Pinus echinata Mill. **Shortleaf Pine**

Pinaceae Pine family

Edwin R. Lawson

Shortleaf pine *(Pinus echinata)* is one of the four most important commercial conifers in the southeastern United States. Depending upon locale, the species is also called shortleaf yellow, southern yellow, oldfield, shortstraw, or Arkansas soft pine. Shortleaf pine tolerates a wide range of soil and site conditions and maintains its growth rate for a relatively long period. However, the species tends to grow slower during the early years after establishment than other southern pines. Shortleaf pine is the most common species regenerated in the northern and western parts of its range.

Habitat

Native Range

Shortleaf pine (fig. 1) has the widest range of any pine in the southeastern United States. It grows in 22 States over more than 1 139 600 km² (440,000

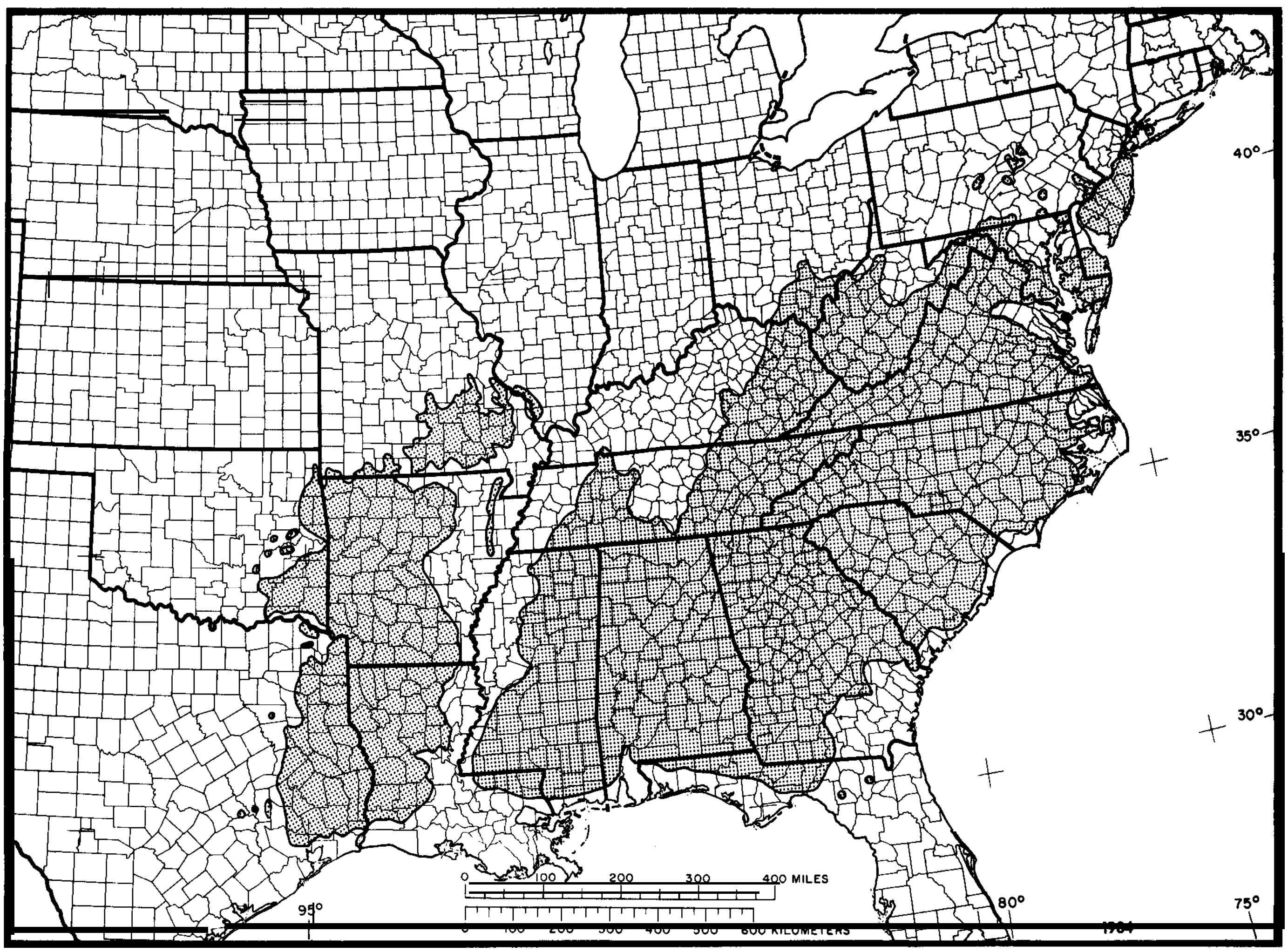

Figure *l-The native range of shortleafpine.*

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mi²), from southeastern New York and New Jersey west to Pennsylvania, southern Ohio, Kentucky, southwestern Illinois, and southern Missouri; south to eastern Oklahoma and eastern Texas; and east to northern Florida and northeast through the Atlantic Coast States to Delaware (33). In 1915, shortleaf pine was reported to grow in 24 States. Fossil pollen found in Michigan suggests that it may have once grown there *(18).*

Climate

Shortleaf pine grows in a fairly humid region but is the least exacting of the southern pines as to temperature and moisture *(18).* Annual precipitation averages between 1020 mm (40 in) on the western edge of its range and 1520 mm (60 in) at the southern tip of its range (59). Snowfall averages less than 41 cm (16 in) over most of the shortleaf pine range but may be twice that amount in some of the higher elevations of the Appalachians northward into Pennsylvania. The region of best development for the species is in Arkansas, northern Louisiana, and the southern Piedmont, where precipitatin ranges from 1140 to 1400 mm (45 to 55 in) and averages 1270 mm (50 in). The 10° C (50° F) average annual temperature isoline closely parallels the northern limit of shortleaf pine. Over its range, average annual temperatures vary from 9" C (48° F) in New Jersey to 21° C (70° F) in southeast Texas.

Soils and Topography

Shortleaf pine's adaptability to a great variety of site and soil conditions partly accounts for its wide distribution. The best growth rate is on South Atlantic and Gulf Coastal Plain soils. However, most of the soils that shortleaf pine occupies are classed in the order Ultisols and suborder Udults. Soils in this suborder are usually moist and relatively low in organic matter in subsurface horizons. They are formed in humid climates that have short or few dry periods during the year. Two great soil groups, Paleudults and Hapludults, include the primary soils occupied by shortleaf pine. Paleudults have a thick horizon of clay accumulation without appreciable weatherable materials. Hapludults may have either relatively thin clay subsurface horizons or a subsurface horizon with appreciable weatherable materials, or both. Shortleaf pine may occupy soils in other orders, but they do not constitute a significant part of its range *(58).*

Shortleaf pine grows best on deep, well-drained soils having fine sandy loam or silty loam textures. These soils are found primarily on flood plains. Site indices for shortleaf pine on these sites may exceed 30 m (100 ft). Very shallow, rocky soils on upland sites in the lower rainfall sections of the species' range have very low site indices, sometimes as low as 10 m (33 ft) *(21).* In the upland areas of its range, site indices at base age 50 years for natural stands average between 15 m (50 ft) and 23 m (75 ft) *(20,25).* In north Mississippi, site indices of sample plots ranged from 6 m (20 ft) to 30 m (97 ft) for shortleaf pine plantations varying in age from 17 to 29 years *(69).*

Shortleaf pine does not grow well on soils with a high calcium content, high pH, or excessive internal drainage. It is also reported to be more abundant than loblolly pine on the drier, better drained, and less fertile soils in the Piedmont. The difference is partly attributable to shortleaf pine's larger root system, lower tolerance to poor soil aeration, and lower demand for nutrients *(18).*

Shortleaf pine grows at elevations as low as 3 m (10 ft) in southern New Jersey and up to 910 m (3,000 ft) in the Appalachian Mountains. It grows up to 300 m (1,000 ft) in Pennsylvania. Its best development is attained at elevations of 180 m (600 ft) to 460 m (1,500 ft) in the Piedmont and 45 m (150 ft) to 350 m (1,150 ft) in Louisiana and Arkansas, although it grows at elevations up to 610 m (2,000 ft) in Arkansas, Missouri, and Oklahoma *(16,18).*

Associated Forest Cover

Shortleaf pine is now considered a major component of three forest cover types (Society of American Foresters, *16*), Shortleaf Pine (Type 75), Shortleaf Pine-Oak (Type 76), and Loblolly Pine–Shortleaf Pine (Type 80). Although shortleaf pine grows very well on good sites, it is genearlly only temporary and gives way to more competitive species, particularly hardwoods. It is more competitive on drier sites with thin, rocky, and nutrient deficient soils. With the species' ability to grow on the medium and poor sites, it is not surprising that shortleaf pine is a minor component of at least 15 other forest cover types.

21	Eastern White Pine
40	Post Oak-Blackjack Oak
43	Bear Oak
44	Chestnut Oak
45	Pitch Pine
46	Eastern Redcedar
51	White Pine-Chestnut Oak
52	White Oak-Black Oak-Northern Red Oak
57	Yellow-Popular
70	Longleaf Pine
78	Virginia Pine-Oak

79 Virginia Pine
81 Loblolly Pine
82 Loblolly Pine-Hardwood
110 Black Oak

In addition to species in the cover types, other common associates include scarlet oak *(Quercus coccinea),* southern red oak *(Q. falcata),* blackgum ***(Nyssa sylvatica),*** sweetgum ***(Liquidambar styraciflua),*** Table Mountain pine *(Pinus pungens),* mocker-nut and pignut hickories *(Carya **tomentosa*** and ***C. glabra),*** winged elm *(Ulmus alata),* sourwood ***(Oxydendrum arboreum),*** red maple *(Acer rubrum),* water oak ***(Quercus nigra),*** willow oak *(Q. phellos),* American beech *(Fagus grandifolia),* and Carolina ash ***(Fraxinus caroliniana).*** Common understory woody plants include mountainlaurel *(Kalmia **latifolia),*** flowering dogwood *(Cornus florida),* redbud ***(Cercis** canadensis),* persimmon ***(Diospyros virginiczna),*** and eastern redcedar ***(Juniperus virginiana).***

Among the more common understory shrubs, vines, and herbaceous vegetation are blueberries *(Vaccinium* spp.), huckleberries *(Gaylussacia* spp.), deerberry *(Vaccinium **stamineum),*** Japanese honeysuckle ***(Lonicera japonica),*** greenbriers ***(Smilax*** spp.), Virginia creeper ***(Parthenocissus quinquefolia),*** poison ivy ***(Toxicodendron** radicans),* grape *(Vitis* spp.), asters ***(Aster*** spp., tick-trefoil ***(Desmodium*** spp.), tickseed ***(Coreopsis*** spp.), bushclover ***(Lespedeza*** spp.), St. Andrews cross ***(Ascyrum hypericoides*** var. ***multicaule),*** birdfoot violet ***(Viola** pedata),* sensitive brier ***(Schrunkia*** spp.), early azalea ***(Rhododendron roseum),*** pussytoes ***(Antennaria*** spp.), butterfly-pea ***(Clitoria mariana),*** senna ***(Cassia*** spp.), bugbanes ***(Cimicifuga*** spp.), longleaf uniola ***(Uniola** longifolia),* panicums ***(Panicum*** spp.), sedges *(Carex* spp.), and bluestems ***(Andropogon*** spp.).

Life History

Reproduction and Early Growth

Flowering and Fruiting-Shortleaf pine is monoecious *(29).* Male and female strobili emerge from late March in the southwestern part of its range to late April in the northeastern sections. Open-grown trees may produce strobili 2 weeks earlier *(18).* Male strobili are more common on the basal part of new shoots, mostly on older lateral branches in the lower crown. The male strobili are arranged in indistinct spirals in clusters 1.3 to 5.1 cm (0.5 to 2.0 in) long. They may be green or yellow to reddish purple before ripening but become brown to light brown at the time of pollen shed. Female strobili emerge from the winter bud soon after the male strobili and are green or red to purple. They are nearly erect at the time of pollination, and 1.0 to 3.8 cm (0.4 to 1.5 in) long. After pollination, scales of the female strobili close and slow development begins. By the end of the first growing season they are about one-eighth to one-fifth the length of mature cones. Cones develop rapidly after fertilization takes place in early spring or summer of the second growing season. They mature by late summer or early fall and are green to light or dull brown when ripe (29).

Shortleaf pine generally does not bear seeds until about 20 years of age, but both male and female flowers have been reported on 5-year-old trees. Viable seeds have been produced on g-year-old trees, although this is exceptional. Trees usually produce seeds abundantly when they reach a diameter of about 30 cm (12 in) ***(18).***

Seed Production and Dissemination-Seedfall usually begins in late October or early November when cones reach a specific gravity of about 0.88 or when they will float in SAE 20 motor oil ***(60).*** As the cones dry, the bracts open, allowing the winged seeds to fall out. Most seeds fall fairly close to the tree from which they originate, but in varying patterns. In an Arkansas study, half of the shortleaf pine seeds fell into a forest clearing within 20 m (66 ft) of forest walls 21 m (70 ft) high, and 85 pecent fell within 50 m (165 ft) of the forest walls *(71).* Wall height and orientation and prevailing wind direction had little effect on the dispersal pattern, probably because of topographic features and frontal winds. In other observations, however, where prevailing winds were from one direction during seedfall, seeds were dispersed in a v-shaped pattern with the apex at the base of the tree. Under such conditions, several times as many seeds were caught in traps at a distance of 40 m (132 ft) from the tree on the leeward side as were caught at a distance of 20 m (66 ft) on the windward side ***(18).***

About 70 percent of the seeds fall within a month after maturity and 90 percent within 2 months. Some seeds continue to fall into April, and cones persist on the tree long after they are empty *(18,71).*

Shortleaf pine cones yield about 25 to 38 full seeds each *(18,72)* or about 0.9 to 1.4 kg (2 to 3 lb) of seeds per 45 kg (100 lb) of cones. The number of cleaned seeds per kilogram ranges from 70,800 to 160,700 (32,100 to 72,900 per pound) and averages 102,100 (46,300) (29). The number of seeds produced per tree and number of seeds per cone can be significantly increased by releasing seed trees from competition *(71),* although the number of seeds per cone may not always increase (43). The average number of cones per tree for unreleased trees was 498 compared with 1,069 for those released from competition (72). Releasing seed trees by removing hardwoods and thinning from below to densities at least as low as 11.5 m^2/ha (50 ft^2/acre) greatly increases seed production in shortleaf pine stands (43).

Good to excellent cone crops occur every 3 to 10 years in the Northeast and 3 to 6 years in the South (18). In the Georgia Piedmont, seed crops were most frequent in the northern portions (6). Shortleaf pine seed production was studied in natural stands in Oklahoma, Arkansas, and Missouri during a lo-year period from 1965 through 1974 (57). The lowest production was 4,900 sound seeds per hectare (2,000/acre) and the highest was 1,845,800/ha (747,000/acre). Seed yields of at least 66,700/ha (27,000/acre) occurred in 7 of the 10 years, and no consecutive 2-year periods had less than 79,100/ha (32,000/acre). In another study *(72),* the lowest seed production from 25 trees per hectare (10/acre) for three consecutive 3-year periods was 761,100/ha (308,000/acre).

Seedling Development — Shortleaf pine seeds that lie on the ground during the winter are naturally stratified and epigeous germination takes place in early spring. There is some evidence that a few seeds do not germinate until the second year, but this phenomenon has not been verified. Many seeds are eaten by birds and small mammals, and only a few actually germinate and produce seedlings. Seedbed treatments that expose mineral soil tend to increase the initial establishment of seedlings *(4,18,31,73).* Scarification during logging and burning provide effective site preparation for natural regeneration of shortleaf pine. Control of hardwood competition is also necessary to insure survival of seedlings, although some residual hardwoods have the beneficial effect of shading and protecting them from drying winds, especially on southerly aspects during the first few years after establishment, Generally, about 100 sound seeds are required to establish each seedling, although this number varies considerably depending on seedbed condition, seed year, and environmental factors (73).

Shortleaf pine seedlings may also be established by direct seeding, the success of which depends on suitability of sites and seedbeds, protection of seeds from birds and rodents, amount of seeds and timing of sowing, and control of competition. Suitable seedbeds are obtainable by mechanical site preparation, such as mowing, disking, shearing and raking, roller drum chopping, ripping, prescribed burning, chemical treatments, or hand methods, such as kicking or raking off litter. Combinations of these techniques are often used to provide the most effective site preparation *(4,47).*

It is necessary to select good quality seeds that have been properly collected, stored, stratified, and treated with bird and rodent repellents. Seedlots should have 95 percent purity and at least 80 percent germinative capacity (4). Even properly stratified seed should be treated with repellents *(13).* Seeding at two or three times the normal rate has been done, but this is an expensive and risky way to combat seed depredation (47).

For broadcast seeding, a rate of about 0.56 kg/ha (0.5 lb/acre) is recommended, although about half this amount is adequate for well-prepared seedbeds (13). For spot seeding, three to five seeds should be dropped on each spot. Row seeding requires single seeds spaced about 30 cm (12 in) apart along the row, furrow, or line (4). It is better to sow at relatively high rates initially with any seeding method, then adjust rates for the local conditions as experience dictates (47). Both natural seedfall and direct seeding have the disadvantage of high variability in achieved stocking levels, although these methods are generally much less expensive to apply.

Shortleaf pine seedlings are commonly produced in nurseries and outplanted as l-year-old, bare-rooted nursery stock. Seeds are usually stratified for about **60** days at 1” to 5” C (34” to 41” F), sown in the spring at the rate of 430/m^2 (40/ft^2), pressed into the soil, and mulched with burlap or chopped pine needles (29). Seedling densities as low as 270/m^2 (25/ft^2) are currently being considered with other nursery practice modifications to provide seedlings that will have better survival and growth (4). Nursery-grown seedlings develop rapidly and are ready for lifting and outplanting by late fall. Occasionally, seedlings are grown to larger sizes for planting on difficult sites or for special purposes. Care must be taken to insure proper lifting, handling, and storage of seedlings throughout the entire planting process. The safest time to plant the seedlings is from late February to early March, after most of the severe weather has passed. Planting in April or May is not recommended because seedlings may be lost to drought and severe competition from established vegetation. Seedlings are currently being planted at spacings of 2.4 x 2.4 m (8 x 8 ft) to 3.0 x 3.0 m (10 x 10 ft), which provide 1,683 to 1,077 seedlings per hectare (681 to 436 per acre), respectively (4).

Planting of containerized seedlings generally allows more efficient use of seed, provides better survival and faster initial growth, and extends the planting season. Depending on the type of container, the seedling may be either planted with the container or removed before planting *(2,3,46).*

Shortleaf pine seedlings develop a persistent J-shaped crook near the ground surface at 2 to 3 months of age. The stem is usually prostrate as shoot growth begins but subsequently turns upward, forming the crook. Axillary and other buds form near the crook and initiate growth if the upper stem is killed by fire or is severed *(18).*

Shortleaf pine seedlings grow slowly as the root system develops during the first year or two after establishment. The developing seedlings and saplings attain most of their height growth early in the growing season, usually by early July *(18).* Shortleaf pines show growth response to late-season rainfall, however, if it is sufficient to replenish soil water. Average annual height growth during the sapling stage ranges between 0.3 and 0.9 m (1 and 3 ft) depending on locality and site conditions *(18,36,53,69).*

Competition from woody plants *(35)* and non-woody plants *(15)* is highly detrimental to growth and development of shortleaf pine seedlings and saplings *(8,31,47).* Preharvest hardwood control by stem injection, soil application of herbicide, and rotary mowing with herbicide spraying facilitated establishment of loblolly and shortleaf pine natural regeneration in a 75- to 80-year-old stand in southern Arkansas. After 3 years, the hardwood control treatments provided optimum pine seedling stocking and significantly taller pine seedlings than the plots without hardwood control *(8).* Ripping of soils on eroded, compacted, or rocky sites followed by planting in the rips has improved performance of seedlings *(4).* Elimination of overstory competition resulted in 60-percent survival of 5-year-old trees compared with 16 percent where the overstory remained. Heights of the tallest seedlings at age 5 were 18 cm (7 in) on the untreated and 122 cm (48 in) on the treated area (18). On the Cumberland Plateau, shortleaf pine seedlings that were suppressed for 2 years after underplanting in a low-grade hardwood stand resumed good growth after the overstory was killed, but a year's height growth was lost for each year of deferred release (47).

Vegetative Reproduction-Shortleaf pine can be vegetatively propagated by either rooting or grafting of scions, but techniques for production of new plants from parts such as pollen grains are lacking. Grafting of scions or twigs from special trees to trees of the same species is the most commonly used method of propagating southern pines. It is possible, but difficult, to root needle bundles and cuttings of twigs. Shortleaf pine can also be air-layered *(14).*

Young shortleaf pines sprout vigorously at the root collar if the crown is killed or badly damaged, a feature which probably contributes much to the species' survival where other species decline. The ability to sprout profusely is generally confined to trees up to 15 to 20 cm (6 to 8 in) in diameter. Most sprouts eventually die, leaving from one to three stems to develop. Shoots also arise from buds developing in needle fascicles below the point of injury *(18).*

Sapling and Pole Stages to Maturity

Growth and Yield-Shortleaf pines (fig. 2) on good sites attain a height of 30 m (100 ft) or more and diameters (d.b.h.) of 61 to 91 cm (24 to 36 in). Heights of nearly 40 m (130 ft) and d.b.h. of 122 cm (48 in) have been recorded *(18),* but the practice of growing trees to over 70 years of age is not commonly followed in managed stands because net growth rates decline rapidly. One of the biggest shortleaf pines grows in Mississippi. It measures 105 cm (41.5 in) in d.b.h. and 42 m (138 ft) tall and attests to the large size these trees may attain.

Considering the importance of shortleaf pine, the information available on growth and yield is limited *(40).* The first variable-density yield information for a variety of sites and ages in natural stands was developed from forest survery data *(39,41).* The model provides volume and basal area predictions for natural, even-aged, shortleaf pine stands in the West Gulf region. For example, a 60-year-old stand with a basal area of 16.1 m^2/ha (70 ft^2/acre) and a site index of 21.3 m (70 ft) would have a sawtimber volume of 119.8 m^3/ha (1,712 ft^3/acre) for trees 23 cm (9 in) d.b.h. and larger (39). For trees 13 cm (5 in) d.b.h. and larger, the volume would be 129.6 m^3/ha (1,851 ft^3/acre)*(41).* These yields are for a broad range of stand conditions, including unmanaged stands and those with a significant hardwood component. Managed stands should provide greater yields. Data from uneven-aged shortleaf pine stands in the Interior Highlands of Arkansas were used to construct a similar model (42). After the cyclic harvest levels have stabilized, the periodic annual growth (based on International 1/4-inch rule) for these stands is 5.3 m^3/ha (381 fbm/acre), with a residual after cut volume of 89.3 m^3/ha (6,378 fbm/acre).

Stand structure and yield data for shortleaf pine plantations in the Tennessee, Alabama, and Georgia Highlands show that with a site index of 18.3 m (60 ft) at base age 25 years, mean annual increment of total volume culminates near age 20 *(54),* at about 15.8 m^3/ha (225 ft^3/acre). Total volume yield (outside bark) of all trees at age 40, where the site index is 9.1 m (30 ft) and denisty is 3,090 stems per hectare (1,250/acre), is about 180 m^3/ha (2,570 ft^3/acre). For the same age and planting density, the volume where site index is 18.3 m (60 ft) is about 451 m^3/ha (6,446 ft^3/acre). Basal areas for these two stand conditions are 31 and 39 m^2/ha (135 and 171 ft^2/acre), respectively. The actual numbers of trees are 1,870 and 875/ha (757 and 354/acre). Thinnings in such stands will likely provide greater volume production through capture of mortality and will increase average diameter (68).

Natural shortleaf pine stands in Missouri showed significantly higher net volume yields when thinned to about 21 m^2/ha (90 ft^2/acre) or above, at age 51. The presence of hardwoods reduced growth and yield of the stands by 8 to 12 percent (48). In south Arkansas, annual growth of uneven-aged shortleaf-loblolly pine stands averaged 5.9 m^3/ha (84 ft^3/acre) during a 24-year measurement period (44). Annual sawtimber growth of these stands averaged 6.0 m^3/ha (432 fbm/acre).

Rooting Habit-Shortleaf pine seedlings can develop a taproot at an early age, which may become quite massive if allowed to grow uninhibited *(38).* If the taproot is damaged, the seedling can grow a new one (34). In much of the region where shortleaf pine grows, however, taproots do not develop because of shallow, rocky soils and in some cases hardpans. Lateral roots tend to grow near the soil surface; they are generally concentrated in the upper 46 cm (18 in) of the soil and rarely occur below a depth of 102 cm (40 in).

Tree growth response tends to be related to root development. The cross-sectional area of roots at groundline and the composite root area or sum of the areas of the first-order lateral roots plus the area of the taproot of 3- to g-year-old shortleaf pines from Arkansas, Oklahoma, and Texas were found to be highly correlated. This suggests that basal stem diameter growth is directly related to root development *(11).* Root systems of trees originating from natural or artificial seeding are more likely to have a single taproot than planted trees. Trees with root systems oriented downward have better height growth than trees with surface-oriented root systems *(26).*

Reaction to Competition—Shortleaf pine is a shade-intolerant species and does not survive or grow well when suppressed *(16).* Young shortleaf pines are generally slower growing and slower to dominate a site than loblolly pine or many hardwood competitors, but they usually will endure competition longer than its common associate, loblolly pine. Shortleaf pine can maintain dominance on most sites after it overtops competing vegetation, but in general hardwoods cannot be eliminated from pine sites *(7,9,10).* On very good sites, however, it may not outgrow competing species such as sweetgum and red maple. Control of both woody and non-woody competition usually results in economic gains *(15,35).*

Figure 2—A mature *shortleaf pine.*

In young, well-stocked shortleaf pine stands, trees begin to compete with each other within a few years after establishment, and diameter growth rates decline *(69).* Even though growth rates decline, shortleaf pine persists in very dense stands. Natural pruning occurs as the canopies close, but it is slower than on loblolly pine *(Pinus taeda)* or longleaf pine *(P. palustris).* Shortleaf pine usually responds well to release, even when the trees are mature *(18,72).* Removal of understory competition may also increase growth rates (5).

Because of its intolerance to shade and other environmental factors, shortleaf pine commonly grows in even-aged stands (fig. 3) (22,321. Natural and artificial regeneration methods are used to establish such stands (4). Uneven-aged management is feasible, however, and may be an attractive alternative for small tracts of land *(44,45,67).*

Damaging Agents-Littleleaf disease is the most serious pathlogical threat to shortleaf pine, occurring on poorly drained soils from Virginia to Mississippi and south to the Gulf Coast *(61).* The disease results from combination of certain factors, including root destruction by ***Phytophthora cinnamomi,*** periodic excessive soil moisture deficits, poor aeration, low fertility, damage from nematodes, and perhaps toxic levels of manganese. These forces combine to impede mineral absorption, particularly nitrogen *(18,27).* Symptoms of the disease usually appear when the stands are 30 to 50 years old, but seldom in stands less than 20 years old. Growth rates of infected trees may be greatly reduced, and mortality may be very high. Fertilization with nitrogen at 224 kg/ha (200 lb/acre) can relieve some of the symptoms in its early stages. No practical control measures for littleleaf disease in forest stands have been developed. It is suggested that proper site selection, species selection, and maintenance of stand vigor are the best defenses against this disease *(18,52).*

Shortleaf saplings and older trees are moderately susceptible to attack by ***Heterobasidion annosum,*** a root rot. Losses in thinned plantations and occasionally in natural stands have occurred, but they have not been in general. Red heart, caused by *Phellinus pini,* may occur in older trees but is rare in stands under 80 years old. Several other relatively unimportant diseases occur in shortleaf pine (27).

Shortleaf pine seedlings are subject to damping off and root rot caused by several fungi, usually when soils have a pH above 6 and weather conditions are wet. Foliage of shortleaf pine normally does not develop serious diseases, but at least eight needle rusts are known to attack the species *(27).* Brown spot from ***Scirrhia acicola*** may be aggressive. The rust, ***Cronartium comandrae,*** has occasionally damaged shortleaf seedlings.

Figure *3-Typical natural shortleaf pine stand showing* **abundance** *of understory hardwoods.*

Young shortleaf pines are attacked by Nantucket pine tip moth *(Rhyacionia frustrana).* This insect has become a major pest in the eastern United States and may have greater impacts on growth than previously believed. Chemical control of this pest is difficult in forest situations, although early results of spray applications have shown promise. The redheaded pine sawfly ***(Neodiprion Zecontei)*** is our most destructive sawfly, and shortleaf is one of its preferred species. Loblolly pine sawfly ***(N. taedae Zinearis),*** attacks shortleaf pine in at least eight States. Reproduction weevils are the most serious insect pests of pine seedlings, reportedly killing 20 to 30 percent of seedlings planted in cutover pine lands. Pales weevil ***(Hylobius pales),*** and pitch-eating weevil, ***(Pachylobius picivorus),*** are most destructive species over the eastern and southern United States *(1,17).*

The southern pine beetle ***(Dendroctonus frontalis),*** occasionally causes great losses. Other important insects are the pine engraver beetles *(Ips* spp.), especially during severe droughts, and the black turpentine beetle ***(Dendroctonus terebrans).***

Shortleaf pine is generally fire resistant, but wildfires in young plantations are very damaging. The crowns are usually killed, but shortleaf pine will sprout from the base and form new stems. Larger trees may be killed by very hot fires, particularly if fuels near the tree bases are heavy. Fire damaged trees are also more susceptible to insect damage *(1).*

Shortleaf pine is generally considered to be windfirm over most of its range, although trees may be uprooted by wind where root systems are shallow *(18).* Shortleaf pines may also be damaged by severe ice storms. A single ice storm resulted in loss of almost one-third of the volume in a very heavily stocked shortleaf pine stand in north Arkansas (37). Thinned, pole-size stands are especially susceptible to damage, which often includes main stem breakage.

Acid rain may reduce growth of shortleaf pine (28). It may also result in aluminum toxicity to the roots of young trees, but could improve growth through increased availability of mineral nutrients (49). Extreme drought can result in or contribute to mortality of shortleaf pine *(70).*

Special Uses

Shortleaf pine is primarily used for lumber, plywood, other structural materials, and pulpwood. Even the taproots are used for pulpwood. The species was commonly planted on eroded lands in Mississippi (68) but does not produce as much litter as loblolly pine and therefore may be less desirable for some reclamation uses. Shortleaf pine is sometimes planted as an evergreen ornamental and as a screen in urban areas.

The seeds of shortleaf pine are eaten by birds and small mammals. Squirrels may cut the cones and eat the seeds before the cones open naturally *(23).* The canopies of shortleaf pine provide protection from the wind and cold for many animals. Stands of shortleaf pine scattered through hardwood forests are especially beneficial to wildlife. Older shortleaf pines with red heart rot *(Phellinus pini)* are primary nesting trees for the red-cockaded woodpecker *(51).*

Genetics

Because of shortleaf pine's wide distribution and the range in elevation at which it grows, considerable racial variation has developed. The Southwide Pine Seed Source Study indicated important racial differences in height, volume growth, survival, and degree of early cone production *(63,65).* Seed collection and planting zones have been drawn for shortleaf pine on the basis of these results *(62,64).* The zones are primarily a function of latitude, with much wider movement of seed being acceptable in an east-west direction than north-south. There is some indication that the shortleaf pine population west of the Mississippi River has an inherently faster growth rate than the eastern population (64).

Other studies have revealed differences in height growth, volume growth, wood specific gravity, chemical content, and foliage color *(14).* Shortleaf pine from some locations grew faster than loblolly pine, but loblolly was generally the faster growing species. In Georgia, South Carolina, and Virginia, shortleaf pine planted on sites where littleleaf disease was likely to occur revealed that trees were healthier from locations west to east, and those from upland locations were healthier than those from coastal plain areas. Specific gravity of shortleaf pine has been shown to increase slightly from the north to the south *(19),* and monoterpene chemical composition of wood oleoresin as found to vary in a clinal pattern, with a-pinene increasing from east to west while ß-pinene decreased *(12).*

Natural hybridization of shortleaf pine and loblolly pine west of the Mississippi River is considered to be extensive and is probably a cause of many inherent variations in the species (24). Such hybridization would contribute to variation among trees through creation of intermediate types and introgression towards one or both parent species. The natural variations of shortleaf pine have been the basis for selecting trees having superior qualities. These qualities include growth rate, stem and crown form, resistance to littleleaf and other diseases, wood specific gravity, tracheid length, extractives, oleoresin content, and seed production *(14).* Many of these traits have been the basis for selecting individual trees for seed orchards, which are rapidly becoming the primary source of seeds for planting programs. In 1974, there were 190.6 ha (471 acres) of shortleaf seed orchards in the United States, with 158.2 ha (391 acres) in Federal management (56); more than half of the total acreage is in Arkansas.

Several artificial hybrids have been produced with shortleaf pine. They are of special interest because they offer the opportunity to combine specific qualities of individual species. For example, shortleaf pine can be crossed with slash pine *(Pinis elliottii)* to yield progeny that are resistant to fusiform rust, a disease to which slash pine is highly susceptible. Shortleaf pine has been successfully crossed with slash, loblolly, longleaf, and Sonderegger pines *(P. elliottii, I? taeda, P. palustris,* and ***P. x sondereggeri)*** *(50,55).* Some of the hybrids have also been backcrossed. Shortleaf pine x loblolly pine hybrids have also shown resistance to fusiform rust, have grown as well as or better than one or both parents, and have shown increased resistance to cold and ice damage *(30).* Characteristics of most shortleaf hybrids, as well as other pine hybrids, are intermediate between the parent species. Fusiform rust resistance of shortleaf x slash hybrids, however, is closer to shortleaf pine than slash pine (66). The longleaf x shortleaf pine hybrid is difficult to produce and crosses have yielded only a few seedlings. These have shown intermediate characteristics, but seedling height growth was not delayed as it is characteristically for longleaf pine. Shortleaf x pitch pine *(P. echinata x P. rigida)* and Table Mountain x shortleaf pine *(P. pungens x l? echinata)* hybrids have also been produced and generally have intermediate characteristics *(14).*

Literature Cited

1. Baker, Whiteford L. 1972. Eastern forest insects. U.S. Department of Agriculture, Miscellaneous Publication 1175. Washington, DC. 642 p.
2. Barnett, James P. 1974. Growing containerized southern pines. *In* Proceedings, North American Containerized Forest Tree Seedling Symposium, August 26-29, 1974, Denver, CO. p. 124-128. Richard W. Tinus, William I. Stein, and William E. Balmer, eds. Great Plains Agricultural Council, Publication 68. University of Nebraska, Lincoln.
3. Barnett, James P., and John M. McGilvray. 1981. Container planting systems for the South. USDA Forest Service, Reasearch Paper SO-167. Southern Forest Experiment Station, New Orleans, LA. 18 p.
4. Barnett, James P., John C. Brissette, and William C. Carlson. 1986. Artificial regeneration of shortleaf pine. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31 - April 2, 1986, Little Rock, AR. p. 64-88. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
5. Bower, David R., and Edwin R. Ferguson. 1968. Understory removal improves shortleaf pine growth. Journal of Forestry 66(5):421–422.
6. Bramlett, David L. 1965. Shortleaf pine seed production in the Piedmont. USDA Forest Service, Research Note SE-38. Southeastern Forest Experiment Station, Asheville, NC. 4 p.
7. Cain, M. D. 1987. Site-preparation techniques for establishing natural pine regeneration on small forest properties. Southern Journal of Applied Forestry 11(1):41–45.
8. Cain, Michael D. 1988. Hardwood control before harvest improves natural pine regeneration. USDA Forest Service, Research Paper SO-249. Southern Forest Experiment Station, New Orleans, LA. 6 p.
9. Cain, M. D., and D. A. Yaussy. 1983. Reinvasion of hardwoods following eradication in an uneven-aged pine stand. USDA Forest Service, Research Paper SO-188 Southern Forest Experiment Station, New Orleans, LA. 8 p.
10. Cain, M. D., and D. A. Yaussy. 1984. Can hardwoods be eradicated from pine sites? Southern Journal of Applied Forestry 8(1):7–13.
11. Carlson, William C., and Constance A. Warrington. 1987. Cross-sectional area relationships in root systems of loblolly and shortleaf pine. Canadian Journal of Forest Research 17:556–558.
12. Coyne, John F., and George C. Keith. 1972. Geographic survey of monoterpenes in loblolly and shortleaf pines. USDA Forest Service, Research Paper SO-79. Southern Forest Experiment Station, New Orleans, LA. 12 p.
13. Derr, Harold J., and William F. Mann, Jr. 1971. Direct-seeding pines in the South. U.S. Department of Agriculture, Agriculture Handbook 391. Washington, DC. 68p.
14. Dorman, Keith W. 1976. The genetics and breeding of southern pines. U.S. Department of Agriculture, Agriculture Handbook 471. Washington, DC. 407p.
15. Dougherty, Phillip M., and Bob Lowery. 1986. Non-woody weed control in pine plantations. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31 - April 2, 1986, Little Rock, AR. p. 135-146. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
16. Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, DC. 148 p.
17. Flavell, Thomas H. 1974. Insect pests of young pines. *In* Proceedings, Symposium on Management of Young Pines. p. 243-248. USDA Forest Service, Southeastern Area State and Private Forestry, Southern and Southeastern Forest Experiment Stations, Atlanta, GA, New Orleans, LA, and Asheville, NC.
18. Fowells, H. A., comp. 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC. 762 p.
19. Gilmore, A. R. 1963. More on specific gravity of shortleaf pine in southern Illinois. Journal of Forestry 61(8):596–597.
20. Graney, David L. 1976. Site index relationships for shortleaf pine and upland oaks in the Ozark-Ouachita Highlands of Missouri, Arkansas and Oklahoma. *In* Proceedings, Central Hardwood Forest Conference. p. 309-326. J. S. Fralish, G. T. Weaver, and R. C. Schlesinger, eds. Southern Illinois University, Carbondale, IL.
21. Graney, David L., and Harold E. Burkhart. 1973. Polymorphic site index curves for shortleaf pine in the Ouachita Mountains. USDA Forest Service, Research Paper SO-85. Southern Forest Experiment Station, New Orleans, LA. 12 p.
22. Guldin, James M. 1986. Ecology of shortleaf pine. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31 - April 2, 1986, Little Rock, AR. p. 25-40. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
23. Halls, Lowell K. 1977. Pines *Pinus* spp. *In* Southern fruit-producing woody plants used by wildlife. p. 200–210. Lowell K. Halls, ed. USDA Forest Service, General Technical Report SO-16. Southern Forest Experiment Station, New Orleans, LA.
24. Hare, R. C., and G. L. Switzer. 1969. Introgression with shortleaf pine may explain rust resistance in western loblolly pine. USDA Forest Service, Research Note SO-88. Southern Forest Experiment Station, New Orleans, LA. 2 p.
25. Harrington, Constance A. 1987. Site-index comparisons for naturally seeded loblolly pine and shortleaf pine. Southern Journal of Applied Forestry 11(2):86–91.
26. Harrington, Constance A., William C. Carlson, and John C. Brissette. 1987. Relationships between height growth and root system orientation in planted and seeded loblolly and shortleaf pines. *In* Proceedings of the Fourth Biennial Southern Silvicultural Research Conference, November 4-6, 1986, Atlanta, GA. p. 53-60. Douglas R. Phillips, comp. USDA Forest Service, General Technical Report SE-42. Southeastern Forest Experiment Station, Ashville, NC.

27. Hepting, George H. 19'71. Diseases of forest and shade trees of the United States. U.S. Department of Agriculture, Agriculture Handbook 386. Washington, DC. 658 p.
28. Johnson, A. H., T. G. Siccama, D. Wang, R. S. Turner, and T. H. Barringer. 1981. Recent changes in patterns of tree growth rate in the New Jersey pinelands: a possible effect of acid rain. Journal of Environmental Quality 10(4):427–430.
29. Krugman, Stanley L., and James L. Jenkinson. 1974. *Pinus* L. Pine. *In* Seeds of woody plants in the United States. p. 598-638. C. S. Schopmeyer, tech. coord. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC.
30. LaFarge, Timothy, and John F. Kraus. 1977. Third-year results of a shortleaf x loblolly pine hybrid progeny test in Georgia. *In* Proceedings of Fourteenth Southern Forest Tree Improvement Conference, June 14-16, 1977, Gainesville, FL. p. 63-69.
31. Lawson, Edwin R. 1986. Natural regeneration of shortleaf pine. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31 - April 2, 1986, Little Rock, AR. p. 53-63. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
32. Lawson, Edwin R., and Robert N. Kitchens. 1983. Shortleaf pine. *In* Silvicultural systems for the major forest types of the United States. p. 157-161. Russell M. Burns, tech. comp. U.S. Department of Agriculture, Agriculture Handbook 445. Washington, DC.
33. Little, Elbert L., Jr. 1971. Atlas of United States trees. vol. 1. Conifers and important hardwoods. U.S. Department of Agriculture, Miscellaneous Publication 1146. Washington, DC. 9 p., 313 maps.
34. Little, S., and H. A. Somes. 1964. Root systems of direct-seeded and variously planted loblolly, shortleaf, and pitch pines. USDA Forest Service, Research Paper NE-26. Northeastern Forest Experiment Station, Upper Darby, PA. 13 p.
35. Lowery, Robert F. 1986. Woody competition control. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem March 31 - April 2, 1986, Little Rock, AR. p. 147-158. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
36. Maple, William R. 1965. Forest species compared in Ozark plantations. USDA Forest Service, Research Note SO-28. Southern Forest Experiment Station, New Orleans, LA. 2 p.
37. Maple, W. R., and Clement Mesavage. 1958, Remarkable shortleaf pine stand. Journal of Forestry 56(4):290–291.
38. McQuilken, William Everett. 1935. Root development of pitch pine, with some comparative observations on shortleaf pine. Journal of Agricultural Research 51(11):983–1016.
39. Murphy, Paul A. 1982. Sawtimber growth and yield for natural, even-aged stands of shortleaf pine in the West Gulf. USDA Forest Service, Research Paper SO-181. Southern Forest Experiment Station, New Orleans, LA. 13 p.
40. Murphy, Paul A. 1986, Growth and yield of shortleaf pine. *In* Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31 - April 2, 1986, Little Rock, AR. p. 159-177. Paul A. Murphy, ed. Arkansas Cooperative Extension Service, Monticello.
41. Murphy, Paul A., and Roy C. Beltz. 1981. Growth and yield of shortleaf pine in the West Gulf region. USDA Forest Service, Research Paper SO-169. Southern Forest Experiment Station, New Orleans, LA. 15 p.
42. Murphy, Paul A., and Robert M. Farrar, Jr. 1985. Growth and yield of uneven-aged shortleaf pine stands in the Interior Highlands. USDA Forest Service, Research Paper SO-218. Southern Forest Experiment Station, New Orleans, LA. 11 p.
43. Phares, Robert E., and Nelson F. Rogers. 1962. Improving shortleaf pine seed production in Missouri. Journal of Forestry 60(5):322–324.
44. Reynolds, R. R. 1969. Twenty-nine years of selection timber management on the Crossett Experimental Forest. USDA Forest Service, Research Paper SO-40. Southern Forest Experiment Station, New Orleans, LA. 19 p.
45. Reynolds, R. R., James B. Baker, and Timothy T. Ku. 1984. Four decades of selection management on the Crossett Farm Forestry Forties. University of Arkansas Agricultural Experiment Station, Bulletin 872. Fayetteville, AR. 43 p.
46. Ruehle, John L., Donald H. Marx, James P. Barnett, and William H. Pawuk. 1981. Survival and growth of container-grown and bare-root shortleaf pine seedlings with *Pisolithus* and *Thelephora* ectomycorrhizae. Southern Journal of Applied Forestry 5(1):20–24.
47. Russell, T. E. 1979. Planting and seeding shortleaf pine. *In* Proceedings, Symposium for the Management of Pines of the Interior South, November 7-8, 1978. p. 7-13. USDA Forest Service, Technical Publication SA-TP2. Southeastern Area State and Private Forestry, Atlanta, GA. 221 p.
48. Sander, Ivan L., and Robert Rogers. 1979. Growth and yield of shortleaf pine in Missouri: 21-year results from a thinning study. *In* Proceedings, Symposium for the Managment of Pines of the Interior South, November 7-8, 1978. p. 14-27. USDA Forest Service, Technical Publication SA-TPP. Southeastern Area State and Private Forestry, Atlanta, GA. 221 p.
49. Schier, George A. 1987. Germination and early growth of four pine species on soil treated with simulated acid rain. Canadian Journal of Forest Research 17(10):1190–1196.
50. Schmitt, Dan. 1968. Performance of southern pine hybrids in south Mississippi. USDA Forest Service, Research Paper SO-36. Southern Forest Experiment Station, New Orleans, LA. 15 p.
51. Scott, Virgil E., Keith E. Evans, David R. Patton, and Charles P. Stone. 1977. Cavity-nesting birds of North American forests. U.S. Department of Agriculture, Agriculture Handbook 511. Washington, DC. 112 p.
52. Sites, William H. 1974. Control of some important diseases of young pines. *In* Proceedings, Symposium on Management of Young Pines. p. 249-254. USDA Forest Service, Southeastern Area, State and Private Forestry, Southern and Southeastern Forest Experiment Stations, Atlanta, GA, New Orleans, LA, and Asheville, NC.
53. Shoulders, Eugene, and Frances V. Walker. 1979. Soil, slope, and rainfall affect height and yield in 15-year-old southern pine plantations. USDA Forest Service, Research Paper SO-153. Southern Forest Experiment Station, New Orleans, LA. 52 p.
54. Smalley, Glendon W., and Robert L. Bailey. 1974. Yield tables and stand structure for shortleaf pine plantations in Tennessee, Alabama, and Georgia Highlands. USDA Forest Service, Research Paper SO-97. Southern Forest Experiment Station, New Orleans, LA. 57 p.

55. Snyder, E. B., and A. E. Squillace. 1966. Cone and seed yields from controlled breeding of southern pines. USDA Forest Service, Research Paper SO-22. Southern Forest Experiment Station, New Orleans, LA. 7 p.
56. U.S. Department of Agriculture, Forest Service. 1974. Forest tree orchards, a directory of seed orchards in the U.S. USDA Forest Service, Southeastern Area State and Private Forestry, Atlanta, GA. 33 p.
57. U.S. Department of Agriculture, Forest Service. 1981. Data on file. Southern Forest Experiment Station, Monticello, AR.
58. U.S. Department of Agriculture, Soil Conservation Service. 1975. Soil taxonomy-a basic system of soil classification for making and interpreting soil surveys. Soil Survey Staff, comp. U.S. Department of Agriculture, Agriculture Handbook 436. Washington, DC. 754 p.
59. U.S. Department of Interior, Geological Survey. 19'70. The National atlas of the United States of America. U.S. Department of Interior, Geological Survey, Washington, DC. 97 p.
60. Wakeley, Philip C. 1954. Planting the southern pines. U.S. Department of Agriculture, Agriculture Monograph 18. Washington, DC. 233 p.
61. Walker, Laurence C., and Harry V. Wiant, Jr. 1966. Silviculture of shortleaf pine. Stephen F. Austin State College, Bulletin 9. Nacogdoches, TX. 60 p.
62. Wells, 0. 0. 1969. Results of the southwide pine seed source study through 1968-69. *In* Proceedings, Tenth Southern Conference on Forest Tree Improvement, June 17-19, 1969, Houston, TX. p. 117-129. Sponsored Publication 30. Southern Forest Tree Improvement Committee, Macon, GA.
63. Wells, 0. 0. 1973. Variation among shortleaf pines in a Mississippi seed source planting. USDA Forest Service, Research Note SO-162. Southern Forest Experiment Station, New Orleans, LA. 8 p.
64. Wells, 0. 0. 1979. Geographic seed source affects performance of planted shortleaf pine. In Proceedings, Symposium for the Management of Pines of the Interior South. p. 48-57. USDA Forest Service, Technical Publication SA-TP2. Southeastern Area State and Private Forestry, Atlanta, GA
65. Wells, Osborn O., and Philip C. Wakeley. 1970. Variation in shortleaf pine from several geographic sources. Forest Science 16(4):415–423.
66. Wells, 0. O., P. E. Barnett, H. J. Derr, D. T. Funk, Timothy La Farge, E. R. Lawson, and Silas Little. 1978. Shortleaf x slash pine hybrids outperform parents in parts of the Southeast. Southern Journal of Applied Forestry 1(1):28–32.
67. Williston, Hamlin L. 1978. Uneven-aged management in the loblolly-shortleaf pine type. Southern Journal of Applied Forestry 2(3):78–82.
68. Williston, Hamlin L. 1978. Thinning shortleaf pine plantations in northern Mississippi. Southern Journal of Applied Forestry 2(4):137–140.
69. Williston, Hamlin L., and T. R. Dell. 1974. Growth of pine plantations in North Mississippi. USDA Forest Service, Research Paper SO-94. Southern Forest Experiment Station, New Orleans, LA. 15 p.
70. Yeiser, Jimmie L., and Fred Burnett. 1982. Fate of forest trees stressed by heat and drought in southeastern Arkansas. Southern Journal of Applied Forestry 6(4):194–195.
71. Yocom, Herbert A. 1968. Shortleaf pine seed dispersal. Journal of Forestry 66(5):422.
72. Yocom, Herbert A. 1971. Releasing shortleaf pines increases cone and seed production. USDA Forest Service, Research Note SO-125. Southern Forest Experiment Station, New Orleans, LA. 2 p.
73. Yocom, Herbert A., and Edwin R. Lawson. 1977. Tree percent from naturally regenerated shortleaf pine. Southern Journal of Applied Forestry 1(2):10–11.