CHAPTER 9

LONGLEAF PINE

The natural range of longleaf pine lies within that of loblolly and shortleaf pines but extends north and west of that of slash pine, as shown in the range map (fig. 2). Being easier to handle silviculturally, the other southern pines are more intensively managed than longleaf. Low priority for planting has also made it less important in forest tree breeding research programs than loblolly or slash pines. And yet, longleaf pine still forms an important component of pine stands throughout the range.

It has the longest needles, largest twigs, cones, and seeds of any southern pine; in addition, it is the only pine with a permanent seed wing and relatively soft seedcoat. The genotypic and phenotypic characteristics of delayed height growth in seedlings are distinctive for longleaf pine, and they are an important factor in tree breeding, progeny testing, and silviculture of the species. The ability of longleaf in the pre-forest-management era to maintain itself on droughty sites and after extensive wildfires is indicative of unusual characteristics lacking in other southern pines. Since longleaf and slash pines provide the basis for the naval stores industry, this ability has been a factor in silviculture and management of both species.

Longleaf pine has received monographic treatment by Mohr (1897) and Wahlenberg (1946). A bioliography by Croker (1968) lists literature from 1946 to 1967.

TREE GROWTH AND WOOD VOLUME YIELD

The delayed height growth characteristic of longleaf pine seedlings influences other traits. During the "grass" stage, as it is known among foresters, the seedling develops a long and strong taproot, but the aboveground stem is very short. On this short stem, the long needles are often so mixed with native grasses that they are hard to identify. During the first year the slow growth of the stem is under strong genetic control (Brown 1964). Even in nursery beds with ideal soil fertility and moisture and adequate growing space, no seedlings have appreciable height growth. This holds true even when there are pronounced differences among seedlings in number and length of needles (fig. 127). Natural hybrids, because they develop stems, are conspicuous.

After the first year of growth, genetic control is very weak or nonexistent, and environmental factors become determining. If site factors are good,

Photo courtesy of Georgia Forest Research Council

Figure 127.—Seedlings from three longleaf pine maternal parents show quite different traits. At left, two rows of seedlings have low germination and vigor; center, two rows show high germination and vigor; at right, two rows show high germination and intermediate vigor. White card indicates a seedling starting height growth. It may be a hybrid with loblolly pine.

height growth will begin; if not, the seedlings remain short until the stem is an inch or larger in diameter, and then height growth will begin. Low soil fertility, excessive loss of needles from brown-spot disease or fire, and strong competition from other plants may delay height growth as long as 15 to 20 years. Individual seedlings are sensitive to the environmental factors, in that some will remain small until others nearby grow to merchantable size. Thus, great variation may exist among individual trees of an even-aged stand. Low stocking of desirable trees in early years of a plantation may result from either seedling mortality or delayed height growth.

After an intensive study, Brown (1964) concluded that from the purely physiological standpoint the dwarf or grass stage was associated with the native auxin, indole-3-acetic acid. Longleaf pine, like other southern pines, can produce the auxin, but unlike them, it is unable to transport it. Brown makes note of the fact that other pines have a stage of delayed height growth also, but Shaw (1914), in his major study, made no attempt to comment on its evolutional significance.

It is of interest here in connection with auxin production and transport to point out that Shaw (1914, p. 70) described longleaf pine as "spring shoots uninodal, rarely multinodal" and all other southern yellow pines as "spring-shoots multinodal. . . ." The reason for attributing uninodal growth to longleaf pine is not clear in view of the importance of the characteristic.

Phenotypic Variation

Tree-to-tree variation in growth has not been carefully studied, there being little incentive for geneticists to systematically establish the range in variation for traits of trees growing under uniform environmental conditions, but some measurements are available from nongenetic studies.

Natural Stands

In virgin stands with relatively low stocking, diameters vary widely among trees (Wahlenberg 1946). In three of five stands a few large trees occurred, although average diameter was low. In the remaining areas the curves more nearly approached normal distribution. Variation under these conditions is attributable to many factors. Economically significant was the observation that the average trees in several stands were no larger than about 15 inches d.b.h. (fig. 128), and among the five locations sampled, few trees were over 20 inches.

In a Florida plantation established for a study of inheritance in oleoresin production, seedlings planted on an unprepared site ranged in height

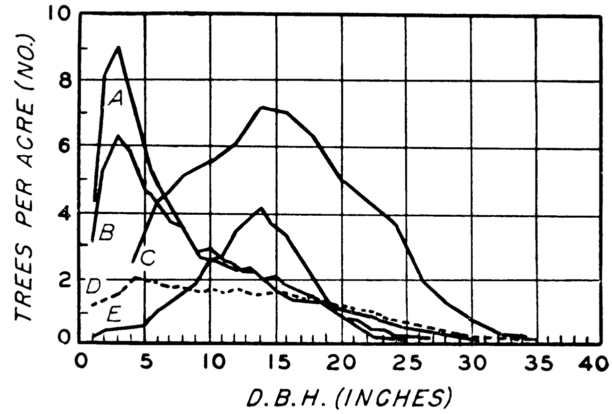

Figure 128.—Number of trees per acre of different sizes in typical virgin longleaf pine forests: in A, South Carolina; B and D, Alabama; C, Louisiana; and E, Florida. Based on samples of 124 to 2,651 acres and representing 1/20 of each forest. (Wahlenberg 1946)

from the grass stage to 38 feet and from 0 to 7 inches d.b.h. after 18 years (Mergen 1954e).

Variation in seedling size and resistance to disease has been used as a guide in planning prescribed burning. Estimates of the need for burning, based on averages for all seedlings, may be in error because only potential crop trees are important, and there may be enough large-sized and disease-free seedlings to make burning unnecessary (Croker 1967).

Slow growth rate may not inhibit flowering. Pessin (1936) observed cones on 16-year-old trees that were only 1 to 4 feet tall. Both Pessin (1934) and Eggler (1961) mention that shoots with female strobili make greater growth than those with male strobili.

Graded Seedlings

Longleaf pine seedlings have proven difficult to plant at times, not only because they require more growing space and careful root pruning in the nursery than other pines, but because they were planted on droughty sites. Thus, there has been considerable interest in seedling grades in relation to survival and growth. Because of the short stems, some seedling grades are based on needle length and stem diameter.

One early test of seedling grades showed that intermediate sizes survived better than either large or small seedlings (Wakeley 1954a). In tests on sandhills soils in South Carolina, McGee and Scott (1965) concluded that grading seedlings improved growth but did not affect survival. By the end of the fifth year, grade 1 seedlings averaged 4.5 feet, and grade 2 seedlings 3.8 feet; furthermore, more grade 1 than grade 2 seedlings were out of the grass stage. Records of individual longleaf pines over a 30-year period indicated that many trees of large size maintained superior growth throughout the period of observation (Wakeley 1971).

In a progeny test, seedling weight was correlated with seed size (66 to 132 grams per 1,000 seed) after a year of growth but not after 8 years (Snyder 1969). Also, seedling size at time of planting was not correlated with sapling size after 8 years (range in seedling sizes tested not indicated).

Seasonal Growth Patterns

Although Shaw (1914) classed longleaf pine as uninodal in growth habit, he recognized there were exceptions. His description, "spring shoots uninodal, rarely multinodal," is not clear as to the period within the growing season concerned, but he does describe the other southern pines as multinodal in growth habit of the spring shoots. The illustration used by Mattoon (1925) for natural growth of longleaf seedlings has both uninodal and multinodal growth over a 4-year period (fig. 129).

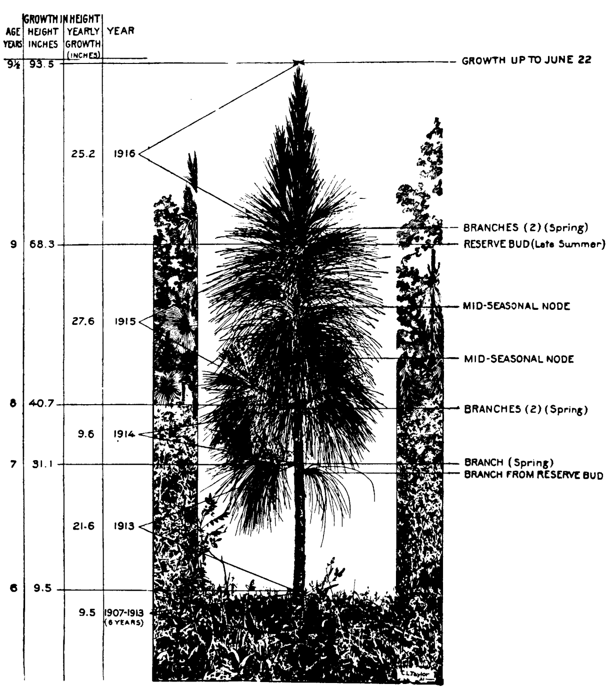

Figure 129.—Natural growth of longleaf pine for the past four seasons under fire protection. The tree was nearly 8 feet tall at 9½ years. Photographed in June during period of rapid upward growth in Jasper County, South Carolina. (Mattoon 1925)

Longleaf pine seedlings observed in southern Mississippi appeared to be capable of continuous growth throughout the growing season (Allen and Scarbrough 1969). Heavy competition tended to reduce summer growth more than spring growth. This would, of course, increase the ratio of springwood to summerwood and explain why certain slow-growing trees have low specific gravity wood. Conversely, trees with exceptionally long growing periods each year may have a high proportion of summerwood and relatively high specific gravity wood. These estimates are based on the assumptions that height and diameter growth periods are directly correlated. In the Mississippi study, most of the growth occurred between March 1 and October 1, but certain seedlings grew very little after June (fig. 130). Seedlings made as many as five or six flushes of growth a year. The periods of elongation of stems in flushes were not clear and distinct, because elongation may have started in the third flush of growth before it ended in the first.

Multinodal growth of longleaf may occur largely in seedlings, but there was a correlation between number of flushes and total summer growth in the last 4-year growth period of saplings 20 feet tall (Allen and Scarbrough 1969). Also, internodes were sufficiently indistinct in a 23-year-old plantation to make careful analyses necessary before Curlin and Box (1961) were confident that the distances between primary internodes indicated yearly heights. Multiple flushes of growth have been observed throughout the crowns of longleaf pine in studies of male and female strobili formation (Eggler 1961), with number of flushes ranging from one to three.

Multinodal growth in longleaf pine may be more common than assumed by Shaw (1914). However, much remains to be learned about the relationship between inherent factors of growth rate and pattern of environmental factors, such as moisture, soil fertility, and competition from other plants. Physiological factors may be complex; for example, individual trees varied so widely in uptake of radioactive iodine that they could be classified as "take" trees or "no take" trees (Hough *et al.* 1965).

Genotypic Variation

Information about inherent variation among longleaf pine trees in growth rate is limited. In a Mississippi test, 100 parent trees were selected at random. After 8 years, significant differences among open-pollinated families were shown in survival and height (Snyder 1969). The parent-height to progeny-height correlation was $r = 0.24$, or a heritability of 0.48. Among the best 75 families, survival ranged from 48 to 83 percent, but the means for this group of families were not significantly different. The lowest family survival was 22 percent. Height of the three best families averaged 10.2 feet, all families 5.8 feet, and the shortest family 0.7 foot (fig. 131). On the basis of growth after 15 years, it was concluded from the study that some wood yield increase could be obtained by parental selection (15 percent) but considerably more by family selection (43 percent), based on the 10 best families (Snyder 1973). Heritability of height

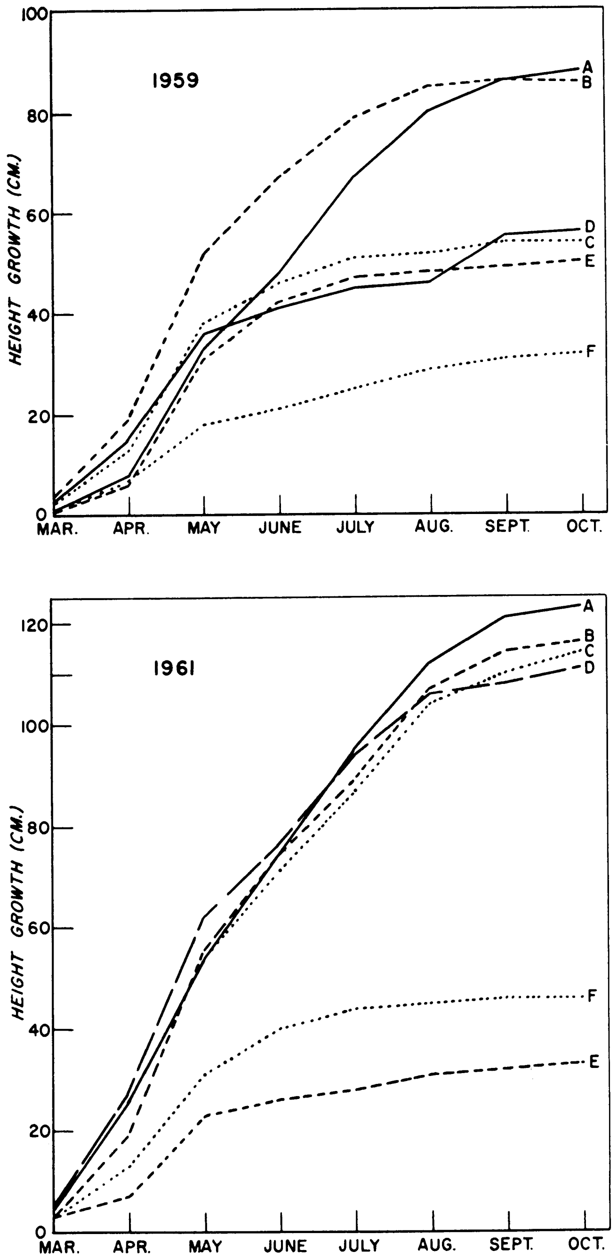

Figure 130.—Cumulative height growth of six longleaf saplings in 1959 prior to release and fertilization, and in 1961 after treatment. Trees A, C, D, and F were released and fertilized; B and E are controls. After release and fertilization, tree A had a long growing season and made greater growth, but the shape of the growth curve did not change. Trees C and D had been growing only in the spring but continued making some growth in October; however, tree F did not show an increase in length of growing season. (Allen and Scarbrough 1969)

growth was 0.51, or slightly higher than at age 8 years. Gains in volume per plot were influenced more by survival, which averaged 59 percent in 1965 but only 39 in 1972, than by height and diameter growth. The results were similar to those from an additional study (Snyder 1961b) with families from 72 parents in which the tallest 10 percent showed superiority at 12 years of 10 percent in height growth and 69 percent in plot volume.

In Florida, test plantings to 3 years of age showed that the 20 best open-pollinated families have outstanding superiority over all other families in percent survival, initiation of height growth, and total height (Goddard 1973).

The open-pollinated progeny tests summarized here indicate that selection plus progeny testing might permit selection of plus trees that would yield superior progeny for growth and wood yield. Additional gains might result if breeding for resistance to brown spot was included in the plans, as discussed later in the section on resistance to pests in this chapter.

The influence of individual longleaf parent trees on growth rate of hybrid progeny is discussed in the chapter on species hybrids.

Progeny of selfed longleaf pine were slower to start height growth than open-pollinated progenies (Derr 1963).

Correlation With Other Traits

Because improvement in growth rate and yield of wood products is the usual objective of longleaf pine breeding, one of the first problems is the relationship between "fast growth" and other important traits. Whether traits are correlated directly, inversely, or associated at random, they must be considered when breeding plans are prepared. Most of the information about correlation of traits with growth rate has been from incidental parts of studies and may not be of sufficient scope to meet needs of tree breeders. Early growth following seedling stage, but not survival, was correlated with seedling size (McGee and Scott 1965) but not growth and seedling weight (Snyder 1969). Also, Snyder found that seedling weight in the nursery, but not 8-year height, was directly correlated with seed weight. No relationship seems to exist between seedling size and susceptibility to brown-spot disease (Verrall 1934; Croker 1967). Stem-diameter growth rate and tree volume are not correlated with wood specific gravity (Johnson 1893; Mohr 1897; Saucier and Taras 1969). Fast growth does not appear to be related to poor stem or crown form, according to experience of tree breeders selecting plus trees for clonal seed orchards. At present there seem to be no important traits inversely correlated with high rate of growth and, thus, none presenting an obstacle to breeding.

Additional information about variation in specific traits that may affect correlation with growth is given in the appropriate sections of this chapter.

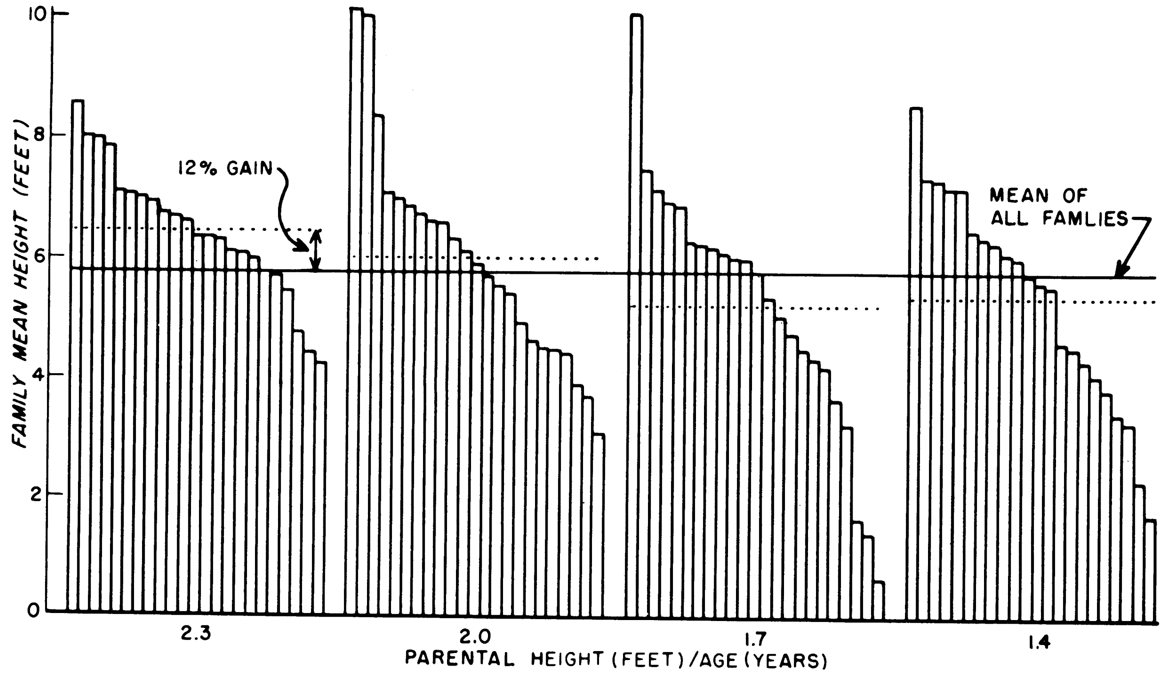

Figure 131.—Height of open-pollinated families of longleaf pine from four groups of maternal parents based on average yearly height growth. For maternal parents that grew fastest, 2.3 feet per year, the mean heights of progeny have a ratio of 100:94:81:84 in decreasing order to the group of parents that made the slowest growth, 1.4 feet per year (dotted lines). There was a wide range in heights among families within each group of maternal parents, but the narrowest range was among progeny of the fast-growing phenotypes. Three families showed greater height growth than the better family of the fast-growing parents, but many families were shorter than the slowest growing family in the group of better maternal phenotypes. Each bar represents an average of 28 trees. (Snyder 1969)

STEM AND CROWN FORM

Within the southern pine group longleaf probably has the best stem and crown form, with a high proportion of trees growing straight stems—in contrast to loblolly pine. Although twigs and branches are larger than those of other species, they are not as numerous or overly long, and natural pruning is reasonably good over a wide range in stocking. The spiral form of stem growth common in loblolly pine is rare in longleaf, although spiral grain occasionally occurs (Herrick 1932).

Consequently, the percentage of trees that would be unsuitable for breeding or seed orchard clones because of poor form is low in stands. The proportion of undesirable trees is an important factor when selection criteria are established. A group of longleaf pine plus trees selected only for good growth, seed production, and wood of a certain specific gravity would contain only a few trees of poor form, whereas a group of loblolly pine selected under a similar system would contain a high proportion of trees of undesirable form.

Branching characteristics vary throughout longleaf pine crowns. An area of two to seven whorls below the topmost branches is thought to be the best location to sample branch diameter, length, and angle with the trunk (Snyder 1961c). Above this area, branches are competing with the leader, and their attachment angles are acute. Below it, the branches are not growing in proportion to the main stem, which makes the angle of attachment nearly horizontal.

Crown size varies among trees, but in old-growth stands Lodewick (1930) found it had little influence on current diameter growth of stems. Although crown form is as a rule good in longleaf pine, there is an impressive range in types among individual trees (figures 132 and 133). Poor form in trees that appear to be longleaf pine may be a result of hybridization with loblolly. The trees may have numerous large branches with a high angle from the horizontal. Open-pollinated longleaf pine families may vary in branch size and angle of attachment (fig. 134) (Stephenson and Snyder 1969).

PEST RESISTANCE

Brown-spot needle blight, caused by *Scirrhia acicola*, the most important disease of longleaf pine, is controlled in the nursery by chemical sprays and in the field by prescribed fire. In certain geo-

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Figure 132.—Longleaf pine plus tree has outstanding height growth, low branch angle, short branches, straight stem, and good natural pruning.

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Figure 133.—Longleaf pine (on the right) with undesirable crown form. Poor natural pruning, branchiness, and excessive stem taper make this a poor mother tree. Trees of better form appear on the left. (Dorman 1952)

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Figure 134.—Rows of open-pollinated progeny of longleaf pine display high uniformity among trees, whether the average is for horizontal or ascending branching habit. In young trees, limb diameter might not be related to branching habit. (Stephenson and Snyder 1969)

graphic locations, it is of sufficient importance to be a factor in silviculture, but it is rarely a consideration in choice of species to plant. The areas in which brown spot is severe on longleaf pine do not always coincide with those where diseases and insect enemies of other pines are important (fig. 135).

Variation among seedlings and saplings in the amount of infection has been known to pathologists for many years (Verrall 1934). An almost disease-free seedling may be growing beside one with a high degree of infection. Both may be growing under the same condition of soil and ground cover, and the susceptible plant may be smaller or larger and have fewer or more needles than the disease-free one. The ability of a seedling to produce oleoresin and block or limit extension of the fungus was found to be a factor in resistance, but the number of resin ducts in the needles was not.

In south Alabama, an area of high rust incidence, 12 percent of the seedlings had no more than 10 percent needle infection, while other seedlings were highly infected, indicating wide phenotypic variation among seedlings (Boyer 1972). Highly susceptible trees may die or fail to successfully compete, and, as longleaf stands develop, the disease-free individual trees account for an increasing proportion of the dominant stand.

In a heavily infected area in the fall of 1937, the pathologist Dr. Paul V. Siggers found and transplanted a disease-free seedling from which later tests of open-pollinated offspring in 1955 showed only light infection in contrast with the controls (Derr 1963). Progeny of crosses between the resistant tree and others showed diferences attributable to the parent and a degree of resistance about equal to that of open-pollinated progeny of the resistant parent. Selfed progeny of the resistant tree had about the same level of resistance as open-pollinated offspring.

In Louisiana, an area of high brown-spot incidence, wind-pollinated families of 227 longleaf pine trees showed family means ranging from 4 to 59 percent of diseased needle tissue (fig. 136) (Derr 1971). Also, Louisiana trees showed higher susceptibility than Alabama, South Carolina, or Florida trees; therefore, resistance to brown spot in the eastern part of the longleaf pine range may be partly genotypic. In a study of northern and southern isolates of *Scirrhia acicola*, those from Wisconsin and Minnesota when compared with those from Mississippi differed in spore germination, growth rate, and pigment formation. The northern race of the disease was more virulent to Scots pine, and the southern to jack, Virginia, longleaf, and loblolly in decreasing order (Kais 1972). Very few tests of this

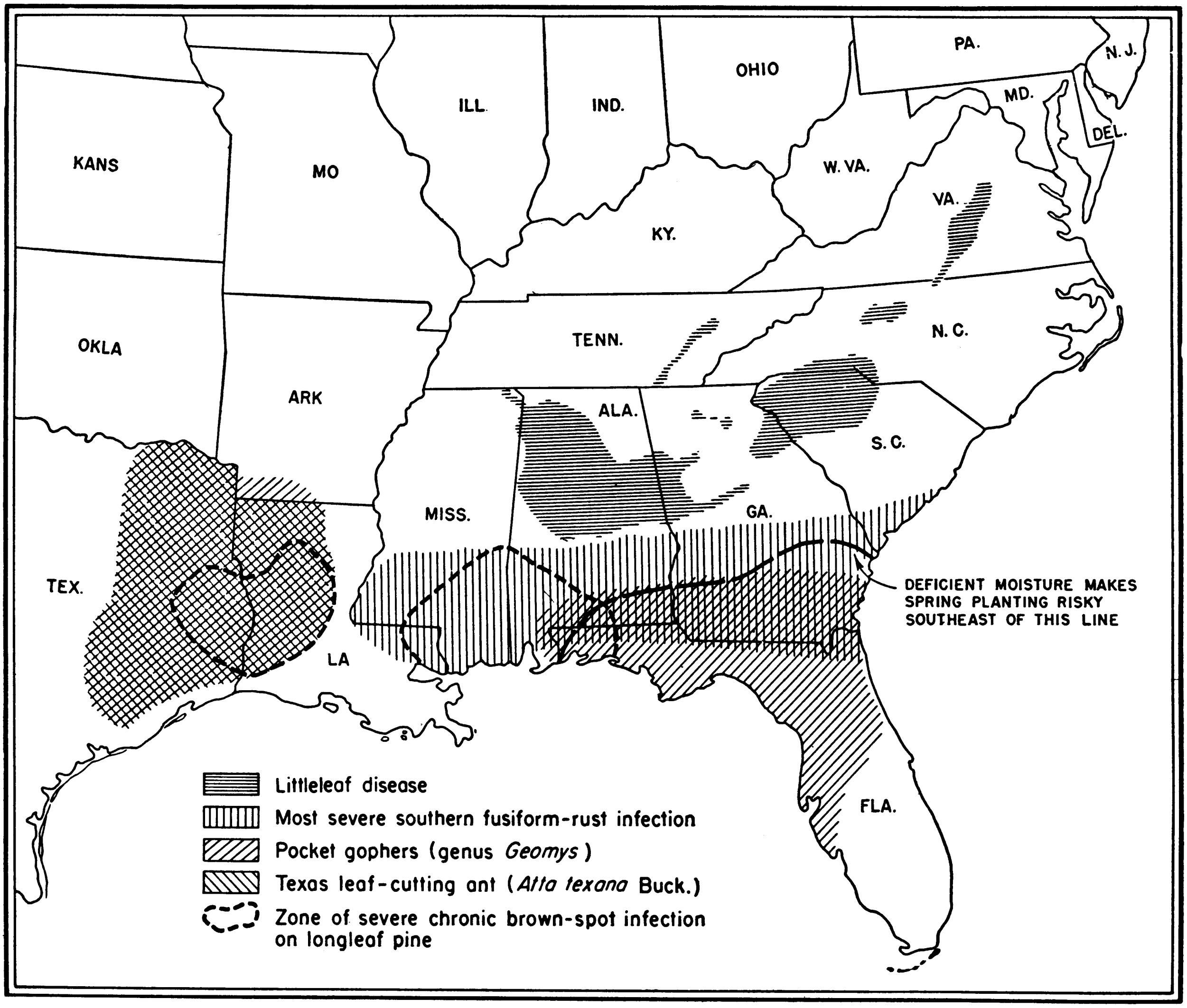

Figure 135.—Approximate locations of some plantation and nursery hazards. The only area where diseases are important in the silviculture of three major southern pines is in southern Alabama and Mississippi. Here, the area of severe brown-spot infection of longleaf pine overlaps that of severe southern fusiform rust infection of both loblolly and slash pines. (Wakeley 1954a)

kind have been made to track down geographic variation in disease and insect enemies rather than in trees.

In studies of interspecific hybrids, families of individual longleaf maternal parents pollinated with the same slash pine pollen mix varied widely in brown-spot infection and other traits, as discussed in the chapter on hybrids (Derr 1966; Schmitt 1968).

The fused needle disease is not important in the United States (Jones 1952).

Insects take a heavy toll of longleaf pine stands at certain times and places, but little is known of variation among trees in inherent resistance. Work is underway to ascertain whether severity of attack is related to chemical characteristics of the oleoresin.

SEED AND SEED PRODUCTION

Seed production in longleaf is neither so consistent among years nor so large in volume as for most of the other southern pines. In fact, seed production is so low it becomes a vital factor in natural regeneration, and special silvicultural treatments are dictated by time and volume of seed crops. Evidence of good inherent seed production should thus be required in selection for clonal seed orchards. In addition to low production as a result of infrequent seed crops, longleaf pine has fewer twigs over the crown than other pines, which reduces the number of conelets that can be produced.

Most observations of phenotypic variation among trees in flowering characteristics have been made in

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Figure 136.—Row of 3-year-old disease-resistant longleaf pine seedlings at right, between two rows of nonresistant seedlings. The resistant seedlings show their superior survival and growth in a central Louisiana test area. The nonresistant seedlings are either dead or lingering in the grass stage beyond the normal time.

connection with studies aimed at stimulating flower production. The results are reviewed in the chapter on sexual reproduction. Briefly, it has been observed that plantation trees vary widely in the age, starting at about 5 years, when conelets are produced; cone and seed yields vary among trees when control pollinated; time of cone ripening based on cone specific gravity varies widely among trees but little within crown of any one tree; and inherent differences among trees in ability to produce cones, indicated by past performance, were more important than cultural treatments, such as fertilization, thinning, and irrigation, in controlling cone production.

As noted, longleaf pine seed with firmly attached seed wings are the largest of southern pine seed.

The *Woody-Plant Seed Manual* (USDA Forest Service 1948b) gives an average of 4,200 seeds per pound, with a range of 3,800 to 6,000. Seed size does not seem to have a lasting effect on seedling size (Snyder 1969).

WOOD PROPERTIES

Longleaf pine is not an important species in seed orchards, and, thus, selection for specific wood properties has not been emphasized. Longleaf pine wood was included with that of the other major species in early studies summarized by Mohr (1897) from various papers. A longleaf pine tree was chosen as the basis for a diagram illustrating the relationship of wood specific gravity to height, diameter, and age (fig. 115). Results of recent studies with various southern pines have confirmed conclusions that were based on work done before the turn of the century.

Some of these early studies reported differences among trees and gave attention to the relationship between wood properties and growth. In connection with the influence of growth rate Johnson (1893, p. 27) in the paper, "Timber Physics. Part II. Progress Report. Results of Investigations on Long-Leaf Pine (*Pinus palustris*)," made the following statement: "It has been well established that strength is no function of the width of the annual rings. It is, however, a function of the proportion of summerwood to springwood in each annual ring, or, since the summerwood is always more dense, this is the same as saying that the strength is a function of the density or of the specific gravity." Forty years later, Lodewick (1933) confirmed this relationship.

In addition to the variation in wood properties that Johnson (1893) described within and among trees, Gomberg (1893), in the same paper, commented that the percent of turpentine in the sapwood was 3 to 4 percent in what he called "rich trees" and 2 to 3 percent in other trees. Kurth (1933) found a range of 3 to 5.5 percent in extractives. He showed also that trees of rapid growth had a higher extractive content than those of slow growth.

For wood specific gravity, estimates only of phenotypic variation are available. The trees used in early studies were 100 to 150 years old, with wood varying from 0.57 to 0.66 (Johnson 1893). In a more recent study, longleaf pine trees in Mississippi averaged 0.55, with a range of 0.40 to 0.80 for trees over 5 years old and under 65 years (Mitchell and Wheeler 1959b). The 1,576 trees sampled for the USDA Forest Service seed orchard project averaged 0.57, with a range of 0.40 to 0.75 and a mean age of 50 years (Saucier and Taras 1969). The standard deviation of 0.040 was comparable to that for other major southern pines. The stem volume of the plus trees was always outstanding for the stand, but their specific gravity did not vary significantly from that of five comparison trees in the vicinity. The wood samples for these studies contained the natural extractives, which would not change the range among trees but may result in an overestimate of 6.0 to 7.5 for mean specific gravity. Also, some error might be attributable to geographic locations.

Extractive content of increment cores from 143 longleaf pine trees over a six-state area averaged 7.36 percent, with a standard deviation of 4.89 percent, indicating that variation among trees was large (Taras and Saucier 1967).

The direction of twisted grain in longleaf pine varied widely among 1,527 trees observed in Louisiana (Herrick 1932). Twenty-three percent of the trees were straight grained, 53 percent twisted to the right, and 24 percent to the left. The limbs were studied on 215 trees and found to have the same direction of twist as the trunk. Roots of 57 trees studied showed 33 percent straight grained, 55 percent twisting to the right, and 12 percent twisting to the left.

Much work remains to be done on the subject of tree-to-tree variation in wood properties of longleaf pine. Results available, largely on wood specific gravity, indicate longleaf has the same general pattern of variability as do the other major southern pines.

OLEORESIN PRODUCTION AND COMPOSITION

Although longleaf pine is one of the two southern pines yielding oleoresin for conversion by the naval stores industry into turpentine and rosin, improving oleoresin yield has not been an objective in longleaf breeding, even within the naval stores region, because the opportunities seemed more promising by working with slash pine. Moreover, the decline in production of naval stores products in recent years has contributed to lack of interest in breeding improved strains.

Longleaf and slash pines often occur in closely adjacent stands in southeast Georgia, where naval stores production is centered, and yield of individual trees is about the same for both species. The chemical composition of oleoresin varies from that of slash pine, but no distinction is made between species in the industry.

There seems to be no great need to breed specific strains for increased yield of oleoresin at present. Oleoresin yield might be considered among other traits in industrial tree breeding projects when an additional product from trees is desirable. Tall oil is an important product that might be considered in breeding plans when strains are to be grown for pulp. The importance of oleoresin yield and chemical composition in breeding for insect and disease resistance has received little attention, but investigation is underway.

Phenotypic variation of considerable magnitude in oleoresin yield among individual trees has been observed ever since research in commercial extractions has been conducted. In a summary of research on oleoresin extraction procedures, Wyman (1935) described a study of two longleaf pine trees that were selected for their similarity in external appearance but whose oleoresin yields varied so widely that, during a 4-year period, one tree produced almost twice as much as the other. In a study of the relationship between oleoresin quality and various characteristics of the tree, Otte (1930) used some longleaf pine trees whose yields were 4.58 times those of low-yielding trees.

Inherent difference in oleoresin yield among longleaf pine trees has been demonstrated by a Florida study (Mergen 1953a). Oleoresin yields of 17-year-old longleaf pine offspring from wind pollination of below-average trees and above-average trees were determined from micro-faces and were significantly different for the two groups of maternal parents. Oleoresin yield was related to diameter of the trees, normal for both longleaf and slash pines, but the level of the regression of yield over diameter was different for the two groups of trees (fig. 137). Yield of trees 5 inches in diameter ranged from 20 grams to more than 70 grams of oleoresin.

Composition of the oleoresin varies widely among individual longleaf pines (Otte 1930). The optical rotation of turpentine was the most variable of the physical constants determined, and significant differences were noted in the turpentine of individual trees (Black and Thronson 1934). The optical rotation of the turpentine from one longleaf pine tree steadily decreased during the last season of work from a maximum of about +13° to +4°, and the yield of oleoresin from the tree steadily decreased throughout the season. Normally, oleoresin yield increases as temperature increases in late spring and early summer, then decreases slightly during the fall season.

As with yield itself, oleoresin physical and chemical properties have not been studied as intensively in longleaf as in slash pine (Squillace and Fisher 1966), but indications are that they are not highly uniform. Results of the studies with slash pine are given in the chapter on tree-to-tree variation in that species, and estimates of variation and inheritance of tall oil yield in slash pine might apply also to longleaf pine. It would be unwise to assume without study that they do not.

Monoterpene composition of basal stem-xylem tissue averaged 25 percent beta-pinene, with a range of 4 to 47 percent; cortex tissue oleoresin of 15 trees averaged 46 percent, with a range of 30 to 65 percent. There was no difference in the average composition among trees from Louisiana, Mississippi, or Florida, but three trees in the Louisiana collection contained 4-, 8-, and 10-percent limonene. Heritability of beta-pinene of cortical tissue, based on sibling intraclass correlation for control-pollinated families, was 0.30, and, based on a regression of family means on mid-percent values, it was 0.60 (Franklin and Snyder 1971).

Physiological as well as chemical traits play an important part in survival of a species; hence, breeding for variability in this group of traits might be desirable in longleaf pine as well as other species if monoculture seems to pose a threat to the southern pines. Improvement in morphological traits might not reduce variability in physiological traits. Well aware that a change in one trait will not cause a change in another unless they are genetically correlated, tree breeders are studying these relationships.

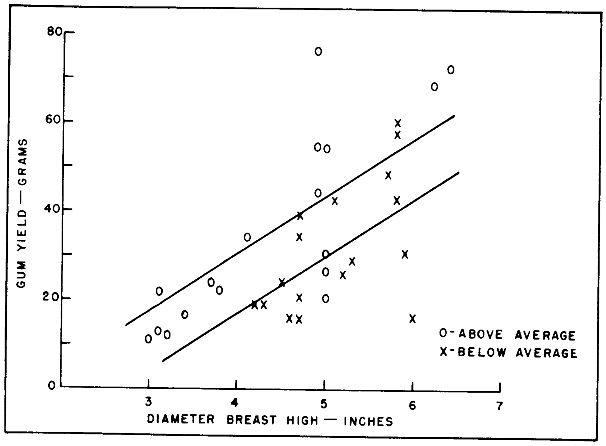

Figure 137.—Offspring of longleaf pine trees with above-average yield (upper regression line) produce more oleoresin than those of maternal parents with below-average yield. (Mergen 1953a)