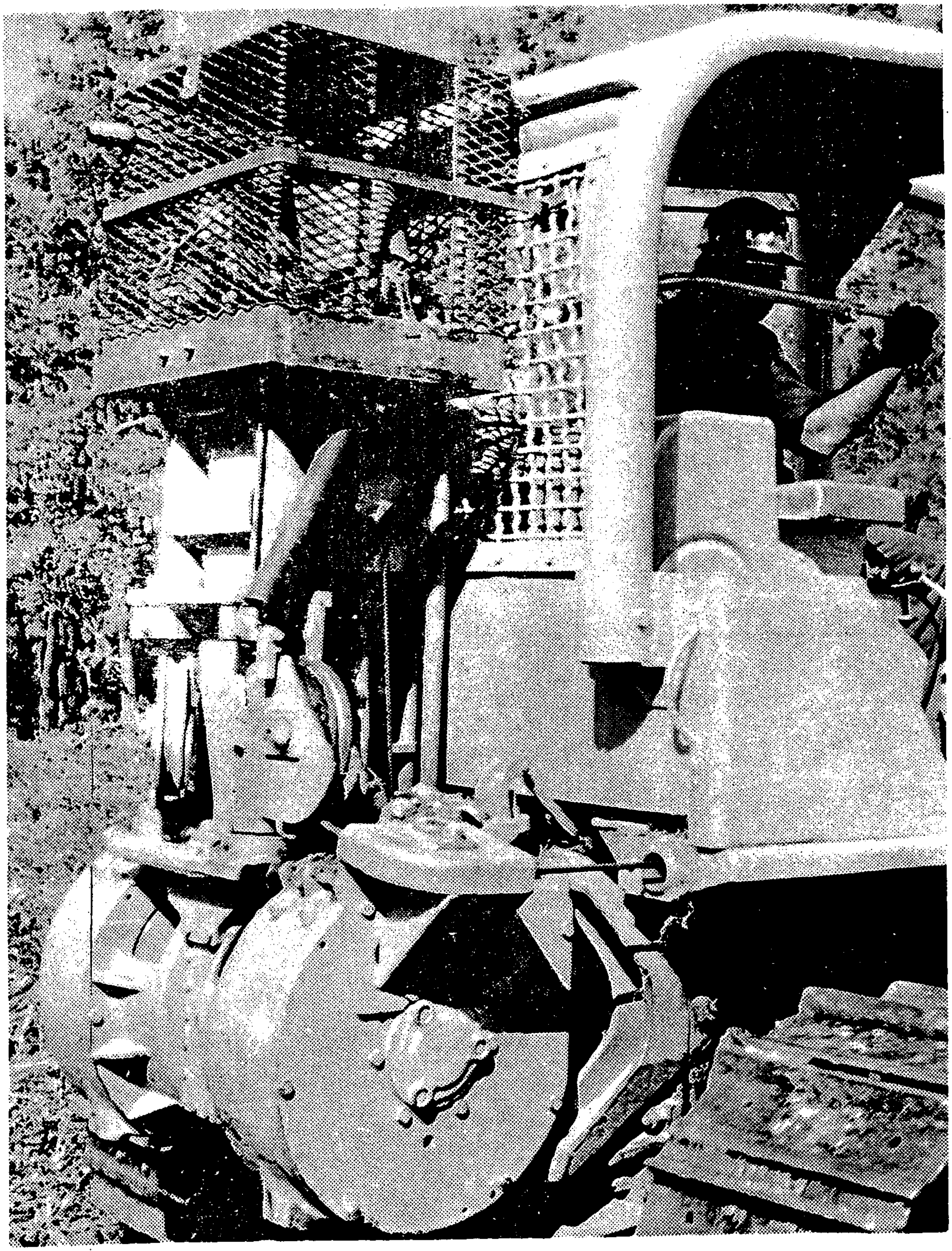

Figure 1. --The Seminole Seeder.

MANAGEMENT OF SAND PINE PLANTATIONS

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Abstract. --Information on site preparation, planting density, thinning, length of rotation, estimated plantation yields, and regeneration is provided for land managers interested in converting sandhill land from scrub hardwoods to sand pine.

INTRODUCTION

The four questions most frequently asked by land managers interested in converting sandhill land from scrub hardwoods to sand pine (*Pinus clausa* (Chapm.) Vasey) are:

A. How should the site be prepared?
B. How many pines should be planted per acre ?
C. Should the plantation be thinned? If so, when and how often?
D. How much volume will a sand pine plantation produce in one rotation ?

The answers to these and related questions form the basis of this paper. These answers are founded on the limited amount of data presently available from sand pine plantations , on best estimates of projected performance, and on the author's 10 years of experience in working with sand pine.

The productive potential of the site and objectives of the land manager are of paramount importance in providing appropriate answers. Sandhill soils are droughty and infertile; the growing season is relatively long, hot, and wet. Under these circumstances, there is little that can be done to alter the site's productive potential economically. Site potential is comparatively low and limits the number of practical alternatives to pulpwood production on a short- to medium-length rotation.

SITE PREPARATION

Previous papers in this symposium have shown that sand pines will survive and grow well when planted among scrub hardwoods but that they grow faster when released from competition or when they are planted on a prepared site. However, the growth stimulus provided by complete and intensive site preparation may not warrant the added expense, especially in the face of increasing costs for machinery, supplies, labor, and money. Integrated management for pulpwood and Christmas trees, as suggested by remarks in a previous paper, may offer an opportunity to offset rising costs. It may also pose additional problems of management and marketing. Therefore, until its practicability has'been tested, management for both pulpwood and Christmas trees cannot be recommended.

The ability of sand pine to survive and grow well with only minimal site preparation is important economically, but the species is also useful in preserving the natural appearance and wildlife potential of woodlands. The previous paper on site preparation showed that sand pines are well-suited for planting on narrow strips prepared in roughs composed of scrub hardwoods and wiregrass. By varying the width of undisturbed rough and by causing prepared strips to meander so as to avoid straight rows, conversion to sand pine can be esthetically acceptable, economically feasible, and can aid in improving the wildlife habitat. The width of prepared strips and undisturbed rough may be varied to meet specific objectives, but, for optimum juvenile growth, prepared strips should be at, least 2 to 4 feet wide. Alternatives include wide, prepared strips planted with several rows of seedlings separated by an undisturbed rough wide enough to provide food and access for game and also to avoid the appearance of a monoculture.

DENSITY AND SPACING OF TREES

The carrying capacity of the site limits the maximum number of sand pine seedlings that should be planted. With normal rainfall, a' prepared acre in the sandhills might be expected to carry about 1,550 trees through age 8; 800 through age 15; 600 through age 20; and 350 to 450 through age 35 without stagnating . This means that if first-year survival of 85 percent and subsequent mortality of about 5 percent can be anticipated, a planting of 500 to 550 seedlings of Choctawhatchee sand pine (P. clausa var. immuginata

Ward) per acre will produce 400 to 450 trees at plantation age 30. If a thinning is planned, about 725 to 775 seedlings per acre can be planted. By age 20 the plantation should contain 600 to 650 trees. Thinning to remove every third row or every third row plus suppressed and diseased trees in the remaining rows will leave about 350 to 425 trees for a later harvest. Similar results can be obtained with Ocala sand pine (P. clausa var. clausa Ward), but more seedlings will have to be planted to compensate for the higher rate of mortality typical with this variety.

The spatial arrangement of seedlings on the acre depends on the number to be planted, degree or method of site preparation, and method of harvest. Row-thinning by machine, for example, requires rows spaced at least 8 or 10 feet apart to avoid seriously damaging residual trees.

On unprepared or completely prepared land, any spacing between trees and rows that results in uniform distribution and provides for the possibility of machine-thinning may be used. If no thinning is planned, 500 to 550 seedlings can be planted per acre; each will have 78 to 88 square feet of growing space. At present there does not appear to be any special advantage associated with square spacing; consequently, spacings of 8 by 10 feet, 8 by 11 feet, or 9 by 9 feet can be used to equal advantage. Extreme rectangularity, e. g., 4 by 22 feet, should be avoided, however, because trees spaced closely within rows become crowded and seldom fully occupy the wide expanse between rows. If a single thinning is planned, planting density can be increased to 725 to 775 seedlings per acre. Spacings of 6 by 10 feet or 7 by 8 feet, with rows no closer than 8 feet, should result in a stand of 600 to 650 trees spaced to accommodate row-thinning with machines at age 20.

A somewhat different situation exists when prepared strips are planted. Individual strips may be wide enough to accommodate several rows of seedlings or so narrow that only a single row can be planted. In either instance, rows --and seedlings within rows --should be spaced within the prepared strip so as to most fully utilize potential growing space in both the prepared land and the adjacent, unprepared rough.

THINNING

Several factors affect the decision as to whether sufficient trees should be planted for a planned thinning. If pulpwood is the objective, more usable cellulose can usually be produced by allowing for anticipated mortality and planting as many trees as the site will effectively support throughout a rotation. In the sandhills, this may mean planting 500 to 550 trees per acre and carrying 350 to 400 for 30 years or more. But measurements of existing, relatively high-density plantations suggest that sandhill sites will support. as many as 600 sand pines per acre through age 20 without excessive crowding. A row thinning to remove one-third or more trees per acre might be made at this time, leaving 350 to 400 for a harvest cut. At this level of stocking, it appears unlikely that more than one thinning would be feasible.

The question remains as to whether total production from the 600-tree stand thinned at age 20 to 400 trees and harvested at about age 30 will sufficiently exceed that of an unthinned, 400-tree stand harvested at the same age so that the added expense for seedlings, planting, marking, and thinning plus accrued interest on the outlay will be justified. In the comparison that follows, data from figures 1 and 2 were used to predict tree size; the equation for merchantable height was developed from a 28-year-old plantation of Choctawhatchee sand pine as reported by Burn6 and Brendemuehl (2): Merchantable height = -47.26138 t 16.85121 d.b.h. - 0.80507 d.b.h.^{2}; and cubic volume to a 4-inch top (outside bark) was computed from table 49 of the "Forestry Handbook" (3) on the basis of the following equation.. Volume in cubic feet = 0.2618 $L\left(\frac{D^2 + d^2 + dD}{144}\right)$, where L = length, D = diameter (outside bark) at large end, and d = diameter (outside bark) at merchantable top.

Site differences do exist even in the seemingly uniform sandhills. Because so few sand pine plantations are of sufficient size to establish indices of site quality, however, differences in site quality cannot be accounted for at this time. 'For this reason, and because at age 20 sand pines are at the threshold of merchantability, too much credence should not be placed in the accuracy of estimated yields in the following discussion. Volume estimates are presented primarily for comparative purposes.

At age 20 the 600-tree stand will average 5.6 inches d. b. h. and 43 feet in height. These trees will contain 21.5 feet of merchantable length to a 4-inch top and 2.66 cubic feet of wood. Probably the cheapest method of thinning a plantation is by rows, because rows need no marking. Theoretically, this method removes a representative number of trees of all sizes; therefore, both the 200 trees removed and the 400 remaining will contain an average of 2.66 cubic feet of wood. The thinning will yield about 535 cubic feet of wood per acre, and the 400 residual trees will contain about 1, 065 cubic feet. In contrast, the 400 trees in the unthinned stand will average 5.8 inches d. b. h. , 23.7 feet of merchantable length, and contain 3.07 cubic feet of wood (about 1,230 cubic feet per acre). Although it seems unlikely that residual trees in the thinned stand will make an immediate response to release, it is assumed that the 400 trees in the unthinned and the residual stands grow at the same rate for the next 10 years.

When harvested at age 30, the 400 residual trees will average 6.7 inches d. b. h. , 28.3 feet of merchantable length, and 4.43 cubic feet of wood. The stand will have produced 535 cubic feet from the thinning and 1,770 cubic feet at harvest, for a total of 2, 305 cubic feet. The 400 unthinned trees will average 6.9 inches d. b. h., 30.5 feet of merchantable length, and 4.97 cubic feet of wood. The stand will have produced 1,990 cubic feet of wood or about 315 cubic feet less volume than the thinned stand. The land manager must decide whether differences in returns justify the additional expense associated with the thinned stand.

Unforeseen events may dictate that a harvest before age 30 is necessary. In this event, the manager may anticipate a return of about 1,600 cubic feet from the 600-tree stand and about 1,230 cubic feet from the 400-tree stand at age 20. The difference in yields from the 400- and 600-tree stands remains essentially the same, i.e., 315 cubic feet at age 30 and 370 cubic feet at age 20.

Bennett (1) has discussed other factors to be weighed before deciding if thinning is practical in slash pine plantations. His remarks seem equally pertinent for the production of sand pine pulpwood on low-quality sites over a 25- to 40-year rotation. He concludes (1, p. 14) that, ". . . in plantation management oriented around products, product objective should determine initial spacing; and, in rotations of short to medium length, thinning should play a secondary role, mostly as a sanitation and salvage measure, and not be viewed as essentially a growth regulator or product developer."

Length of Rotation

There is no apparent advantage to borrowing money at 6 percent and investing it at 6 percent, or less. The same principle should hold true for managing a pine plantation. When a plantation no longer produces wood at a rate sufficient to show a profit above that needed to offset establishment costs and the interest charged against that investment, it should be harvested. Economically, this is the rotation age.

From the standpoint of volume growth, length of pulpwood rotation should coincide with, or slightly precede, the age at which curves depicting current annual increment (CAI) and mean annual increment (MAI) intersect. Our sand pine plantations are too young to yield these data. However, with slash pine (1), loblolly pine (4), and presumably other southern pines including sand pine, comparable patterns of CAI and MAI exist. The curves intersect later for poor sites than for high-quality sites and, for any given site quality, later for densely stocked stands than for lightly stocked stands. The quality of sandhill sites is poor. Available data indicate that the optimum stocking level on most sandhill sites is about 400 sand pine per acre. If so, then the coincidence of CAI and MAI curves for sand pine will occur at about plantation age 35. However, because the two curves presumably intersect at a slight angle, harvesting could conceivably be done as early as plantation age 30 with no meaningful sacrifice in volume. From both an economic and a technical standpoint, it presently appears that a rotation of about 30 to 35 years will be most practical for the management of sand pine plantations.

YIELDS AT PLANTATION AGE

Existing plantations are too young and too limited in number and diversity of site to permit accurate estimates of merchantable volume for sand pine. Only one plantation of Choctawhatchee sand pine is of sufficient size to provide useful information. On an unprepared site, 354 trees per acre produced approximately 3, 125 cubic feet of merchantable pulpwood at age 35 (2). Data extrapolated from this plantation and mediated somewhat by measurements from younger plantations on prepared sites are presented in table 1. They represent a reconstruction and projection of average tree size and merchantable volume at several ages and densities of stocking.

REGENERATION

Some natural regeneration will undoubtedly occur. Serotinous cones of Ocala sand pine open when heat reflected from the sand is trapped in the logging slash. An understory of Choctawhatchee sand pine will probably exist before harvest in light- and medium-stocked stands. If the harvest is timed to take advantage of the current seed crop of Choctawhatchee sand pine, additional seedlings will result. If, within 1 year of harvest, natural seedlings are distributed over the area in manageable numbers, nothing further need be done. Seldom does this occur to the satisfaction of the land manager, however .

In naturally regenerated stands, as in direct-seeded stands, uneven distribution and extremes of stocking are the rule rather than the exception. Too many pine seedlings can be as troublesome as too few. Rarely does interplanting to bolster stocking and rectify patchy distribution or noncommercial thinning to prevent stagnation of an overly stocked stand give satisfactory results.

Planting 1-0 seedlings during the dormant season is currently the most reliable method of insuring desired stocking levels and uniform distribution. Choctawhatchee sand pine is the recommended variety to plant. First-year survival usually averages 10 to 40 percent higher than that of Ocala. sand pine, and, with Choctawhatchee sand pine, there is less likelihood of subsequent mortality from mushroom root rot (Clitocybe tabescens *(Fr.)* Bres.). Early survival of both varieties can be improved by planting dormant seedlings deep in the sand. To do so,, nursery stock must be obtained in January or February and' planted so that the lowest whorl of green needles is covered with soil. One additional advantage to planting for the second rotation is the future availability of superior seedlings of sand pine. Some seed orchards of sand pine may be in full production in about 10 to 15 years.

Disease, insects, natural pine reproduction, existing and sprouting hardwoods, and slash from the previous harvest may pose problems. The

Table 1. --Estimates of merchantable size and volume per acre at various ages and densities as projected from measurements of a 35-year-old plantation of Choctawhatchee sand pine and supplementary data

Trees per acre (number)	At plantation age-- 20 years D. b. h.[a/]	Height[b/]	Vol./acre[c/]	25 years D. b. h.[a/]	Height[b/]	Vol./acre[c/]	30 years D. b. h.[a/]	Height[b/]	Vol./acre[c/]	35 years D. b. h.[a/]	Height[b/]	Vol./acre[c/]
	In.	Ft.	Cu. ft.		Ft.	Cu. ft.	In.	Ft.	Cu. ft.		Ft.	Cu. ft.
300	6.2	25.5	1.075	6.8	30.7	1,475	7.3	34.1	1,825	7.8	36.5	2.100
350	6.1	24.9	1,200	6.8	30.2	1,675	7.3	33.6	2,050	7.7	36.1	2,400
400	6.0	24.1	1.325	6.7	29.5	1,850	7.2	33.2	2,300	7.6	35.7	2,675
450	6.0	23.5	1.425	6.6	29.0	2.000	7.1	32.7	2.500	7.6	35.3	2.950
500	5.9	22.7	1.500	--	--	--	--	--	--	--	--	--
550	5.8	22.0	1,575	--	--	--	--	--	--	--	--	--
600	5.7	21.2	1,625	--	--	--	--	--	--	--	--	--

a/ D.b.h. (in.) = -1.8093 + 6.4956 ($\log_{10}$ age) - 0.0015 (No. trees/acre). $R^2 = 0.87$.

b/ Merchantable height (ft.) = -109.4261 + 38.0947 (d. b. h.) - 3.2026 (d. b. $h.^2$) + 0.0922 (d. b. $h.^3$). $R^2 = 0.70$.

c/ Merchantable volume to a 4-inch top outside bark (rounded to nearest 25 cu. ft.)

= 0.2618 (merchantable height - .05 ft.) $\left(\frac{d.b.h.^2 + 4^2 + 4\ d.b.h.}{144}\right)$ (No. trees/acre).

probability of infecting the new plantation with root rot caused by *Fomes annosus* (Fr.) Karst.) can be lessened by treating freshly cut stumps with granular borax. Damage from reproduction weevils can be avoided by waiting one growing season before planting. Problems with natural reproduction, scrub hardwoods, and slash disposal may be remedied with a light- or medium-weight chopper, depending upon local conditions. Prescribed burning cannot be recommended because, in addition to other adverse environmental effects, fire destroys organic matter needed to maintain the productivity of infertile sandhill soils.

SUMMARY

Complete, intensive site preparation appears to be unnecessary for the successful establishment of sand pines in the sandhills. Site preparation in strips may serve as well and, in addition, promises to improve both the. wildlife habitat and the esthetics of the area. Low productivity of most sandhills limits stocking to about 600 trees per acre through age 20 and to 350 to 400 trees per acre through age 35.

Choctawhatchee is preferred over Ocala sand pine because of its greater resistance to mushroom root rot and its higher rate of survival. Planting 500 to 550 Choctawhatchee sand pine per acre should provide 350 to 425 trees for harvest at a pulpwood rotation estimated to be between 30 to 35 years. Planting density for sand pine should be aimed at maximum pulpwood production; thinning to achieve this end does not appear practical. Depending upon site quality, an unthinned stand of 400 sand pine might be expected to yield as much as 2, 975 cubic feet of merchantable pulpwood at plantation age 35.

Future technology and the availability of superior growing stock of sand pine obviate recommendations other than deep planting and the use of 1-O planting stock for regenerating harvested plantations for a second rotation.

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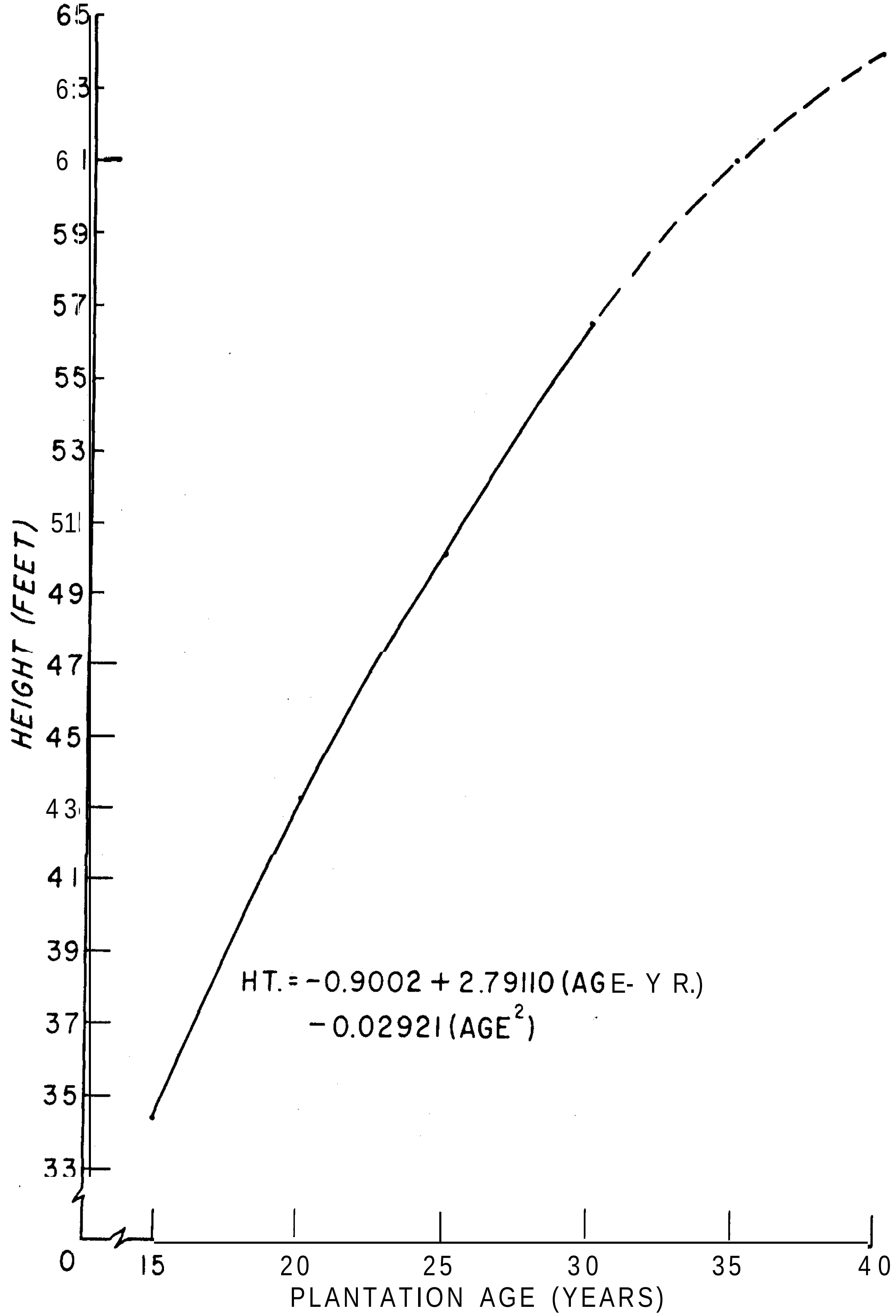

Figure 1.--Average tree height as projected from available data on Choctawhatchee sand pine.

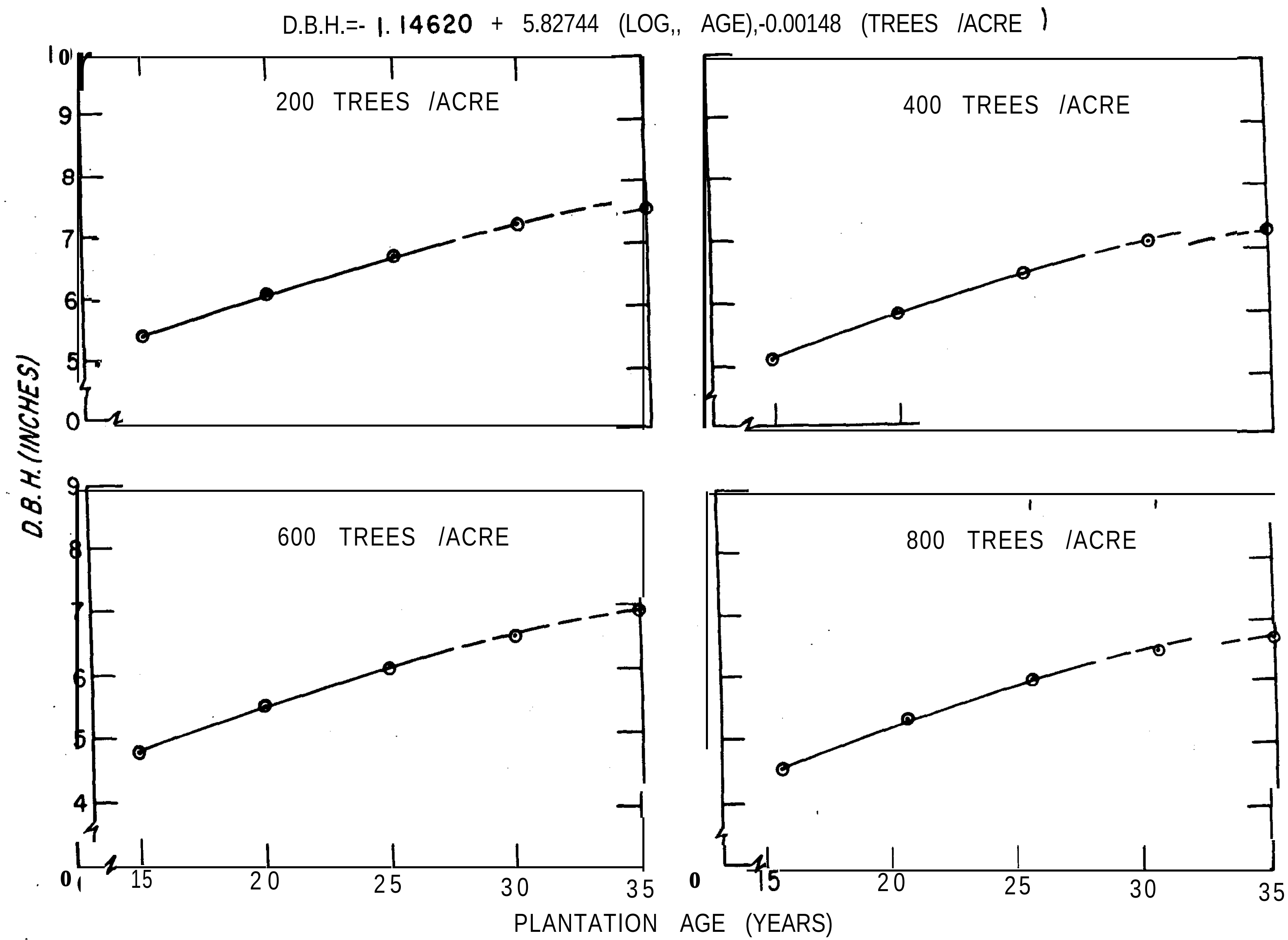

Figure 2. --Average d. b. h. of existing plantations of Choctawhatchee sand pine at various densities.

SOME RESPONSES OF SAND PINE TO FERTILIZATION

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Abstract. --Sand pine seedlings growing on a common sandhill soil, the Lakeland series, have been fertilized with N and P under greenhouse and field conditions. P has proven to be the major plant nutrient that is most deficient for tree growth on this type of soil. A marked growth response to added N fertilizers results after correction of the P deficiency. Foliar nutrient concentrations associated with the maximum growth produced in sand pine seedlings during these investigations are as follows: N = 1.4 percent, P = 0.16 percent, K = 0.6 percent, C = 0.6 percent,. and Mg = 0.04 percent.

Sand pine (*Pinus clausa* var. *clausa* and var. *immuginata* Ward) at first glance appears better suited to grow on a medium of sand and water than all the other southern pines. Soils common to its natural habitat are deep, excessively drained sands. These soils are extremely infertile and lack characteristics which favor moisture retention even for short periods of time. Soils which fit this description and support natural stands of sand pine include the Lakeland, Kershaw, Astatula, and Wicksburg series.

An examination of either natural stands or plantations of sand pine also lends support to the idea that the nutrient and moisture requirements of this species are extremely low. Understory vegetation is usually sparse or completely lacking. The sites do not appear to support much in addition to sand pine. Somewhat the same impression is given when one examines the scrub oak and wiregrass cover common to large areas of the sand ridges. Total plant production or total biomass of these scrub oak communities is much smaller than the total volume of plant material produced by a sand pine plantation.

If we compare the nutrient concentrations of sand pine needles with those of other southern pines, we find the former to be substantial (table 1).

Table 1. --Nutrient concentrations in needles of some southern pines

Species	Tree age	Nutrient concentration N	P	K	Ca	Physiographic region
	Yr.	- - - - - Percent	- - - - -			
Pinus clausa var. clausa Ward	7	1.28	0.10	0.30	0.41	Sandhills
P. clausa var. immuginata Ward	7	1.40	.11	.32	.37	Sandhills
P. elliottii Engelm.	7	.96	.08	.29	.34	Sandhills
P. palustris Mill.	15-20	1.02	.08	.52	.18	Sandhills
P. elliottii Gngelm.	10	.96	.09	.30	.21	Coastal Plain (5)[a] al
P. taeda L.	7-21	1.02	.10	.43	.29	Piedmont (2)[a]

[a] Numeral refers to literature citation.

In the sandhills, the native habitat of sand pine, the nitrogen (N) concentration of sand pine needles may be 20 to 25 percent greater than that of another sandhill native, longleaf pine (P. palustris Mill.). We find essentially the same relationships when comparing the phosphorus (P) concentrations in the needles of these two sandhill natives.

A comparison of the N and P concentrations in sand pine needles with those in slash pine needles produces much the same answer. Sand pine needles have a higher concentration of both N and P than do those of slash pine growing either in the sandhills or the Coastal Plain. Further examination of table 1 shows the N and P concentrations in loblolly pine needles to be greater than those in either slash or longleaf pine needles but lower than those in sand pine needles. The same relationships do not hold true for potassium (K) and calcium (Ca) concentrations in the needles of the pines listed in table 1, but the values for these elements in sand pine are comparable to those in the other species.

By now it should be readily apparent that sand pine does not thrive on just sand and water. It also requires N, P, K, and other elements essential for plant growth. Because it thrives where other species fail, sand pine must also be extremely efficient at extracting essential growth elements from the soil and at maintaining a desirable internal balance of nutrients and moisture. This capacity gives us the opportunity to modify the nutrient supply of sandhill soils, perhaps to the advantage of this pine species.

SEEDLING RESPONSES TO FERTILIZATION

Several greenhouse studies have been conducted by the Southeastern Station at Marianna to determine the effects of N, P, and K fertilizers on the growth of sand pine seedlings. Both the Ocala (OSP) and Choctawhatchee (CSP) varieties have been included in these studies. This discussion is limited primarily to the work concerned with CSP, but in genera! the results also apply to OSP seedlings.

The fertilizer treatments applied in these studies included N (as ammonium nitrate) at rates up to 240 pounds of N per acre, P (as monocalcium phosphate) at rates up to 350 pounds of P per acre, and K (as potassium chloride) at rates up to 150 pounds of K per acre. These fertilizer treatments were applied in factorial combinations, and the effects were tested statistically by appropriate analysis of variance procedures.

Soil used for greenhouse studies of this type was collected from the 0- to lo-inch portion of a Lakeland sand profile. The soil was collected from an undisturbed scrub oak stand on a sand ridge site in the Chipola' Experimental Forest in Calhoun County, Florida. This soil was analyzed by appropriate laboratory procedures . The results of these analyses are reported in table 2.

Table 2.--Summary of soil analyses of Lakeland sand at 0 to 10 inches

Sand	Silt	Clay	Organic matter	Total N	Ext. P	Ext. K	pH
-----------	-----------	Percent	-----------	-----------	-- P.p.m. --		
92.5	2.5	5.0	1.10	0.03	0.37	14.0	5.4

The usual procedure followed when establishing these greenhouse studies was to weigh out 26 pounds (air-dry basis) of this soil, mix the soil with an amount of fertilizer appropriate to the treatment assigned, and then place the mixture in a 2-gallon earthenware container. Test seedlings were established by planting an adequate number of run-of-the-woods seeds in each container of soil. The seedlings *were* thinned to a uniform stand, generally 10 per container, when satisfactorily established. Normally, the test seedlings were grown for about 10 months, the seeds were planted in early spring, and. the seedlings *were* harvested the following winter. Soil moisture was not a limiting factor *in* these studies.

CSP seedlings subjected to these fertilizer treatments responded significantly (0.01 level) to the treatments applied. Top weight, root weight, and total seedling weight *were* significantly affected by applications of N and P. A decided NP growth interaction (significant at the 0.01 level) resulted from the applied fertilizer treatments. Total plant response of the CSP seedlings to the N and P treatments applied is shown in figure 1. Total seedling weight decreased with each added increment of N but increased as the quantity of applied P increased. Growth increased markedly when N and P were applied in combination; this was the significant NP interaction referred to above .

Potassium fertilizer applied alone or in combination with N or P has not significantly (0.01 level) influenced the growth of sand pine seedlings in these greenhouse studies. On the basis of results such as these, we have concluded that P is the major plant nutrient that is most deficient in sandhill soils such as the Lakeland series. If we intend to fertilize these soils, the P deficiency must be corrected. When this deficiency is corrected, sand pine can also be expected to respond to applications of N fertilizer.

Needle samples including both primary and secondary needles were normally collected from the seedlings produced in the greenhouse studies and analyzed for their nutrient contents by appropriate laboratory procedures. The effect of N and P fertilization on the N concentration of seedling needles is shown in figure 2. From this figure, it is apparent that as the amount of N applied alone increased, the N content of the needles also increased. Foliar N decreased as the amount of P applied alone or in combination with N increased. This decrease in the N concentration is not actually a decrease in N uptake, but rather a dilution effect resulting from the marked growth response to the N and P applied.

Phosphorus fertilization affected the nutrient concentration of the seedling needles in the same manner as did N. That is, P accumulated in the needles as the amount of P applied as fertilizer increased and decreased as the amount of N applied as fertilizer increased (fig. 3). The minimum concentration of P in the needles occurred in those seedlings grown in soil to which the maximum amount of N alone had been applied. Concentrations of P intermediate between these extremes were produced by the maximum combined applications of the N and P fertilizers included in these tests; these fertilization rates also produced the greatest growth response.

Thus, it has been demonstrated that CSP seedlings respond to the fertilizer treatments and that these same fertilizer treatments influence the nutrient concentration of seedling needles. The question naturally follows: Is there a relationship between seedling growth and the nutrient content of plant parts --in'this case, the needles ? To provide an answer to this question, data on seedling growth and associated concentrations of foliar nutrients from a fertilization study with CSP seedlings were grouped into seedling weight classes, and class averages were computed. These data are illustrated graphically in figure 4.

An examination of this figure shows that foliar N decreased appreciably with increased growth, with the lowest N concentration occurring in the largest seedlings. Foliar P demonstrated a concentration pattern directly opposite to that for foliar N, that is, foliar P increased as seedling size increased. This trend in foliar P concentration lends support to the previous statement that P is the nutrient element in shortest supply in soils such as Lakeland sand and is limiting to plant growth. Foliar K followed a pattern of change much like that shown by N--but to a lesser degree. The Ca con-. centration of these seedling needles increased with increased growth, as did foliar P, while the Mg content of the seedling needles was essentially constant over the range of seedling weight classes.

Results such as these do not permit one to state that the concentrations of N, P, etc. reported for CSP seedling needles are either critical or optimum levels for seedling growth. This is true because, by'definition, the critical nutrient concentration of a plant is that concentration of a given nutrient which is just deficient for maximum growth of that particular plant (4). From figures 1 and 4, it is readily apparent that seedling growth is continuing to increase in response to the fertilizer treatments applied. A leveling off or maximum was not attained.

However, from the data on the nutrient status of the CSP seedlings in these studies, one can make statements which may serve as guidelines for judging the nutrient status either of nursery-grown CSP seedlings or of CSP plantations. Figure 1 shows a continued growth response up to the highest levels of N and P applied. If we assume size to be an indicator of plant nutrient status and maximum size to be an indicator of adequate nutrition, then from figure 4 approximate foliar values for this level of CSP seedling nutrition may be assigned as follows: N = 1.4 percent, P = 0. 16 percent, K = 0.6 percent, Ca = 0.6 percent, and Mg = 0.04 percent.

PLANTATION RESPONSES TO FERTILIZATION

Fertilization of sand pine plantations is still very much in the experimental stage. Test plots have been established in plantations of both the Ocala and Choctawhatchee varieties of sand pine. These plantations were established at several locations in the northwest Florida sandhills and are representative of varying sandhill conditions. The planting sites all supported a stand of scrub oak and wiregrass prior to the establishment of the plantations. Mechanical methods of site preparation were used to eliminate this scrub vegetation. In most instances, the method employed for control of scrub vegetation was double chopping with an 11 -ton, duplex brush cutter.

Seedlings for these studies were produced from run-of-the-woods seeds either by the Florida Division of Forestry or by the Southeastern Station at Marianna. Standard nursery practices such as those discussed by Sampson (3) were followed to produce these seedlings. Planting stock was 1-O when transplanted to the test sites.

Initial spacing within each test planting was about 3. 5 by 9 feet. During the third growing season after the establishment of a test, the plantation was thinned to a spacing of about 7 by 9 feet. This procedure was followed to establish uniform stand density among plots within a given teat. Achieving uniform stand density within CSP plantations is relatively simple because the survival of this variety of sand pine is normally high after transplanting. It is more difficult to obtain the same uniformity within OSP plantations because this variety is more difficult to transplant.

Commercial grades of ammonium nitrate, ordinary and concentrated superphosphate, and diammonium phosphate fertilizers were used in these field tests. All fertilizers were applied with conventional farm implements. This equipment functioned satisfactorily; however, when the fertilization of sand pine is attempted on an operational basis, distribution equipment suited to conditions in rough woods should be developed if it is not already available.

The fertilization trials already established with sand pine are intended to test the following:

A. Rates of fertilizer application, with major emphasis being given to N and P

B. Methods of applying P fertilizer; that is, surface applications in contrast to various methods of mixing P fertilizer with the soil or placing it in the root zone

C. Frequency of fertilizer application; that is, comparing a single, heavy application of fertilizer with the response produced by frequent, light applications of the same fertilizer.

The oldest of these fertilization tests are located on the Chipola Experimental Forest. Prior to establishment of these test plantations, the scrub oak vegetation was removed by double chopping with an 11 -ton, duplex brush cutter. Treatments that have been or will be applied to these plantations are listed in table 3.

Table 3. - -Fertilization rates and methods of application

Treatment No.	Treatment applied[a]
1	None
2[b] [c]	60 lb. of P/acre applied to soil surface in strips 2.5 feet wide, rows of trees planted on center of fertilized strips
3	60 lb. of P/acre applied to soil surface in strips 5 feet wide, rows of trees planted on center of fertilized strips
4	60 lb. of P/acre applied in strips 2. 5 feet wide and mixed with soil to depth of about 6 inches by disking, trees planted on center of fertilized and disked strips
5	60 lb. of P/acre applied to soil surface in strips 5 feet wide and mixed with soil to depth of about 6 inches by disking, trees planted on center of fertilized and disked strips
6	120 lb. of P/acre applied, trees planted as in 2
7	120 lb. of P/acre applied, trees planted as in 3
8	120 lb. of P/acre applied and mixed with soil, trees planted as in 4

Table 3.--Fertilization rates and methods of application (continued)

Treatment No.	Treatment applied[a]
9	120 lb. of P/acre applied and mixed with soil, tree8 planted as in 5
10	120 lb. of P/acre applied with a side -dressing, machine to each side of row of trees and about 4 inches below soil surface, P fertilizer applied a few days after trees were planted
11	120 lb. of P/acre applied in strips 2.5 feet wide on each ride of rows of trees at plantation age8 1 and 6 years, P fertilizer mixed with soil to depth of 3 inches by dishing
12	120 lb. of P/acre applied as in 11 at plantation age8 2 and 7 years
13	60 lb. of P and N/acre applied as in 11 at plantation ages 1, 2, 6, and 7 year8
14	40 lb. of P and N/acre applied as in 11 at plantation age8 1, 2, 3, 6, 7, and 8 years

a/ Fe rtilicer material8 applied: N a8 ammonium nitrate (0-33-O)) and P as superphosphate (0-20-O).

b/ For treatments 2 through 9, P fertilizer war applied a 'few days prior to planting.

c/ For treatment8 2 through 12, an amount of N equal to the amount of P specified for a given treatment was adminietered in a split application: one-half was applied 1 year after a P application and the balance was applied the following year.

Growth response8 to there treatment8 through plantation age 7 are given for OSP and CSP in table 4. Both varieties of sand pine have responded to the fertilizer treatment8 applied. In general, a8 the amount of ● pplbd fertilizer increared, growth increared but not necessarily in proportion to the increase in fertilizer application. OSP ha8 shown a greater response in height growth than ha8 CSP, especially to the higher rate8 of fertilization. Diameter growth of CSP in response to fertilization has increared more rapidly than that of OSP, with a resultant increase in total volume. Frequent, light applications of fertilizer have produced a greater growth response than a single, heavy application of the same materials. This type of response suggests a need for slow-release sources of N and P for sandhill fertilization.

Table 4.--OSP and CSP response to fertilization to age 7

Treatment No.[a]	OSP Avg. height	OSP Avg. d.b.h.	OSP Total vol. /acre[b]	CSP Avg. height	CSP Avg. d.b.h.	CSP Total vol. /acre[b]
	Ft.	In.	cu. ft.	Ft.	In.	cu. ft.
1	17.5	2.51	166	17.4	2.74	194
2	17.8	2.67	190	17.9	3.02	239
3	18.1	2.70	196	18.0	2.91	224
4	18.5	2.78	212	18.5	3.17	270
5	18.9	2.92	237	18.5	2.93	234
6	19.6	2.94	248	18.7	3.21	280
7	19.7	2.94	248	18.2	3.17	266
8	19.6	2.85	234	18.4	3.16	267
9	19.7	2.76	221	18.3	2.85	219
10	19.9	2.90	245	19.2	3.17	280
11	20.3	3.03	271	18.6	3.21	278
12	18.9	2.85	226	18.7	3.19	276
13	19.6	2.99	256	19.1	3.20	283
14	20.2	3.08	278	19.8	3.41	331

[a] See table 3 for rates and time of fertilizer application.

[b] Total volume based on 650 trees/acre.

Needle samples have been collected annually during January from a random sample of trees within each fertilization study. The needles collected have been analyzed by standard laboratory procedures to determine the concentration of N, P, etc. contained in the samples. This information is another measure of tree response to the fertilizer treatments applied and may serve as an indication of the nutrient status of these plantations.

A summary of the N and P concentrations in the needles of OSP and CSP at plantation age 7 is given in table 5. The treatment numbers in this table correspond to those given in table 3. An examination of this 'tab.18 shows an obvious varietal difference in the N and P concentrations in CSP and OSP needles. Both the N and P concentrations in CSP needles for all treatments applied were greater than those in OSP needles. A decided increase in the P concentrations in the needles of both varieties in response to treatments applied is evident. Of interest is the N concentration of the needles of both varieties for treatment 1, the unfertilized control. For all treatments, except treatment 7 for OSP, the N concentration of the needles of unfertilized trees was greater than that of trees that had been fertilized with both N and P. This is an example of the dilution effect noted earlier, that is, *a* decrease in the concentration of a given element per unit of weight as *a rcoult* of increased growth. These results also illustrate the dangers of assuming that a high foliar concentration of a given element, in this case N; means that the N supply is sufficient for good growth. Also of note is the fact that, as the P concentration of the needles increased in response to fertilization, the N concentration decreased. These responses to N and P fertilization are identical to the seedling responses to these-same fertilizers as discussed earlier.

Table 5. --Concentrations of N and P in needles of fertilized OSP and CSP at age 7

Treatment Nod	OSP N	OSP P	CSP N	CSP P
	Percent			
1	1.28	0.09	1.40	0.11
2	1.26	.10	1.37	.13
3	1.20	.11	1.34	.13
4	1.27	.12	1.36	.13
5	1.24	.12	1.35	.13
6	1.20	.12	1.37	.13
7	1.24	.12	1.'37	.14
8	1.29	.13	1.33	.14
9	1.18	.13	1.30	.14
10	1.21	.11	1.34	.12
11	1.24	.13	1.31	.14
12	1.19	.14	1.30	.14
1 3	1.19	.14	1.24	.14
14	1.21	.13	1.32	.14

a/See table 3 for rates and time of fertilizer application.

At this point we might ask if these trees are growing at optimum nutrient levels. Growth has increased as a result of fertilization. The P concentrations of the needles of these saplings have increased as a result of fertilization, but they are still lower than those values associated with maximum seedling growth as noted earlier in this paper. Mead and Pritchett (1) have pointed out that needles of older trees often contain lower concentrations of nutrients than needles of seedlings or young trees. This does not necessarily mean that lower nutrient concentrations in needles of large trees are optimum. It is quite possible that large trees are actually functioning at less than full capacity because the supply of available nutrients is inadequate to maintain optimum nutrient levels in the mass of needles found in such trees. Perhaps "optimum" nutrient levels are less dependent on tree age and more dependent on the supply of available nutrients.

An economic analysis of the fertilizer responses.discussed in this paper has not been made. Even though certain fertilizer treatments have increased total volume as much as 50 to 60 percent, there seemed to be little pojnt in extrapolating data for plantation age 7 to a rotation age of 25 years. .

It is encouraging, however, to note that after 7 years the P concentrations in the needles of those trees fertilized at even the lowest rates are still substantially higher than the P concentrations in the needles of unfertilized trees. This has not been true of slash pine growing on the same soils and fertilized at comparable rates. Foliar P concentrations of fertilized slash pine have dropped to those of unfertilized slash pine over a 'I-year period. Earlier in this paper, it was pointed out that sand pine must be extremely efficient at extracting essential growth elements from the soil and at maintaining a desirable internal balance of nutrients and moisture. It therefore appears entirely possible that, after a sand pine plantation has been fertilized, the trees will be capable of recycling a substantial portion of the added nutrients within the trees or stand and that tree growth will be increased for a major portion of a plantation rotation.

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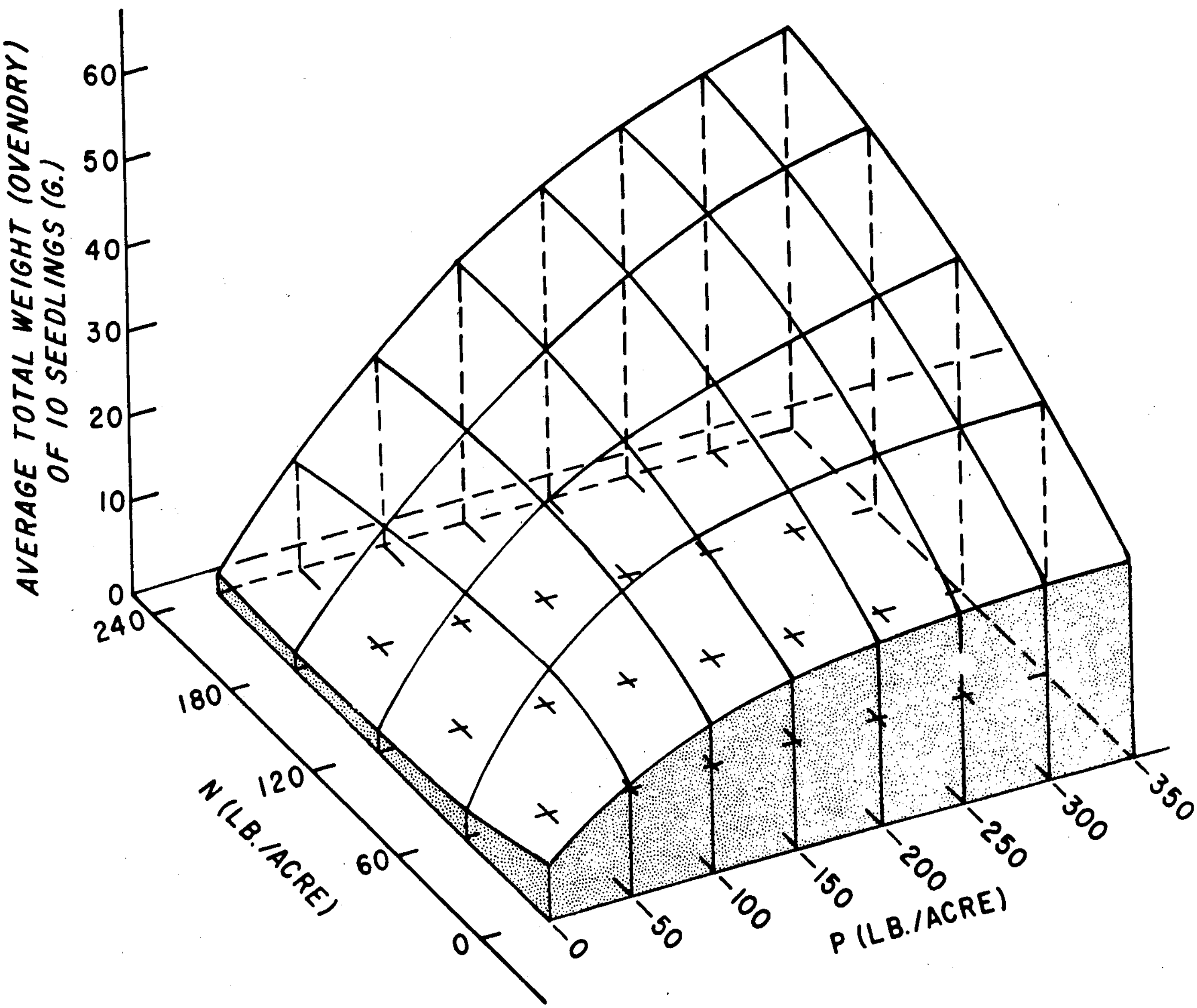

Figure 1. -- Effect of N and P fertilization on average total weight **(ovendry)** of 10 CSP seedlings.

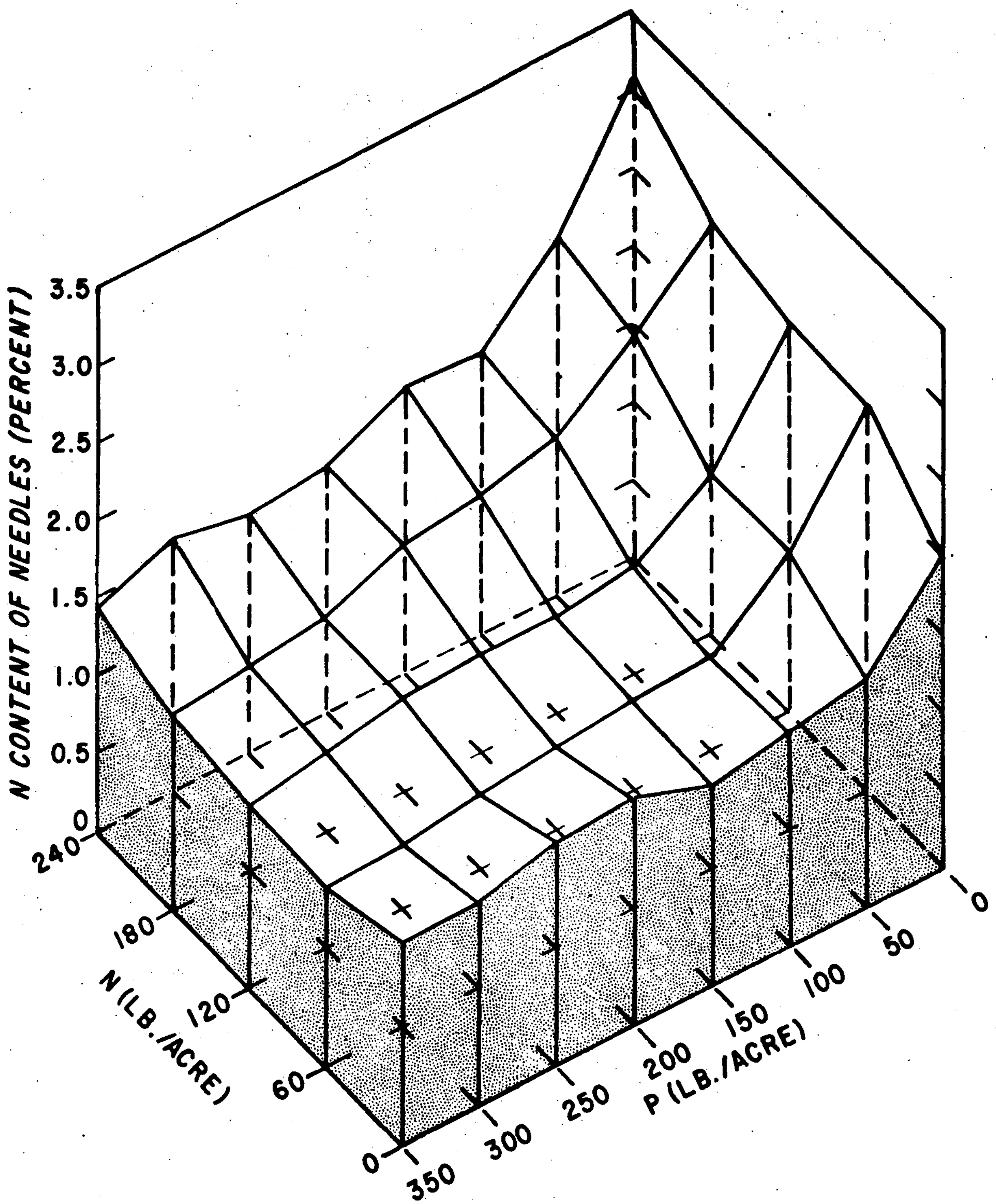

Figure 2. --Effect of N and P fertilization on N content of sand pine needles.

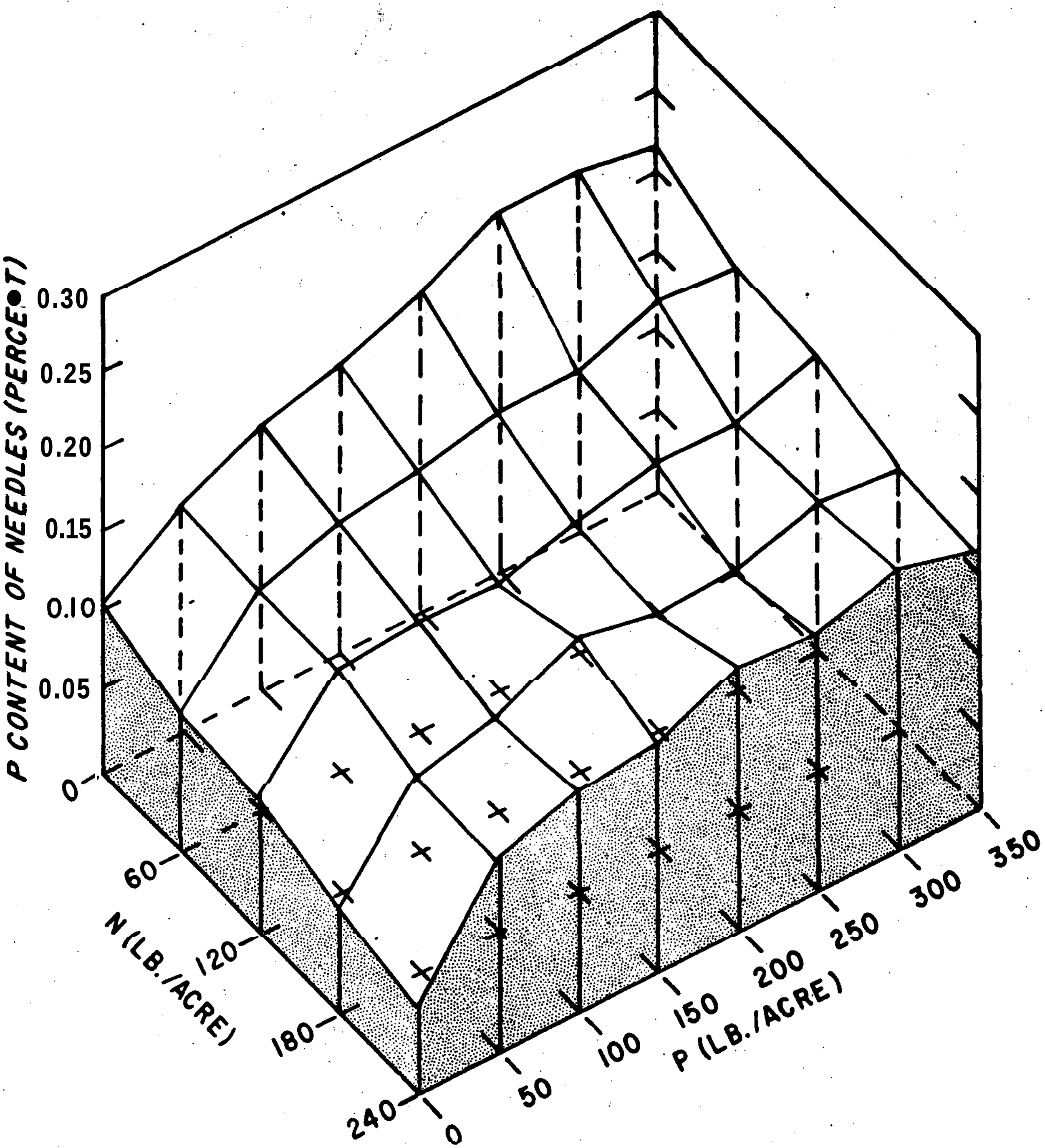

Figure 3. --Effect of N and P fertilization on P content of sand pine needles.

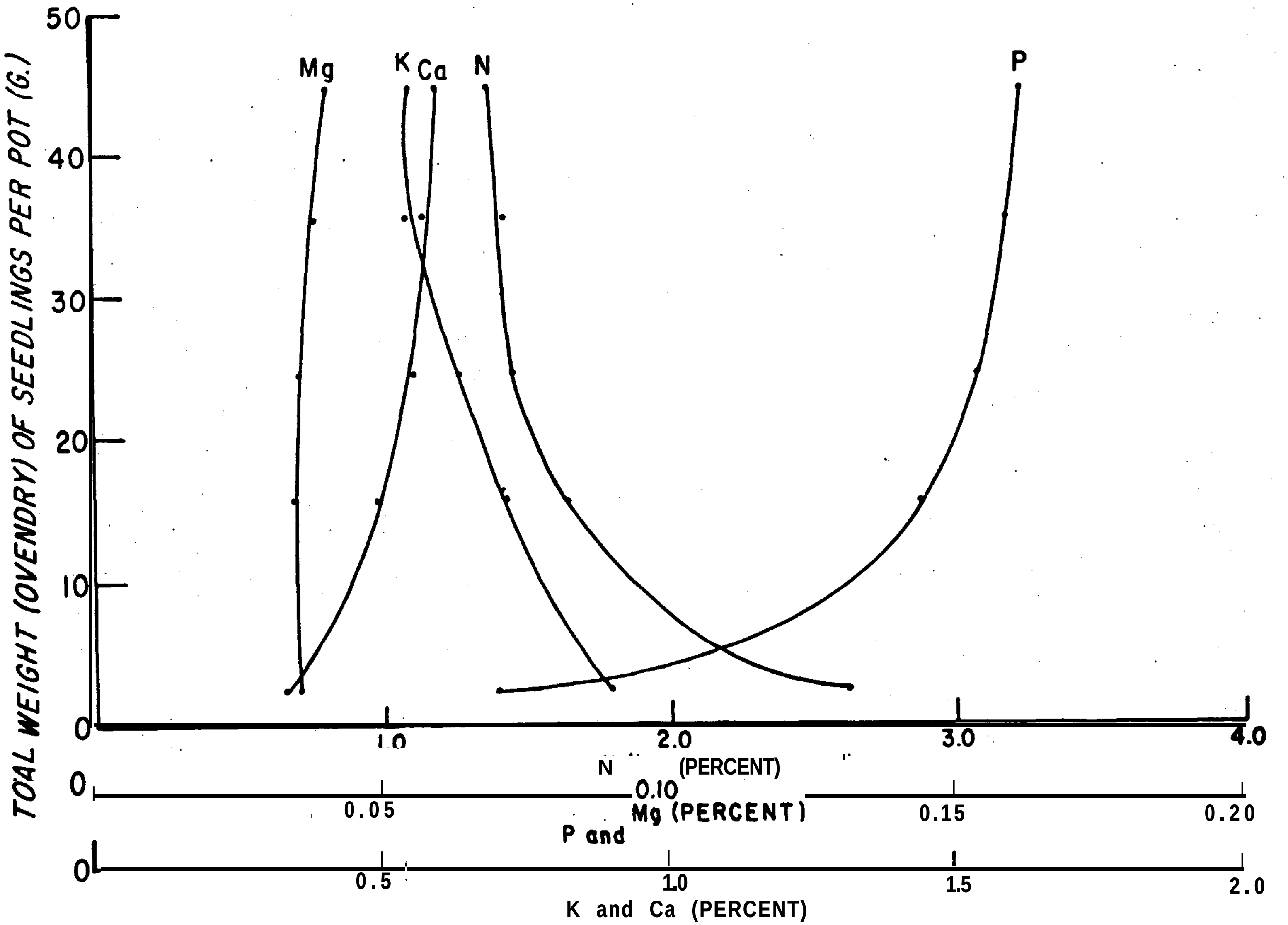

Figure 4. --Variation of total weight (ovendry) of CSP seedlings with nutrient concentration of needles.

UNDERSTORY VEGETATION, WILDLIFE, AND RECREATION IN SAND PINE FORESTS

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Abstract. --With adequate planning and integrated management, the sandhills of Florida have a potential for providing wildlife and recreational uses along with wood production. Understory vegetation in the longleaf pine-turkey oak and sand pine-scrub oak associations presently supports small populations of many wildlife species and makes these areas popular for hunting. Recreation other than hunting is also a major use of some areas.

INTRODUCTION

In forest management, it is natural to concentrate our efforts on the production of wood because this product is relatively easy to see, measure, harvest, and appreciate. It permits straightforward management practices and is readily converted into money. But we must not become blinded so that we cannot see the forest for the trees. There are other products and aspects' of the forest that merit our attention.

Some of the environmental aspects of forests, such as clean air, clean water, and open space, are intangible, that is, they are hard to see .or measure or harvest. Yet we know these products are becoming increasingly valuable. Other products of forests, such as wildlife, recreational areas, and understory vegetation, are more readily seen, measured, and appreciated. They, too, are increasing in value and should receive more attention in our management plans.

One approach to this task is integrated management for multiple-product yields, an approach that helps us take advantage of the total potential of the forest. Integrated management is the simultaneous, harmonious use of a resource for more than one product. Inte grated management plans give full consideration to each alternative combination of 'products, 'such as wood-wildlife or livestock-timber-water or deer-pulpwood-camping-orchids. Management must consider the requirements of each product and the many interactions between products to determine the' compatibility and compromises required to implement an integrated plan.

A number of forces are pushing us closer each day to integrating management of our resourcet3. Economists tell us that we need to 'receive full returns from our investment, in this case our landholdings. Integrated management works on the assumption that greater benefits or returns (not necessarily financial returns) accrue with it than with single-use management. In many areas, integrated management is required by law, but more frequently we see it practiced because of personal desires of the landowner. Pressure of public demands will, no doubt, influence: many managers to adopt multiple • use. Fortunately, our southern forests, including the 'sand pine fore'ets, are adaptable to multiple -product management:"

BACKGROUND

The sandhills in the Southeast are comprised primarily of soils from marine deposits. These soils are well to excessively drained, acidic, infertile, and thick, varying from a few feet to more than 60 'feet. They extend from southwestern Alabama to the Carolinas, with an estimated 3 million acres in Florida. Moisture-holding capacity of the soils is poor, and only drought-tolerant plants are able to survive.'

Repeated turpentining and cutting of timber from about 1890 to 1930 ultimately removed most of the longleaf pine (<u>Pinue palustris</u> Mill.) 'from the longleaf -turkey oak association. Thereafter, much of the land became dominated by scrub hardwood species such as turkey oak (<u>Quercus laevis</u> Walt.), bluejack oak (<u>Q. incana</u> Bartr.), sand post oak (<u>Q. stellata</u> var. <u>margaretta</u> (Ashe) Sarg.), and dwarf live oak (<u>Q. minima</u> (Sarg.) Small). In the sand pine-scrub oak association where sand pine (<u>Pinus clausa</u> (Chapm.) Vasey) has been removed by harvesting or fire, the area becomes dominated over long periods by scrub oaks, such as Chapman oak (Q. chapmanii Sarg.), myrtle oak (Q. myrtifolia Willd.), and sand live oak (Q. virginiana var. maritima (Michx.) Sarg.). Overall, the sandhills are a harsh environment for man's use, but there is a good mixture of other vegetation types, such as swamps, marshes, hammocks, and prairie, that provide good wildlife habitat and excellent opportunities for recreation.

Use of these harsh sites to meet man's needs for wood, wildlife, open space, clean air, clean water, and recreation requires careful management and manipulation of the soil and vegetation. Our present knowledge about understory vegetation, wildlife, and recreation on the sand pine forests of the sandhills, along with some concepts of integrated management about these areas, are the subjects of this paper.

UNDERSTORY VEGETATION

Some early descriptions and comments on the vegetation of the Florida sandhills were made by Nash (13) in 1895, Harper (8) in 1914, and Gano (2) in 1917, along with later descriptions by Mulvania (11) in 1931, Pessin (15) in 1933, and Webber (20) in 1935. More recent descriptions by Strode (18) and Harlow (5, 6) provide information for planning the use and management of these forest types. The sand pine-scrub oak and longleaf-oak uplands are typical vegetation types of the sandhills; the former is limited primarily to the Ocala National Forest, whereas the latter occurs throughout north and central Florida.

The species of plants in the understory vary with locality. Detailed locale lists may be found for north Florida in Gano (2), for central Florida in Mulvania (11) and Nash (13), and for central and west Florida in Harlow (5, 6). Pineland threeawn (Aristida stricta Michx.), also called wiregrass, is the principal understory herb. Other plants present in most localities are gophe rapple (Chrysobalanus oblongifolius Michx.), saw-palmetto (Serenoa repens (Bartr.) Small), and goldaster (Chryeopsis spp.).

Forage yields from different locations and sites within the sandhills are highly variable (table 1). Except for some of the better longleaf pine site s, these dry, infertile 'sites offer little potential for livestock grazing or farming.

Harvesting of timber or pulpwood from the sandhille allows hardwoods and other understory plants to increase their growth rate and, frequently, to dominate the site completely, The oaks are especially efficient in this regard. Annual plants are also abundant for the first year or two after soil disturbance, and foods for wildlife increase with either thinning or complete harvesting of the timber overstory. Harlow (5) measured 435 pounds of browse per acre under a 30-year-old mature stand of Ocala sand pine, whereas production was 1,021 and 689 pound6 per acre at 2 and 4 year6 after pulpwood harvest and brush cutting.

Table 1. --Forage yield6 from two type6 of sandhill vegetation on the Ocala National Forest, Withlacoochee State Forest, and Eglin Air Force Base, Florida[a]

Forage6	Pine-oak scrub	Pine-oak upland6		
	Ocala	Withlacoochee	Eglin	Ocala
	- - - - - - - - - - Lb. /acre - - - - - - - - - -			
Grasses and sedges	3	206	10	121
Forbs	10	48	2	7
Woody plants[b]	738	66	5	39

a/ Adapted from Harlow (5).
b/ Primarily green leaves.

Site preparation for planting pines is generally considered essential in the sandhills. Chopping for this purpose increased yield6 and numbers of species of understory vegetation on longleaf-turkey oak sites in the Apalachicola National Forest (table 2).[1] These treatments also improved wildlife habitat by providing more forage, seeds, and plant species to satisfy animal preferences. Grelen (3) found that single chopping killed few of the native plants and merely "cultivated" the oaks and pineland threeawn. However, this treatment could be very beneficial for wildlife if some reduced growth of planted pine was acceptable.

In 1955, eight site-preparation treatments were installed on the Chipola Experimental Forest in northwest Florida. Response of the pine seedlings was best on the double-chopped sites, and Grelen (4) followed species succession for 4 years. The first year after treatment, he counted 36 species in April, 50 in July, and 55 in October. The most conspicuous plant early in the year was yellow button6 (Balduina angustifolia Pursh), followed by September prairieclover (Petalostemon corymbosus Michx.) in September; two perennial grasses, a panicum (Panicum malacon Nash) and

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1/ McDaniel, J. C. An evaluation of the effects of pine-site preparation, oak thinning, and bulldozing titi thicket6 on the Apalachicola National Forest. 1965. (Mimeogr. Final Rep. on Project W-41-R-13, Fla. Game & Fresh Water Fish Comm.)

fall witchgrass (Leptoloma cognatum (Schult.) Chase), then became predominant. During the second year, numerous annuals were present, but dogfennel (Eupatorium compositifolium Walt.) was most abundant and broomsedge (Andropogon virginicus L.) began invading the area. During the fourth year, dogfennel was the herbaceous dominant and broomsedge was abundant, although Panicum malacon Nash and fall witchgrass remained the most prevalent grasses. Pineland threeawn and the hardwoods were almost nonexistent.

Table 2. --Number of species and yields of browse and herbaceous plants after site preparation in 1958 in longleaf pine-turkey oak of the Apalachicola National Forest[a]

Treatment	1959		1961		1963		1965	
	Species	Yield	Species	Yield	Species	Yield	Species	Yield
	No. / acre	Lb. / acre	No. / acre	Lb. / acre	No. / acre	Lb. / acre	No. / acre	Lb. / acre
No treatment	19	204	20	313	16	631	19	171
Single chop	21	582	27	1,130	25	821	19	809
Double chop	22	188	30	799	24	1,361	29	714

[a] Adapted from: McDaniel, J. C. An evaluation of the effects of pine -site preparation, oak thinning, and bulldozing titi thickets on the Apalachicola National Forest; 1965. (Mimeogr. Final Rep. on Project W-41-R-13, Fla. Game & Fresh Water Fish Comm.)

Hebb (9) reported the trends concerning the important wildlife food plants on Grelen's plots for 13 years. Many species, especially the oaks, gophe rapple, and grassleaf goldaster (Chrysopsis graminifolia (Michx.) Ell.), decreased, while blackberry (Rubus enslenii Tratt.), milkpeas (Galactia spp.), and dogfennel increased in number of plants (table 3). The noseburns (Tragia spp.) and broomsedge ended up with about equal numbers on chopped and unchopped plots. Overall, there was a small decrease in the number of desirable game food plants with double chopping. However, a less severe form of site preparation might have improved wildlife habitat.

It is readily apparent that man's activities influence understory conditions in the sandhills. Proper management of understory vegetation is essential for protecting watershed values while maintaining and enhancing the use of forests by wild or domesticated animals, game or nongame birds, and man in his esthetic and recreational pursuits. We have much to learn about obtaining balance between the reduction of plant competition with pines and the maintenance of desirable plants for other uses.

Table 3. --Trends in numbers of wildlife food plants after chopping in both May and September 1955 on the Chipola Experimental Forest[a/]

Class and species	Chopped plots after -- 1 yr.	3 yr.	6 yr.	8 yr.	10 yr.	13 yr.	Unchopped plots after 13 yr.
	---------- Thousands/acre ----------						
Woody plants							
Bluejack oak	0.2	0.1	0.1	0.2	0.4	0.4	4.0
Turkey oak	2.0	.4	.4	.4	.4	.4	2.4
Dwarf live oak	.4	.8	.4	1.6	2.0	1.6	14.0
Gophe rapple	6.4	3.2	2.0	4.0	5.2	7.6	23.2
Blackberry	.0	.O	.8	5.6	10.0	14.4	.0
Grasses							
Pineland threeawn	.4	.4	.2	.2	.2	.2	59.2
Broomsedge	.8	6.0	8.4	22.0	54.4	49.6	45.6
Forbs							
Goldaster	.O	.1	.0	.1	.4	.4	16.8
Milkpeas	1.2	.8	.4	2.0	2.0	4.4	1.6
Prairie clover	1.6	2.4	1.2	1.2	.8	.4	.4
Noseburn	3.6	1.2	1.6	2.0	3.2	2.8	3.6
Dogfennel	.4	32.4	8.8	26.0	19.6	6.8	.0

a/ Adapted from Hebb (9).

WILDLIFE

The sandhills provide satisfactory habitat for many species of wildlife but are unable in most instances to sustain large populations. The more common game species are deer, hogs, squirrels, rabbits, quail, doves, and ducks. Endangered and rare species found in protected sandhill areas such as Eglin Air Force Base are Florida sandhill crane (*Grus canadensis pratensis*), southern bald eagle (*Haliaeetus leucocephalus*), peregrin falcon (*Falco peregrinus anatum*), southern red-cockaded woodpecker (*Dendrocopos borealis hylonomus*), Florida panther (*Felis concolor coryi*), and American alligator (*Alligator mississipiensis*). No doubt, the interspersion of vegetation types allows wildlife species to find their favored habitat and helps maintain a varied wildlife population in the sandhills.

Although habitat requirements of each species of wildlife are different, the qualities that provide good habitat for one species are frequently important qualities to other species. When most habitat requirements of several wildlife species are present in a particular vegetation type, severe competition may develop. However, through knowledge of these habitat requirements, we can often manage the vegetation in such a way that many conflicts are minimized, if not eliminated.

Activities of man affect wildlife populations by changing habitat conditions. For example, the increasing number of white-tailed deer (Odocoileus virginianus) in the South coincided with major reforestation efforts following World War II, but bobwhite quail (Colinus virginianus) populations decreased during this period of reforestation and fire exclusion. Furthermore, clearing of land, diversification of farm crops, and rapid expansion of improved pastures for cattle have created ideal habitat for mourning dove (Zenaidura macroura) by improving sites for nesting and increasing food supplies (21).

Populations of eastern wild turkey (Meleagris gallopavo) are fairly low in those areas where sand pine predominates and water is often scarce (16). However, they are able to persist in bottom-land hardwoods along the streams and swamps that intersperse the type, and they frequently move into the upland scrub oaks. Turkeys will eat almost anything, but acorns make up a majority of their diet during the fall and winter, along with seeds and fruits of legumes, grasses, and other hardwoods as they become available during the year. Conversion of bottom-land hardwoods to agricultural cropland has reduced some prime habitat, but planting large areas to pines increases favorable habitat if several large hardwoods are left on the area. Prescribed burning in pinelands at about 3-year intervals will improve the quality of turkey habitat.

The presence of white-tailed deer has always made the sandhills a favorite hunting area, although populations are not extremely high. However, in Florida the highest deer populations occur in these areas. Strode (18) estimated that the deer population on the Ocala National Forest was one deer per 43 acres and that maximum carrying capacity was one deer per 35 acres. Harlow (5) estimated maximum carrying capacity of pure sand pine-scrub oak type to be one deer per 70 acres, but the interspersement of other vegetation types increased the overall carrying capacity. The potential carrying capacity for both pine-oak uplands and sand pine-scrub oak sandhills was estimated to be one deer per 34 acres (7). Cover for deer is generally abundant; there - fore, the limiting habitat factor seems to be the amount of quality food available.

Food habits of deer in the sandhills have not been studied except during the fall-winter period, which is considered the most critical for adequate nutrition. During the fall and early winter, mast (acorns and saw-palmetto berries) are the most important deer foods throughout Florida and in the sandhills, but they are gone by late winter (fig. 1). Browse (leaves, stems, and berries of woody plants) and herbaceous material (forbs and grasses) assume greater importance as mast becomes less available. Mushrooms are used whenever available. The more important browse species are oaks, shining sumac (Rhus copallina L.), greenbrier (Smilax spp.), pine (Pinus spp.), ground blueberry (Vaccinium myrsinites Lam.), sandhill kalmia (Kalmia hirsuta Walt.), and garberia (Garberia fruticosa (Nutt.) A. Gray).

Management practices that will maintain or improve deer habitat in the sandhills are oriented around the need to maintain enough oaks to provide acorns and browse. Where timber stand improvement is practiced, about 5 to 10 large, mature oaks per acre should be left alive (18). Pulpwood harvest should be in small blocks (20 to 100 acres) that are well scattered over the forest. Wherever possible, prescribed burning every 3 or 4 years will improve quality and availability of browse.

Beckwith (1) found that, when preparing sandhill sites for planting pine, strips of oaks should be left throughout the planting area. Leaving lo-&in-wide strips of undisturbed land every 10 or 30 chains in a mile resulted in better deer use of cleared areas in central Florida than when square -mile blocks were totally cleared. Site preparation consisted of chaining to remove the large trees and then chopping after 4 to 6 weeks to kill the lesser vegetation. Deer made heaviest use of the cleared strips in the spring, about equal use of cleared and uncleared areas in the summer, and heaviest use of uncleared areas in the fall. This pattern seemed to coincide with availability of succulent forage and acorns.

Bobwhite quail populations are fairly low in the sandhills, but Stoddard (17) believed that such country could produce quail in abundance when cultivated to remove the dominance of scrub oak and wiregras s. Murray and Frye (12) also considered the rolling sand pinelands of the longleaf pine-turkey oak association to be major quail habitat in Florida, particularly when eucceesion is set back by burning, chopping, or disking, each of which produces a greater abundance of seed-producing forbs and grasses . Native plants frequently used as quail foods in northwest Florida in the winter are acorns, tickclover (Desmodium spp.), common lespedeea (Lespedeza striata (Thunb.) H. & A.), partridgepeas (Cassia spp.), milkpeas, flowering dogwood (Cornus florida L.), bull paspalum (Paspalum boscianum Flugge), and pine seed.

Many wildlife species are naturally at home in the sandhille. If given some management consideration, they should find desirable habitat in sand pine forests and increase the benefits and productivity of this resource.

RECREATION

During the last two decades, the availability of more leisure time, less strenuous work, greater affluency, and greater ease of travel have resulted in a boom in recreational activities. Strohm (19) recently reported some statistics from the Bureau of Outdoor Recreation which show the following participation of Americans in various outdoor activities:

Activity	People (millions)	Activity	People (millions)
Picnicking	82.1	Camping	35.2
Swimming	77.3	Nature walks	30.5
Walking for pleasure	50.3	Hunting	20.9
Fishing	49.4	Horseback riding	16.1
Boating	41.4	Bird watching	7.5
Bicycling	37.1	Wildlife photography	4.9

Frequently, the demand for recreational areas and facilities exceeds the supply. It has become necessary to begin limiting the number of visitors to some of our larger recreational areas, such as National Parks and Wilderness Areas. These increasing needs prompt us to look at some rather inhospitable areas, such as the sandhills of the Southeast, for opportunities to create additional recreational facilities.

The Ocala National Forest in central Florida, our largest single expanse of sand pine-scrub oak, has for years been a popular recreational area. James and Harper (10) reported that 1.2 million visits in one year resulted in 24,212,639 man-hours of recreational use, with the following breakdown:

Activity	Man-hours (millions)	Activity	Man-hours fmillions)
Camping	7.6	Sightseeing	1.2
Recreation residences	7.4	Swimming	1.1
Fishing	2.7	Picnicking	.5
Hunting	3.0	Boating, hiking, etc.	.5

The intensity of use on this area has increased over the years. With the opening of Disney World, the demands have accelerated and, no doubt, will continue to do so.

Another example of effective planning and use of the recreational potential in the sandhills is Eglin Air Force Base in the Florida panhandle (14). Military installations have programs in the management and conservation of natural resources to guide the use of land not directly used in the military mission, Generally, development of recreational areas has received emphasis. For example, Eglin Air Force Base encompasses 460,320 acres, with 406,000 acres being forested and about 264,000 acres open for hunting. Some 34 ponds and lakes are stocked and managed for fishing; these are used to supplement fishing on 150 miles of natural streams. Other recreational opportunities are provided by 50 picnic tables, 8 'miles of bridle paths, and 3 miles of hiker trails. About 1, 000 acres are planted with supplemental foods for wildlife. A checklist of over 400 birds identified on Eglin is also provided for birdwatchers.

In 1970, 2,326 fishermen purchased permits to fish on Eglin, and 8,551 hunters were provided over 100,000 man-days of hunting. Harvested were 2,206 deer, 299 hogs, 3,462 quail, 16, 335 doves, 22, 566 squirrels, 1,512 ducks, and many tons of fish.

These examples illustrate opportunities and successful attempts for recreational use of the sandhills. The recreational and wildlife potentials can become reality if integrated management is practiced as greater areas of the sandhills are converted from scrub oak to sand pine. In these efforts to integrate management, we need to be constantly aware of natural beauty and attempt to duplicate it. For example, when rows of trees are planted or strips of oaks are left, straight lines should be avoided in favor of meande ring, naturalistic patterns. Roads should be paralleled and land or water contours should be followed. It must be remembered that scenery is also a forest value.

CONCLUSIONS

The sandhills offer good potential for development of recreational opportunities and increased wildlife populations through effective management of the understory vegetation. But we have much to learn about good manipulation of vegetation, especially as related to sand pine, because no detailed studies have been made of understory vegetation under planted stands. Because sand pine can compete successfully when planted in native vegetation and also responds to site preparation, our research will be concentrated on how sand pine and the understory respond when this pine is planted in native vegetation and on how they respond to varying levels of site preparation.

If pines are planted in narrow, chopped rows amid intervening, unchopped strips of varying widths, we. have the opportunity of achieving increased growth of pines and maintaining much of the native vegetation while decreasing the cost of site preparation. These prepared rows can also be planted with supplemental wildlife foods. If fertilization is limited to the rows of trees, greater response by the trees or planted understory will be achieved. Techniques for prescribed burning of sand pine for the improvement of wildlife habitat also need to be developed.

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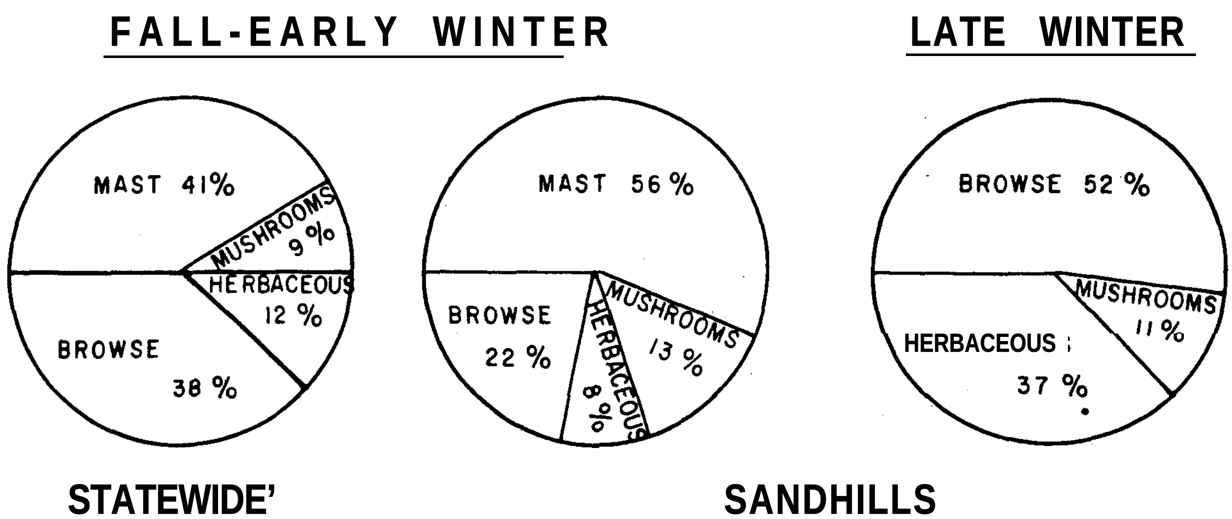

Figure 1. --Percentage breakdown of categories of food eaten by white-tailed deer in Florida from November through February, as based on stomach contents. Browse was primarily leafy material. [Adapted from Harlow (5, 6).]

INSECTS OF FLORIDA'S SAND PINE

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Abstract. --Life cycles and characteristic damage to eand pine in Florida are summarized for the following ineecte: bark beetles, black turpentine beetles, twig beetles, ambrosia beetles, reproduction weevils, deodar weevils, pine sawflies, pine webworms,. pitch moths, tip moths, sand pine geometrids, pine pitch midges, aphids, and scales. Bark beetles, reproduction weevils, and sawflies will probably cause the greatest losses to Florida plantations of sand pine in the future.

Many species of insects attack and kill, deform, *or* cause growth loss to sand pine. Most of theee pests are found throughout the range of sand pine, but a few are restricted to limited areas. The majority of these pests also attack the other species of pine in Florida.

The emphasis on sand pine in recent years hae been spectacular--*from* a weed to a valuable tree. In many areas of the State it is the only tree suitable *for* planting, as we have learned. Much research has been undertaken to determine the proper methods of growing and managing this tree; however, research on the destructive insect and disease pests has lagged far behind.

What are the occurrences and potentials of sand pine insects? Over the past several years I have observed insects associated with this species throughout the State, but by no means would I say the following list is complete.

1. Bark beetles: Ips calligraphus (Germar), I. grandicollis (Eichh.), and I. avulsus (Eichh.). All three species have been found attacking and killing sapling-sized to mature sand pines. The first two species are much more commonly found, and normally attack the upper and lower trunk of the tree. I. avulsus normally attacks the crown area of the tree. The life cycle, from egg to adult, requires as little as 25 days in summer. Winter weather conditions can restrict development activity, and a generation may require as much as $2\frac{1}{2}$ months. It is possible to have as many as six to eight generations each year when conditions are favorable. Stress factors, such as drought, flooding, construction work, mechanical damage, lightning, fire, and crowded stand conditions, are necessary for epidemics to develop. Summer thinnings have frequently been accused of causing Ips attacks, but observations indicate otherwise. I feel you can harvest safely and selectively if soil moisture is normal and logging is done carefully. Selective harvesting may be essential if root rot is a serious problem. Keeping a healthy forest is the cheapest and most practical way to prevent losses. During outbreaks of bark beetles, salvage the infested areas, if practical, for monetary return and reduction of beetle populations. The use of pesticides may be necessary under certain conditions, either in combination with salvage or alone. The smaller sized trees can also be shredded.

2. Southern pine beetle, Dendroctonus frontalis (Zimmerman). I want to mention this insect even though it has not been reported infesting sand pine. The beetle readily attacks Virginia pine and would, I suspect, be adaptable to sand pine.

3. Black turpentine beetle, Dendroctonus terebrans (Olivier). This insect attacks larger sand pine, but apparently prefers other pine species. The life cycle requires approximately 3 months to complete, and three or four generations a year are possible. Again, the previously mentioned stress factors are very important in causing attacks. Black turpentine beetles will be present and usually in direct competition with Ips, although their activity is normally confined to the lower 6 to 8 feet of the trunk of the tree. During outbreaks, salvage the infested trees when possible. Insecticides are usually effective in controlling this beetle because of its longer life cycle and can be used alone or in conjunction with salvaging.

4. Twig beetles, Pityophthorus sp. These very small (1/16 inch) scolytid beetles are secondary pests that normally attack dead and dying

twigs. I have observed them attacking apparently healthy sand pines 1 and 2 inches in diameter and causing mortality. I believe etress factors were present that had severely weakened the trees. Grafted *scions* in nurseries have also been attacked and killed by these beetles. The life cycle is completed in 6 to 8 weeks. Controls under woodland conditione are impractical, but high-value seedlings can be protected with insecticides.

5. Ambrosia beetles, Platypus sp. These insects attack treee that are dead or dying and only use the tree for rearing young. They do not feed on any part of the tree, but carry a fungus on their bodies that they culture for the larvae. Piles of fine eawdust at the base of the tree indicate their presence. They will be found in treee infested with Ips and black turpentine beetles. No controls are practical for thie pest.

6. Reproduction weevils, Pachylobius picivorue (Germar) and Hylobius paH se rbst). Both of these weevils are primary killers of seedling and small sapling-sized pines. The larvae develop in the etumpr and large roots of recently harvested or killed trees; they require about 6 monthe for their life cycle. There are two generations each year in Florida. The adults attack natural or planted seedlings in the general area. Serious problems have occurred in recent years with block cutting of other pine species. The weevils develop, emerge, and then fly to adjacent young plantings where they cause severe feeding damage and mortality. Delaying planting in harvested areas for 9 to 12 months will easily prevent attacks and economic losses. Insecticides applied as seedling dipe or by spraying after the trees are planted give very effective control. Another limiting factor is that *larger* stumps and roots are required for successful development of the weevil. As we practice shorter rotations, suitable host material may not be present, and the weevil problem may be eliminated or greatly reduced.

7. Deodar weevil, Pissodes nemorensis (Germar). This weevil has attacked small sapling-sized trees that have been weakened by one or more stress factors. It is considered a secondary pest at this *time* and no control is practical. It has one generation a year in Florida.

8, Pine sawflies: a blackheaded pine sawfly, Neodiprion excitans (Rohwer); a redheaded pine sawfly, Neodiprion lecontei (Fitch); and a sand pine sawfly, Acantholyda circumcincta (Klug). These insects attack sand pine; however, the first two normally prefer other species of pines. The third appears to be an exclusive sand pine feeder. All *three* species attack small'sapling-sized to mature timber. The Neodiprion species have three to five generations per year, whereas the sand pine sawfly has only one. A. circumcincta is known to occur only on the Choctawhatchee variety of sand pine, and to date has been found only in Walton and Okalooea Counties in northweet Florida. In general, sawflies do not kill the trees, although there have been some notable exceptions, and natural entmiee usually bring outbreaks under control in one or two generations or in 1 year. Growth loss appears to be the major problem and approaches 90 percent in severe infestations. Several chemicals give excellent control of the larvae stage, particularly in the early instars. Research is being conducted on bacterial and viral diseases used as sprays to control the sawflies. The sawflies are quite cyclic and will be a serious, usually local, problem for 1 year and then disappear for several years.

9. Pine webworm, Tetralopha robustella (Zeller). This pest primarily attacks 1- and 2-year-old seedlings, but it will infest saplings on occasion. Some growth loss is sustained, and seedlings are occasionally killed. Sometimes, large planted areas will be severely infested and others nearby very lightly infested. Frequently, after a large infestation in 1-year-old seedlings, very few or no attacks may be found the succeeding year. Multiple generations a year occur in Florida. Egg laying takes place on the needles, and temperature determines the incubation period of the eggs. Hatching may be prolonged if cool weather persists. The larvae feed on the needles and start constructing the frass and webbing mass on the seedlings. Chemical controls are usually not necessary under forest conditions, but may be required in nurseries or special plantings. Several insecticides will give excellent control.

10. Pitch moth, Dioryctria amatella Hulst. Usually this insect is associated with tree wounds, although attacks have become more common in seed orchards during the past few years. I believe that fertilization programs have accelerated tree growth and successful attacks are occurring at the junction of the trunk and branches. The Ocala variety appears to be more susceptible, and *some* mortality has occurred. The pitch mass is similar to that of the bark beetles, but very much larger. The larvae feed in the phloem beneath the bark, usually adjacent to the tree wound. The larval gallery has an irregular shape and may be several inches in length. The mature larvae pupate in the resinoue mass, usually in the areas of original infestation, and just prior to adult *emergence,* work their way near the surface of the pitch mass. Some larvae pupate and emerge as adults in a short period of time, and others will be inactive for several months before pupating. In Florida there are three to four generations each year. Control measures are usually impractical under forest conditions. Infested trees of high value, such as those in seed orchards or genetic studies, should be treated if infested, particularly when the trees are small. Several insecticides will give excellent control.

11. Tip moths, Rhyacionia spp. These insects readily attack sand pine and cause severe damage and dieback to terminals and lateral twigs. Observations indicate that no lasting deformity occurs and only a negligible amount of height growth is lost. Losses of conelets in seed orchards are high, however. Attacks normally cease after the tree reaches a height of 10 to 15 feet. Browning and dying of the infested twigs is usually the first noticeable sign of attack, and close examination of the shoots will reveal an accumulation of resin.and fine webbing. When the infested shoots or buds

are broken open, the larvae or pupae may be observed *or* empty pupal cases will be present if the adult moths have emerged. In Florida, the adult moths mate and egg laying usually begins during the early spring. Temperature determines the incubation period of the egg, and hatching may be prolonged if cool weather persists. The newly hatched larvae feed on the new growth for a short time before boring into the shoot. The larvae continue to feed inside the shoots until they reach maturity and then pupate. Four or five generations occur in Florida each year; most twig damage and the largest populations occur during the first two generations. Control measures are usually impractical for large acreages of planted pines. However, when severe and repeated infestations occur for 2 or 3 years, chemical controls may be desirable. Trees of high value in seed orchards and in genetic studies should probably be protected. If chemical controls are used, the, most important consideration is the timing of the spray application. The insecticide should be applied when hatching of the eggs occurs, so that the young larvae are subjected to a lethal dose of poison before entering the shoot.

12. Sand pine geometrid, Nepytia semiclusaria (Walker). This insect has been observed feeding on seedling, sapling, and pole-sized sand pine in central Florida. Feeding was confined to the previous year's foliage, and no mortality was observed. One generation per year is produced, and the life cycle is completed in approximately 2 months.

13. Pine pitch midge, Retinodiplosis retinodiplosis (0. S.). The adult flies are delicate, grayish-brown insects approximately 1/8 to 1/5 inch long and resemble mosquitoes in form. The mature larvae are reddish orange, about 1/4 inch long, with an indistinct head at the pointed end of the body. In the spring the female flies lay their eggs on the twigs, and the larvae begin feeding on the tender tissues. This feeding causes the resin to flow and results in pitch masses. The larvae continue to feed on the tender tissues, then mature and pupate in the pitch mass. No apparent damage occurs to the trees when attacked by this pest. One and possibly two generations occur in Florida. No insecticide controls are recommended.

14. Aphids and scales. Several species of aphids and scales have been observed on sand pine. Large populations frequently occur on individual or small groups of trees. No tree mortality has been observed, but some growth loss certainly occurs. Several generations are present each year, but natural enemies normally keep populations in check. Aphids are mobile and feed by sucking plant juices from the tender, succulent tissue and cause stunting or distorted, chlorotic needles. Scales differ in that they attach themselves to the plant and become immobile after the first nymphal or crawler stage. Heavy infestations of either insect are sometimes first detected by the presence of black sooty mold, a saprophytic fungus growing on the "honeydew" secreted by the insect. No chemical controls are recommended except, possibly, for high-value trees that are severely infested.

These insects may become more serious in the future and may also be capable of transmitting some tree diseases.

DISCUSSION

After discussing several of the insects that occur on sand pine, you might ask, "What species are economically important and how will they influence future management practices?"

1. Bark beetles, both *Ips* and the black turpentine beetle, will probably cause the most volume loss.

2. Reproduction weevils will be important, but losses will depend on the management practices used.

3. The various species of sawflies will be most important from the standpoint of growth loss. New species of insects that adapt to sand pine may be destructive tree killers, as recent observations seem to indicate.

4. Aphids, scales, and mealy bugs may also contribute significant growth loss, but no detailed research has been undertaken to date.

The other insects listed can be considered as minor in importance. I suspect conditions will change if a monoculture develops, and any of the already-known pests could change their habits and become destructive. Also, pests not presently attacking sand pine could adapt if conditions became favorable. It is also possible that a minor insect could well be an important vector of a serious disease.

In closing, I would like to stimulate some advanced planning, so that we can avoid crisis answers and crash programs. Insect research is necessary if we are serious about intensive management of sand pine. Very little research has been done, and I feel that many questions need answers. Research will require certain procedures and time to: (1) properly identify the pests, (2) measure their impact on trees, (3) determine their life cycles and behavior, (4) evaluate their insect enemies and other natural control factors, and (5) develop practical pest management methods that are effective, inexpensive, and safe. If we are serious about sand pine, we should begin now.

IMPORTANT DISEASES OF SAND PINE

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Abstract. --Important diseases of sand pine in the nursery include black root rot and nematodes. Diseases in plantations include Clitocybe tabescens, Phytophthora cinnamomi, an.d Fomes annosus. As sand pine is planted farther from its native range, new disease problems will probably arise.

INTRODUCTION

The increasing popularity of growing sand pine (Pinus clausa (Chapm.) Vasey) for pulpwood in the South has focused attention on the pathology of this species. The past history of sand pine suggests few serious disease problems. Most records and observations of the incidence of disease were made in natural stands where enphytotic conditions exist. Where pathogens and their hosts have existed together for many years, disease conditions usually are stabilized and severe epiphytotics are rare. Hence, generally innocuous diseases such as needle rust (Coleosporium vernoniae (B. & C.), needle casts (Hypoderma (syn. Ploioderma) lethale Dearn. and Hypoderma (syn. Ploioderma) hedgcockii Dearn.), twig blight (Atropellis tingens Lohm. & Cash), and eastern gall rust (Cronartium quercuum (Berk.) Miy. ex Shirai) dominate most of the early reports (7). A root and butt rot caused by Polyporus schweinitzii Fr. and heart rot caused by Fomes pini (Thore) Lloyd have been reported occasionally in sand pine; the latter usually is not a problem until the stands are more than 40 years old (7).

NURSERY PROBLEMS

Black Root Rot

Potentially, the most serious disease problem of sand pine seedlings in the nursery is black root rot caused by a complex of organisms involving Sclerotium bataticola Taub. and Fusarium spp. (6, 8). Rowan (19) established the susceptibility of sand pine seedlings to black root rot in a greenhouse study. However, this disease should pose no problem to the production of nursery seedlings because it can be easily controlled by soil fumigation. Smalley and Scheer (21) reported symptoms of black root rot in 2- to 3-year-old plantations of sand pine in west Florida. I have found occasional mortality with symptoms similar to those of black root rot in recent investigations of 1 - to 3 -year -old plantations, but the problem does not appear to be severe or widespread.

Nematodes

Nematodes may cause some damage to sand pine seedlings in nurseries. Hopper (9) reported that Meloidodera floridensis Chitwood, Hannon, & Esser caused severe injury and mortality to sand pine seedlings in a Forest Service nursery at Olustee, Florida. Ruehle (20) found that both the Ocala and the Choctawhatchee varieties of sand pine seedlings are susceptible to the lance nematode (Hoplolaimus galeatus (Cobb) Thorne). As with black root rot, soil fumigation should easily control nematode problems in nurseries. Although further investigations are needed, past history suggests that nematodes will not cause severe problems in plantations.

IMPORTANT DISEASES IN SAND PINE PLANTATIONS

Clitocybe tabescens

In 1956, Rhoads (12) reported Clitocybe tabescens (Fr.) Bres. as a killing root rot of sand pine in Brevard and Lake Counties, Florida. Since then, poor survival and high mortality in plantations of Ocala sand pine have been reported (1). I have examined a number of plantations of Ocala and Choctawhatchee sand pines in Georgia and Florida; up to 39 percent of some plantings of the Ocala variety were killed or infected by C. tabescens, but only minimal losses occurred in plantings of the Choctawhatchee variety (15).

A greenhouse study was therefore established in Athens, Georgia, to determine the susceptibility of the two varieties of sand pine to C. tabescens. Seedlings were grown in a fumigated medium of sand, sandy loam soil, and pine bark (1:1:1) until the stem diameter at the soil line reached 3 to 5 mm. and the height was 20 to 30 cm. Seedlings were then inoculated by cutting away a narrow l-inch strip of bark to cambial depth at the root collar and attaching over the wound a piece of oak wood (3 to 4 cm. by 10 cm.) on which C. tabescens had been growing for 6 months. Inoculated seedlings were repotted with the attached inoculum buried in the soil medium. Within 3 to 4 weeks, high rates of mortality occurred in both varieties of inoculated sand pine and in the noninoculated controls. No evidence of infection by C. tabescens could be found in any of the seedlings. Isolations from the soil medium with a modified Kerr's medium (5) and from feeder roots of the seedlings with the apple technique (2) consistently yielded Phytophthora cinnamomi Rands. The study was inconclusive.

Another study was therefore designed to determine the susceptibility of both varieties of sand pine to C. tabescens and the virulence of different isolates of the pathogen. Threehundred 1-O seedlings of each variety from the Chipola Experimental Forest Nursery were planted in 6-inch clay pots in a steam-sterilized sandy soil from Geneva, Georgia. These seedlings were inoculated in the same manner as described in the first study.except that four different isolates of C. tabescens, numbers 188, 190, 193, and 200, were included. Except for isolate 193, which was collected from infected slash pine (Pinus elliottii Engelm. var. elliottii), all of the isolates were collected from infected root tissue of Ocala sand pine. Isolate 188 was collected from Bunnell, Florida, isolate 190 from Darien, Georgia, isolate 193 from Geneva, Georgia, and isolate 200 from Eglin Air Force Base, Florida. Mortality, apparently caused by C. tabescens, began 6 weeks after inoculation. Eighteen months after inoculation, the seedlings apparently killed or infected by C. tabescens were tabulated (table 1). Up to 7 months after the be ginning of the experiment, only one cut (but noninoculated) control seedling of each variety was lost to mortality from an undetermined cause. After 8 months, however, necrosis of the feeder roots and a high percentage of seedling mortality which could not be attributed to C. tabescens occurred in both varieties. Large populations of P. cinnamomi were again isolated from the roots and from soil surrounding the roots of dead seedlings and those exhibiting symptoms of the disease. This finding, of course, reflects upon the validity and significance of the data in table 1. Because no attempt was made to detect P. cinnamomi early in the experiment, it could not be determined at what point or to what extent this organism affected the seedlings. Again, the study had to be abandoned with inconclusive results. These results do suggest that the Ocala variety is more susceptible to infection by C. tabescens and that some isolates of the pathogen are more virulent than others. However, I cannot explain the contamination by P. cinnamomi, as it could not be isolated from the potting soil or the nursery soil where the seedlings were grown. Although precautions were taken to prevent contamination, it is possible that inoculation occurred when pots were moved to an outdoor lath house 4 months after establishment of the study.

Table 1. --Percent of seedlings of Ocala and Choctawhatchee sand pine killed or infected by Clitocybe tabescens 18 months after inoculation.

Isolate No.	Ocala		Choctawhatchee	
	Dead[a]	Infected[b]	Dead[a]	Infected"
	- - - - - - - - - - - - Percent	- - - - - - - - - - - -		
188	24.4	11.0	11.0	15.5
190	4; 4	17.7	2.2	2.2
193	4.4	15.5	0	4.4
200	2.2	8.8	0	0

[a] A seedling was considered to have been killed by C. tabescens if the perforate mycelial mat or the black xylostroma of the organism was present on the stem or roots.

[b] A seedling was considered to be infected by C. tabescens if it was still living but had no (or incomplete) callus formation around the wound, copious resin exudation from the wound, soaking of stem or root wood, and necrotic tissue around the wound at the point of inoculation.

Phytophthora cinnamomi

Phytophthora cinnamomi is widespread throughout the South and Southeast (3, 4). The involvement of this pathogen in the etiology of the little-leaf disease has been well-documented (3). Mortality of Douglas -fir seedlings and ornamental plantings in the Pacific Northwest has been attributed to P. cinnamomi, but serious problems are not expected in forest stands in that region because of the pathogen's apparent inability to withstand the climatic extremes (10, 18). Ross and Marx (17) proved that P. cinnamomi is a virulent pathogen on both varieties of sand pine seedlings. Because P. cinnamomi had never been associated with decline and mortality of sand pine in the field, we collected soil samples from eight locations in Florida and Georgia. Natural and planted stands of both varieties of sand pine were sampled in areas where trees had been killed by C. tabescens and also in disease-free areas. We found P. cinnamomi in soils from four of seven plantations where mortality and C. tabescens were present, but we did not find it in natural stands (table 2).

Table 2.--Recovery of *Phytophthora cinnamomi* from soils in planted and natural stands of Ocala and Choctawhatchee sand pine

Location of stand	Variety of sand pine[a]	Type of stand[b]	Mortality and *Clitocybe tabescens* present	*P. cinnamomi* recovered in air-dried soil
				Maximum propagules/g.
Eglin AFB Reservation				
Stand 1	0	P	Yes	1.8
Stand 2	C	P	No	0
Stand 3	0	P	No	0
Stand 4	C	N	No	0
Stand 5	C	N	No	0
Chipola Experimental Forest				
Stand 1	C	P	No	0.6
Stand 2	c	P	No	0
Stand 3	0	P	Yes	0
Bristol, Fla.				
Stand 1	0	P	Yes	0
Stand 2	C	P	No	0
Panama City, Fla.	C	N	No	0
Ocala National Forest				
Stand 1	0	N	No	0
Stand 2	0	N	No	0
Yulee, Fla.				
Stand 1	0	P	Yes	3.0
Stand 2	0	P	Yes	5.2
Darien, Ga.	0	P	Yes	0.8
Geneva, Ga.	O	P	Yes	0

a/ 0 = Ocala; C = Choctawhatchee.

b/ P = planted; N = natural.

These findings do not prove conclusively that *P. cinnamomi* is a pathogen of sand pine under field conditions. However, the proof of its pathogenicity on seedlings in the greenhouse, as well as its association with areas where mortality of sand pine was attributed to *C. tabescens*, strongly suggests its involvement in the etiology of the root disease complex.

Fomes annosus

Root rot caused by *Fomes annosus* (Fr.) Karst. has become a serious problem in planted pines in the United States over the past 20 years. A 1960 survey revealed high percentages of infection in thinned plantations of slash and loblolly pines (11). Freshly cut stumps left in thinning operations have been recognized as the primary pathway by which *F. annosus* enters and causes mortality in the residual stand (13). I reported sand pine as a new host of *F. annosus* root rot in 1968 (14). This serious root disease of other southern conifers was not a problem in any of the several plantations of sand pine I examined throughout the South. As plantation management of sand pine increases, and especially as thinning operations become more common, some losses to *F. annosus* can be expected. Studies on other southern pine species suggest that, within the region where sand pine is likely to be grown, *F. annosus* can be easily controlled by integrated practices such as summer thinning (16) and application of granular borax to the freshly cut surfaces of stumps.

SUMMARY

I have mentioned the few known diseases of sand pine likely to cause severe problems in managing plantations of sand pine through a pulpwood rotation. This species appears to be relatively disease-free in natural stands. As sand pine is planted more widely, farther from its native range, and under varying site and climatic conditions, and as it is maintained under different management practices, new disease problems will probably arise.

The most serious disease presently limiting the successful establishment of plantations of sand pine, particularly of the Ocala variety, is *C. tabescens* root rot. This disease may be severe in areas where hardwood stumps and root debris are left in the soil after site preparation. The pathogen readily colonizes the hardwood debris and attacks young sand pine at points of root contact. Losses to *C. tabescens* may be avoided by completely removing hardwood debris during site preparation; however, this removal may not be economical. Field observations suggest that the Ocala variety is more susceptible to *C. tabescens* than is the Choctawhatchee variety, but conclusive experimental evidence is still lacking to support this observation. if, from a silvicultural standpoint, it is desirable to plant seedlings of the Choctawhatchee variety instead of the Ocala variety, research to date on tree diseases has revealed no reasons to discourage such a program.

A confusing aspect of the problem of root rot in sand pine is the involvement of P. cinnamomi. Greenhouse studies suggest that both varieties of sand pine are highly susceptible to attack by this pathogen. Its association with areas where sand pine has declined and died in the field suggests that it may contribute to a root disease complex. A possible mode of action may be the destruction of the fine feeder roots, as occurs in littleleaf disease (3), and a resulting reduction in tree vigor and subsequent attack by C. tabescens. P. cinnamomi usually does not cause serious damage in well-drained, sandy soils; therefore, this pathogen is not expected to be a problem in such areas. Heavy clay or poorly drained soils may support populations of P. cinnamomi. Without exception, the areas in Florida and Georgia where planted sand pines had been killed by C. tabescens and where P. cinnamomi was later recovered were either shallowly underlain by clay soils or were composed of imperfectly drained sandy soils. Losses attributed to P. cinnamomi may be eliminated by avoiding such sites when planting.

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FIRE AND SAND PINE

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Abstract. --Although many acres of Ocala sand pine in north-central Florida owe their existence to wildfires, the burning. of standing trees is not an acceptable form of forest management.. Most wildfires in this fuel type occur from February through June. Except during the spring, wildfires in stands of Ocala sand pine are easily controlled by plowed firelines, aerial tankers, suppression firing, and sand casters. Prescribed burning has not been effective in the management of sand pine except in the stands of the Choctawhatchee variety in west Florida.

Fire and Ocala sand pine (*Pinus clausa* var. *clausa* Ward) seem to go together. At least that seems to be the case on the Ocala National Forest in north-central Florida where the largest single concentration of this variety of sand pine is found. Many acres of sand pine forests in this part of Florida actually owe their very existence to fire. When a killing fire sweeps through a stand of cone-bearing trees, the serotinoue cones open and release tremendous quantities of seed (1 million or more seed per acre), If conditions are favorable, dense stands of reproduction usually follow. However, the standing trees are killed, and a potentially valuable resource is lost. This method of regeneration cannot be considered an acceptable form of forest management.

When young stands that have not reached seed-bearing age are destroyed by fire, the lack of an adequate seed supply preclude6 regeneration. In most instances, sand pine is replaced with scrub oak and other inferior scrubby species. These occurrences are known as "double burns"--they result when two or more burn6 take place within a time interval of about 10 years or less on the same piece Of ground.

It is evident that fire and sand pine are not really as compatible as a cursory glance may indicate. We cannot afford to sacrifice wide-scale timber resources for the mere sake of producing a new generation of trees.

In comparison with the other southern pines, the Ocala variety of sand pine is very susceptible to fire kill. It usually grows in dense, even-aged, pure stands as a direct result of past fires. It is thin barked, attains an age of about 70 years old, and grows to a height of about 65 feet and a maximum diameter of 18 inches. The general stand characteristics lend themselves to easy and rapid fire' spread under certain weather conditions. When a stand is composed principally of one species of tree, with all trees about the same age and size and with stems very close to one another, experience has shown that fires can spread from crown to crown with a minimum of surface or ground fuel. The fact that sand pine is a relatively small tree with very little in the way of protective bark make6 it highly vulnerable to fire damage and kill.

Under most conditions, however, it is difficult to generate high-intensity fires in this timber type. When understory vegetation and ground cover are sparse, when fuel moistures and relative humidities are moderately high, and when strong wind movement is lacking, fires burn slowly and are easily subdued--often going out of their own accord. During the past 50 years, the Ocala forest has averaged less than two wildfire6 annually of 10 or more acres. Although several of these wildfires were of disastrous proportions, this infrequent occurrence over a long period illustrates the impracticability of generating many high-intensity fires, Past record6 also'show that 80 percent of these wildfire6 occurred in the 5-month period from February through June. In the past 50 years, only 12 fires of any consequence occurred outside this seasonal period.

A rather complex combination of fuel and weather factors appears to be responsible for the occasional occurrence of blowup fires in sand pine stands during the spring. Hough (2) has identified some condition6 that, when encountered 'in the right combination, help explain the reasons for large fires during the spring and may be of value to the land manager in formulating preparedness and manning schedules:

"A complex combination of fuel and weather factors accounts for the dangerous fires that often develop during the spring in sand pine forests of Florida. Moisture content of live needles is lowest in March, and resin and energy contents reach their yearly highs during the 4-month period from February through May. These fuel properties become critical, however, only when they are accompanied by rainfall deficiencies that begin in the fall and winter and continue through the spring and by unstable air masses with low relative humidities and high winds. "

Although Hough's findings were based on data from the Ocala variety of sand pine, there is evidence to indicate that the same fuel properties exist in other varieties. Preliminary tests show that understory vegetation also undergoes cycles in moisture, mineral, and extr'active contents very similar to those in sand pine crowns.

FIRE CONTROL PROBLEMS

When fuel and weather conditions are ideal for burning, spring wildfires in dense stands of sand pine crown easily and are difficult to control. During many months of the year, however, conditions are less favorable for burning and stands of sand pine are not considered fire hazards. They are, in reality, often used as buffers or safety strips into which wildfires or prescribed fires are directed because of the inability of the fire to continue its spread through this type. Understory fuels are generally on the sparse side and, consequently, do not carry fire readily except under extreme weather conditions.

Disastrous wildfires in sand pine stands are few and far between. Under ordinary circumstances, plowed lines are effective in containing the small wildfire and it seldom reaches disastrous proportions. But when everything is right, small fires literally explode within a brief time span and the resulting conflagrations often defy normal control efforts. Under these conditions, early fire detection and prompt control are essential. Once the wildfire gains momentum, it fans up into the tree crowns where usual suppression measures are inadequate. Plowlines are not effective, and other ground attacks are equally futile.

Attacks with aerial tankers loaded with suppressants and retardants are showing the greatest promise of effective control of crown fires today. They are capable of knocking a fire out of the crown and bringing it back to the ground where it can be tackled by conventional tactics and equipment. Where large, contiguous areas of sand pine are encountered, aerial tankers armed with firefighting chemicals appear to be the best safeguard against a crown fire conflagration.

Suppression firing (i. e. , the intentional application of fire to speed or strengthen control action on free-burning wildfires) may offei additional opportunities to break up or halt the advance of sand pine fires more effectively. Spot-fire patterns set well ahead of the wildfire head appear to be particularly suited for this type of treatment. The spots will consume most of the understory fuel ahead of the fire spread. In addition, if they are permitted to develop moderate intensities of their own, they will consume some over story fuel, thereby creating breaks in the crown canopy. In this manner, it becomes virtually impossible for the crowning wildfire to continue its forward advance. For the most part, it is relatively easy to predict the spread patterns of wildfires in sand pine stands because these patterns are basically wind-controlled.

The Michigan sand caster (1) was found to be a particularly effective suppression weapon. In addition to building excellent lines .to halt the advance of surface fires, the sand caster spread large quantities of soil and water into the overstory--enough so that crown fires were broken up and stopped.

PRESCRIPTION BURNING

Unfortunately, prescribed fire has not been a particularly effective tool in the management of sand pine. For the most part, failure to make effective use of fire in the form of a prescription is the result of our inability to control intensities. Under some conditions, sand pine is an explosive fuel type; under other conditions, it is an "asbestos forest." There seems to be little middle ground between these extremes. Interest in pre scription burning stemmed from the species' past history of fire and regeneration. Natural seedfall from standing trees is sparse except when stands are exposed to killing wildfires that open closed cones. When stands are harvested, the seed supply is left intact in the tops of trees. Lopping and scattering of the cone - bearing branches, followed by mechanical ground scarification, result in cone opening, seed release, exposure of mineral soil, and subsequent regeneration. But the costs are relatively high. The question arose as to whether fire (a relatively cheap tool) might do the job just as well. To date, we have not been able to make it succeed. If it sustains itself in slashings, it burns too hot and consumes most of the seed. Burns conducted for seedbed preparation prior to harvesting have, on occasion, been successful, but they still remain a gamble. The same situation prevails for hazard reduction burns. An additional consideration: The most hazardous stands of sand pine are those less than 20 years old because such stands generally cannot withstand a good fuel-consuming burn without sustaining serious damage or kill.

There are, nevertheless, a few places where prescribed fire is applicable --mostly in west Florida. On the Eglin Air Force Base, burning for hazard reduction is a common practice during 'the winter months. Understory fuels associated with sand pine are relatively light and produce low-intensity fires at this time of the year. In the more open stands, the fires often help to prune some of the lower limbs. During the drier times of the year, it is difficult to maintain low-intensity fires; excessive damage and kill are more likely to occur.

Except for these special cases, prescription burning is not currently recommended except possibly for purposes of slash disposal in clear-cut areas which are to be regenerated artificially.

OTHER CONSIDERATIONS

For the most part, my remarks have been directed primarily toward Ocala sand pine found on the Ocala National Forest in north-central Florida--locally known as "The Big Scrub." In western Florida, the open-coned variety is known as Choctawhatchee sand pine. It frequently occurs in uneven-aged stands and often. invades adjacent sites where fire protection is adequate.

The fire problem in natural stands of Choctawhatchee sand pine is not nearly as critical as it is in stands of the Ocala variety. The trees are more open-grown and are generally found in smaller, more accessible blocks. As a result, they are less likely to be involved in wildfire conflagrations. Nevertheless, a potentially dangerous fire situation may exist if either variety is used in extensive plantations. Because of its capacity to grow well on dry, infertile sites, sand pine is finding favor as a preferred species for planting in much of Florida. It is commonly used in converting scrub oak sites to pine. Sand pine plantations are characterized by dense, even-aged stands with long crowns. Under certain burning conditions, these characteristics make it relatively easy for surface fires to flare up into the crowns and spread rapidly through the plantation. Spread rates of 5 miles or more per hour are likely; control measures are difficult and often ineffective. Possible solutions may include wider spacings or pruning of the lower limbs when the stand is 10 to 20 years old.

If sand pine is to be managed as a productive natural resource, killing wildfires cannot be tolerated. As with so many other species with similar characteristics, this prohibition is easier to state than to follow. Once a large blaze is allowed to blow up, only a change in weather or a break in fuel continuity brings about complete control. The best manmade solution appears to lie with a more effective fire prevention program, improved detection, a quicker initial response to the wildfire, the use of aerial tankers, and the identification of critical fuel-weather situations for manning and preparedness purposes.

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ICE AND COLD DAMAGE TO SAND PINE--WEIGHING THE RISK

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Abstract. --The planting of sand pine north of its range increases the possibility of damage from cold and ice. The seriousness of this threat, the types of injuries sustained, and the likelihood of recovery are discussed. Consideration of tree and stand characteristics related to susceptibility suggests that proper management of sand pine stands to reduce the threat would emphasize proper spacing and no thinning.

This paper brings together information on the threat that ice storms and freezing temperatures pose to managed stands of sand pine. Sand pine management is in its infancy, and, where the species is most common, ice storms are few. Consequently, information is meager. Because sand pine is now being pushed northward, we must evaluate the potential hazarde involved in the extension of the range of this species. For this paper, I have drawn upon written sources and unreported personal experiences of those who have worked with sand pine. Where experiences with other species appear relevant, they are included.

TYPES OF DAMAGE

The agent causing ice damage is most often termed "glaze" and is **defined** as a layer of ice formed by the freezing of rain on a surface whose temperature is at freezing or below. Whatever the term, we are concerned with storms that build up heavy layers of ice on stems and branches of trees.

The most common damage glaze causes to sand pine is mechanical and is due to the weight of ice building up on the surfaces of the trees. About 37 percent of the Ocala sand pines and 25 percent of Choctawhatchee sand pines in a 5-year-old plantation in South Carolina were damaged by a severe ice storm in 1969 (11). The weight of ice causing this type of damage has been estimated as being 15 to 20 or even 30 times the weight of the twigs or branches themselves (2, 3, 31). The most severe damage occurs when glaze storms are accompanied by wind. From experience with other species, we would expect eventually to encounter breakage of terminals and general stem breakage of sand pine, as well as uprooting on shallow soils (3, 8, 15, 27).

Physiological damage --killing of plant tissues by low temperature -- is also possible. Harms (10) found symptoms indicating freezing as the primary cause of high mortality of Ocala sand pine introduced on sites near Columbus, Georgia, and Cheraw, South Carolina. Research in Florida has not revealed this effect, though freezing weather often occurs there. Two commercial planters in Florida have noticed no cold damage to sand pine over the last 5 years (Don Blizzard and George Eubank, personal communications, 1972). Poor planting technique is considered a greater hazard. Noah Corbin (personal communication, 197 1) reports that the only damage occurring to sand pine at Eglin Air Force Base during the past 35 years has been the freezing of some baled seedlings when ambient temperatures fell below 20° F. (-7° C.). Glaze was not a factor in these reports. Sand pine on the Ocala National Forest has been subjected to ice: ". . . in 1957 almost all the Big Scrub was iced over," but damage was negligible (Spurgeon McDuffie, personal communication, 1972).

W. E. Howell (personal communication, 1972) reports that a small stand of Ocala sand pine on the Atomic Energy Commission's Savannah River Project in South Carolina came through a severe ice storm that decimated slash pine. Many green needles were knocked off the sand pine, but the trees are healthy now.

In growing pines in southern nurseries, freezing can be troublesome if care is not taken. Wakeley (33) reported that newly germinated seeds of the southern pines can suffer freezing damage, but he felt such damage could be overcome by not planting when germination would occur during a hazardous period. There 'are reports (Wilbert E. Schowalter, personal communication, 1971) that grafted sand pines in the Ashe Nursery in Mississippi have been damaged by cold weather. There is some possibility, however, that other factors were responsible.

Once pines have been injured by low temperatures or ice, the injured stems can suffer further damage from exposure to infection by fungi and invasion by insects. Fortunately, such damage seems to occur with far less frequency than would be expected (24, 29). Russell (29) reports that a storm broke virtually every stem (most within the crown) of a 25-acre loblolly pine stand in northern Louisiana. Although the stand wae not treated in any way for a year, there was no reported damage from insects and disease. In a survey of damage from the Louisiana ice storms of 1944 and 1947 in loblolly, longleaf, shortleaf and slash pines, Muntz (24) found no eerious damage from insect attack, Cool et al. (6) found a buildup of insects in injured timber, but these insects did not spread to healthy trees.

Nevertheless, we should watch for possible insect attack after *severe* weather. Kirby (16) attributed the epidemic of the southern pine beetle in southwestern Mississippi in 1952 to the ice storm of January 1951. In his opinion, the buildup was aided by the storm's injury to birds that were insect predators.

MAGNITUDE OF THE RISK

Likelihood of ice damage is related to the regional frequency of storms. As might be expected, the greatest incidence of storm-s occurs in the northern United States, particularly in the eastern half of the country (3, 6).

Figure 1 shows a section of the southeastern United States with the sandhills outlined and zones of ice-storm frequency demarcated. The occurrence of glaze storms over the 27-year period from 1925 to 1953 is indicated in each zone. Four zones are apparent in the region. The lack of ice storms south of central Georgia during the 27-year period does not entirely exclude the possibility of such storms there in the future (19). According to Lemon's information (19), the occurrence of glaze was moderate in the zone that crosses central Georgia, and Cool et al. (6) list the maximum number of storms in this area during the 27-year period as two. After studying weather records for this area from 1893 onward, Jones (14) concluded that damaging ice storms occurred there once every 12 years. This zone covers the eastern sandhills in Georgia and then follows the coastal plain in the Carolinae. Because the sandhills in the latter states are in a. zone *where* as many as six glaze storms occurred during the period, the risk of future storms there is three times as great as in the zones nearer the coast. Still '*greater* occurrence (13 storms) was recorded in the next zone inland. Although this zone may appear too far inland to be of concern to us, it does border the Carolina sandhills.

Frequency does not tell the whole story. In 1947, Muntz (24) cited reports which indicated that in a particular area, an ice storm of great severity had not occurred in 40 years. He went on to say (24, p. 142), ". . . yet, two have occurred within ['a period of } 4 years." Obviously, a recent storm does not diminish the risk of a second occurrence in the near future. Generally, though, the risk can be linked with the frequency of storms in the past, and cold and ice storms will be greater hazards to growing sand pine as it is planted farther north, where storm severity and frequency are likely to be greater.

CONDITIONS AFFECTING DAMAGE

Apart from severity of the storm, the conditions that affect the amount of damage done are species (as embodying differing morphology and physiology), size, and age of the trees. Characteristics of the stand that are important are stand density and distribution and whether the stand is natural or planted.

Species

Ice damage har been found to occur to all of the southern piner. Relative rurceptibility is uncertain because of differences in ". . .age, size, density, or location. . . . " (24, p. 143). Thir may be the cause of the variable and contradictory replies that Cool et al. (6) received to their questionnaire on the sus ceptibility of individual species. On plots where conditions were under stricter control and data were more methodically obtained, slash pine was found to be the most susceptible species.

Hebb (11) reported that, after a storm in South Carolina, Choctawhatchee sand pine wae about equal to slash pine in ewceptibility. Actually, the performance of Choctawhatchee sand pine could be judged superior because the two species sustained equal damage even though the sand pinee were taller and had a lower stand density than the slaeh pines. (Tree height and density of stocking are both factors that affect the degree of ice damage and will be discussed later in this paper.) About 25 percent of the trees in the stands of Choctawhatchee sand pine, rlash pine, and longleaf pine were damaged. Ocala sand pine fared much worse, with 37 percent damage, and loblolly pine was the least affected, with 13 percent.

The effect of glaze is not only a function of the quantity of ice, but is also related to the etrength of the wood, the arrangement of the branches (19) and probably their number, and to the length of the needler. Trees of similar anatomy should behave similarly. Gross morphology is important because the ice forms on surfaces. McKellar (21, p. 797) attributes the greater susceptibility of elash and longleaf pines over that of loblolly pine to ". . . their deneer and more persietant foliage, which accumulates a greater ice load. " And, according to Lemon (19, p. 24), "Medium-sized branches. . . have more strength in proportion to surface area than extremely large or extremely small branches." Lemon (19, p. 24) believes that a "... strong central trunk with small flexible side branches might be resistant."

Though we have no great store of data for sand pine, we might expect that it would behave somewhat like shortleaf or even loblolly pine because all three have similar, short needles. This similarity' is encouraging because loblolly and shortleaf pines are comparatively resistant to ice damage. Virginia pine, a northern species morphologically similar and genetically related to sand pine (20, 22), readily recovers from bending by heavy blankets of snow (9). The short branches and stem flexibility of plantation-grown sand pine should give it a similar advantage (28).

Overriding these apparent affinities are differences even among varietie 8. Though gross anatomical differences are evident, the two varieties of sand pine also differ physiologically. The Ocala variety breaks dormancy before the Choctawhatchee variety and, indeed, may *grow* continuously, exposing the tree to damage from sudden cold spells. Żelawski and Strickland (34) report, that under controlled conditions, the Ocala variety broke dormancy more readily than the Choctawhatchee variety. It is not surprising that damage in the 'Carolina plantings was greatest to the Ocala variety (11). Although Harms (10) acknowledges the necessity for further test plantings, he believes Ocala sand pine's susceptibility to cold would probably rule it out as a planting choice for the Georgia-Carolina sandhills. If variation of sand pine demonstrated by Morris (23) can be utilized, it may be possible to develop genetic resistance to freezing and ice damage from within the species.

Intraspecific variations relating to ice damage in other species were reported by Jones and Wells (15). When planted in central Georgia, loblolly pines from colder, inland seed sources were harmed less by ice storms than those from areas with a more moderate climate.

Size

The average size of the trees in the stand also affects the severity of the damage. It is difficult to generalize, but stocky trees appear better able to resist bending and breakage, and very slender trees tend to bend with the weight of ice and then usually recover. However, stems between these two extremes are not supple enough to resist breakage; consequently, they usually break or are uprooted.

It may be a mistake to try to link damage to a definite size --except in a very general way. The relationship will vary with the weight of the ice, the wind velocity, and the proportions of the stems. Moreover, glaze occurrence itself is rather spotty (6). Pole-sized trees appear to be most easily damaged, but there have also been reports of severe storms damaging trees the size of small saw logs (6). Young pulpwood-sized trees with good crowns and stocky stems appear able to withstand glaze storms best: Downs (8, p. 2) notes that "... damage is light and consists mainly of slight bending and a little top breakage" and that "... the most prevalent type of damage for trees 6-10 inches d. b. h. is bole and top breakage, with uprooting heavy at times." Tall, spindly trees with sparse crowns--the type of trees developed under crowded conditions and dense overstories--usually are greatly damaged (6, 8, 25).

Because the trees observed by Hebb (11) after the Carolina storm were only 5 years old, the legitimate inferences that can be drawn from the data are limited to the varying responses of the different species on the study plots. The effects of storms on older, larger sand pine at that latitude may be different. Certainly, damage reached catastrophic proportions in neighboring plantations of pole-sized slash pine.

Age

Older trees affected by glaze tend to break rather than bend, but it is difficult to document any precise relation to age. Most observers responding to the questionnaire sent out by Cool et al. (6) agreed that trees less than 6 to 10 years old usually bent under the load of ice. Breakage was *more* common in older trees. Daley (7) felt that stands older than 12 to 15 years were damaged most. These observations may indicate that the degree of damage changes with the stages in the development of the trees (30), but this problem has not yet been formally studied.

Stand Density

In the survey initiated by Cool et al. (6), nine respondents believed glaze damage was greater in dense stands and seven thought it was less. In addition to stand density, other factors are involved; as these factors vary, the results that appear to be due to density also vary. Merely relating ice damage to density is an oversimplification.

Some observers believe that a heavily stocked forest is a safeguard against ice damage because the trees provide mutual support and that isolated trees are more prone to breakage (8, 12, 19). Slocum and Miller (32) felt this relationship was true of Virginia pine, which resembles sand pine. Downs (8), on the other hand, felt that, in such stands, breakage could be severe because the spindly nature of the trees would place them at a disadvantage. Muntz's (24) data show ice damage of slash pine to be greater in denser stands. Muntz points out that this relationship is of no practical importance because greater numbers of undamaged trees will remain in the dense stands after the storm. Abel (1) observed higher damage in heavily stocked stands and attributed it to the damage wrought on adjacent trees by weaker ice-loaded trees as they bent. Respondents to the questionnaire of Cool et al. (6) felt that open-grown trees were resistant, and others (8) have seen greater taper and more robustness in open-grown trees, hence, a greater ability to withstand the onslaught of ice and wind. Thus, there is much confusion as to the effect of stand density. Although isolated trees are more exposed and fully stocked stands are more protected, the very protection of the fully stocked stands fosters the growth of tall and spindly trees susceptible to bending and breaking.

A major source of trouble can be the sudden reduction of density resulting from thinning or opening up the stand, as in clearing or preparing rights of way. In plantations of loblolly pine that were being thinned experimentally, Brender and Romancier (5) found severe destruction after a glaze storm. Damage was markedly less in plots that were not thinned. Daley (7) noted that recreational areas were hard hit by ice storms, possibly because such areas are'customarily left open.

Some observers believe that unbalanced crowns may be a cause of much of the bending that occurs in glaze storms (13). This imbalance is thought to be the reason that trees bordering roads and other openings are 60 apt to bend: the side of the crown toward the opening is generally more heavily developed. This theory is not fully accepted. In Louisiana, Kuprionis (17) observed that a number of slash and loblolly pines with one-sided crowns were not bent more readily than neighboring trees with symmetrical crowns. Perhaps more damage is noticed at road edges because the damage is most readily seen there.

REDUCING THE RISK

How can we lessen the threat of ice damage without taking sand pine out of the scene entirely? It appears to be the best species for reforestation of deep sands. High-risk regions can be avoided, but any location will pose some threat. Moreover, the problem cannot be solved merely by deciding not to move northward, for there are variables within location. To decide with assurance, we will probably have to wait until we know more about the performance of sand pine in different areas. The work unit of the Southeastern Forest Experiment Station at Marianna, Florida, is presently installing more studies of,, sand pine north of its original range. Such studies will give us more knowledge of survival and growth and of disease and insect hazards, and this knowledge will enable us to make more reliable decisions.

Management can help reduce the risk by manipulating the density with restraint. Altering density in a drastic way' can make the remaining stands very susceptible. Thus, thinning, harvesting, clearing--any cutting that leaves part of the stand exposed--will make it more susceptible, as demonstrated for loblolly pine by Brender and Romancie'r (5), for slash pine by Daley (7), and for Virginia pine by Slocum and Miller (32). However, thinning practices can be used that will leave a strong stand: thinning from below by taking out the smaller trees, and thinning only lightly, as advocated by Munta (24) for longleaf pine, to avoid glaze damage.

Thinning in dense stands of tall, slender trees should be avoided'if pos sible (8). Respondents to the questionnaire of Cool et al. (6) thought that maximum damage occurred in recently thinned stands of close-grown trees. Thus, if thinning is to be carried out, it must be done early in the life of the stand in order to allow the development of a stand of vigorous residuals. If it is delayed until only slender trees can be left, thinning should not be attempted at all.

AFTER THE STORM

If a storm does hit, what should we do? First of all, we should not simply rush in and start to work. It is best to wait before actually assessing the damage, because the first impression is usually false, and many damaged trees recover. Damage is often far less than is feared. Although the buildup of insect populations and the danger from fire must be guarded against, panic leading to overcutting should be avoided (18). Planning is an important factor in minimizing losses that result from glaze (6).

There is no harm in letting the stand alone for a while. Little additional damage has been found to occur, and there is little deterioration. Except for breakage of the lower bole and uprooting, there seems to be little evidence of death resulting directly from ice damage. This was the conclusion of Jones and Wells (15) after studying a stand of loblolly pine in Georgia. Kuprionis (17) attributedthe death of slash pine in northern Louisiana to a snow storm, but the deaths took place in the second year after the storm and the trees were bent over and never recovered.

Pines can recover from many of the principal types of damage we are concerned with. 'Uprooted trees are generally too far gone and too much in the way to be saved,, but bent-over trees often recover, and broken trees, if they still bear some limbs, survive and may even grow. Muntz (24) observed that small trees recover better than taller trees.' McKellar (21), while studying loblolly, longleaf, and slash pines, observed that 90 percent of the slightly bent trees recovered completely, as did 40 to 56 percent of the badly bent trees. An additional 20 to 30 percent made partial recovery. In Mississippi, Roberts and Clapp (26) found that pruning aided recovery of bent slash pine.

Permanent bending, or "set" as it is called, is common after ice damage to hardwoods of the northeastern United States (19). Hough (12) describes its occurrence in black cherry and the sprouting that subsequently took place all along the stems. Russell (29) feels that the usual pattern in the

South is for recovery to be rather common and for severe damage and breakage to occur only in patches. Kuprionis (17) reports that glaze -damaged loblolly and shortleaf pines recovered 18 years after damage: of 125 trees from four plots, 35 percent were straight, 49 percent were slightly crooked, and only 16 percent were permanently crooked.

What we ultimately do about glaze damage will depend on the goals of our management. If we are managing for special products and not simply for pulpwood, we probably have thinning schedules and can salvage damaged trees in the course of thinning. In Louisiana, Russell (29) used such a tactic to restore a stand of loblolly pine in which every stem was broken and up to half of each crown was lost. He postponed any cutting for a year and then applied successive thinnings to clean up the stand.

If the management scheme does not include thinning, as it probably will not in growing sand pine for pulpwood, damaged trees can possibly be left until the final harvest. Slightly bent trees should be no problem for pulpwood. Muntz (24) observed that leaning trees continued to produce volume. Cool et al. (6) reported that broken trees with only a few branches were still alive a year after the storm.

Salvage of down timber is a harvesting problem. Once there is a large quantity of such wood that will not grow and will not keep, the problem is to get it out before it loses weight or deteriorates. Cool et al. (6) noted complaints of weight loss as early as 2 months after the storm, but most complaints came 4 months later. Deterioration was noticeable in 4 months, but most was noticed 6 months after the storm. Topwood completely broken from the stem became a problem somewhat earlier. This is a problem that can be solved by planning. Hasty action is not called for, but time and resources must be carefully utilized.

CONCLUSION

As sand pine is extended to more northern sites, we can apparently expect an increase in the frequency of exposure to glaze. Damage from low temperature itself seems remote if the Ocala variety is avoided; the principal threat is mechanical damage from heavy deposits of ice. The threat to sand pine should be no greater than that to slash pine. In establishing stands of sand pine, crowding should be guarded against, for it makes the stands susceptible to ice damage. When pulpwood is the final product, management should emphasize proper spacing, with a goal of 75 square feet per tree, and no thinning.

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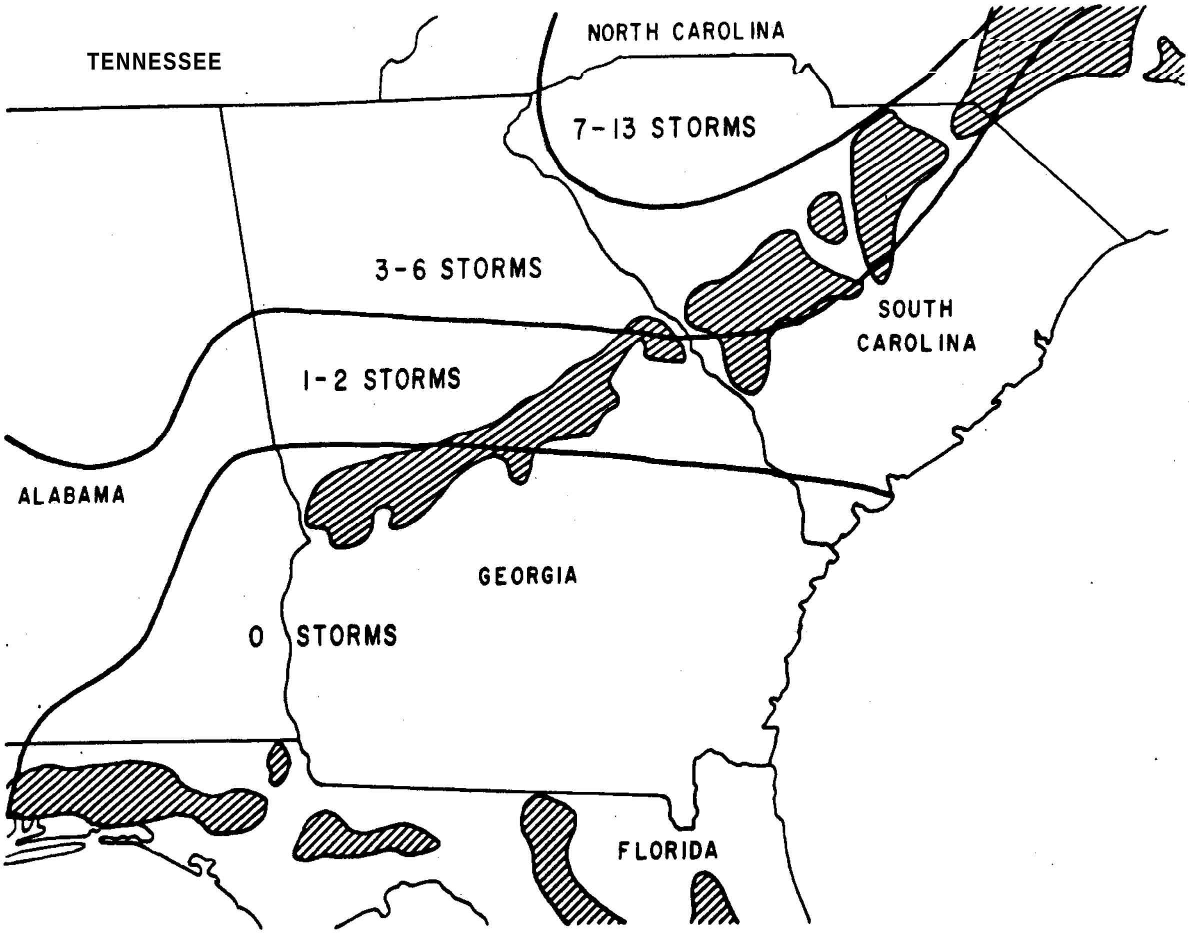

Figure 1. --Zones of ice-storm frequency in the southeastern United States for the period 1925 to 1953. The sandhills are indicated as crosshatched areas. [Map adapted from Bennett (4).]

GENETICS OF SAND PINE AND THE PROGRAM FOR SUPERIOR TREE SELECTION[1/]

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Abstract. --Choctawhatchee sand pine has better tree form and a higher survival rate than does Ocala sand pine, but the latter is superior in first-year growth and weight increase. The two varieties also differ in cone and seed traits, wood specific gravity, and susceptibility to mushroom root rot. Variation among stands is much greater than within-stand variation. Numerous selections of both varieties are now available for tree improvement programs, and improvements are anticipated in average straightness, natural pruning, and growth.

Among the southern pines, sand pine is uniquely adapted to growth on the deep, infertile sandhill soils in Florida. Sand pine naturally occurs on approximately one-half million acres (4). On a substantial portion of

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more than 2 million additional acres of sandhill land in the State, sand pine is the forest tree species capable of best economic growth (1). Sand pines produce usable wood, but the tree form is not one that brings delight to the logger's eye. Stands contain many crooked, limby, medium- to small-sized stems. However, because of projected wood requirements and the need to increase the productivity of the sandhills, there has been a great increase in interest in planting sand pine since 1960. This interest, in turn, brought pressure for the genetic improvement of planting stock of sand pine.

The present paper is concerned with studies of natural variation in tree characteristics of this species and with cooperative efforts to develop improved seed sources.

VARIATION IN TREE CHARACTERISTICS

Data Acquisition

In 1965, personnel from the USDA Forest Service Research Center at Marianna, Florida, the Florida Forest Service, St. Regis Paper Company, and the University of Florida coordinated the search for outstanding sand pine trees and the collection of data to provide a basis of comparison of the trees selected. Superior phenotypes of sand pine were first selected in natural stands on Eglin Air Force Base in west Florida. With approximately 25 excellent trees located, a series of measurements were made of selected trees and of 10 nearby dominant trees of the same species at the site of each selection.

Selections were also made by the same group on the Ocala National Forest and other sand pine stands in that area. In addition, permission was granted for use of a number of selections made independently on the Ocala National Forest by personnel of Region 8, National Forest Administration.

In the stands of each variety--Choctawhatchee and Ocala--of sand pine, measurements of each selected and check tree were made as follows:

1. D.b.h.
2. Total height
3. Lean--the horizontal distance between the bole center at the base and at the top (omitted in stands of the Choctawhatchee variety)
4. Crook--number of deviations from a straight line in the merchantable bole

5. Maximum deviation of the bole --the distance of the bole center at the largest crook from a straight line drawn between bole centers above and below the crook

6. Branch-free length--measured from the base to the lowest living or dead branch or branch stub

7. Limbiness--number of branches between 20 and 30 feet above the base

8. Branch diameter--an estimate of the average diameter of the limbs in major whorls in the lower one-third of the crown (omitted in stands of the Choctawhatchee variety)

9. Branch angle--an estimate of the average angle from the vertical to the branches in major whorls

10. Crown diameter--measured across the widest and narrowest portions of the crown

11. Length of live crown

12. Number of annual rings at breast height

13. Bark thickness at breast height.

Specific crew members were assigned the various measurements or estimates in order to obtain a degree of consistency in values recorded. On the basis of measurements made, certain other characteristics were calculated:

14. Merchantable volume in cubic feet

15. Surface area of conical crowns

16. Crook index--number of deviations per tree multiplied by maximum deviation.

Among the Choctawhatchee variety, 15 stands containing 150 check trees were measured. Similar ‘observations were made on 21 stands and 205 check trees of the Ocala variety.

RESULTS AND DISCUSSION

Data from the two populations were analyzed separately to determine, for each measured and calculated characteristic, the variance among and within stands. Means of the selected and check trees were calculated, and the pooled mean standard deviations within stands of each population were used as a measure of the selection differential (table 1). The means of the check trees were assumed to be representative of the dominant tree populations.

The different variances of the several traits in the two populations reflect, to a large extent, the different stand conditions. The Ocala variety typically grows in dense, even-aged stands in contrast to the less crowded, more uneven-aged stands of the variety in west Florida. Thus, selections of the Ocala variety tended to have somewhat larger crowns than did the crowded, smaller trees surrounding them. In contrast, selections of the Choctawhatchee variety could be found with more volume and more compact crowns than their relatively open-grown checks.

The combined selection for compact *crowns* and large boles could have a compound effect on volume production per unit area. On the assumption that crown spread indicates the area required per tree, a fully stocked stand with crowns the size of the selections of the Choctawhatchee variety would contain 376 trees per acre as opposed to the 221 check trees. If these 376 trees had the same volume per tree as the selections, there would be an increase of 90 percent in volume per acre over a rotation. Although not so striking, similar calculations for the selections of the Ocala variety indicate a 34-percent increase in volume per acre. Even with low heritability of the se traits, substantial increases in production per acre can be anticipated through use of selected sand pine progenies.

The data reported here also agree with the general observations that the form of Choctawhatchee sand pine trees is better than that of Ocala sand pine trees. In all measurements of bole crookedness, the check trees of the Ocala variety scored worse than the Choctawhatchee sand pine population, although it was possible to locate selections in both varieties with very acceptable straightness. Furthermore, many trees in the stands of the Ocala variety have a pronounced lean. This tendency is lacking in the population of the Choctawhatchee variety and was not measured. The west Florida trees tend to be slightly more limby, partially because of their lower stand density, and to have a sharper branching habit.

In addition to distinct differences between the two main populations, analysis of variance indicated highly significant differences among stands in both populations for all traits except branch angle. In other words, if we exclude the selected trees, variation among stands was much greater than within-stand variation. As there were substantial differences in age and

Table 1.--Means and variations of the characteristics of selected and average sand pine trees of two varieties

Trait	Ocala variety				Choctawhatchee variety			
	Selected trees	Check trees	Standard deviation	Selection differential[a]	Selected trees	Check trees	Standard deviation	Selection differential[a]
D. b. h. (in.)	10.5	9.6	1.46	0.61	10.3	-10.1	0.91	0.21
Height (ft.)	70.4	65.1	5.31	1.00	63.9	58.2	3.65	1.57
Bark thickness (in.)	.83	.83	.17	.01	.4	.43	.10	.12
Volume (cu. ft.)	23.5	17.0	7.66	.85	19.2	17.0	3.78	.57
Lean (ft.)	1.3	3.4	2.6	.80	---	---	---	---
Crooks (No.)	.8	3.2	1.5	1.58	1.6	2.4	1.3	.66
Maximum crook (in.)	2.9	12.0	7.6	1.19	1.7	3.7	2.2	.89
Crook index	2.4	41.9	40.7	.97	3.8	11.0	10.9	.67
Branch-free length (ft.)	9.8	6.3	4.3	.81	7.8	4.0	2.1	1.81
Limbiness (No.)	13.9	14.9	4.2	.23	15.5	19.0	3.5	.99
Branch diameter (in.)	1.8	1.8	.5	.07	---	---	---	---
Branch angle (degrees)	65.4	65.3	8.6	.02	47.8	47.3	8.7	.06
Crown radius (ft.)	7.6	7.5	1.6	-.02	7.1	8.9	1.5	1.19
Crown length (ft.)	27.7	26.2	6.3	-.25	24.8	26.1	4.6	.27
Crown surface area (sq. ft.)	744	680	262	-.25	588	799	237	.89
Age (yr.)	34.4	35.5	2.3	.44	36.9	36.0	2.0	-.42

[a] Difference between selected and check trees divided by the standard deviation.

stand density of the various stands, large differences in average size could be anticipated. Such differences in crook measurements are not as easily explained. Similarly large stand differences in the specific gravity of sand pine were previously observed'by the authors. Such distinct stand differences suggest that interbreeding populations of sand pine are quite small in number of individuals and in area, even in the large, continuous total population that occurs on the Ocala National Forest. Such distinct stand differences over relatively short distances are not frequently observed in other southern pine species.

SURVIVAL, GROWTH, AND OTHER TRAITS

In a study of morphological and physiological traits of sand pine under greenhouse conditions, Morris (6) found significant differences among seed sources in response to plant nutrients and a general superiority in first-year growth of the Ocala variety. Similarly, Zelawski and Strickland (8) reported a more rapid weight increase for the Ocala variety. However, both reports mentioned that seedlings of the Ocala variety had a lower survival rate than did those of the Choctawhatchee variety, under experimental conditions and in operational field plantings.

In order to gain further data on the relative survival and growth of seedlings of the two varieties under field conditions, a series of test plantings was established in 1970. In addition to seedlings from representative seed collections from Eglin Field and the Ocala National Forest, a third seed source from'the Withlacoochee River State Forest was used. Test plantings were established on typical sites of deep sand in several east and west Florida locations. Overall planting success was varied and depended upon local weather and site conditions, but superior survival of the Choctawhatchee variety was evident at all locations (table 2). Growth of the surviving trees of the Ocala variety was good; but wood production per acre will be reduced by poor survival.

Worthy of note is the performance of seedlings from the Withlacoochee source. Morris (6) found that, although trees from this area have many similarities to those of the main population of the Ocala variety, they have several distinctly different traits..

Several other characteristic differences between the sand pine varieties have been reported, including cone and seed traits, wood specific gravity, and susceptibility to mushroom root rot caused by Clitocybe tabescens (table 3). Also, ovulate strobili of Ocala sand pines are receptive in late December or early January, whereas peak receptivity for the Choctawhatchee variety is usually 2 or 3 weeks later. Thus, the two varieties have numerous differences of economic or biological importance, and these differences have direct bearing on decisions concerning their genetic improvement.

Table 2. --Early survival of sand pine seedlings from three seed sources

Seed source	Location and planter					
	Volusia County, Florida Forest Service	Volusia County, Union-Camp Corp.	Alachua County, Univ. of Florida	Calhoun County, USDA Forest Service	Walton County, U.S. Air Force[a]	Bay County, St. Joe Paper co. [b]
	Percent survival					
Choctawhatchee	88	49	37	94	90	87
Ocala	60	36	20	68	78	60
Withlacoochee	57	50	14	82	85	75

[a] In the Walton County planting, mean 2-year heights (in feet) were 2.6 for Choctawhatchee, 2.8 for Ocala, and 2.5 for Withlacoochee.

[b] In the Bay County planting, mean 3-year heights (in feet) were 3.4 for Choctawhatchee, 3.8 for Ocala, and 3.7 for Withlacoochee.

Table 3. --Contrasting characteristics of Ocala and Choctawhatchee sand pines

Characteristic	Ocala	Choctawhatchee	Reference
Cone opening	Serotinous	Nonserotinous	Little and Dorman (5)
Seed size	89,800 seed/kg.	109,200 seed/kg.	Morris (6)
	104,000 seed/kg.	123,700 seed/kg.	Barnett and McLemore (2)
Seed color	Dark	Light	Morris (6) Barnett and McLemore (2)
Wood specific gravity	0.439	0.485	Clark and Taras (3)
Susceptibility to root rot	Susceptible	Resistant	Ross (7)

IMPROVEMENT PROGRAMS FOR SAND PINE

A number of excellent phenotypes of both Ocala and Withlacoochee sand pines were added to the original selections, and early selections that scored poorly were deleted. Selections now available, including new ones made in west Florida in 1970 and 1971, for use in the program for the improvement of sand, pine include. the following:

Variety and location	Selections (No.)
Ocala	
Ocala National Forest.	63
Withlacoochee State Forest	11
Outlying stands in Volusia and Clay Counties	12
Choctawhatchee	
Eglin Air Force Base and vicinity	76
Franklin County stands	17

Clonal orchards for both varieties were established by the Florida Division of Forestry and St. Regis Paper Company. These orchards are now producing some cones. Although no data are available on inheritance of important traits in sand pine, we expect, on the basis of results with other southern pine species, that progenies of these orchards will be appreciably better than common planting stock.

In other pines, traits related to stem quality are highly heritable. Because of the selection differentials for sand pine (table 1), we anticipate appreciable improvement in average straightness of orchard progenies along with some increase in natural pruning tendencies. Furthermore, as discussed earlier, growth should be better than with unimproved stock.

Recently, several companies have initiated establishment of sand pine orchards. Because of the problem with initial planting survival of the Ocala variety and its susceptibility to mushroom root rot, improvement efforts are being concentrated'on the Choctawhatchee variety. Both clonal and seedling orchards have been started or are being planned.

Clonal orchards employ established methods of grafting and are similar in design to those of other species. Because of the ability of sand pines to produce cones at a very early age, the species is well adapted to the establishment of seedling orchards and to a rapid turnover of breeding generations. Open-pollinated cones from selections of the Choctawhatchee variety were collected for this purpose,. Seedlings planted at relatively close spacing will be thinned at age 5 years. Supplemental tests will aid selection of the best families, and the best individuals within these families will be left for seed production. We anticipate that controlled pollinations can be made in seedling orchards prior to the 10th year in order to provide seedlings for another round of selection.

Greater attention should be given subpopulations away from the main population centers, particularly subpopulations of the Ocala variety. There is ample evidence of the existence of stands with desired characteristics that are superior to those of the main population of the Ocala variety. Such subpopulations may also lack other deficiencies of the Ocala variety yet retain the growth superiority of the Ocala over the Choctawhatchee variety.

Even without genetic improvement, sand pines have the ability to make reasonable growth on sands too poor for other species. The main de • traction of the species is its scrubby tree form. Even though its natural range is limited, the species has great variability and many good phenotypes have been located. We confidently expect to produce sand pines of greatly improved tree quality and growth.

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FINGERPRINTING SUPERIOR GROWTH IN SAND PINE

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Abstract. --Electrophoretically separated protein from non-superior Ocala sand pines consistently contained fractions that were absent in the protein from superior trees; these 'fractions were between Rf 0.29 and 0.39 of the polyacrylamide gel. Absence of fractions within this range suggests a genetic marker of superior growth. Neither the migration rate nor enzymic activity of glucose-6-phosphate dehydrogenaee or malate dehydrogenaee (MDH) isoenzymes provided a marker for rapid growth in superior sand pines. The migration rate of MDH isoenzymes and protein fractions, the activity of MDH ieoenzymee, and the quantity of protein in protein fractions appeared to be influenced by a number of factors, not least of which were age, environment, soil, and genetics. Hypotheses concerning these factors and that of the genetic marker await confirmation.

INTRODUCTION

Superior wood-producing trees are fast growing and have a desirable morphology. They are sought and propagated principally to ehorten the rotation age of plantations, i. e., the time needed for planted trees to reach an optimum, merchantable size. Selection of superior trees is based primarily on comparisons between the candidate and neighboring trees of the same species and age in the forest. True superiority is adjudged by the ability of progeny of grafted stock to exhibit superior characteristics similar to those of the selected candidate. The approach is sound but very time-consuming.

Much time and work would be saved if candidate trees could be screened for the rapid-growth characteristic before they ever left the forest. This screening should be possible. Tree growth is cumulative and genetically controlled. Assimilation, the.basic growth process, depends upon the speed and duration of certain biochemical reactions. Enzymes are organic catalysts that control the rate of these reactions and the rate at which a tree grows. Therefore, differences between the rate at which superior and nonsuperior trees grow in a given locality should be reflected by the activity of enzymes controlling these reactions. Enzymic activity would thus serve as an index of growth and a means of ascertaining that a candidate tree does have detectable, genetically transmittable attributes for rapid growth.

This paper summarizes results of experiments leading to the possible detection of a genetic indicator of superior growth and to associated factors.

METHODS

Procedures and techniques used in these experiments are tedious but not complicated. Specific details of the methods used with appropriate references are reported elsewhere (1). A synopsis of significant methodology, refe rences, and results follows.

The work was carried out in two parts, The firet eeries of experiments was designed to identify the metabolic pathways' and enzymes involved in the photosynthetic fixation of carbon. Ocala sand pine (*Pinus clausa* var. *clausa* Ward) seedlings grown from nonsuperior tree seed were exposed to radioactively labeled carbon dioxide ($^{14}CO_2$) under controlled time, temperature, and light intensity. Radioactivity of sugars, organic acids, and amino acide in ethanol extracts prepared from green tieeue of seedlings was measured, components of each of the three fractions were identified, and the relative amount of radioactive carbon in each compound was compared.

A second series of experiments meaeured the activity of some of these enzymes in the *green* tissue of five parent trees judged- superior by tree improvement personnel of the University of Florida, private industry, the Florida Forest Service, and the U. S. Fores-t Service and in the green tissue of 25 neighboring parent trees that were nonsuperior. Included in this series of experiments were 50 half-sibling progeny from each superior and non-superior parent tree; half of those progeny were grown in pots of Paola sand and half in pots of Lakeland coarse sand (for a total of 1, 500 half-sibs). Because direct measurement was thwarted by the presence of endogenous polyphenols, quinones, resins, etc., in the extract, the following indirect approach was adopted.

Proteins were extracted from acetone powders of green tissue (5), and these were separated electrophoretically in polyacrylamide gels. Protein fractions were stained with coomassie blue, and the isoenzymes of glucose-6-phosphate dehydrogenase (G-6-PDH) and of malate dehydrogenase (MDH) were stained by using coupled reactions leading to reduced nitroblue tetrazolium. The intensity of the coloration obtained with these techniques is related to the activity of the enzyme (4) and to the quantity of protein (3). Protein fractions and isoencymes were identified by the distance each had migrated througb the gel with respect to a dye front (Rf-value): and were quantified from densitometer tracings of scanned gels. These data. were then analyzed statistically.

RESULTS AND DISCUSSION

In the first series of experiments, the sugar fraction contained 75 percent of the radioactively labeled carbon, organic acids contained 19 percent, and amino acids contained 6 percent. Glucose, fructose, and, to a lesser extent, galactose in the sugar fraction contained ^{14}C, as did malic acid in the organic acid'fraction, and aspartic acid, glutamic acid, and either of the related compounds lysine or arginine of the amino acid fraction.

Sugars constituted the major photosynthates leading to formation of organic and amino acids and, eventually, to protein synthesis.. Thus, the data suggested that the glycolytic pathway, the pentose phosphate shunt, and the tricarboxylic acid cycle were mechanisms for interconversion of these compounds. For this reason, the activity of key enzymes along these biochemical pathways was expected to provide an index of superior tree growth for sand pine.

Isoenzymes and protein bands. are separate entities. Any one can act as a marker of genetic variation between superior and nonsuperior trees. To be meaningful, however, differences must be consistent in tissue from superior and from nonsuperior trees growing on the same soil. In the second series of experiments, none of the three isoenzymes of G-6-PDH nor any of the six isoenzyrnes of MDH provided an index of superiority. The two individual comparisons differed statistically, but neither was consistent for all nonsuperior trees.

Some indication of a genetic marker for superior growth was found in data obtained for the protein fractions, however. The mobility of individual proteins within the gel matrix during electrophoresis depends upon their ionic charge and molecular dimensions (2). All things being equal, proteins from trees of similar genetic constitution can be expected to produce a similar number of fractions and similar patterns of protein separation. Proteins from the superior and nonsuperior parent trees used in this study separated into 17 fractions serially arranged along the length of the gel. The pattern of arrangement differed, however, indicating possible genetic variation. Gels of the protein from superior parents had no fractions between Rf 0.29 and 0.39, whereas protein from nonsuperior parents contained one or more fractions within these Rf limits. The difference was consistent among all parent trees but not among their open-pollinated, half-sibling progeny. This pattern suggests either that a genetic marker for superior growth exists and that genes for rapid growth might be recessive, or that pollen from superior trees fertilized only a small proportion of flowers on neighboring nonsuperior trees and that very little "selfing" occurred on superior trees. The latter seems most probable, because all flowers were open-pollinated.

The aforementioned hypothesis is based upon limited experimentation and needs confirmation. If further testing confirms results of this comparison, a relatively few hours of laboratory work can substitute for the years required by progeny testing.

Just as applied nutrients can stimulate growth of a plant, so can external factors influence physiological processes. Statistical data from these experiments indicated that some of the external factors and some of the isoenzymes and protein fractions affected by them could be identified. Such knowledge provides a useful tool for possible future manipulation of physiological processes.

Indications of causal relationships were suggested in the orthogonal comparisons shown in table 1. The possibility of their existence appears to be supported by the following data.

The first comparison utilized data from tissue of 750 half-sibling seedlings grown in a greenhouse on each of two sandhill soils. Because each sample was comprised of tissue from superior and nonsuperior seedlings, the comparison was actually between soils, i. e., Lakeland sand developed under thermic conditions (LT) and Paola sand developed under hyperthermic conditions (PH). For this reason, significant responses were attributed to SOIL factors.

The second comparison was between tissue from 750. half-sibling seedlings grown in a greenhouse on LT and on PH and that from 30 parent trees growing in situ on hyperthermic sand (OH). Significant responses were

Table 1. --Statistical comparisons of differences in malate dehydrogenase (MDH) isoenzymes and protein fractions from tissue of (A) sand pine seedlings grown on one of two soils and (B) sand pine progeny grown on two sandhill soils and their parents grown in situ.

A. SEEDLINGS GROWN ON LAKELAND (LT) VS. THOSE GROWN ON PAOLA (PH) SAND

MDH isoenzymes significantly greater in one of the two sets of tissue as determined by--		Protein fractions significantly greater in one of the two sets of tissue as determined by--	
Rf value[a/] [b/]	Enzymic activity[b/]	Rf values[a/] [b/]	Quantity of protein[b/]
---------------- Identifying number ----------------			
n. s.	2*, 3*	n. s.	7*, 12*, 14**, 16*, 17*
B. SEEDLINGS GROWN ON LT AND PH VS. PARENTS IN SITU (OH)			
2*, 3*, 4**	n. s.	12*, 16*	2*, 8*, 15**, 12**, 16*

[a/] Rf = $\frac{\text{Distance isoenzyme or protein fraction migrated}}{\text{Distance dye front migrated}}$

[b/] n. s. = No significant difference between the two sets of tissue.

* = 5-percent probability of a chance occurrence of greater Rf value or enzymic activity in only one set of tissue.

** = 1-percent probability of a chance occurrence of greater, Rf value or enzymic activity in only one set of tissue.

[open box] Attributed to soil factors.

[dark shaded box] Attributed to genetic factors.

[dotted box] Attributed to soil and genetic factors.

attributed primarily to GENETIC factors (Sibling vs. Parent) and to a lesser extent to SOIL factors (LT t PH vs. OH). Differences in age of the plants and conditions under which siblings and parents grew undoubtedly contributed to the response, but, because green tissue of the same age and from the sarne parts of the trees was used and because the comparisons were made with the same isoenzymes and protein fractions, these factors were not considered to be as important as genetic factors..

Results of the two orthogonal comparisons show that migration rates (Rf's) of MDH isoenzymes 2, 3, and 4 and of protein fraction 12 and 16 were significantly greater for seedlings grown in LT and PH than for parents in OH (genetic and soil factors). However, Rf's in the LT 'vs. PH comparison (soil factor) did not differ significantly; thus, this lack of insignificant difference suggests that genetic factors affected the migration rate of these isoenzymes and protein fractions much more than soil factors. Accordingly, these factors were labeled GENETIC.

Activity of MDH isoenzymes 2 and 3 was significantly higher in seedlings grown in LT than in PH (soil factor) but was not significant in the LT t PH vs. OH comparison as influenced by genetic and soil factors. This pattern suggests that the activity of MDH isoenzymes 2 and 3 was affected more by soil than by genetic factors; otherwise, significant difference also would have appeared in the latter comparison. Activity of MDH isoenzymes was therefore labeled SOIL.

Similarly, the quantity of protein in fractions 7, 12, 14, 16, and 17 was significantly higher in LT than in PH (soil factor). Here, however, the quantity in fractions 12 and 16 also was significantly higher in the LT + PH vs. OH (genetic and soil factor) comparison, as were fractions 2, 8, and 15. This pattern implies that the quantity of protein in some fractions, e. g. , 12 and 16, was affected more by soil than by genetic factors. In other fractions, it was affected principally by soil, e. g., 7, 14, and 17. And in still other fractions, it was affected principally by genetic factors, e. g., 2, 8, and 15. All were appropriately labeled.

Validity of the SOIL and GENETIC labels was tested with other statistical data. Comparisons of protein fractions and MDH isoenzymes were made between parent trees on OH and those seedlings growing on PH. PH and OH soils are very similar, if not identical. PH was selected as representative of sands on which the parent trees were located. All soils in that area developed under hyperthermic conditions. For these reasons, the influence of soil factors on isoenzymes and protein fractions was considered negligible . Genetic factors (sibling vs. parents) were of primary importance in these comparisons. If the SOIL and GENETIC labels from previous comparisons were correctly assigned, only those isoenzymes and protein fractions bearing GENETIC labels should appear significant in results of the PH vs. OH comparison.

The labels appear to be correct (table 2, column 5). All isoenzymes and protein fractions bearing a GENETIC label and one with a SOIL t GENETIC label were significant. All those labeled SOIL and one labeled SOIL t GENETIC were nonsignificant. The probability that all 13 isoenzymes and protein fractions bearing a single label would be confirmed strictly by chance, if each is considered an independent and mutually exclusive event, as 1 in 8,192.

Table 2. --Statistical comparison of the factors that appeared to influence specific isoenzymes and protein fractions in the previous test (table 1) with the factors determined from tests of parent trees on OH and progeny growing on PH

(1) Isoenzyme or protein	(2) Item	(3) Isoenzyme or protein fraction	(4) Influencing factor and significance[a] (From table 1)	(5) Sibling vs. parents on similar soils[a] (Genetic factor)
		Identifying No.		
MDH	Rf[b]	2	Genetic *	**
		3	Genetic *	**
		4	Genetic**	**
	Activity	2	Soil *	n. s.
		3	Soil *	n. s.
Prote	Rf[b]	12	Genetic *	**
		16	Genetic *	**
	Quantity	2	Genetic *	**
		7	Soil *	n. s.
		8	Genetic *	**
		12	Soil * t Genetic **	**
		14	Soil **	n. s.
		15	Genetic **	**
		16	Soil * t Genetic *	n. s.
		17	Soil *	n. s.

a/ n. s. = no significant difference.
* = 5-percent probability of a chance occurrence.
** = 1 -percent probability of a chance occurrence.

b/ $Rf = \frac{\text{Distance isoenzyme or protein fraction migrated}}{\text{Distance dye front migrated}}$

SUMMARY

Experiments were conducted to find an index of rapid growth in superior selections of Ocala sand pine. Migration rates and activity of electrophoretically separated isoenzymes of glucose-6-phosphate and malate dehydrogenase (MDH) and the migration rate and quantity in protein fractions from superior and nonsuperior pines were compared. Differences in the migration rate of protein fractions served to differentiate between superior and nonsuperior parent trees but not between their open-pollinated, half-sibling progeny. Some of the factors that appeared to affect the migration rates of MDH isoenzymes and protein fractions, the activity of MDH isoenzyme 8, and the quantities in protein fractions were tentatively identified. Hypotheses concerning these factors and that of the genetic marker await confirmation.

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INTERSPECIFIC HYBRIDIZATION INVOLVING SAND PINE--PAST ATTEMPTS AND FUTURE POTENTIAL [1]

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Abstract. --Previous results of artificially hybridizing sand pine with Virginia pine and with slash pine are summarized. Results to date indicate that it may be feasible. to move sand pine germ plasm into more northerly locations through hybridization with Virginia pine but that tolerance to fusiform rust and mushroom root rot will not be automatically conveyed to slash x sand pine hybrids by their parents. Hybrids between sand pine and other southern pines may be possible, but obtaining commercial production through interspecific hybridization will require long-term investments and commitments.

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INTRODUCTION

Although not now widely used, interspecific hybridization is a technique that eventually must be evaluated in most tree improvement programs. Utility of the technique will depend on a variety of factors, such as the degree and type of variation extant within the species under consideration, the need to develop new types (such as those tolerant to diseases, insects, excessively dry or wet conditions, poor sites, etc.), and the ever present need to increase volume growth and improve wood quality.

It is important to evaluate the potential of interspecific hybridization involving sand pine at this time because of the increasing economic value of the species and because heritable variation in this species of small geographic range and narrow edaphic adaptation is thought to be relatively limited. This paper attempts such an evaluation.

PREVIOUS HYBRIDIZATION RESULTS

Most of the economically important species Of southern pines hybridize naturally, and in many instances artificial hybrids can be obtained rather easily (2). This is especially true for the subsection Australes, which includes such species as loblolly pine (*Pinus taeda* L.), pitch pine (*P. rigida* Mill.), shortleaf pine (*P. echinata* Mill.), longleaf pine (*P. palustris* Mill.), and slash pine (*P. elliottii* Engelm.). On the other hand, members of the subsection Contortae, which includes two pines with southeastern distributions --Virginia pine (*P. virginiana* Mill.) and sand pine (*P. clausa* (Chapm.) Vasey)--are not known to hybridize as extensively. In fact, the only reported hybrid involving Virginia pine is an artificial cross with sand pine (2, 4); one additional hybrid involving the latter species has been reported and that is the interesting inter-subsectional cross of slash x sand pine (9).

Natural hybridization involving sand pine has not been reported to date. This is not surprising considering its limited distribution (3). The shortest distance between populations of sand pine and the related Virginia pine is estimated to be more than 100 miles, although individual trees of Virginia pine may be found closer to sand pine populations (8).

Three successful attempts at artificial hybridization are known. As listed above, one of these is the Virginia x sand pine hybrid and the other two involve crosses of slash x sand pine. It is virtually impossible to determine the total number of attempts that have been made at crossing sand pine with other species because failures are rarely reported. However, Critchfield (2) did list attempts with spruce pine (*P. glabra* Walt.) and Table-Mountain pine (*P. pungens* Lamb.) as unsuccessful. He and Goddard et al. (5) also reported obtaining seed from a cross between sand and loblolly pine, but in both cases the seedlings all died soon after germination.

Information being accumulated about the two varieties of sand pine (Ocala and Choctawhatchee) indicates that differences between them may be greater than originally recognized. For example, there is some indication that the Choctawhatchee variety is more resistant to cold and certain insects and diseases; it also seems able to survive planting operations better than the Ocala variety in certain environments (1, 6). As such superiority becomes better understood, strong consideration must be given to differences between the two varieties in parental selections for hybridization. Experience with other species has shown how vital the selection of parental varieties is to hybrid performance.

A number of crosses have been made with sand pine and other species of pine by personnel of the Hoerner-Waldorf Corporation.[2/] Although many of these were not successful, seed were obtained from several interesting crosses (a partial summary is given in table 1). Plans have been made to have seedlings obtained from these crosses evaluated to verify hybridity by USDA Forest Service personnel at the Institute of Forest Genetics in Placerville, California.

The successful cross between Virginia and sand pine was produced by personnel at the Institute of Forest Genetics (IFG) at Placerville in 1953. Although information about the parents is limited, it is known that the sand pine pollen used was collected near Pensacola, Florida. Seventeen cones eventually were harvested from the cross, and these contained 366 sound seed and 76 hollow seed, for an average of 21.5 sound seed per cone. Such high seed yields compare favorably with the results of many artificial intraspecific crosses, and if generally obtainable would indicate mass production of this hybrid may be possible. Results from the Hoerner-Waldorf Corporation project (table 1) tend to support this possibility in that they show some of the highest seed yields from this cross (e.g., average of 13.1 sound seed/cone).

Seedlings from the IFG Virginia x sand pine cross were planted in two different locations. Six seedlings were established in the arboretum at Placerville, and a test planting that included 50 hybrid and 37 Virginia pine seedlings (open-pollinated progeny from the female parent of the hybrids) was established in the General Smallwood State Park, Charles County, Maryland. Measurements and observations to confirm hybridity and evaluate performance were made at various periods (4). Some of the observations were as follows.

Authenticity of the hybrids was established on the basis of needle, cone, oleoresin, and "flowering" characteristics. At Placerville, five of

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2/ Personal communication from Ray Brown, Hoerner-Waldorf Corporation, Roanoke Rapids, North Carolina.

Table 1. --Cone and seed yield of eight different interspecific hybrid combinations involving sand pine[a]

Hybrid: Female	Hybrid: Male	Different crosses attempted.	Cones at bag removal	Yearling cones	Cones harvested	Total seed	Sound seed	Sound seed/cone
		- - - - - - - - - - - - - - - - -	- - Number - - - - - - - -					- - - - - - - -
P. taeda	x P. clausa	2	23	18	11	438	75	6.8
P. clausa	x P. taeda	2	9	5	4	5	1	0.3
P. banksiana	x P. clausa	6	62	33	28	8	0	0
P. clausa	x P. banksiana	M[b]	36	30	30	565	12	0.4
P. rigida	x P. clausa	3	15	14	10	75	-39	3.9
P. clausa	x P. rigida	2	23	14	9	18	2	0.2
P. pungens	x P. clausa	3	10	4	2	3	2	1.0
P. pinaster	x P. clausa	6	34	13	9	301	65	7.2
P. clausa	x P. pinaster	M[b]	5	6	6	42	0	0
P. echinata	x P. clausa	2	25	20	18	363	29	1.6
P. clausa	x P. echinata	4	22	10	10	51	5	0.5
P. virginiana	x P. clausa	4	84	67	63	1,725	823	13.1
P. clausa	x P. virginiana	6	33	27	26	531	301	11.6
P. thunbergii	x P. clausa	6	233	196	175	1,453	491	2.8
P. clausa	x P. clausa	2	14	14	14	354	178	12.7

[a] Unpublished data, courtesy of Hoerner-Waldorf Corporation.
[b] Number of crosses unknown because a pollen mix was used at least once.

the six hybrids survived for measurement at age 5 when the average height was 5.2 feet; at 10 years, heights ranged from 11.9 to 14.4 feet, with an average of 13.0 feet.

Survival of the Virginia x sand pine hybrids was excellent in Maryland, with 47 trees (94 percent) alive 10 years after planting; survival of the Virginia pine checks was 84 percent. The average height of the hybrids at 6 years was 8.4 feet, which was 15 percent greater than that for the Virginia pine. At age 10, the average hybrid height was 17.6 feet (ranging from 14 to 21 feet), while the average height for Virginia pine was 15.6 feet (ranging from 7 to 19 feet). The hybrids also had larger diameters.

The performance of the Virginia x sand pine hybrids at the Maryland location is important and shows potential. It would not be correct technically to express their performance in terms of hybrid vigor because progeny from the paternal species were not included in the test. Practically, it could be considered as such, however, because sand pine would not be expected to grow well or even to survive that far north. Certainly, the results thus far. indicate the feasibility of moving sand pine germ plasm into more northerly locations through hybridization with Virginia pine; this movement could be of value in improving production on some of the poorer, droughty, deep sand sites.

Hybrids involving slash and sand pines have been produced on two separate occasions. Saylor and Koenig (9) reported the production of such hybrids in a large interspecific hybridization program by the Woodlands Research Department of Union Camp Corporation and the North Carolina State University-Industry Cooperative Tree Improvement Program. The slash pine parents for the crosses were superior tree selections located in the Union Camp Seed Orchard, and the sand pine parents were select trees located in the Ocala National Forest.

Eighteen different parent tree combinations were tried in 1962 and again in 1963, but sound seed were obtained from only three crosses. Average yield of sound seed was a meager 0.5 seed per cone for the slash x sand combinations; reciprocal crosses were a complete failure, with only hollow seed being obtained from a few crosses.

Measurements and observations of the hybrids and open-pollinated progeny from the parental trees of both species were made at 8, 16, and 22 months while the seedlings were' growing in a greenhouse. Verification of hybridity, as based on stem, branch, and needle characteristics, was relatively easy. Growth patterns of the three groups changed noticeably over the 22-month measurement period; at the final measurement the hybrids were the tallest, although they were the smallest at 8 months and intermediate at 16 months. Mean measurements for the hybrid, sand, and slash pine seedlings were 54.6 cm., 51.6 cm., and 46.1 cm., respectively, at 22 months.

After the greenhouse study, the five remaining hybrids were planted in the School of Forest Resources arboretum near Raleigh, North Carolina. When planted during the spring of 1966, the hybrids were quite vigorous and remained so until they were damaged by the cold during the winter; from that time on they declined because of cold damage each year until the last one died in 1970. In 1969 several grafts of the hybrids were made on slash pine rootstock at Savannah, Georgia. Graft survival is 75 percent and growth has been good except that two (out of seven) ramets show signs of incompatibility. Unfortunately, the hybrid grafts are susceptible to fusiform rust, as is their slash pine parent; indications of tolerance that could be provided by the sand pine parents have not yet become manifest.

Although not reported previously, a number of slash x sand pine hybrids have been produced by personnel of the tree improvement program of St. Regis Paper Company. In 1966, crosses involving three different parental combinations were attempted. Again superior tree selections were used, and again the sand pine selections were of the Ocala variety. 'Detailed compatibility data were not recorded, but it was noted that considerable difficulty was encountered.[3] Seed yield was less than 20 percent of results normally obtained from intraspecific crosses for progeny testing. Only one cross produced enough seed for a complete field test, while a second produced just a few seed, and a third produced no sound seed at all. (Subsequent crosses in 1970 and 1971 appear to be producing results similar to the 1966 crosses.)

Test plantings were established in 1969 at two locations in Florida, at the King Forest in Walton County, and in Hamilton County. The plantings in both areas were on very deep sand sites with index values of less than 60 feet (i. e., base 50 years). Ten replications were established at both locations within which 10 tree row plots of the following species were planted: Slash pine (St. Regis - random seed lot), slash pine (University of Florida - uniform check lot), sand pine (Choctawhatchee variety), longleaf pine (general nursery stock from State nursery), and slash x sand pine hybrids from two crosses.

Survival of the slash x sand pine hybrids was 83 percent at 3 years of age (table 2). This survival was slightly higher than that of one group of slash pine (80 percent) and considerably higher than that of all other checks. Height growth of the hybrids was also impressive in that it was equal to the best of the checks (sand pine), with an overall average of 3.6 feet at 3 years of age.

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[3] Personal communication from H. H. Gresham, Southern Timberlands Division, St. Regis Paper Co., Pensacola, Florida.

	plot	plot	plot	plot	plot	plot	plot	plot	plot	plot	plot
	Feet	Number	Feet	Number	Feet	Number	Number	Feet	Number	Feet	Number
I	2.9	10	2.4	2	2.7		2	2.9	8	3.5	5
2	2.5	9	1.4	1	3.6	a	0	3.1	7	2.9	8
3	3.6	3	2.8	2	3.6	4	0	3.6	a	2.7	6
4	3.3	9	3.3	1	3.0	9	1	3.5	9	--	--
5	3.9	6	2. a	6	3.7	7	0	3.3	9	--	--
6	3.0		3.0	5	3.0	4	I	4.0	a	--	--
7	3.4	a	3.7	7	2. a	5	0	3.7	9	--	--
a	3.2	a	2.3	2	1.8	5	1	3.8	10	--	--
9	3.3	9	3.0	4	2. a	4	5	2.9	9	--	--
10	4.1	9	2. a	3	2.7	3.	3	3.9	a	--	--
Avg. / replication	3.3	a.0	2.8	3.3	3.0	5.0	1.3	3.5	a.5	3.0	6.3
WALTON COUNTY PLANTATION											
1	3.7		4.2	5	3.6	4	1;	3.5	8	--	--
2	3.6	8	3.3	6	4.1	3	6	3.7	10	--	--
3	3.0	10	2.5	3	4.1	4	4.	a	10	--	--
4	4.1	9	3.4	7	5.3	a	2	4.2	7	--	--
5	3.4	10	2.7	5	4.0	3	2	3.3	a	--	--
6	2.8	8	3.4	4	4.2	3	3	3.6	7	--	--
7	2.8	9	3.0	8	4.5	3	4	2.4	10	2.6	10
a	2.5	a	3.8	a	4.0	3	7	3.9	7	3.9	9
9	3.4	7	2.8	6	4.4	5	2	3.6	6	--	--
10	4.4	6	2.7	4	3.4	7	4	3.7	8	3.8	7
Avg. / replication	3.4	8.1	3.2	5.6	4.2	4.3	3.6	3.7	a. 1	3.4	a.7
Overall avg. ht.	3.3		3.0		3.6			3.6		3.2	
		Percent		Percent		Percent	Percent		Percent		Percent
Overall survival		80		45		46	25		83		75

a/ Unpublished data courtesy of St. Regis Paper Company.
b/ Because of grass stage, seedlings were too small to measure.
c/ Only enough ● cedlingr of this cross were available for six rows.

The slash x sand pine cross might be a hybrid combination of value, considering its excellent survival characteristics and growth performance, which to date has at least equaled that of the better parent (sand pine). In addition, there is a good chance that the wood specific gravity of the hybrid will be increased significantly above that of sand pine because values for slash pine are so high (e. g., 0.43 versus 0.56 for sand and slash pine, respectively). This is a major objective of the St. Regis Paper Company's hybridization project, but the hybrids are still too small to determine specific gravity.

According to present crossability data, mass production of slash x sand pine F1 progeny may not be economically feasible. However, one means of possibly overcoming this drawback is to go to a system of back-crossing from the hybrid to the sand pine parent. Through proper selection, this system also offers greater opportunity for developing trees that more closely resemble the desired sand pine parents while incorporating the useful characteristics of the slash pine parent.

Results to date indicate that tolerance to fusiform rust will not be conveyed automatically to the slash x sand pine hybrids from the sand pine parent, nor will complete tolerance to mushroom root rot (Clitocybe tabescens) be provided by the slash pine parent. Thus, careful attention must be given these characteristics when selecting parental trees for the initial crosses. As with other features, backcrossing may be the best means of obtaining the desired combination of traits.

Of the verified sand pine hybrids, the Virginia x sand pine combination appears to have the greatest utility in extending the range of sand pine germ plasm into the colder, more northerly regions. Tests involving crosses from superior tree parents seem appropriate for the deep sand sites (especially in the coastal regions) that exist from Florida to Maryland. Although the chance for increasing volume production on these nonproductive sites appears good, little can be done to increase wood specific gravity of the hybrid because the parental species are so similar.

Hybrids between sand pine and other species of southern pines may be possible , considering the fact that one inter-subsectional cross involving sand pine has already been documented and seed have at least been obtained from several others. Crosses of sand pine with shortleaf and loblolly pines could be of special significance for commercial production in southeastern regions of the United States. The possibility of growing loblolly-like trees on the currently nonproductive deep sand sites seems particularly attractive in light of predicted increased needs for wood in the future.

Yet it is important to emphasize again that obtaining commercial production through interspecific hybridization in most cases will require long-term investments and commitments. Initial efforts will almost invariably

Degree of infection by Cronartium fusiforme was evaluated for the Hamilton County plantation. No fusiform rust was observed on the sand and longleaf pine checks, while it was rather prevalent among the slash pine checks (6.2 percent and 35.4 percent of the trees had bole and limb infections, respectively). For the hybrids, 4.8 percent had bole infections while 18.3 percent had limb infections. In this case, it appears that some resistance to fusiform rust may have been provided the hybrids by the sand pine parent.

POTENTIAL USE OF SAND PINE HYBRIDS

Thus far, interspecific hybridization has not been widely used operationally in forestry. This disuse undoubtedly is related to the fact that, historically, wood has been in plentiful supply in many regions of the world and that most economically important tree species contain a wealth of intraspecific variation. As a result, tree improvement efforts have been wisely concentrated on utilizing the within-species variation through selection and breeding programs rather than on improvement through the more costly and time -consuming approach of hybridization between species.

The primary objective of interspecific hybridization is to produce trees with unique combinations of traits not found in the parental species. Such combinations allow these hybrids to be used for specific purposes. Important benefits might be better adaptation to adverse sites, extension of the commercial range of valuable species, greater tolerance to insects and diseases, etc. Certain southern pine hybrids have already demonstrated such benefits. Examples include (a) the pitch x loblolly pine hybrid adapted to sites with poorer soils and colder temperatures than those favorable for loblolly pine, and (b) the loblolly x shortleaf pine hybrid for resistance to fusiform rust.

It is difficult at this time to determine what value interspecific hybridization involving sand pine might have. However, certain factors and conditions indicate that further efforts may be warranted, even though the results are likely to be of greater value academically than they are in immediately enhancing commercial production.

The most outstanding feature of sand pine for production forestry is its ability to grow well on deep, sandy soils where other species do poorly (1, 6, 7). Consequently, it is now recognized as an important commercial species, especially by the pulp and paper industry.

On the other hand, two features that restrict utilization of the species include its limited geographic range and its relatively low wood specific gravity. Through a program of selection and interspecific hybridization, however, these restrictions might be overcome at the same time the above exceptional attribute is exploited.

involve obtaining basic information and developing the stock to use as a basis for possible crosses in future production. Returns on investments are difficult to determine, and during the initial stages there is frequently a high element of risk involved concerning any return at all (except perhaps for academic purposes).

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