Pinus elliottii Engelm. Slash Pine

Pinaceae Pine Family

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Slash pine *(Pinus elliottii)* is one of the hard yellow pines indigenous to southeastern United States. Other names occasionally used for this species include southern pine, yellow slash pine, swamp pine, pitch pine, and Cuban pine. It is one of the two southern pines used for naval stores and one of the most frequently planted timber species in North America. Two varieties are recognized: *P. elliottii* var. *elliottii,* the slash pine most frequently encountered, and *P. elliottii* var. *densa,* that grows naturally only in the southern half of peninsula Florida and in the Keys.

Habitat

Native Range

Slash pine (fig. 1) has the smallest native range of the four major southern pines. The range extends over 8° latitude and 10" longitude, and 45 percent of the present growing stock is in Georgia (53). Slash pine grows naturally from Georgetown County, SC, south to central Florida, and west to Tangipahoa Parish, LA. Its native range includes the lower Coastal Plain, part of the middle Coastal Plain, and the hills of south Georgia. The species has been established by planting as far north as Tennessee, in north central Georgia, and Alabama. It has also been planted and direct-seeded in Louisiana and eastern Texas where it now reproduces naturally.

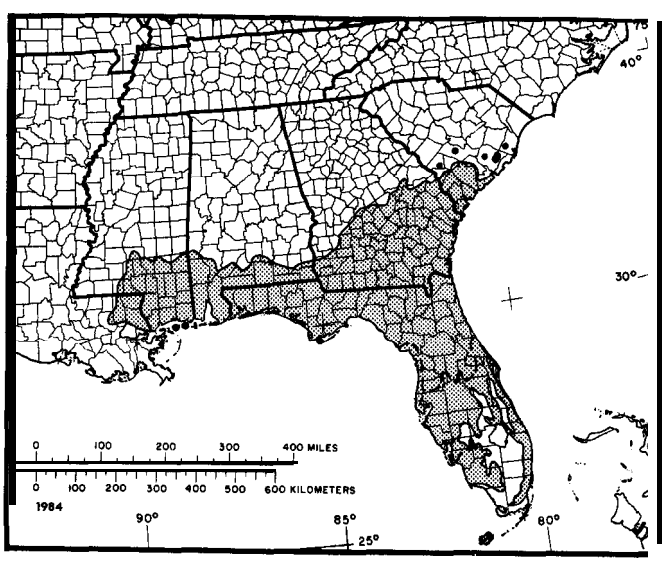

Figure 1-The ***native range of slash pine. The broken line separates northward the typical variety and southward, South Florida slash pine,*** P. elliottii *var.* densa.

Within its natural range, the distribution of slash pine was initially determined by its susceptibility to fire injury during the seedling stage. Slash pine grew throughout the flatwoods of north Florida and south Georgia.

It was also common along streams and the edges of swamps and bays *(21).* Within these areas either ample soil moisture or standing water protected young seedlings from frequent wildfires in young forests.

With improved fire protection and heavy cutting of longleaf pine *(Pinus palustris),* slash pine has spread to drier sites, replaced longleaf pine in mixed stands, and invaded abandoned fields. This increase in acreage was possible because of slash pine's frequent and abundant seed production, rapid early growth, and ability to withstand wildfires and rooting by hogs after the sapling stage.

Climate

The climate within the natural range of slash pine is warm and humid with wet summers and drier falls and springs. Rainfall averages about 1270 mm (50 in) per year and summer rains of 13 mm (0.5 in) or more occur about four times per month. The mean annual temperature in the slash pine region is 17° C (63" F), with extremes of 41" C (106° F) and -18" C (0° F), and a growing season of 250 days. It has been suggested that the average minimum temperature may be the most critical factor limiting the distribution of slash pine; however, precipitation, fire, or competition may be important in specific areas *(21).*

Soils and Topography

Soils within the range of slash pine are mostly Spodosols, Ultisols, and Entisols. Spodosols and Entisols are common along the coasts of Florida while the Ultisols are in the northern part of the range. The most frequently found suborders are Udults, Aquults, Psamments, and Aquods. Topography varies little throughout the southeastern Coastal Plain, but

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small changes in elevation frequently coincide with abrupt changes in soil and site conditions.

Although slash pine is adaptable to a variety of site and topographic conditions, it grows best on pond margins and in drainages where soil moisture is ample but not excessive and the soil is well aerated. Growth is unsatisfactory on deep, well drained sands (sandhills) and on poorly drained savanna soils with high water tables (crawfish flats). Growth is intermediate on inadequately drained soils. Specific factors related to height growth, and hence to productivity, vary somewhat, but the most influential are those related to the amount of water or space available to tree roots.

Height growth of slash pine plantations in Florida was estimated from three soil factors: depth to a fine textured horizon, depth to a mottled horizon, and silt plus clay content of the finest textured horizon in the soil profile. The first two alone explained 89 percent of the variation in height at a given age and gave height estimates adequate for field use *(21)*. Where internal drainage was adequate, the height of slash pine increased directly with the amount of silt and clay in the subsoil *(12)*. Average site index (base age 50 years) ranged from 22.9 m (75 ft) for sands and loamy sands to 27.4 m (90 ft) for silty clays and other fine textured soils.

In the Carolina sandhills, slash pine heights increased with thickness of the A_1 soil horizon and decreased with depth to fine textured horizons (44). In southeastern Louisiana, site index increased with depth of the least permeable layer, sand content of the subsoil, and degree of internal drainage. Site index decreased where the least permeable layer was too deep, the topsoil was too sandy, or the soil was excessively drained internally (36).

Mean total height of dominants and codominants was related to seasonal rainfall, slope, and potential available moisture storage of the subsoil in 87 test plantings throughout Louisiana and southern Mississippi. Optimum conditions within the range of data were 610 mm (24 in) of rain from April through September, 790 mm (31 in) of rain from October through March, 5 percent slope, and 7 percent available moisture storage capacity in the subsoil. Dominant and codominant trees average 19.6 m (64.3 ft) tall at 20 years under these conditions (49).

Associated Forest Cover

Slash pine is a major component of three forest cover types including Longleaf Pine-Slash Pine (Society of American Foresters Type 83), Slash Pine (Type 84), and Slash Pine-Hardwood (Type 85) *(18)*. The species is also included as an associate in the following cover types:

70 Longleaf Pine
74 Cabbage Palmetto
81 Loblolly Pine
82 Loblolly Pine-Hardwood
97 Atlantic White-Cedar
98 Pond Pine
100 Pondcypress
103 Water Tupelo-Swamp Tupelo
104 Sweetbay-Swamp Tupelo-Redbay
111 South Florida Slash Pine

Since it has been artificially propagated far outside its natural range, slash pine can now be found in association with many other species.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Slash pine is monoecious and wind pollinated. Flowering begins at a relatively early age for conifers, usually between 10 and 15 years, but occasionally as early as 3 years *(2)*. Bisexual cones have been observed *(41)*. Open-grown trees that are fertilized and irrigated tend to flower at an early age. Similar treatments in close-spaced plantings do not result in earlier flowering. Mature scions grafted to seedling rootstocks begin flowering after 2 to 3 years and flower normally by 8 years if planted at wide spacings.

Early development of male strobili begins in June and continues for several weeks. Strobili become visible as small knobs near the base of vegetative buds in the fall. They usually occur in clusters of 12 or more, arranged spirally around the base of the current year's branches in the middle or lower crown. Further growth is delayed until midwinter. The staminate strobili are purple and 5 cm (2 in) long when pollen is shed in late January and February.

Development of female strobili begins between late August and mid-September. The female strobili are visible by December or January; they occur singly or in clusters and are most abundant on primary and secondary branches in the upper crown. They continue to grow until fully developed, by February in Florida and March further north. Female strobili are about 2.5 cm (1 in) long and red to purple at the time of pollination. They are receptive to pollen for a few days; receptivity of all strobili on a single tree may span a 2-week period. Outcrossing is normal because pollen shed and receptivity of female strobili occur at different times on the same tree. Selfing can, occur under natural conditions and in seed orchards, but

both yield of viable seed and vigor of trees produced is low.

Seed Production and Dissemination-Some seeds are produced each year, with good crops about every third year. In natural stands, cone production was increased by 50 to 100 percent after each of the following treatments: heavy thinning or crown release, stem injury, and fertilization applied before flower bud initiation. Wide initial spacing, fertilization, competition control, and irrigation are used to maintain a high level of production in seed orchards, Age, crown size, and genetic and environmental factors interact to influence seed production once a tree begins to bear cones.

Slash pine cones mature during September, approximately 20 months after pollination. There is a wide variation in time of cone maturation among trees, regions, and years. The specific gravity of **cones** with mature seeds is about 0.9 and they float in SAE 20 motor oil. Cones begin to open when the specific gravity decreases to 0.7. Natural seedfall occurs primarily in October but may be hastened by dry weather or delayed by wet weather. A few seeds may fall until March. Seed viability is increased if collected cones are stored several weeks before seeds are extracted.

There are 21,160 to 42,550 seeds per kilogram (9,600 to 19,300/lb) and the average is about 29,760/kg (13,500/lb) (55). More than 90 percent of the winged seeds usually fall within 46 m (150 ft) of the parent tree. A slash pine plantation 13 to 16 years old, 15.2 m (50 ft) tall, grown initially at a spacing of 5.8 by 5.8 m (19 by 19 ft) or 297 stems per hectare (120/acre), will produce seeds at an average of 30.3 kg/ha (27 lb/acre) per year.

Seedling Development-Seed viability is usually good. Fresh seeds germinate rapidly, many within 2 weeks of natural seedfall if soil moisture is adequate. Those kept in cold storage for a year or more benefit from stratification *(38)*. Germination is epigeal (55). Newly germinated seedlings have an average of 7.2 cotyledons, 30 mm (1.18 in) long. Hypocotyls average 37 mm (1.46 in) in length and 0.89 mm (0.035 in) in diameter. Seedlings in the cotyledon stage cannot be positively distinguished by external characteristics from those of loblolly *(Pinus taeda)* or Virginia *(P. virginiana)* pines (37).

Seed size, which is quite variable, does not influence germination in the laboratory or nursery. Small seeds produce smaller seedlings than medium or large seeds, but field survival and average heights 1 to 2 years after field planting are similar for trees from seeds of all sizes.

Root development of seedlings is influenced by soil texture and structure. In one field study, taproot length was similar for first-year seedlings in all soils, but number of laterals and total length of all roots were largest on a clay, intermediate on a loam, and least on a sandy soil *(23)*. The presence of mycorrhizae has an important beneficial influence on survival and early growth of bare-root seedlings of all morphological grades (24).

Juvenile trees past the seedling stage make from two to four height-growth flushes each year. The first begins when the winter bud elongates to become the spring shoot. Spring shoot growth begins slowly in February and gradually increases until it reaches a mean daily increment of about 7 mm (0.28 in) between mid-March and mid-April. Growth of this first shoot is completed by early June. First summer buds form in April, while the spring shoot is still growing, and second summer shoots are formed by the end of May Winter buds are present in July and height growth is slow thereafter, although some growth may occur as late as October. The spring shoot makes up 62 percent and the summer shoots 38 percent of the annual height increment.

Height growth patterns may be influenced by silvicultural practices, previous land use, and competing vegetation. Site index curves for plantations on recently abandoned fields that were cultivated and fertilized are different from those for stands on areas formerly in timber and having a dense ground cover of brush or other low vegetation when planted to trees.

Radial growth begins in early February, about the same time as height growth, and continues throughout the summer and into October or November, as long as soil moisture is adequate. Root growth accelerates in early February, before terminal and radial activity begin. Root growth rates are fastest and the percentage of actively growing tips is highest in summer when soil moisture is optimum, but some root growth takes place during all seasons of the year.

Survival and early growth of seedlings are frequently stimulated by intensive site preparation treatments such as flat disking, chopping, or bedding. Disking and chopping are effective on deep, dry, sandy soils where they control competing vegetation, incorporate organic matter into the topsoil, and may alter nutrient availability (9). On sites with a shallow water table, bedding provides increased rooting space, improves aeration, and may increase growth (39). Surface drainage may produce a similar response (26). On droughty sites, weed control and irrigation may be effective (1). Many slash pine sites are low in available phosphorus and nitrogen. In-

creased volume growth may result from fertilization with either element alone or a combination of both, depending on soil conditions *(20,43)*. Combinations of mechanical site treatment and fertilization may be more effective than either treatment alone *(1)*.

Vegetative Reproduction-Vegetative reproduction of slash pine rarely occurs naturally, but several techniques have been developed to reproduce specific individuals for use in seed orchards, clone banks, and genetic studies. Scions from mature trees are grafted onto seedling rootstocks in seed orchards and this is probably the most widely used technique of vegetative reproduction. The "cleft" graft is used with either succulent or dormant material. Normally, dormant scions are grafted onto stock plants just beginning active growth in early spring.

Air-layering (rooting undetached branches on young trees by girdling and treating them with a rooting hormone) has been more than 85 percent successful in some tests. Factors influencing results include age of the tree, concentration of the rooting hormone, season of treatment, and geographic location. Air layers usually develop a balanced root system and grow rapidly.

Cuttings from branches are difficult to root, especially those from older trees. There is considerable variation in results among trees, seasons, chemical treatments, and environmental factors. Enhanced carbon dioxide and a heated rooting medium greatly increase rooting. Needle fascicles can also be rooted, but the results are as poor and inconsistent as those with branch cuttings. In addition, most of the fascicles that form roots never begin height growth.

Sapling and Pole Stages to Maturity

Growth and Yield-Slash pine makes rapid volume growth at early ages and is adaptable to short rotations under intensive management. Yield tables have been available for natural stands since 1929 *(4,45,47,56)* and for plantations since 1955 *(13,211.*

Stand basal area density has a strong influence on merchantable yield at any age (table 1). Also, almost three-fourths of the 50-year yield is produced by age 30, regardless of stand basal area.

Current merchantable volume increment in thinned stands reaches a maximum rate before 20 years and declines thereafter (table 2). The instantaneous volume growth rate culminates at a high density in young stands and at progressively lower densities as age increases. Heavy thinning reduces periodic growth in young stands, but any density above 23 m^2/ha (100 ft^2/acre) at 20 to 30 years, or above 17 m^2/ha (75 ft^2/acre) at age 40, results in near-maximum volume growth.

Table l-Estimated merchantable yields for unthinned natural stand of slash pine on average sites, 24.4 m (80 ft) at 50 years, by age and stand density'

Age	Yields at basal areas of 11.5 m^2/ha or 50 ft^2/acre	23.0 m^2/ha or 100 ft^2/acre	34.4 m^2/ha or 150 ft^2/acre
yr		*m^3/ha*	
20	76.8	140.6	200.3
30	113.6	208.0	296.2
40	138.2	253.0	360.4
50	155.4	284.5	405.2
yr		*ft^3/acre*	
20	1,097	2,008	2,861
30	1,623	2,971	4,232
40	1,974	3,614	5,148
50	2,220	4,064	5,789

'Adapted from Bennett *(5)*. Yields are for volumes (outside bark) above a 15.2 cm (6 in) stump for trees 11.7 cm (4.6 in) in d.b.h. and larger to a 10.2 cm (4 in) diameter top outside bark.

Table 2—Estimated annual merchantable volume growth in thinned natural stands of slash pine on average sites, 24.4 m (80 ft) at 50 years, by age and stand density[1]

Age	Growth at basal areas of II.. m^2/ha or ft^2/acre	23.0 m^2/ha or 100 ft^2/acre	34.4 m^2/ha or 150 ft^2/acre
yr		*m^3/ha*	
20	7.98	10.50	11.41
30	6.23	7.56	7.49
40	5.04	5.74	5.25
50	4.13	4.55	3.92
yr		*ft^3/acre*	
20	114	150	163
30	89	108	107
40	72	82	75
50	59	65	56

'Adapted from Bennett*(5)*.

Plantation yields are influenced by previous land use and interspecies competition, so there is wide variation in estimated wood production (table 3). Early yields are usually highest on recently abandoned fields where the young trees apparently benefit from the residual effects of tillage or fertilizer and the nearly complete lack of vegetative competition. Plantations established after the harvest of natural stands and without any site treatment other than burning generally have lower survival and, con-

Table 3-Range of estimated merchantable yields in unthinned slash pine plantations on average sites, 18.3m (60 ft) at 25 years, by age and number of surviving trees[1]

Age	Merchantable yield when surviving trees number		
	741/ha or 300/acre	988/ha or 400/acre	1235/ha or 500/acre
yr		*m^3/ha*	
20	109.3 to 147.6	125.5 to 166.7	139.8 to 182.7
25	156.0 to 194.4	175.8 to 218.3	189.4 to 238.1
30	190.2 to 232.8	212.6 to 262.8	230.4 to 287.9
yr		*ft^3/acre*	
20	1,562 to 2,109	1,793 to 2,382	1,997 to 2,610
25	2,228 to 2,777	2,511 to 3,118	2,706 to 3,402
30	2,717 to 3,325	3,037 to 3,754	3,291 to 4,113

'Adapted from Clutter and Dell *(10)*. Yields are for volumes outside bark above a 15.2 cm (6 in) stump for trees 11.7 cm (4.6 in) in d.b.h. and larger to a 10.2 cm (4 in) top diameter outside balk.

sequently, lower basal area and volume than stands on old fields *(13)*. Yields in plantations established after timber harvest and intensive site preparation such as disking or bedding are usually intermediate *(10)*.

Below age 30, maximum cubic volume yields are usually produced in unthinned plantations, so landowners seeking maximum yields on a short rotation will seldom find commercial thinning beneficial. Where sawtimber is the objective, commercial thinnings provide early returns while improving the growth and quality of the sawtimber and maintaining the stands in a vigorous and healthy condition *(11)* **(fig. 2).**

Figure *&A slash pine plantation after* a *commercial thinning in which every third row was harvested.*

Rooting Habit-Slash pine develops an extensive lateral root system and a moderate taproot. Maximum length of the lateral roots was more than double the tree height in three out of four site preparation treatments at 5 years. Taproots may be deformed as a result of poor planting technique, a restricting soil horizon, or a high water table (46).

Reaction to Competition-Slash pine is relatively intolerant of competition and is classed as intolerant of shade. Stands protected from fires are invaded and replaced by more tolerant hardwood species. Unreleased seedlings established by direct seeding under a hardwood overstory seldom exceed 15 cm (6 in) in height the first year, while those freed from competition may reach 41 cm (16 in) (38). Increased survival and growth of young trees on intensively prepared sites is attributed largely to the control of competing vegetation.

Because of this intolerance, even-aged management is usually recommended for slash pine *(21,33)*. Either the seed-tree or shelterwood system of natural regeneration may be used (34) (fig. 3). Exposed mineral soil is of primary importance in establishing natural regeneration. Overstory seed trees should be removed promptly after the new seedlings are well established. Failure to do so may retard growth in height, diameter, and merchantable volume of the next crop *(19)*. An alternative to natural regeneration is to clearcut and establish a new stand by planting or direct seeding.

Damaging Agents-The most serious disease of slash pine is fusiform rust caused by the fungus ***Cronartium quercuum*** f. sp. ***fusiforme.*** Most of the southern oaks serve as alternate hosts but the fungus damages only pines. Many trees are killed and others may become too deformed for high value products. Site treatments such as fertilization or vegetation control increase susceptibility to the disease. Resistance to the fungus is inherited, and attempts are being made to breed resistant strains.

Annosus root rot, caused by the fungus ***Heterobasidion annosum,*** is another serious disease of slash pine. It is most damaging on soils with good surface and internal drainage and is not a problem in flatwoods or shallow soils with heavy clay within 30 cm (12 in) of the surface. Infections begin when spores germinate on a fresh stump surface; the fungus then spreads to adjacent trees through root con-

tacts. Diseased or dead and dying trees are usually found in groups.

Pitch canker, caused by the fungus ***Fusarium moniliforme*** var. ***subglutinans,*** causes heavy damage to slash pines in nurseries, seed orchards, and plantations. Cankers high in the crown may kill only the leader and a few laterals; the tree survives with a stem deformity and reduced growth. Cankers below the crown may eventually girdle the trunk and kill the tree (8).

The pales weevil ***(Hylobius pales)*** invades logging areas, feeds on the bark of seedlings, and may girdle the stem, causing wilting and eventual death. Small trees may be defoliated by the pine webworm ***(Tetralopha robustella),*** blackheaded pine sawfly ***(Neodiprion excitans),*** redheaded pine sawfly *(N. lecontei),* and Texas leafcutting ant *(Atta texana).* The black turpentine beetle ***(Dendroctonus*** *terebrans)* and engraver beetles (*Ips* spp.) can become problems. Slash pine is not particularly susceptible to injury by the southern pine beetle (*D.* ***front&is)*** except where it is growing under environmental stress.

Other agents generally cause little damage, but some cause considerable losses under certain conditions. Senna seymeria ***(Seymeria cassioides)*** is one of a number of native root parasites that attack slash pine. Damage of economic importance is well documented but rare. Root rots may be a problem in tree nurseries or over-mature stands. Red heart ***(Phellinus*** *pini)* is usually associated with mature or overmature timber and is not a problem in well-managed stands. Southern cone rust ***(Cronartium*** *strobilinum)* may destroy a cone crop and is particularly damaging in seed orchards as are several seed and cone insects ***(17).***

Figure *3-Dense natural reproduction under a partial overstory* ***of*** *mature slash pines established by planting in central Louisiana.*

Young slash pines are susceptible to injury by wildfires until they are 3.0 to 4.6 m (10 to 15 ft) tall and the bark has thickened. Up to 50 percent of the needles may be scorched, but not consumed, with little mortality or growth loss.

Slash pine may suffer severe damage from glaze, particularly heavily thinned stands. It is subject to windthrow on shallow soils and wherever it does not develop a strong root system ***(14).***

Special Uses

Slash pine is worked for naval stores. This industry, one of the oldest in the United States, has supplied a large portion of the resin and turpentine used throughout the world since colonial times. In many early forests, gum was the primary and sometimes the only product harvested. Chipping the trees for oleoresin increases bark thickness and reduces volume growth inside the bark 20 to 25 percent. A strain of inherently high-gum-yielding slash pine has been selected, and seedlings are commercially available in Florida and Georgia.

Cattle frequently graze the slash pine forests. Moderate grazing does little damage to trees past the seedling stage and may be indirectly beneficial by preventing the buildup of a dense and highly flammable understory.

Slash pine seeds are eaten by a variety of birds and small mammals. The dense foliage provides protective cover for many wildlife species during inclement weather. Slash pine may be planted to stabilize the soil on eroding slopes and strip mine spoil banks, where its rapid early growth is an advantage over slower growing species.

Genetics

Population Differences

Geographic variation among slash pine stands in different locations tends to be clinal due to a gradual change from a north temperate to a subtropical

climate *(15)*. The variation among stands is less in the north than in the south.

Slash pine seeds from many sources have been grown in replicated provenance tests at several geographic locations *(51,57)*. When north Florida–south Georgia seed sources were planted north or west of their natural range they did not survive planting or grow as well as trees from South Carolina or Louisiana *(51)*. Trees from southern sources planted in the north do not grow or survive as well as those from northern sources *(28)*. In a northeast Florida plantation, all the trees broke bud at the same time, but trees grown from northern seed sources attained most of their growth early in the season, while trees from southern sources grew the most in the latter part of the season. The southern trees were never able to attain the growth of the northern trees *(3)*.

Seed source plantings outside the natural range of slash pine in South Carolina, western Louisiana, and central Mississippi have shown that trees from the southern part of the range are not well adapted to the more extreme northern and western environmental stresses of cold, ice, and extreme drought *(51,54)*.

A provenance test in western Louisiana showed that trees from seed sources in northeast Florida and south Georgia did not survive or grow as well in Louisiana as those from the western part of the slash pine range *(51)*. The most rapidly growing trees in east-to-west plantings came from seed sources in Georgia, western Florida, and southern Mississippi *(22)*.

Twelve morphological traits have been studied in cones, seeds, and foliage of five parent trees from each of 54 locations, and 13 traits have been studied in their seedlings (52). The coefficients of variation tended to be highest for seedlings within mother trees and lower among stands and among mother trees within stands. Genetic variation among mother trees within stands was usually not much greater than stand-to-stand variation, suggesting that genetic gains are feasible through selection among stands as well as among individuals within stands.

The highest incidence of fusiform rust occurs among sources in southern Georgia, but no clear geographic patterns are apparent. There is also a strong interaction of seed source with site in the occurrence of fusiform rust (22).

Races

South Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) is a variety of slash pine found on about 121410 ha (300,000 acres) (48) in the southern half of the peninsula of Florida *(21,32,35)*. It grows in pure stands on flatwood sites in the southern part of its range and on swampy or streamside sites in the northern part (32). Where its range overlaps with the typical slash pine, there is a transition zone where morphological traits show clinal variation between the two varieties (52). The range of South Florida slash pine also overlaps with that of longleaf pine *(P. palustris)* in transition zones between wet and dry sites, with longleaf more numerous on the drier sites (32). South Florida slash pine is characterized by long needles, although they are not as long as those of longleaf, in fascicles of two, rarely three *(21)*; a thick needle hypodermus; 5 to 10 resin canals per needle (58); thick branches with needles appearing clumped at the end; hard wood; whitish bud scales; a high specific gravity of 0.894, due to wide summerwood rings; and cones 20 percent smaller than typical slash pine *(27)*. The seedlings have a grass stage similar to longleaf pine and a thick taproot *(21)*. Mature trees have an irregular crown *(58)*.

Even-aged management, accomplished by leaving 15 to 25 trees per hectare (6 to 10 trees/acre) after a cut of 62 to 99 shelterwood trees per hectare (25 to 40/acre), appears to be the most successful silvicultural system for South Florida slash pine *(33,34)*. If a stand is clearcut, direct seeding in the fall will give the best stand *(40)*. Intensive site preparation is highly beneficial in reducing competition and available ground fuel. Problems with uneven-aged stand management include a lack of full stocking, fire hazard, since ground fuel accumulates when prescribed burning is prohibited, and root rot. Heavy thinning will give more sawtimber quickly, while light thinnings will give more total growth for pulpwood *(33)*.

When wildfires occurred in young stands, one-third of the surviving grass stage seedlings were observed to sprout from the root collar, but sprouts on the leader died back (25). South Florida slash pine is more fire resistant than the typical variety in the seedling and sapling growth stages due to its thicker bark *(6,34)*. Controlled burns are possible when the trees are 3.7 to 4.6 m (12 to 15 ft) tall (25).

South Florida slash pine was found to be superior to other southern yellow pines for wood properties except elasticity and shear parallel to the grain. This makes it an excellent timber for construction purposes (42).

In its natural range, direct seeded South Florida slash pine will survive and grow as well as the typical variety but will not have as good survival and growth if nursery stock is planted *(6,40)*. For plantings, it is recommended that the typical variety be planted in the South Florida slash pine range using

seed from Alachua County in northern Florida *(16)*. Height growth is better if seedlings are planted on beds *(21)*. Drought does not affect diameter growth of older trees, but excessive water will slow it down *(31)*.

Once height growth commences, South Florida slash pine has fewer insect and disease problems than the typical variety (6). Pitch canker does affect this variety *(7)*, and as a grass stage seedling it is susceptible to brown spot ***(Scirrhia acicola)***.

Site index curves and volume tables have been developed for South Florida slash pine *(29,30)*. With a site index of 15.2 m (50 ft) at base age 50 years the average d.b.h. of 1,112 trees per hectare (450/acre) at 20 years was 15 cm (6 in) with growth of 4.6 m^3/ha (65 ft^3/acre) per year.

Hybrids

Slash pine crosses naturally with the South Florida variety where their ranges meet and introgression has occurred among trees in the transition zone to the degree that it is difficult to distinguish between the two varieties *(52)*.

In areas where the natural distribution of slash pine overlaps that of the other pines, natural hybridization is usually precluded by phenology. Sand pine *(P. clausa)* is the earliest flowering pine and is followed by slash, longleaf, loblolly, and shortleaf *(P. echinata)* pines, the latter of which tend to shed pollen when slash pine strobili are no longer receptive. Late flowering sand pine or early flowering longleaf pine may hybridize with slash pine. Successful artificial hybridization depends on the choice of the female parent species as well as the particular individual of the species. There has been more successful sound seed produced in the slash x longleaf cross than in the reciprocal and no sound seeds were obtained in the sand x slash pine cross.

Slash pine has been artificially crossed with longleaf, loblolly, shortleaf, pitch *(P. rigida)*, and Caribbean *(P. caribaea)* pines. None of the offspring show potential hybrid vigor. The longleaf x slash hybrid shows the most potential because height growth begins quickly; it grows almost as fast as slash pine, self prunes well, is fairly resistant to both brown-spot needle disease and fusiform rust, and resembles longleaf pine in form and branching habit. On swampy sites in Australia there is some indication the Caribbean x slash hybrid progeny show superior yield to either parent alone. Slash x shortleaf hybrids have up to 16 percent dwarfs with some polyploids and mixoploids.

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