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Genecology of Longleaf Pine in Georgia and Florida

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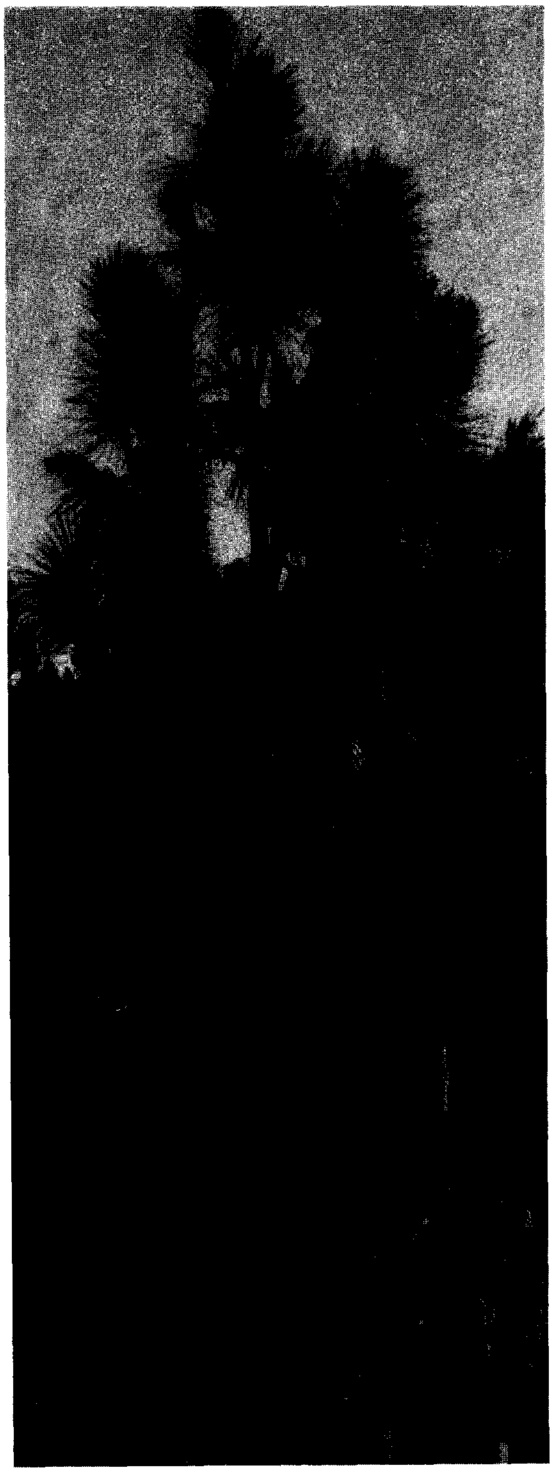

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ABSTRACT

Fourteen seed sources of *Pinus palustris* from Georgia, five from Florida, and one from Alabama were grown at five locations in Georgia and at two in Florida. Data collected through the 15th year in the field show: (1) survival and early height growth were best among the northern sources, possibly related to introgression with *P. taeda*; (2) individual stand or seed source contributed strongly to the components of variation, which could be due to stand history; i.e.; past logging practices; (3) significant seed source x plantation interaction for growth traits, interaction which possibly could be useful in selecting a suitable seed source for a particular site; and (4) a generally broad zone of adaptability in Georgia precludes the necessity for conducting more than one breeding program for longleaf pine for Georgia at this time.

Keywords: *Pinus palustris*, geographic variation, survival and growth traits, adaptability.

Introduction

Longleaf pine (*Pinus palustris* Mill.) constituted much of the pine forest in southeastern North America when European settlers arrived. Extensive lumbering, destructive fires, and difficulties with artificial regeneration have-resulted in conversion of much of the forest acreage once occupied by longleaf pine to other species, such as loblolly pine (P. *taeda* L.) and slash pine (P. *elliottii* Engelm.). Many years of forest management experience have revealed, however, that longleaf pine is better adapted to grow on deep sand sites formerly occupied by the species than are loblolly and slash pines. For this reason, plus the highly favorable timber and wood qualities of longleaf pine, commercial forest-land owners are showing increasing interest in management of the species.

The range of longleaf pine, which extends from southeastern Virginia to eastern Texas, includes over two-thirds of the State of Georgia and more than half of Florida (fig. 1). Approximately 40 percent of the rangewide growing stock is found in these two States. Longleaf pine is of major commercial importance from the Piedmont-Coastal Plain boundary in Georgia south to central Florida. Its commercial importance requires that forest-land owners learn how to plant and manage it successfully. A prerequisite to its successful management is a knowledge of the species' genetic variation.

The objective of this study was to determine the pattern of racial variation in longleaf pine in Georgia, and to supplement the Southwide Pine Seed Source Study by including sources from a north-south transect in Florida to as near the southern limit of the species'

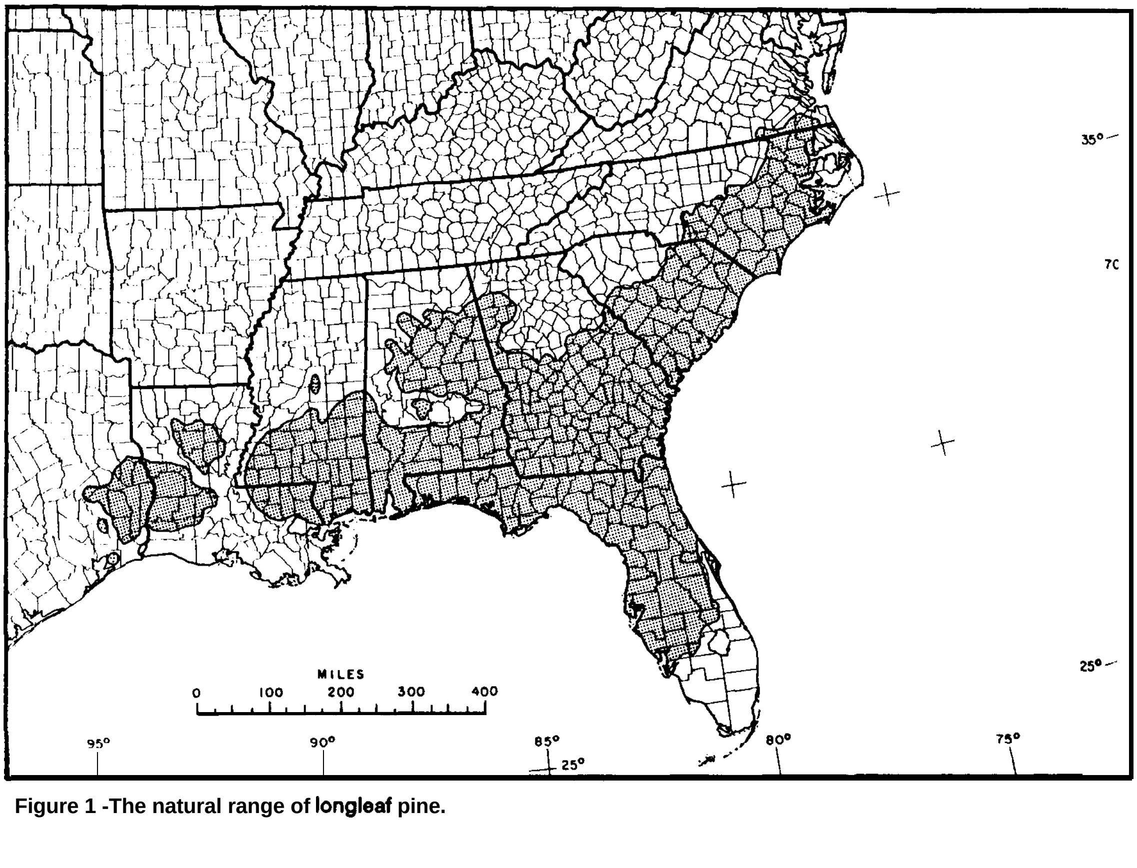

Figure 1 -The natural range of longleaf pine.

range as possible. This study provides the much-needed information previously lacking for this very important portion of the range of longleaf pine.

In 1967, when this research was begun, only two longleaf pine racial variation plantations were located in Georgia. Both of these were in Dooly County and were part of the Southwide Pine Seed Source Study[1]. Each plantation contained only one Georgia seed source, from Treutlen County. All the other known studies containing Georgia sources of longleaf pine were located outside of the State.

Past Work

Survival

Published reports from longleaf pine racial variation studies have generally shown no strong patterns of variation associated with seed source in planting survival of seedlings, Significant differences in individual plantations have been to some extent associated with the performance of one or two seed sources, usually from the extremes of the species' range. A Hillsborough County, FL, seed source, for example, had exceptionally poor survival in several different plantations in the Southwide Study (Allen 1961; Shoulders 1965; Wakeley 1959, 1961, 1963; Wells 1969; Wells and Wakeley 1970). At the other extreme, in a longleaf pine seed source plantation in Nansemond County, VA, the local seed source had the best survival after 6 years (Allen 1961).

Survival differences among the other seed sources in these Southwide Study plantations generally appeared to be random (Bethune and Roth 1960; Collins 1964; Harms 1967; Wells and Snyder 1976). There were, however, significant differences in survival among 10 seed sources planted in Rapides Parish, LA. These differences proved to have a significant relationship with mean annual temperature of the seed source, indicating that it might be safer to move seed from cooler to warmer climates than the reverse (Shoulders 1965; Shoulders and Terry 1968).

In some cases, differences in planting survival among seed sources may be associated with cultural practices in the nursery. In other cases, the mortality is an indication of inherent differences in resistance to brown-spot needle blight, caused by *Scirrhia acicola* (Dearn.) Sigg. (Snyder and Allen 1968).

Growth

The 10- and 15-year results from the Southwide Pine Seed Source Study show that growth of seed sources from the central Gulf Coast Region has been better than that of other sources on most sites, ranging from central Louisiana to central Georgia and north to the Alabama Piedmont. Local sources grew best in areas northeast of central Georgia and west of central Louisiana (Collins 1964; Wells 1969, 1975; Wells and Wakeley 1970). The seed source from Hillsborough County, FL, was consistently slow growing in two plantings, one in Virginia (Allen 1961) and one in central Louisiana (Shoulders and Terry 1968).

In a study in South Carolina, after 10 years there were no significant differences in growth among eight seed sources from the Sandhills and Lower Coastal Plain planted in the Sandhills in 3 consecutive years (Harms 1967). When six coastal Mississippi and six mountain Alabama sources were compared in reciprocal plantings on sites in Mississippi and Alabama, the local sources had the best volume growth after 10 years (Snyder and Allen 1968). After 12 years in a south Mississippi planting, the family-within-area differences were greater than the geographic differences for height, diameter at breast height, and volume growth of longleaf pine progenies from three trees in each of 20 areas in south Georgia, 2 in Alabama, and 1 each in Mississippi and Louisiana (Wells and Snyder 1976).

A longleaf pine seedling seed orchard in central Florida contained 34 families after roguing at 4 years. Fifteen of these families (44 percent) were from the Gulf Coast "optimum zone." Only eight families from the optimum zone were completely or heavily rogued, The orchard originally contained 65 families. Indications were that the optimum zone should include southeast Georgia and north Florida (Rockwood and Kok 1977).

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[1] Working plan for cooperative study of geographic sources of southern pine seed. Committee on Southern Forest Tree Improvement, Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Southern Forest Experiment Station, New Orleans, IA. 35 pp. illus. 1952.

Disease

Most of the longleaf pine plantations in the Southwide Pine Seed Source Study were sprayed during their early years with Bordeaux mixture to prevent infection by the brown-spot needle blight fungus. Four plantings established in southern Mississippi with 16 seed sources were left unsprayed to test for geographic variation in resistance to that disease. After 5 years, there were clear-cut differences: sources from the western and eastern extremities of the range were more heavily infected than those from the central Gulf Coast. Even in the plantations that were sprayed to protect them from brown spot, seed sources from central Louisiana and east Texas were more heavily infected than those from the central part of the range (Bethune and Roth 1960; Wells 1969). Among the seed sources from east of the Gulf Coast optimum zone, there was no pattern to the variation in disease resistance (Henry and Wells 1967). In the reciprocal plantings of coastal Mississippi and Alabama mountain sources, the Alabama mountain sources were significantly more heavily infected by brown spot than the Mississippi sources, probably because there has been little natural selection for resistance to this disease in north-central Alabama where its incidence is low (Snyder and Allen 1968).

Two tests of wind-pollinated progenies from more than 750 individual-tree selections have produced data showing geographic variation in resistance to brown-spot needle blight. In one of the tests, which included 227 selections, the most resistant progenies were produced by parents from Alabama, South Carolina, and Florida and the least resistant progenies were from trees selected in Texas, Louisiana,and North Carolina (Derr 1971). In the other test, 540 wind-pollinated longleaf pine progenies were grown in two plantations in Gulfport, MS, and one in Alexandria, LA. In those plantings, progenies from southwestern Alabama were more resistant to brown-spot needle blight than those from central or southwest Georgia, north Florida, Mississippi, and Louisiana (Snyder and Derr 1972).

Longleaf pine generally is considered to be relatively resistant to the fusiform-rust fungus (*Cronartium quercuum* f. sp. *fusiforme*). Data from three plantations of the Southwide Pine Seed Source Study indicate that sources from east Texas and central Louisiana are more resistant to that disease than are sources from Alabama and central Georgia (Wells and Wakeley 1970).

Other Traits

Although longleaf pine generally is considered to be a straight, well-formed timber tree, it often shows a tendency to fork in young plantations. In the Dooly County, GA, planting of the Southwide Pine Seed Source Study, forking showed significant differences at 5 years but not at 10 years, with some indication that the western sources from Louisiana and Texas might have less tendency to fork than other sources when grown in central Georgia (Bethune and Roth 1960; Collins 1964).

At two locations in southwest Alabama, inherent geographic variation in the production of female flowers was evident in lo-year-old longleaf pines from 11 seed sources, ranging from Texas and west Florida to North Carolina. Trees from a Richmond, NC, seed source produced over 70 percent of the female flowers counted at age 10 in the study (Boyer and Evans 1967).

Variation in root morphology of longleaf pine seedlings from 20 Georgia sources has been studied. Results showed that seedlings from sources in eastern Georgia had more fibrous root systems than those from west of a line between Laurens and Echols Counties (Snyder 1961).

Allen and McGregor (1962) detected no differences in growth under long and short photo-periods among longleaf pine seed sources in a greenhouse study. The seed sources used did not cover a wide range of latitudes, however, and since the study was discontinued after 6 months, the results may not be considered conclusive.

This review of the literature reveals a rather sketchy picture of the geographic and local genetic variation in longleaf pine. Particularly noticeable is the paucity of information for Georgia. The purpose of this study is to more completely fill in the picture for this very significant portion of the range of the species.

Materials and Methods

Seed Collections

Seed collections in Georgia were by physiographic province. Three collections were made in each of the Flatwoods, Lower Coastal Plain, Upper Coastal Plain, and Sandhills Provinces; two collections were made in the western Piedmont Province. Five collections were made in Florida to sample the latitudinal variation of the species in that State. The Baldwin County, AL, source was included for a further test of its performance. In total, there were 20 seed sources (fig. 2).

Cones were obtained at each location from at least 15 representative trees and from up to as many as 26 trees at one location. Cones were kept separate by individual tree. Usually, 15 to 20 cones per tree were collected.

The seeds were extracted by hand, kept separate by individual tree, and stored at -7 °C until used. Samples of winged seeds were saved, on which the seed wing lengths and widths were measured. Data were obtained from an average of 8 wings per tree from 20 trees in each of 16 seed sources and from 21 and 26 trees in two of the other sources.

For the major part of the study, bulk seedlots were made up for each source. Except for the Pasco County, FL, source, bulk seedlots were cornposited from 42 grams of seed from each of 20 individual trees per seed source. Due to relatively low seed yields from the Pasco County collection, almost all available seed from those 25 trees was used in making up that bulk seedlot.

Each of the bulk seedlots was divided into two parts. The Florida Forest Service received one part, consisting of 225 grams per seed source, for sowing in the Andrews Nursery near Chiefland, FL The Georgia Forestry Commission received the other part of each lot for sowing in the Morgan Nursery near Byron, GA.

Nursery Procedures

The bulk lots from 20 seed sources were sown in the Morgan Nursery in November 1968. Three seedbeds that had been fumigated with methyl bromide were used, with each seedbed serving as a nursery replication. The seed sources were randomized within each replication, and each source was broadcast-sown on a 15-foot section of nursery bed.

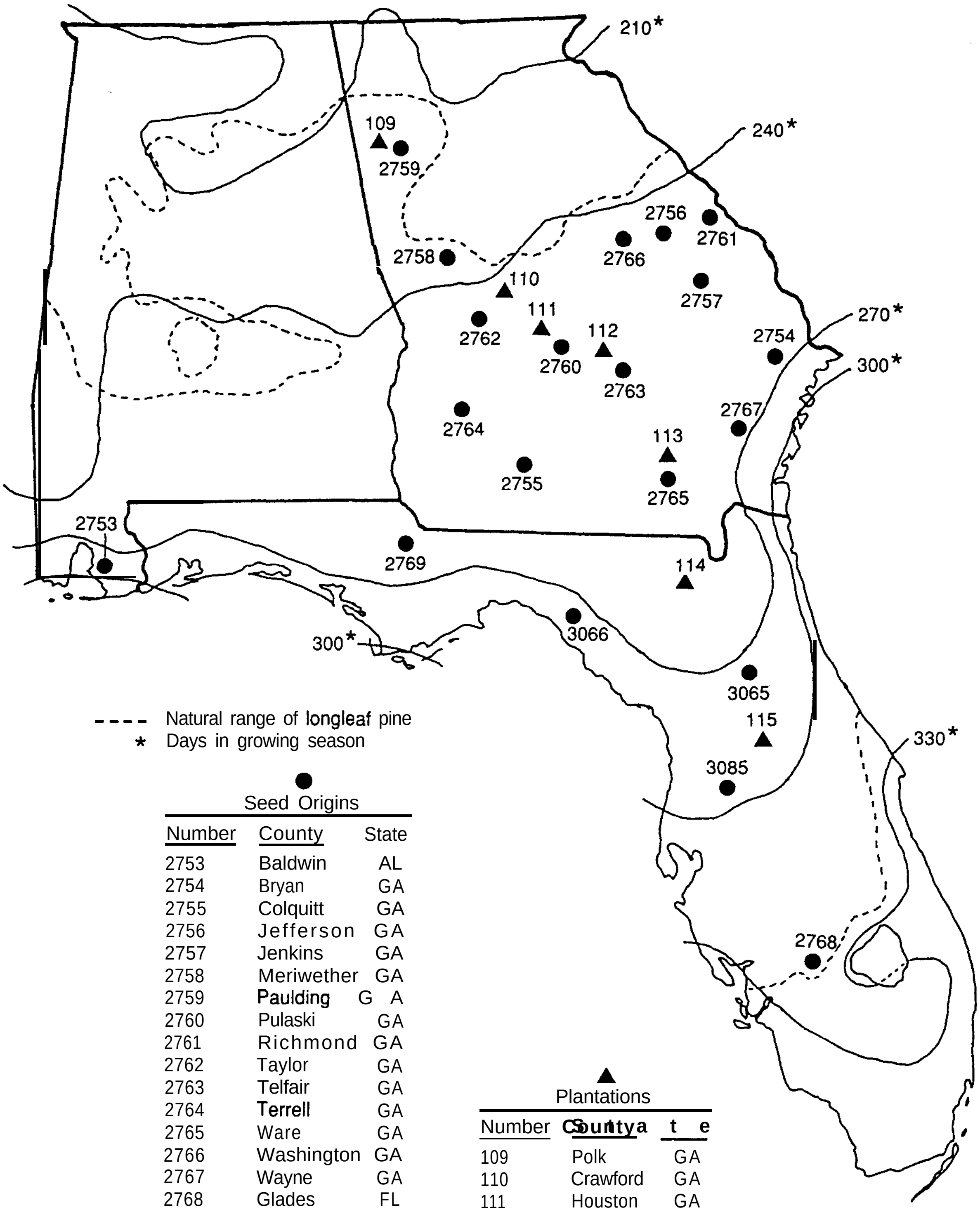
In addition to the bulk lots, seeds from 313 of the individual-tree lots were sown in two replications. In the first replication, which occupied one bed, each individual-tree seedlot was sown in a single row across a 4-foot bed, with the seed source locations randomized and the individual-tree lots randomized within locations. The second replication of the individual-tree lots occupied two nursery beds; the same randomization was used, but, instead of single rows, the seeds of each seedlot were broadcast over an area equivalent to two rows in the first replication.

Watering, weeding, and nursery culture generally followed standard nursery practices. In the late spring of 1969, the bulk seedlots were hand-thinned to a density of approximately 15 seedlings per square foot.

In both bulk and individual-tree lots, seedlings having normal green cotyledons but yellow primary foliage were tallied and marked after germination was complete in the spring. Root injury caused by a root parasitic nematode, *Tylenchorhynchus claytoni*, was severe in some seedlings. Badly injured seedlings were discarded during lifting, but some mortality following planting may have been due to this pest.

Sonderegger seedlings (the longleaf x loblolly F-l hybrid) were tallied in September 1969 in the individual-tree progenies. They were not discarded during lifting and planting but were treated as part of the population being studied.

In the fall of 1969, differences in seedling needle length in the nursery were obvious. Consequently,



Seed Origins

Number	County	State
2753	Baldwin	AL
2754	Bryan	GA
2755	Colquitt	GA
2756	Jefferson	GA
2757	Jenkins	GA
2758	Meriwether	GA
2759	Paulding	GA
2760	Pulaski	GA
2761	Richmond	GA
2762	Taylor	GA
2763	Telfair	GA
2764	Terrell	GA
2765	Ware	GA
2766	Washington	GA
2767	Wayne	GA
2768	Glades	FL
2769	Jackson	FL
3065	Marion	FL
3066	Taylor	FL
3085	Pasco	FL

Plantations

Number	County	State
109	Polk	GA
110	Crawford	GA
111	Houston	GA
112	Laurens	GA
113	Ware	GA
114	Baker	FL
115	Lake	FL

Figure 2-Location of longleaf pine seed sources and planting locations.

needle-length data were collected by measuring 15 needles in each plot of the bulk seed-source lots and 10 needles per plot of 10 individual-tree progenies in each seed source. In addition, seedlings were obtained in the spring of 1970 from the other sowing at the Andrews Nursery, and needle length was measured on an average of 20 seedlings per seedlot from each of the three replications there.

Only seedlings from the Georgia nursery were used for outplanting. Seedlings for each plantation were lifted separately, a day or two before planting. Seedlings from each seedlot were tied in plot-size bundles, tagged, assembled into field replications, and wrapped with wet moss in moisture-barrier paper.

Planting Location and Design

Seedlings from the bulked seedlots were outplanted December-February 1969-1970 at seven locations – five in Georgia and two in Florida. In Georgia, one planting was established in each of the five physiographic provinces. In Florida, the plantings were located in the northern and central portions of the species' range (fig. 2). Each planting was a randomized complete-block design with six replications of 25-tree plots planted in squares of 5 x 5 trees. Spacing between trees was 2.5 x 2.5 meters. A two-row isolation border was planted around each plantation. There were not enough seedlings of seedlot 3085 (Pasco County, FL) to plant this source at all locations, so it was used only in the Georgia Upper Coastal Plain and central Florida plantings. The most nearly local seed source was substituted for seedlot 3085 in the six remaining plantings.

Field Data Collection

The first year after planting, survival was counted at all plantations. The second year after planting, the number of living trees and the number of trees that had begun height growth were counted in four of the plantations: Crawford County (Sandhills), Houston County (Upper Coastal Plain), and Laurens County (Lower Coastal Plain), GA, and in Baker County, northern Florida.

Data recorded for all plantations at 5 years after planting were: survival, total height, number of years out of the 'grass stage' (0.2 foot or taller) for the trees that had begun height growth, and percentage of brown-spot infection. The average annual height growth rate was calculated for all trees that had begun height growth.

At 10 years, total-tree height and diameter at breast height were measured; fusiform-rust infections per tree were counted; and trees having forks, ramicorn branches, and broken tops were recorded. Average annual height growth rate between the 5th and 10th year; tree volume; and percentages of trees with fusiform rust, forks, and ramicorn branches were calculated. Field data collected at 15 years were on the same traits as at 10 years.

Data Analysis

All percentage data were analyzed after transformation to the arc sine $\sqrt{\%}$. Differences among seed source means and among province means were tested for significance by analysis of variance (ANOVA) and Duncan's multiple range test. Principal components analyses were used to identify seed sources that stood out from the general population.

Results

Seed Wings

Harlow and Harrar (1958) in their dendrology textbook described the seed wing of longleaf pine as 'striped and used such a wing in their illustration. In the collections made for this study, trees with striped seed wings occurred with a much lower frequency than those having solid-colored wings (table 1). There appeared to be no latitudinal or other pattern to the variation in wing pigmentation.

ANOVA of the seed wing measurements showed highly significant differences among individual trees within source for seed wing length, width, and the width/length ratio for all 18 seed sources evaluated for the traits. ANOVA among sources showed highly significant differences for the width/length ratio only, and principal components analysis indicated that most of the variation was due to the relatively short seed wings of the Glades County, FL, source (fig. 3).

Nursery Observations

Xanthescens – Seedlings having normal green cotyledons but yellow primary foliage (xanthescens) were tallied in the spring after germination was complete. There was no clear geographic pattern to their occurrence (table 2). The relatively higher frequency of xanthescens seedlings in the Taylor and Washington Counties, GA, sources was probably due to individual-tree carriers.

Hybrids-Although there was considerable variation in their frequency within seedlots, Sonderegger seedlings were found only in Georgia progenies from the Piedmont, Sandhills, and Upper Coastal Plain (table 3). Presumably,the possibilities for hybridization of *P. palustris* with *P. taeda* are greater in these areas of species range overlap combined with possible overlap in flowering time (Boyer 1978).

Seedling Needle Length

ANOVA's of all three sets of needle-length data showed highly significant differences among seed-source means. The average needle lengths of seedlings from the Piedmont, Sandhills, and Upper Coastal Plain sources were shorter than those of the Lower Coastal Plains, Flatwoods, and Florida sources (table 4).

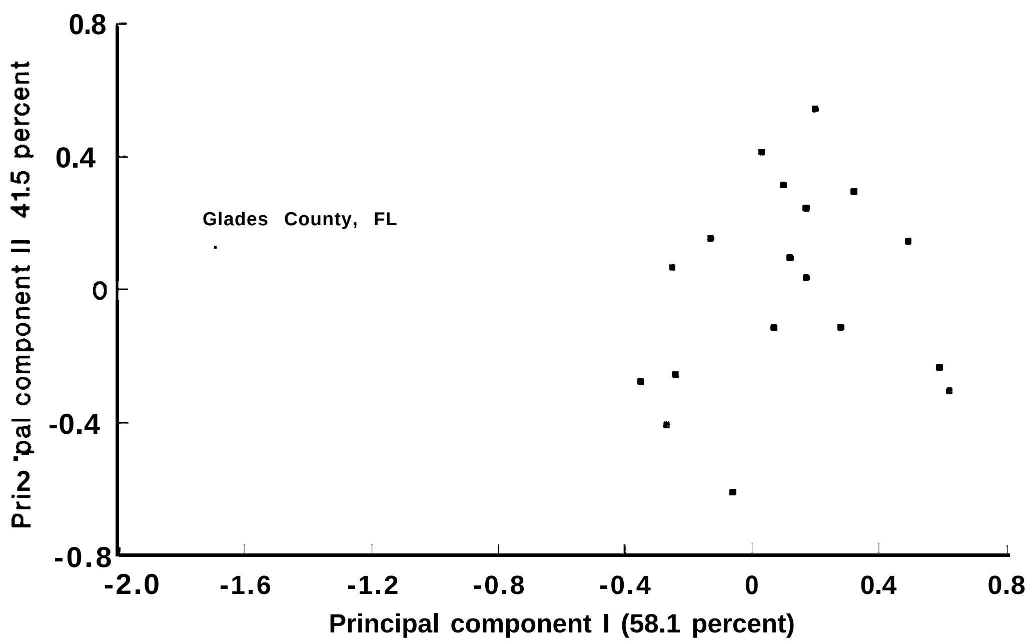
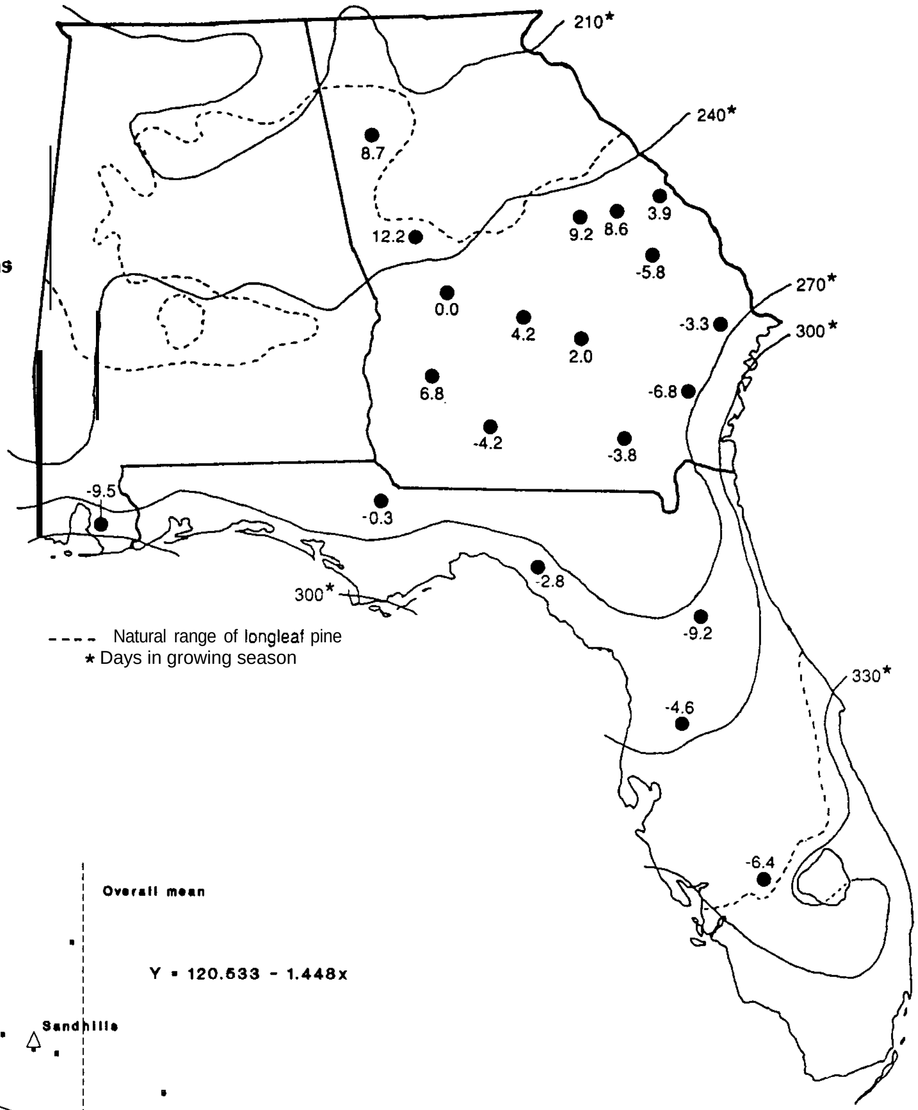


Figure 3-Principal components analysis of seed wing measurements of longleaf pine.

Figure 4—Seedlot mean first-year survival averaged over all plantations and plotted as deviations from the grand mean (percent).



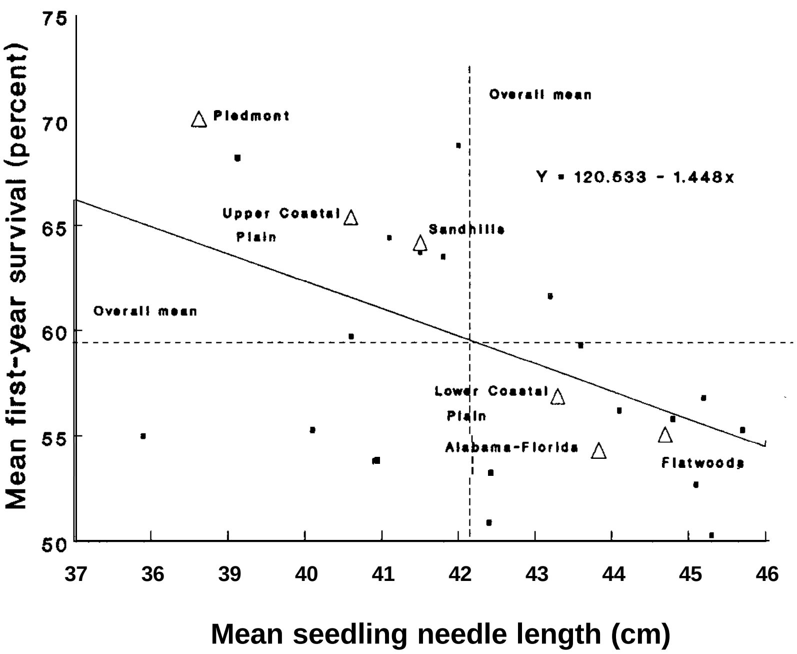


Figure 5—Regression of mean first-year survival on mean seedling needle length. A = mean of physiographic province.

First-Year Survival

Analysis of first-year survival showed the greatest source of variation to be that among plantations. Among seed sources, the best survival over ail plantations was in sources from the Upper Coastal Plain and northward (table 5). A small but highly significant source x plantation interaction probably was due to the poor survival of Lower Coastal Plain sources in the plantation in central Florida. The deviations of the individual seediots from the survival grand mean are shown in figure 4, plotted at the seed source locations; the minus deviations are predominantly from the southern seed sources. The regression of first-year survival on seedling needle length was significant at the 5-percent level of probability ($r^2=0.30$; fig. 5).

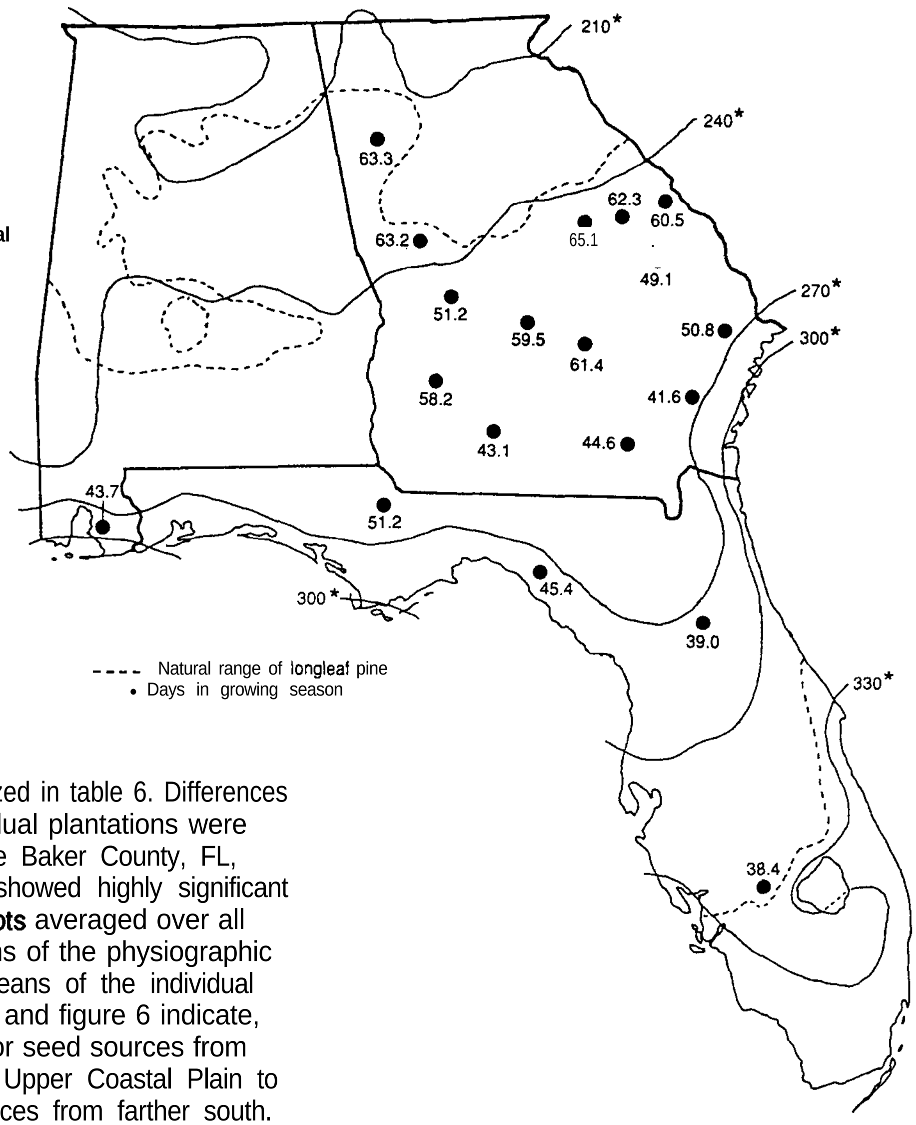


Figure 6—Seedlot mean second-year percentage survival averaged over the plantations in Crawford, Houston, and Laurens Counties, GA, and Baker County, FL.

Second-Year Results

Survival at 2 years is summarized in table 6. Differences among seedlots in the individual plantations were highly significant except in the Baker County, FL, planting. Combined analysis showed highly significant differences among the seedlots averaged over all plantations, among the means of the physiographic provinces, and among the means of the individual outplantings. As both table 6 and figure 6 indicate, there is a definite tendency for seed sources from the Piedmont, Sandhills, and Upper Coastal Plain to survive better than seed sources from farther south.

The percentage of trees out of the 'grass stage" 2 years after planting showed highly significant differences among the seedlots and significant differences among the means of the physiographic provinces when averaged over the four plantations in which this trait was studied (table 7). Differences among seedlots were significant within three of the four plantations. The tendency for seedlots from the Upper Coastal Plain, Sandhills, and Piedmont to have a higher percentage of seedlings out of the 'grass stage" at this early age was rather distinct (fig. 7).

Fifth-Year Results

Fifth-year data summaries for survival, number of years out of the 'grass stage,' total height, and height growth rate are shown in tables 8-l 1. Differences among outplanting locations were highly significant for'all four traits, Variation among seedlots within province was highly significant for all traits, while that among province means was significant only for survival.

For survival, there were highly significant differences among the seedlots and among the means of the physiographic provinces averaged over all plantations (table 8). The same trend existing after the first and second years was still evident: the Upper Coastal Plain, Sandhills, and Piedmont sources had higher survival than seed sources from farther south.

Most of the seed sources apparently came out of the 'grass stage' during their third year in the field. Based on averages over all plantations, the differences among seed sources were highly significant, but the differences among the means of physiographic provinces were not significant (table 9).

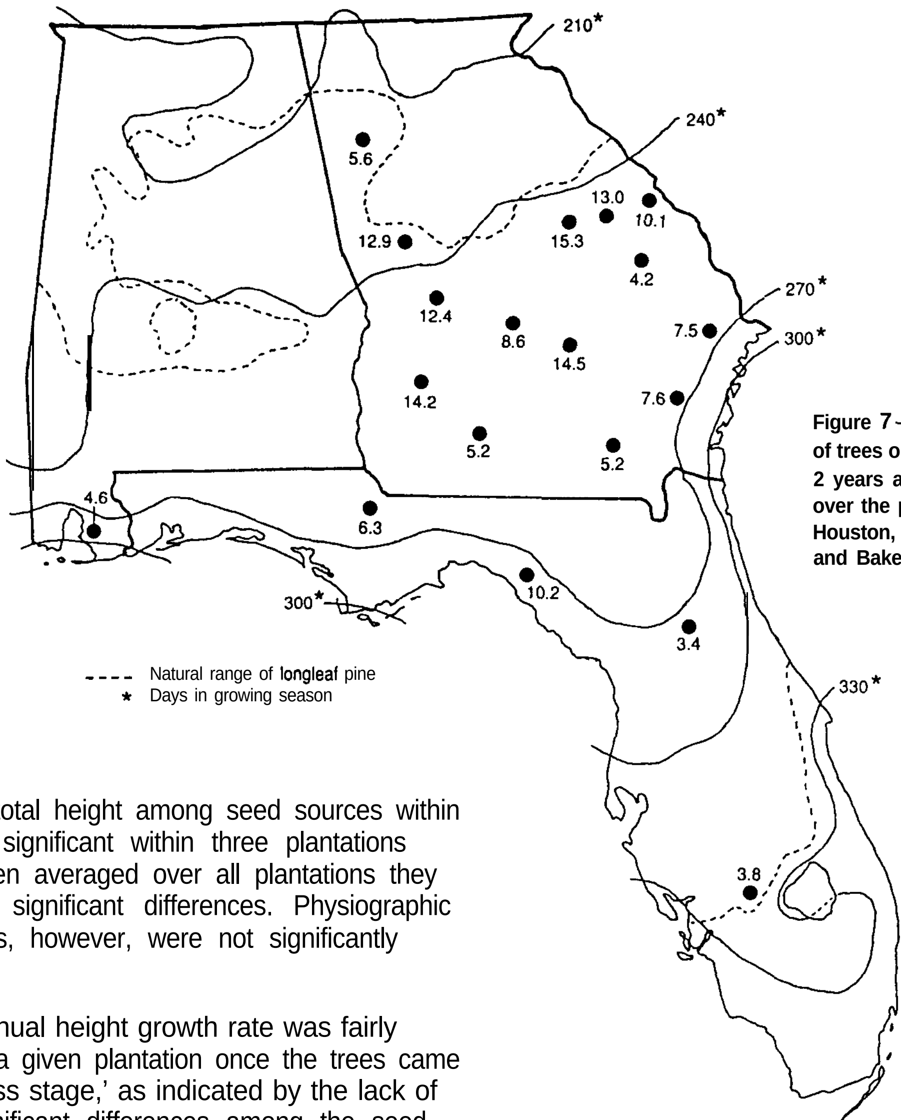


Figure 7—Seedlot mean percentage of trees out of the 'grass stage' 2 years after planting averaged over the plantations in Crawford, Houston, and Laurens Counties, GA, and Baker County, FL.

Differences in total height among seed sources within province were significant within three plantations (table 10). When averaged over all plantations they showed highly significant differences. Physiographic province means, however, were not significantly variable.

Apparently, annual height growth rate was fairly uniform within a given plantation once the trees came out of the 'grass stage,' as indicated by the lack of statistically significant differences among the seed sources at any of the individual plantations (table 11). Based on the means over all plantations, however, differences among seed sources were highly significant but did not show any significant relationship with physiographic province.

No significant interactions were noted between plantations and physiographic provinces for any traits at age 5 years, indicating that the relative performance of the provinces was similar at the different plantation locations. Interaction between plantation and seed source within province for total height and survival was highly significant, however.

During the 5th-year assessment, 15 trees were tallied as putative hybrids, based on needle length and crown form; 13 of these were from Piedmont, Sandhills, or Upper Coastal Plain seed sources and were probably natural longleaf x loblolly crosses. Of the other two hybrids, one was from Marion County and the other from Glades County, FL. The hybrid from Marion County could be longleaf x loblolly since both species occur in that area, but the Glades County hybrid is probably a natural cross between longleaf pine and South Florida slash pine (*P. elliottii* var. *densa* Liile & Dorman).

Tenth-Year Results

When the 10th-year data were combined over all plantations, percentage of survival was the only trait showing a significant difference among provinces (table 12). The three northern provinces (Piedmont, Sandhills, Upper Coastal Plain) all had better survival than the overall mean. Based on the combined data, differences among seed sources within province were highly significant for survival, average height, average annual height growth, average individual-tree volume, and percentage of fusiform-rust infection. Also significant were differences among sources for percentage of trees with forks.

The tallest seed sources were from the Georgia Lower Coastal Plain and northwest Florida. If survival and average tree volume also were considered, the best seed sources were those from the Upper Coastal Plain of Georgia.

A principal components analysis based on survival, height, height growth rate, diameter, and volume over all plantations showed the most northern seed source from Paulding County, GA, and the two most southern seed sources from Pasco and Glades Counties, FL, to be farthest removed from the general grouping of the other seed sources (fig. 8).

In the individual plantations, variation in growth rate was quite evident among the seed sources, with the fastest growing sources at any one planting location seldom including the local source. There was, however, a slight indication of a north-south trend in growth rate. The eight fastest growing seed sources in the Piedmont plantation originated at an average latitude of 32°58'N, while the average latitude of the seven fastest growing seed sources in the central Florida plantation was 30°51'N.

Fusiform-rust infection was relatively heavy in the Upper and Lower Coastal Plain plantations, averaging 56 percent in the former and 12 percent in the latter. Both locations showed highly significant differences among the seed sources but not among physiographic provinces (Kraus 1985). The three most southerly sources from Marion, Pasco, and Glades Counties in Florida had the lowest fusiform-rust infection.

Fffteenth-Year Results

The survival data combined from all the plantations showed significant differences among the physiographic provinces of seed origin (table 13). The Piedmont, Sandhills, and Upper Coastal Plain seed sources had the best survival. Differences among the individual seed sources were highly significant. The seed source from Glades County, FL, was significantly lower in survival than any of the others. No significant differences were associated with the physiographic province of seed origin for any of the other traits.

Differences among individual seed sources for height, average annual height growth, and average individual-tree volume (table 13) were highly significant. The

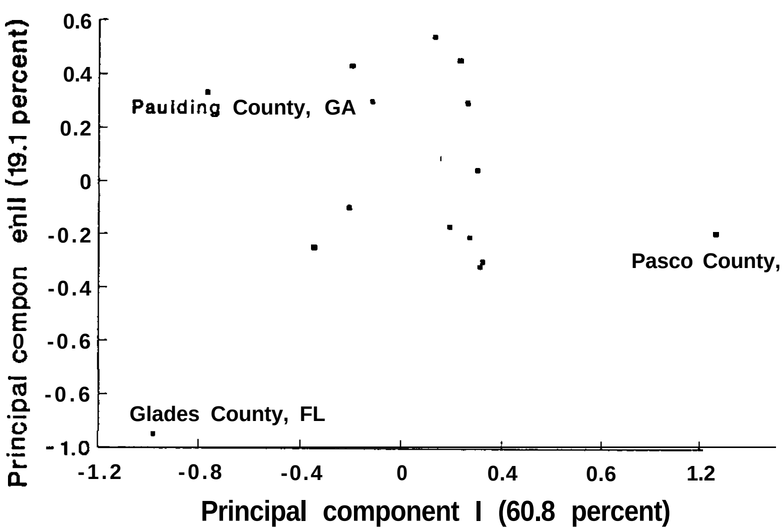


Figure 8-Principal components analysis of geographic sources of longleaf pine based on 10th-year survival, height, height growth, diameter, and volume over all plantations.

Pasco County, FL, seed source was significantly taller than any of the others. Average annual height growth was slowest in the Paulding and Meriwether Counties, GA, sources and in the Glades County, FL, source. The Paulding and Meriwether Counties sources also had the lowest average individual-tree volumes.

Fusiform-rust infection was severe in the Upper Coastal Plain plantation, with an average of 70 percent of the trees having stem and/or branch infections. It also was a problem in the Lower Coastal Plain plantation, with an average infection of 24 percent. Over all plantations combined, there were highly significant differences among the individual seed sources in fusiform-rust infection. The seed sources having the lowest rust infection were from Glades and Pasco Counties, FL.

Significant interaction was observed between plantation location and physiographic province of seed source for height, diameter breast height, and volume (table 14). This interaction is illustrated by the differential growth of the seed sources from the Piedmont vs. those from Florida (fig. 9). Also, there was highly significant interaction between plantations and individual seed sources for survival, height, average annual height growth, and volume (table 15). Again, the interaction was associated with the differential response of the northern vs. the southern seed sources when planted at the northern and southern extremes of the species' range.

The occurrence of forking also showed significant interaction between plantation and source province. As at 10 years, seed sources from the northern provinces tended to have the highest percentage of forking overall, but the interaction occurred in the sources from the Upper Coastal Plain, the Flatwoods, and the Sandhills.

Discussion

What sort of genetic differences should we have expected among populations of longleaf pine? The species occupies a range without great extremes of temperature. In the northern part of Georgia longleaf pine is subject to freezing temperatures yearly, and

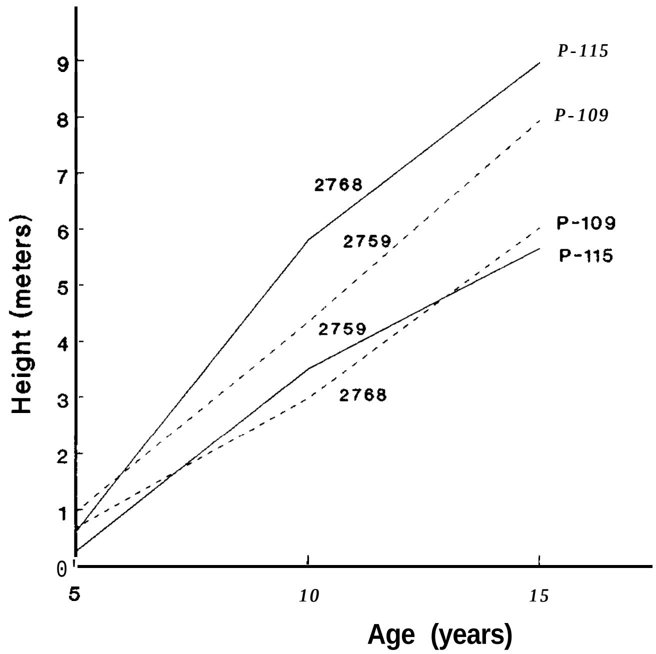


Figure 9—Comparison of the most southern (2768) and most northern (2759) seed sources at the most southern (______) and most northern (-----) sites. At both locations the local seed source has grown better than the others.

light snow or ice is not uncommon. Except at its most southerly occurrence, freezing temperatures are likely to occur at some time during the normal lifetime of a tree as shown by the recent (1984-l 985) repeated devastating cold damage to the citrus groves as far south as Orlando, FL. Throughout the longleaf pine range east of the Mississippi River, rainfall seldom is limiting and soil moisture would only be a factor on sites so wet that longleaf could not compete with slash pine or hardwoods, or on the most extreme sandy soils occupied by sand pine (P. *clausa* (Chapm. ex Engelm.) Vasey ex Sarg.). Most of the longleaf pine range is below 500 feet (152 m) elevation in a region in which changes in elevation are more likely to be associated with differences in soil type than with climate. Undoubtedly the combined effects of temperature, rainfall, soils, and elevation exert some genetic selection pressure on longleaf pine, but it has not likely produced extremes of variation among seed sources.

A significant factor with which longleaf pine must contend for survival is brown-spot needle blight, and there is evidence for marked differentiation in susceptibility to this disease among longleaf pine seed sources. Wells and Wakeley (1970) reported high infection in Texas and Louisiana sources. The Glades County, FL, source was highly susceptible in this study (Kraus 1986).

Another potentially significant source of genetic variation in longleaf pine is its ability to hybridize naturally with both loblolly pine (Chapman 1922) and slash pine (Perry and Wang 1957). In general the separation of flowering times is greater between longleaf pine and slash pine than between it and loblolly pine, so the possibility of introgression with slash pine is much less than with loblolly. The natural hybrid with loblolly is much more common than with slash. There was some evidence of hybridization with loblolly in the cones collected for this study. At least one tree from Meriwether County (2758) had typical longleaf foliage and buds but smaller than normal cones with spinosity and color resembling loblolly pine, and collections from two trees in Pulaski County (2766) had cones which were not typical for longleaf pine. Concrete evidence for longleaf x loblolly pine hybridization was found in the nursery (table 3). It should be noted that all of the Georgia hybrids were in sources from Piedmont, Sandhills, or Upper Coastal Plain collections. Early descriptions of the southern pine forests emphasize that the 'pine-barren flats' (Flatwoods) and the 'rolling pine hills' (Lower Coastal Plain) were dominated by Savannah-like stands of longleaf pine (Mohr 1897, Plate 1), while in the 'belt of mixed growth' (Upper Coastal Plain) loblolly pine and shortleaf pine (P. *echinata* Mill.) were the dominant species. Given their interspecific crossability and the mixed character of the virgin stands, it is easy to suggest that the needle lengths measured on the seedlings (table 4) reflect past and present introgression of longleaf and loblolly pines.

Another potential source of genetic differentiation in longleaf pine is past logging history. One of the larger sources of variation in this study was the differences among seed sources within physiographic province. Such differences could be the result of timber harvests conducted in such a way that the subsequent regeneration was largely from trees genetically inferior for growth and timber characteristics (dysgenic selection) on some areas and from average or better trees on other areas.

One might expect to find evidence of longleaf x loblolly pine introgression in the seed wing data, but such was not the case. Seed wing striping was obviously an individual-tree characteristic not associated with geographic seed source. The seed wing measurements showed no evidence of shorter or slimmer seed wings resembling loblolly pine among the seed sources from the Piedmont, Sandhills, or Upper Coastal Plain.

Additional evidence of possible longleaf x loblolly pine introgression comes from the nursery measurements of seedling needle lengths (table 4), where the more southerly seed sources show a distinct tendency to have longer needles than the sources from the part of the range where loblolly pine is the dominant species. The major exception was the Pasco County, FL, source-which had germinated poorly in the Morgan nursery and produced only enough seedlings to be used at two planting locations.

The survival data for the first 5 years (tables 5, 6, 8; figs. 4, 6) correlate well with the nursery needle-length data (fig. 6) and tend to support the idea that the northerly sources of longleaf pine contain some loblolly pine genetic material. With survival, there could also be an element of climatic selection involved. Longleaf pine seeds generally germinate soon after seedfall and overwinter as seedlings, growing a taproot when temperatures are favorable. It is conceivable that natural selection for cold and drought tolerance could take place during the seedling stage, and that seedlings having some level of interspecific hybridization would be more likely to survive.

The ability to tolerate adverse conditions early in life may carry over for a year or two. Although most of the differences in number of years out of the 'grass stage' (YOG) at age 5 were among seed sources within province, the more northerly seed sources tended to begin height growth younger than those from farther south. This ability to get an early start in height growth is important and has long-lasting effects. There is a highly significant correlation (R = 0.66) between YOG and average 15th-year height, but not between YOG and growth rate between 10 and 15 years.

It will probably be several more assessment intervals before the results of this study will be conclusive. Some of the seed sources are still growing well at the most northern site (fig. IO), but the height growth of both the fastest and slowest growing sources has apparently culminated (fig. 11) at the most southern site. The strong effect of planting site is evident in the growth of the most southern and most northern seed sources, both of which have slowed down in their height growth rates at the very sandy, well-drained Sandhills and central Florida locations (figs. 12, 13). Other seed sources also seem to be slowing down; at the most fertile site (Upper Coastal Plain), and at the poorest site (Sandhills), both the fastest and slowest growing seed source at each location appear to be slowing in their height growth (fig. 14).

To better define the interaction between seed source and plantation for height growth, the average latitude of the tallest seed source in each plantation was regressed on the plantation latitude. This regression was done for ages 10 and 15 years. The results show that the farther north of latitude 31°36' N. a plantation was located, the farther south of the planting site was the average latitude of the best seed source (fig. 15). The inverse applied to plantations south of latitude 31°36' N., with the average latitude of the best seed sources in the most southerly plantation being almost 2° north of the planting location. Based on these results, an optimum seed collection zone for longleaf pine to be grown in Georgia would lie between 30°39' N. and 32°30' N. (fig. 16).

Based on these growth data, it is possible to use figure 17 to locate an approximate area from which to obtain seed for a given planting location. For example, with a proposed planting site at latitude 30° N., one would want to go 1 .0° north for seed, always keeping in mind the strong effect of individual stand variation. For a planting site at 33° N., one would look about 0.9" south for seed, remembering that survival might be somewhat lower with a southerly seed source.

One of the objectives of this research was to determine the necessity of establishing separate longleaf pine breeding programs for different parts of Georgia. At this time, that does not seem necessary. The optimum zone shown in figure 16 is quite broad, and the variation among seed sources within province is so great that a longleaf pine breeding population for Georgia can include trees from good stands anywhere in the lower half of the State.

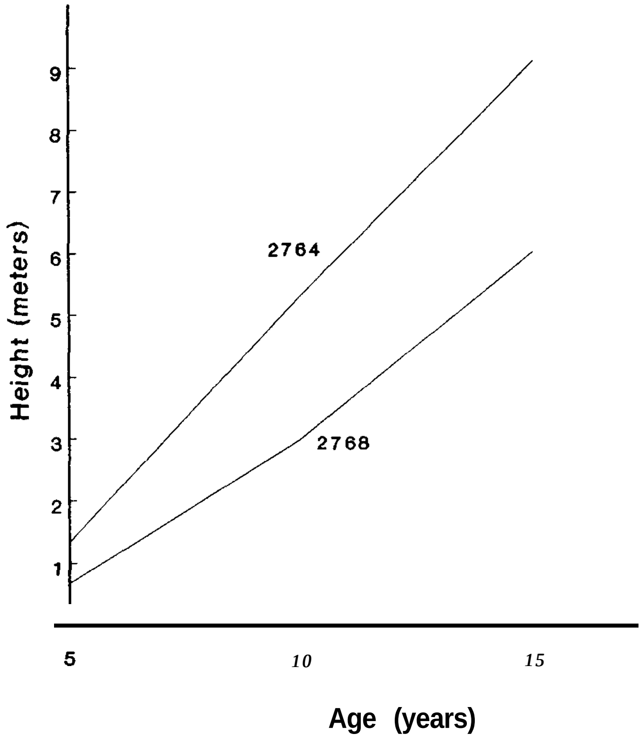


Figure 10 – Comparison of fastest and slowest growing seed sources at the most northern site (P-109). Both sources are from Florida, and there is no indication that the rate of height growth has culminated.

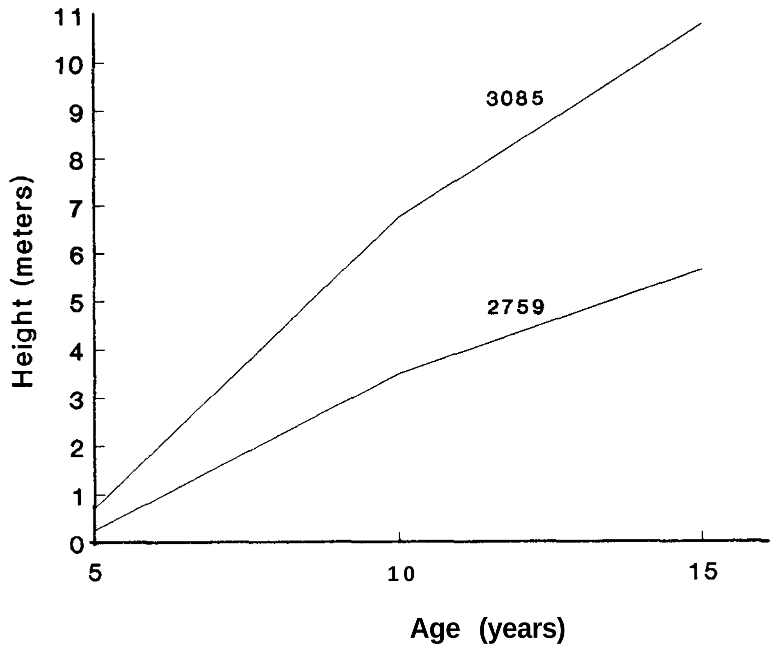


Figure 11 -Comparison of fastest and slowest growing seed sources at the most southern site (P-115). Rate of height growth has apparently culminated for both sources.

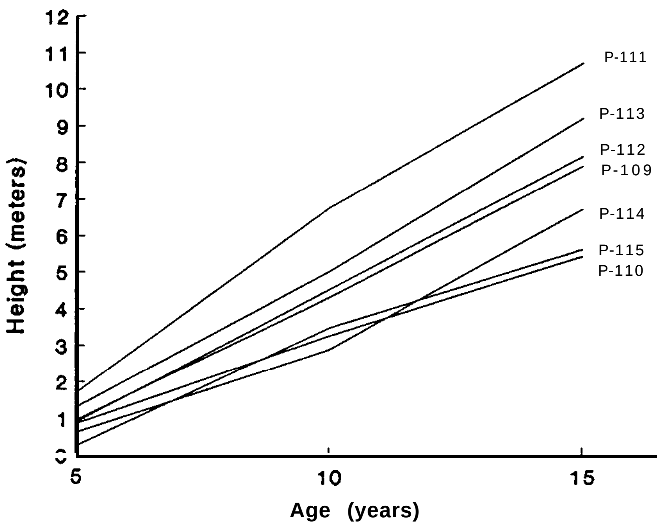


Figure 12—Comparison of height growth of the most northern seed source (2759) at all sites. Rate of growth has slowed down at the Sandhilk (P-l 10) and central Florida locations (P-l 15) but increased in north Florida (P-l 14).

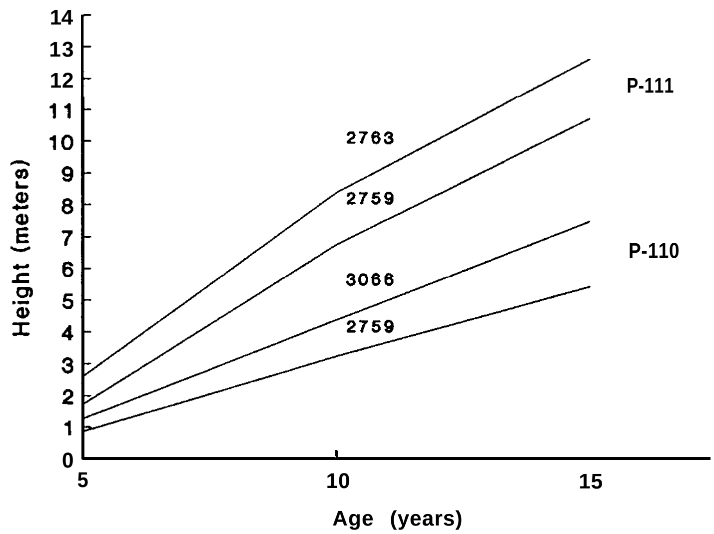


Figure 14—Comparison of fastest and slowest growing seed sources at the best and poorest sites. Growth is apparently beginning to slow down.

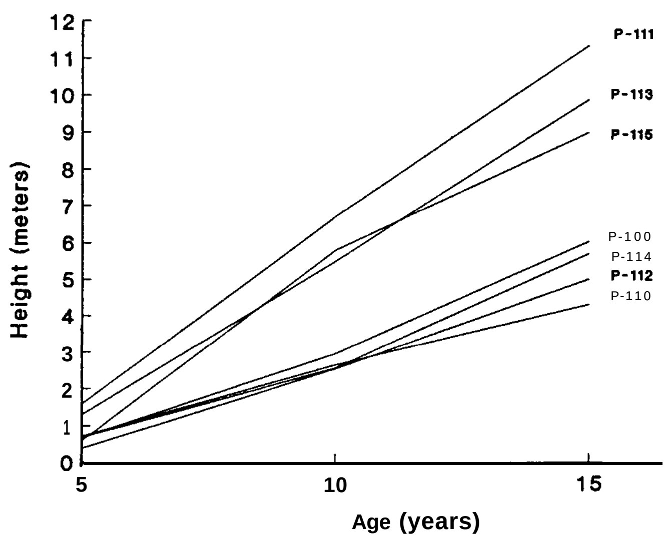


Figure 13—Comparison of height growth of the most southern seed source (2759) at all sites. Rate of growth has apparently culminated at the Sandhills (P-l 10) and central Florida (P-l 15) locations but increased at the Piedmont (P-109) and north Florida (P-l 14) sites.

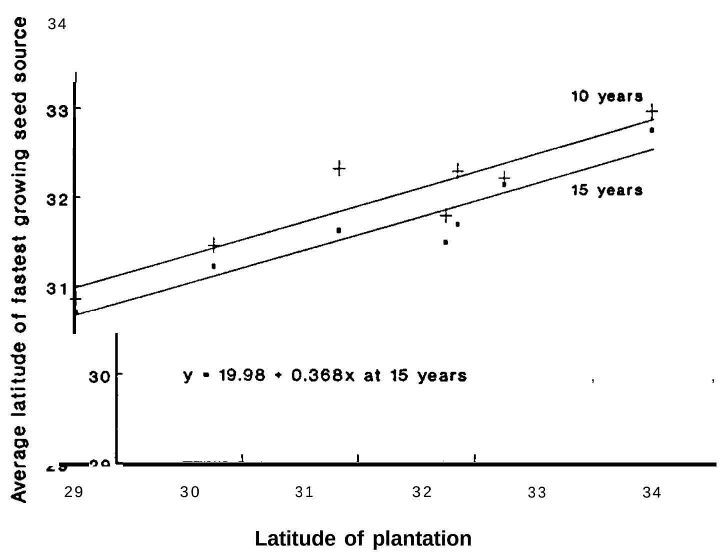
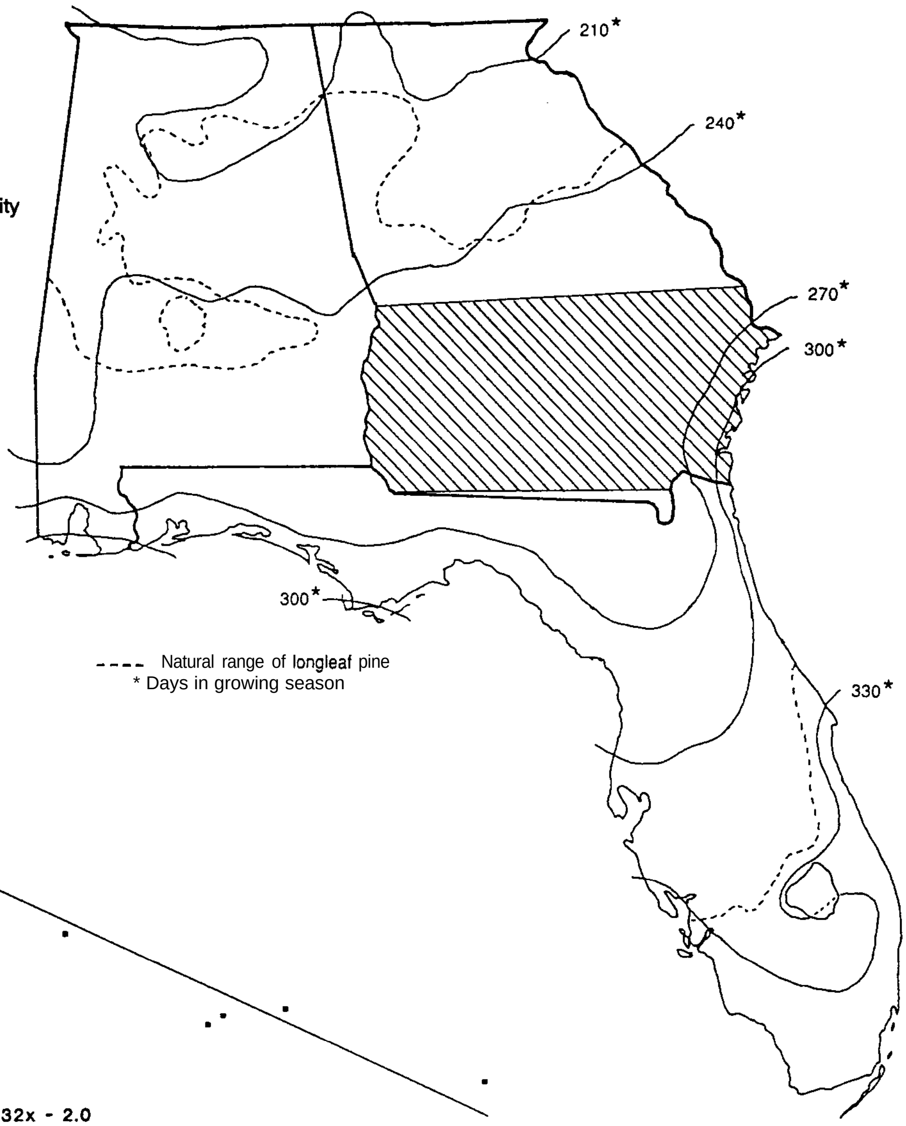


Figure 15 -Regression of average latitude of best seed sources on plantation latitude at 10 and 15 years. The slopes of the regressions are almost identical, but the average latitude of the fastest growing sources has shifted slightly south.

Figure 16--Zone of best general adaptability of longleaf pine in Georgia.



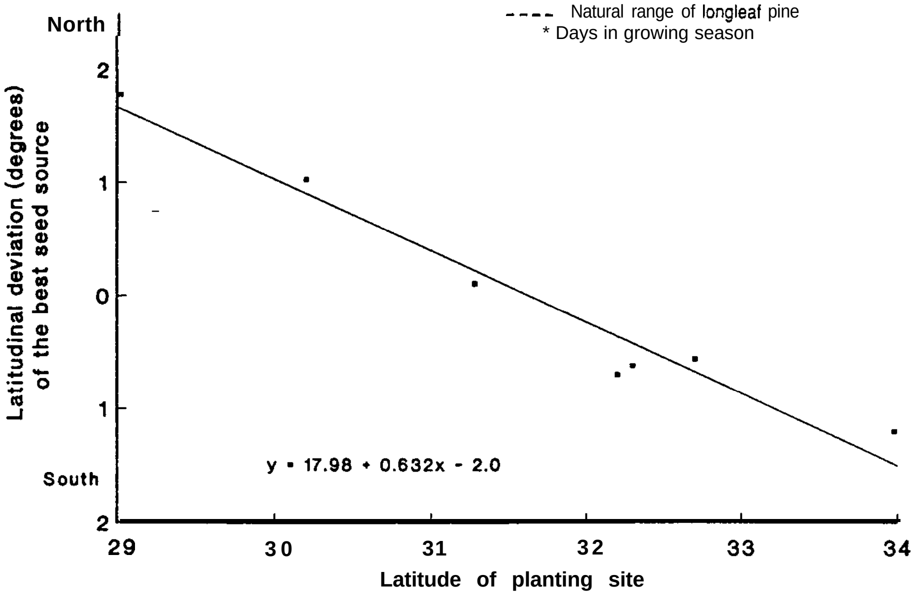


Figure 17-Regression on planting site latiiude of deviation of latitude of fastest growing seed source from planting latitude. This can be used to locate an appropriate area from which to obtain seed for a given latitude.

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Table 1--Numbers of longleaf pines having solid-colored vs. striped seed wings

Seed source, by State and county		Trees with seedwings: Solid color	Striped
		Number	
Alabama	Baldwin	18	2
Florida	Glades	15	5
	Jackson	18	2
	Marion	15	0
	Taylor	20	0
Georgia	Bryan	20	0
	Colquitt	20	0
	Jefferson	18	2
	Jenkins	18	2
	Meriwether	19	2
	Paulding	17	3
	Pulaski	17	3
	Richmond	20	0
	Taylor	18	2
	Telfair	18	2
	Terrell	16	4
	Ware	23	3
	Washington	18	2
	Wayne	17	3
Total		345	37

Table 2--Seedlots with xanthescens[1] seedlings at Morgan Nursery

Seedlot number	Seed source, by county and State	Seedlings
		Number
	Bulked lots	
2754	Bryan, GA	1
2755	Colquitt, GA	2
2756	Jefferson, GA	1
2762	Taylor, GA	2
2765	Ware, GA	1
2766	Washington, GA	3
2767	Wayne, GA	1
3065	Marion, FL	1
	Individual-tree lots	
2912	Richmond, GA	1
2927	Colquitt. GA	1
2999	Washington, GA	4
3084	Taylor, FL	3
3961	Jackson, FL	1

[1] Cotyledons are normal green; primary foliage is yellow.

Table 3--Individual-tree seedlots from Georgia with Sonderegger seedlings

Seedlot number	Seed source (county)	Seedlings
		Number
2814	Jefferson 1	1 of 22
2821	Jefferson 10	12 of 27
2824	Jefferson 14	2 of 26
2862	Meriwether 15	1 of 27
2886	Paulding 20	2 of 25
2901	Pulaski 16	1 of 39
2918	Richmond 13	4 of 35
3010	Washington 16	1 of 33

Table &-Needle lengths of longleaf pine seedlings after 1 year of growth in a Florida and a Georgia nursery

Seedlot number	Origin		Physiographic province	Needle length					
	County	State		Andrews Nursery, FL		Morgan Nursery, GA		Morgan Nursery, GA[1]	
				----------Centimeters----------					
				**	*	**	n.s.	**	n.s.
			Piedmont		35.2		43.1		37.7
2759	Paulding	GA		33.1		42.5		35.7	
2758	Meriwether	GA		37.3		43.6		39.6	
			Sandhills		39.6		44.5		40.3
2762	Taylor	GA		39.9		43.0		38.9	
2766	Washington	GA		39.8		45.2		41.0	
2761	Richmond	GA		39.1		45.2		41.0	
			Upper Coastal Plain		40.3		42.1		39.2
2764	Terre11	GA		41.1		41.9		40.2	
2760	Pulaski	GA		42.4		42.8		39.2	
2756	Jefferson	GA		37.3		41.5		38.3	
			Lower Coastal Plain		41.6		46.5		41.7
2755	Colquitt	GA		44.1		48.4		44.7	
2763	Telfair	GA		41.4		46.5		41.7	
2757	Jenkins	GA		39.5		44.4		40.1	
			Flatwoods		42.9		48.2		42.6
2765	Ware	GA		43.9		46.4		44.0	
2767	Wayne	GA		42.4		49.9		42.2	
2754	Bryan	GA		42.5		48.4		41.5	
			Alabama & Florida		43.0		45.2		40.3
2753	Baldwin	AL		40.5		47.0		39.7	
2769	Jackson	FL		42.2		46.6		42.4	
3066	Taylor	FL		45.8		49.9		42.0	
3065	Marion	FL		45.0		47.8		--	
2768	Glades	FL		44.3		46.2		37.4	
3085	Pasco	FL		40.4		34.3		--	

** Within the indicated column, means differ significantly at the l-percent level.
* Within the indicated column, means differ significantly at the 5-percent level.
n.s. Within the indicated column, means do not differ at the 5-percent level.

[1] Means of 10 individual-tree progenies per source.

Table 5--Summary of lst-year survival by seed source origin

Seedlot number	Physiographic province	Mean lst-year survival: Seedlot	Mean lst-year survival: Province	Deviation from grand mean
		---Percent---		
		n.s.	**	
2759	Piedmont	68.3		
2758		71.8	70.0	10.4
2762	Sandhills	59.6		
2766		68.8		
2761		63.5		
			64.0	4.4
2764	Upper Coastal Plain	64.4		
2760		63.6		
2756		68.2		
			65.4	5.8
2755	Lower Coastal Plain	55.4		
2763		61.6		
2757		53.8		
			56.9	-2.7
2765	Flatwoods	55.8		
2767		52.8		
2754		56.3		
			55.0	-4.6
2753	Alabama & Florida	50.1		
2769		59.3		
3066		56.8		
3065		50.4		
3085		55.0		
2768		53.2		
			54.1	-5.5
	Grand mean	59.6		

** Within the indicated column, means differ significantly at the l-percent level.

n.s. Within the indicated column, means do not differ significantly at the 5-percent level.

Table 6--Summary of overall second-year survival of longleaf pine seed sources

Seedlot	Origin County	Origin State	Physiographic province	Plantation location, by county and State: Crawford GA	Houstpn GA	Laurens GA	Baker FL	Means: Seedlot	Means: Province	Deviation from grand mean
				--------percent------			------		**	
			Piedmont	**	**	**	n.s.	**	63.2	11.0
2759	Paulding	GA		56.3	42.4	72.4	82.0	63.3		
2758	Meriwether	GA		68.7	47.9	61.6	74.5	63.2		
			Sandhills						58.9	6.7
2762	Taylor	GA		38.8	32.2	56.6	77.2	51.2		
2766	Washington	GA		68.4	55.9	71.1	65.1	65.1		
2761	Richmond	GA		75.6	35.9	63.4	67.1	60.5		
			Upper Coastal Plain						60.0	7.8
2764	Terre11	GA		55.2	43.4	65.6	68.6	58.2		
2760	Pulaski	GA		66.1	29.5	74.7	67.7	59.5		
2756	Jefferson	GA		69.0	50.0	62.3	67.9	62.3		
			Lower Coastal Plain						51.2	-1.0
2755	Colquitt	GA		34.2	20.6	50.2	67.4	43.1		
2763	Telfair	GA		66.1	49.5	63.4	66.4	61.4		
2757	Jenkins	GA		44.8	21.6	57.5	72.5	49.1		
			Flatwoods						45.7	-6.5
2765	Ware	GA		27.0	24.4	57.6	69.4	44.6		
2767	Wayne	GA		43.7	33.1	27.6	62.1	41.6		
2754	Bryan	GA		53.7	32.7	48.8	67.9	50.8		
			Alabama & Florida						43.9	-8.3
2753	Baldwin	AL		31.6	41.7	35.4	66.0	43.7		
2769	Jackson	FL		49.3	32.9	47.6	74.8	51.2		
3066	Taylor	FL		35.7	33.6	48.3	63.8	45.4		
3065	Marion	FL		32.2	29.7	37.7	56.3	39.0		
3085	Pasco	FL		--	--	51.8	--	--		
			Mean**	50.2	36.0	53.9	68.5	52.2		

** Within the indicated row or column, means differ significantly at the l-percent level.
n.s. Within the indicated column, means do not differ significantly at the s-percent level.

Table 7--Summary of overall percentage of trees out of the "grass stage" 2 years after planting for longleaf pine seed sources

Seedlot	Origin: County	Origin: State	Physiographic province	Plantation location, by county and State: Crawford GA	Houston GA	Laurens GA	Baker FL	Means: Seedlot	Means: Province	Deviation from grand mean
				----------------Percent	------------	------------	------------		•	
			Piedmont	*	•	n.s.	•	•	9.2	0.5
2759	Paulding	GA		12.6	2.6	3.3	4.0	5.6		
2758	Meriwether	GA		11.9	23.2	6.7	9.9	12.9		
			Sandhills						12.6	3.9
2762	Taylor	GA		12.4	21.3	6.4	9.5	12.4		
2766	Washington	GA		28.4	15.3	12.0	5.4	15.3		
2761	Richmond	GA		29.8	4.5	4.0	2.0	10.1		
			Upper Coastal Plain						11.9	3.2
2764	Terre11	GA		24.8	21.0	6.6	4.6	14.2		
2760	Pulaski	GA		10.6	11.9	6.4	5.6	8.6		
2756	Jefferson	GA		19.8	23.5	5.7	3.1	13.0		
			Lower Coastal Plain						8.0	-0.7
2755	Colquitt	GA		10.7	.3	4.3	5.3	5.2		
2763	Telfair	GA		17.3	24.4	16.0	.2	14.5		
2757	Jenkins	GA		4.5	7.4	4.1	.9	4.2		
			Flatwoods						6.8	-1.9
2765	Ware	GA		7.1	7.6	1.9	4.0	5.2		
2767	Wayne	GA		15.5	9.1	1.1	4.8	7.6		
2754	Bryan	GA		4.2	13.8	5.4	6.5	7.5		
			Alabama & Florida						5.7	-3.0
2753	Baldwin	AL		1.7	13.3	2.0	1.3	4.6		
2769	Jackson	FL		4.8	10.2	.5	9.6	6.3		
3066	Taylor	FL		16.0	10.9	5.5	8.6	10.2		
3065	Marion	FL		2.6	1.6	2.8	6.7	3.4		
2768	Glades	FL		8.4	2.2	2.2	2.3	3.8		
3085	Pasco	FL		--	--	28.9	--	--		
			Mean **	12.8	11.8	6.3	5.0	8.7		

** Within the indicated column or row, means differ significantly at the l-percent level.
• Within the indicated column, means differ significantly at the 5-percent level.
n.s. Within the indicated column, means do not differ significantly at the 5-point level.

Table 8--Summary of overall fifth-year survival of **longleaf** pine seed sources

Seedlot number	Origin County	Origin State	Physiographic province	Plantation location, by county and State: Polk GA	Crawford GA	Houston GA	Laurens GA	Ware GA	Baker FL	Lake FL	Means: Seedlot	Means: Province	Deviation from grand mean
				Percent									
				**	*	**	n.s.	**	n.s.	n.s.	**	**	
			Piedmont									65.3	11.3
2759	Paulding	GA		47.4	53.3	48.6	73.3	89.5	78.0	54.7	63.5		
2758	Meriwether	GA		58.7	63.8	52.8	68.4	91.3	72.1	61.9	67.0		
			Sandhills									59.6	5.6
2762	Taylor	GA		29.5	39.3	40.5	71.9	94.7	74.2	52.8	57.6		
2766	Washington	GA		35.9	63.8	60.7	82.3	93.5	58.8	50.2	63.6		
2761	Richmond	GA		42.5	71.4	38.9	66.4	77.2	63.6	43.2	57.6		
			Upper Coastal Plain									63.1	9.1
2764	Terre11	GA		55.4	51.8	46.7	71.8	87.3	64.1	51.4	61.2		
2760	Pulaski	GA		41.7	62.6	35.6	77.7	93.0	67.3	47.6	60.8		
2756	Jefferson	GA		61.9	63.8	56.8	73.5	95.0	68.2	51.4	67.2		
			Lower Coastal Plain									51.9	-2.1
2755	Colquitt	GA		20.0	34.2	28.7	59.0	73.0	66.1	52.8	47.7		
2763	Telfair	GA		47.6	52.8	54.4	68.2	80.5	62.3	37.6	57.6		
2757	Jenkins	GA		41.3	45.3	25.8	65.1	81.1	71.1	22.5	50.3		
			Flatwoods									48.4	-5.6
2765	Ware	GA		41.3	25.9	32.1	57.5	78.5	62.3	36.2	47.7		
2767	Wayne	GA		18.9	41.7	39.3	43.0	73.5	50.7	48.6	45.1		
2754	Bryan	GA		30.5	48.8	38.4	56.4	88.0	63.6	40.5	52.3		
			Alabama & Florida									45.7	-8.3
2753	Baldwin	AL		24.2	27.8	44.6	47.6	90.6	62.4	43.9	48.7		
2769	Jackson	FL		37.4	45.8	38.2	53.7	82.7	74.8	48.6	54.5		
3066	Taylor	FL		17.5	33.6	33.4	56.1	al.7	60.4	54.2	48.1		
3065	Marion	FL		la.5	31.0	30.5	47.6	71.1	51.9	52.1	43.2		
2768	Galdes	FL		13.9	35.7	28.1	27.5	58.0	46.2	22.3	33.1		
3085	Pasco	FL		--	--	--	56.8	--	--	42.2	49.5		
			Mean • *	36.0	47.0	40.7	61.2	83.2	64.1	45.7	54.0		

• * Within the indicated row or column, means differ significantly at the l-percent level.

• Within the indicated column, means differ significantly at the s-percent level.

n.s. Within the indicated column, means do not differ significantly at the s-percent level.

Table 9--**Summary** of average number of years out of the "grass stage" **5 years** after planting for **longleaf** pine **sources**

Seedlot number	Origin County	Origin State	Physiographic province	Polk GA	Crawford GA	Houston GA	Laurens GA	Ware GA	Baker FL	Lake FL	Means Seedlot	Means Province	Deviation from grand mean
				Year									
				*	n.s.	**	n.s.	*	n.s.	n.s.	**	n.s.	
			Piedmont									1.9	0.0
2759	Paulding	GA		1.8	1.8	2.8	1.9	2.0	1.3	1.2	1.8		
2758	Meriwether	GA		2.0	1.9	3.0	1.5	1.8	1.6	1.6	1.9		
			Sandhills									2.1	.2
2762	Taylor	GA		1.9	1.9	3.0	2.2	2.2	1.5	1.7	2.1		
2766	Washington	GA		2.3	2.3	3.1	2.1	2.5	1.5	1.7	2.2		
2761	Richmond	GA		2.4	2.4	2.8	2.4	2.4	1.3	1.5	2.2		
			Upper Coastal Plain									2.1	.2
2764	Terrell	GA		2.4	2.2	3.2	2.1	2.3	1.4	1.8	2.2		
2760	Pulaski	GA		1.7	1.8	2.7	2.0	2.0	1.4	1.6	1.9		
2756	Jefferson	GA		2.6	2.2	3.0	1.7	2.5	1.4	1.7	2.2		
			Lower Coastal Plain									2.0	.1
2755	Colquitt	GA		2.4	2.2	3.0	1.6	1.8	1.3	1.4	2.0		
2763	Telfair	GA		2.0	2.1	3.4	2.5	2.5	1.3	1.3	2.2		
2757	Jenkins	GA		1.9	2.1	2.9	2.2	2.2	1.0	1.4	2.0		
			Flatwoods									1.8	-.1
2765	Ware	GA		1.9	1.9	2.3	1.6	1.8	1.6	1.0	1.7		
2767	Wayne	GA		1.9	2.0	2.9	1.4	1.7	1.1	1.4	1.8		
2754	Bryan	GA		1.8	1.7	3.2	2.1	2.4	1.5	1.6	2.0		
			Alabama & Florida									1.8	-.1
2753	Baldwin	AL		1.5	1.7	3.2	1.3	1.9	1.3	1.9	1.8		
2769	Jackson	FL		1.9	2.1	3.0	1.9	2.1	1.7	1.9	2.1		
3066	Taylor	FL		2.2	2.0	3.0	1.5	2.0	1.5	1.7	2.0		
3065	Marion	FL		1.5	1.6	2.7	1.5	1.8	1.4	1.2	1.7		
2768	Glades	FL		1.5	1.6	2.1	.8	1.1	.7	.8	1.2		
3085	Pasco	FL		--	--	—	2.5	—	—	2.6	2.6		
			Mean **	2.0	2.0	2.9	1.8	2.0	1.4	1.6	1.9		

** Within the indicated row or column, means differ significantly at the 1-percent level.
* Within the indicated column, means differ significantly at the 5-percent level.
n.s. Within the indicated column, means do not differ significantly at the 5-percent level.

Table 10--Summary of overall fifth-year average height of longleaf pine seed sources

Seedlot number	Origin County	Origin State	Physiographic province	Polk GA	Crawford GA	Houston GA	Laurens GA	Ware GA	Baker FL	Lake FL	Means Seedlot	Means Province	Deviation from grand mean
				Feet									
				*	n.s.	*	n.s.	**	n.s.	n.s.	•*	n.s.	
			Piedmont									3.14	-0.39
2759	Paulding	GA		2.77	2.59	5.34	2.88	3.67	1.67	1.59	2.93		
2758	Meriwether	GA		3.07	3.12	6.76	2.35	3.34	2.27	2.59	3.36		
			Sandhills									3.83	.30
2762	Taylor	GA		3.24	3.09	6.98	2.69	4.41	2.23	2.63	3.61		
2766	Washington	GA		3.99	4.20	6.91	3.54	5.36	2.35	2.47	4.12		
2761	Richmond	GA		4.09	4.17	5.71	2.98	5.08	1.71	2.53	3.75		
			Upper Coastal Plain									3.87	.32
2764	Terre11	GA		4.20	3.89	7.39	2.98	4.82	2.29	3.27	4.12		
2760	Pulaski	GA		2.49	3.00	6.00	3.07	4.26	2.02	2.68	3.36		
2756	Jefferson	GA		4.64	3.58	7.42	2.79	5.41	2.11	3.04	4.14		
			Lower Coastal Plain									3.75	.22
2755	Colquitt	GA		3.99	4.51	6.34	2.78	3.82	1.97	2.46	3.70		
2763	Telfair	GA		3.29	3.42	8.17	3.57	6.31	1.89	2.23	4.13		
2757	Jenkins	GA		3.20	3.45	6.49	2.69	4.71	1.44	2.09	3.44		
			Flatwoods									3.31	-.22
2765	Ware	GA		2.94	2.88	5.22	2.42	3.64	2.38	1.81	3.04		
2767	Wayne	GA		3.29	3.41	6.55	1.92	3.68	1.56	2.41	3.26		
2754	Bryan	GA		2.93	2.46	6.93	3.28	5.23	2.09	2.58	3.64		
			Alabama & Florida									3.32	-.21
2753	Baldwin	AL		2.29	2.57	7.73	2.17	4.10	1.83	3.18	3.41		
2769	Jackson	FL		3.16	3.67	6.60	2.69	4.49	2.83	3.40	3.83		
3066	Taylor	FL		3.72	3.52	7.16	2.44	4.20	2.38	3.20	3.80		
3065	Marion	FL		2.04	2.40	6.09	2.27	3.79	2.20	2.01	2.97		
2768	Glades	FL		2.06	2.05	4.40	1.19	1.75	1.14	1.31	1.99		
3085	Pasco	FL		--	--	--	4.63	--	—	6.09	5.36		
			Mean •*	3.23	3.26	6.54	2.77	4.32	2.02	2.68	3.53		

•* Within the indicated row or column, means differ significantly at the l-percent level

• Within the indicated column, means differ significantly at the s-percent level.

n.s. Within the indicated column, means do not differ significantly at the s-percent level

Table 11--**Summary** of overall annual height growth rate to age 5 years of **longleaf** pine seed sources

Seedlot number	Origin county	Origin State	Physiographic province	Plantation location, by county and State: Polk GA	Crawford GA	Houston GA	Laurens GA	Ware GA	Baker FL	Lake FL	Means: Seedlot	Means: Province	Deviation from grand mean
				Feet									
				n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	
			Piedmont									1.59	-0.11
2759	**Paulding**	GA		1.55	1.41	1.86	1.49	1.77	1.17	1.29	1.51		
2758	Meriwether	GA		1.54	1.60	2.22	1.57	1.85	1.33	1.56	1.67		
			Sandhills									1.71	.01
2762	Taylor	GA		1.66	1.56	2.27	1.44	1.99	1.40	1.51	1.69		
2766	Washington	GA		1.69	1.77	2.19	1.67	2.09	1.43	1.41	1.75		
2761	Richmond	GA		1.72	1.70	2.04	1.43	2.09	1.33	1.49	1.69		
			Upper Coastal Plain									1.75	.05
2764	Terre11	GA		1.72	1.70	2.30	1.53	2.05	1.40	1.73	1.78		
2760	Pulaski	GA		1.43	1.56	2.16	1.59	2.10	1.37	1.59	1.69		
2756	Jefferson	GA		1.77	1.55	2.43	1.58	2.15	1.43	1.65	1.79		
			Lower Coastal Plain									1.73	.03
2755	Colquitt	GA		1.63	1.90	2.11	1.66	2.06	1.41	1.71	1.78		
2763	Telfair	GA		1.70	1.54	2.39	1.53	2.38	1.32	1.68	1.79		
2757	Jenkins	GA		1.66	1.58	2.23	1.36	2.10	1.29	1.05	1.61		
			Flatwoods									1.67	-.03
2765	Ware	GA		1.56	1.46	2.21	1.48	1.88	1.38	1.54	1.64		
2767	Wayne	GA		1.66	1.69	2.18	1.40	2.01	1.31	1.52	1.68		
2754	Bryan	GA		1.55	1.40	2.17	1.57	2.23	1.36	1.55	1.69		
			Alabama & Florida									1.69	-.01
2753	Baldwin	AL		1.64	1.45	2.36	1.58	2.05	1.25	1.62	1.71		
2769	Jackson	FL		1.61	1.72	2.15	1.35	2.06	1.54	1.78	1.74		
3066	Taylor	FL		1.58	1.68	2.35	1.55	2.07	1.41	1.79	1.78		
3065	Marion	FL		1.45	1.45	2.16	1.56	2.08	1.41	1.63	1.68		
2768	Glades	FL		1.36	1.25	2.03	1.40	1.40	1.37	1.45	1.47		
3085	Pasco	FL		—	--	--	1.85	—		2.23	2.04		
			Mean **	1.60	1.58	2.20	1.53	2.02	1.36	1.58	1.70		

** Within the indicated row or column, means differ significantly at the l-percent level.
n.s. Within the indicated column, means do not differ significantly at the s-percent level.

Table 12--Summary of 10th-year data from longleaf pine seed sources. all plantations

Seedlot number	Origin County	Origin State	Physiographic province	Survival	Height	Average annual growth 5-10	Volume x 100	Fusiform rust infection	Forking
				Percent	m	m	m^3	Percent	Percent
				• * •	•*	**	•	•	•
			Piedmont	58.6					
2759	Paulding	GA		56.3	4.5	0.65	1.03	11.0	5.0
2758	Meriwether	GA		60.9	5.0	.72	1.40	14.5	5.0
			Sandhills	55.6					
2762	Taylor	GA		52.3	5.0	.72	1.35	12.9	4.0
2766	Washington	GA		59.0	5.4	.73	1.51	13.7	5.0
2761	Richmond	GA		55.4	5.1	.69	1.43	13.1	3.5
			Upper Coastal Plain	58.5					
2764	Terre11	GA		57.2	5.5	.75	1.56	20.2	6.4
2760	Pulaski	GA		55.8	5.4	.a0	1.62	20.9	5.3
2756	Jefferson	GA		62.4	5.3	.70	1.64	15.3	6.9
			Lower Coastal Plain	47.3					
2755	Colquitt	GA		42.7	5.6	.79	1.64	18.4	3.1
2763	Telfair	GA		52.8	5.6	.73	1.71	17.5	5.5
2757	Jenkins	GA		46.3	5.7	.85	1.63	15.9	3.3
			Flatwoods	46.2					
2765	Ware	GA		45.5	5.0	.78	1.27	15.7	6.7
2767	Wayne	GA		43.1	5.4	.73	1.66	a.4	4.3
2754	Bryan	GA		50.0	5.3	.73	I. 58	11.7	3.2
			Alabama & Florida	41.4					
2753	Baldwin	AL		47.4	5.3	.79	1.43	18.0	6.3
2769	Jackson	FL		51.2	5.6	.78	1.57	21.6	4.4
3066	Taylor	FL		44.9	5.4	.78	1.65	14.3	2.6
3065	Marion	FL		36.8	5.1	.77	1.49	a.0	3.9
2768	Glades	FL		21.7	4.5	.62	1.24	5.8	1.2
3085	Pasco	FL		46.3	6.2	.91	1.96	.4	2.9
			Mean	49.4	5.3	0.75	1.52	13.9	4.4

** Within the indicated column, means are significant at the l-percent level.

• Within the indicated column, means are significant at the 5-percent level.

Table 13--Summary of 15th-year data from longleaf pine seed sources. all plantations

Seedlot number	Origin county	Origin State	Physiographic province	Survival	Height	Average annual growth 10-15	Volume x 100	Fusiform rust infection	Forking
				Percent	m	m	m^3	Percent	Percent
				**	**	**	**	**	n.s.
			Piedmont	55.3					
2759	Paulding	GA		53.1	7.9	0.72	3.88	12.1	5.2
2758	Meriwether	GA		57.5	8.3	.72	4.41	14.0	4.8
			Sandhills	53.5					
2762	Taylor	GA		50.3	8.4	.75	4.56	15.6	8.2
2766	Washington	GA		56.8	9.2	.79	5.02	15.3	6.3
2761	Richmond	GA		53.3	8.7	.76	5.06	17.2	5.7
			Upper Coastal Plain	55.8					
2764	Terre11	GA		54.8	9.2	.79	5.25	19.6	8.1
2760	Pulaski	GA		53.2	9.1	.77	5.21	21.3	6.9
2756	Jefferson	GA		59.5	8.9	.76	5.38	15.6	8.1
			Lower Coastal Plain	44.3					
2755	Colquitt	GA		39.4	9.4	.80	5.99	19.3	3.7
2763	Telfair	GA		49.7	9.4	.79	5.54	17.9	5.8
2757	Jenkins	GA		43.8	9.0	.78	5.05	15.1	4.9
			Flatwoods	43.4					
2765	Ware	GA		42.0	9.0	.85	5.05	15.7	3.1
2767	Wayne	GA		40.7	9.3	.82	5.63	13.2	3.6
2754	Bryan	GA		47.4	9.0	.76	5.67	15.6	5.6
			Alabama & Florida	38.8					
2753	Baldwin	AL		45.3	8.9	.77	4.64	18.4	5.5
2769	Jackson	FL		48.2	9.4	.80	5.63	20.8	4.9
3066	Taylor	FL		40.7	9.2	.81	5.69	17.0	4.1
3065	Marion	FL		33.8	9.0	.82	5.32	12.8	6.5
2768	Glades	FL		19.1	7.8	.72	4.92	9.2	2.9
3085	Pasco	FL		45.7	10.2	.79	6.38	10.2	2.6
	Overall Mean			46.7	9.0	.78	5.21	15.8	5.3

** Within the indicated column, means are significant at the l-percent level.
* Within the indicated column, means are significant at the 5-percent level
n.s. Within the indicated column, means are not significant at the 5-percent level.

Table 14--Summary of 15th-year combined analysis. showing variance components and their significance

Source of variation	d.f.	Survival	Fusiform rust infection	Height	DBH	Average annual height growth 10-15 years x 10	Volume x 10	Forks
		Traits						
		------------------------Variance components------------------------						
Plantations	6	76.82**	413.17**	3.05"'	7.87**	23.63**	11.30**	37.55""
Replications in plantations	35	9.98**	7.66**	.31**	.53**	2.82**	.64**	3.02*
Province	5	21.54'	0	.03	0	.35	.08	1.06
Seedlots in provinces	13	18.34**	6.02**	.18**	.25**	.38*	.20**	.58
Plantations x province	30	.88	0	.07*	.16*	.43	.19*	3.79*
Plantations x seedlots in province	79	16.45"	4.52	.06**	.21**	.53*	.11	2.72
Replications in plantations x provinces	175	0	0	0	0	0	0	0
Error	495	71.17	81.81	1.00	1.87	10.46	2.70	90.42

• Significant at the 5-percent level.

• * Significant at the l-percent level.

Table 15--Components of variation as a percentage of the total variation at 15 years from combined data of all longleaf pine sources and plantations

Source of variation	Survival	Height	Average annual height growth 10-15 years	Volume	Fusiform rust infection
	Percent				
Physiographic provinces	10.01"	0.63	0.93	0.54	0.00
Seedlots	17.41""	4.48""	1.80""	1.79""	.96
Seedlots in provinces	8.52**	3.94""	1.00"	1.32**	1.18""
Plantations x provinces	.41	1.44"	1.13	1.28*	.00
Plantations x seedlots	8.11**	2.52**	2.40""	1.84""	.87
Plantations x seedlots in provinces	7.65""	1.28""	1.40"	.73	.89

* Significant at the 5-percent level.
** Significant at the l-percent level.

Kraus, John F.; Sluder, Earl R. 1990. Genecology of longleaf pine in Georgia and Florida. Res. Pap. SE-278. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 31 pp.

Fourteen seed sources of *Pinus palustris* from Georgia, 5 from Florida, and 1 from Alabama were grown at five locations in Georgia and at two in Florida. Results through the 15th year show: (1) survival and early height growth were best for the northern sources; (2) individual stand or seed source contributed strongly to the components of variation; (3) the seed source x plantation interaction was significant for growth traits; and (4) the species has a generally broad zone of adaptability in Georgia.

KEYWORDS: *Pinus palustris*, geographic variation, survival and growth traits, adaptability.

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KEYWORDS: *Pinus palustris*, geographic variation, survival and growth traits, adaptability.

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