Pinus clausa (Chapm. ex Engelm.) Vasey ex Sarg. Sand Pine

Pinaceae Pine family

R. H. Brendemuehl

Sand pine *(Pinus clausa)* is also known as scrub pine and spruce pine. The majority of trees in natural sand pine stands of western Florida, especially between Panama City and Pensacola, bear cones that open when mature. These stands tend to be uneven-aged, somewhat open, with abundant reproduction developing in the openings. Sand pine stands in eastern and central Florida are generally dense and even-aged with a majority of the trees bearing serotinous cones. Two geographic races have been distinguished on the basis of cone characteristics: Ocala (var. *clausa*) from northeastern to south Florida and Choctawhatchee (var. *immuginata* D. B. Ward) in northwest Florida and Baldwin County, AL *(25)*.

Habitat

Native Range

Sand pine (fig. 1) is one of the minor southern pines with a natural range limited almost entirely to Florida. The largest sand pine concentration is a block of the Ocala variety covering about 101 170 ha (250,000 acres) in north-central Florida, an area often referred to as the "Big Scrub." This variety of sand pine also grows in a narrow strip along the east coast of Florida from St. Augustine southward to Fort Lauderdale. On the Gulf Coast small tracts of Ocala sand pine can be found scattered from a few kilometers north of Tampa southward to Naples. The less abundant Choctawhatchee variety is found growing along the coast in western Florida from Apalachicola to Pensacola and extending westward into Baldwin County, AL. Natural stands of Choctawhatchee sand pine are most abundant in Okaloosa and Walton Counties, FL, covering an area of about 40 470 ha (100,000 acres). Scattered stands of this variety of sand pine can be found 32 to 40 km (20 to 25 mi) inland from the coast in this section of Florida. Sparse stands of sand pine are also found on many of Florida's offshore islands *(15,24)*.

Climate

The climate of north-central Florida is characterized by hot summers with abundant precipitation and mild, rather dry winters. Precipitation varies from 50 to 75 mm (2 to 3 in) per month from October until April to as much as 200 to 230 mm (8 to 9 in) per month in June, July, and August. About 55 percent of the average rainfall of 1350 mm (53 in) occurs in the 4 months from June through September. Temperature extremes of -11" and 41" C (12° and 105" F) have been recorded. A frost-free period of 290 days is normal.

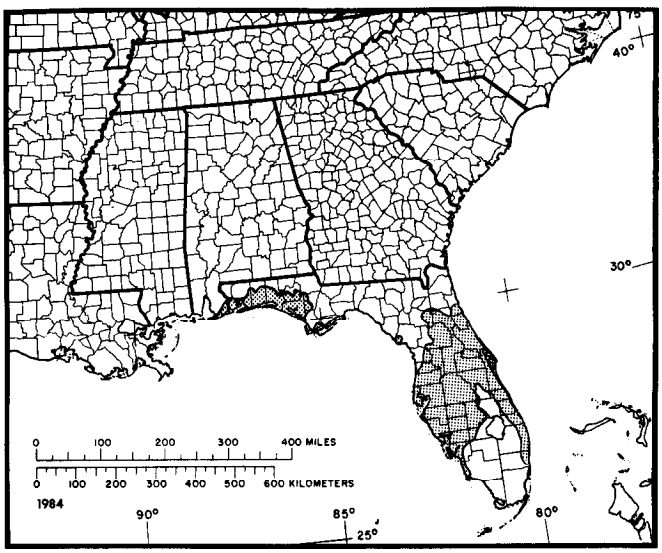

Figure *1-The native range of sand pine.*

Choctawhatchee sand pine thrives in western Florida under climatic conditions that are somewhat different from those of north-central Florida. Rainfall from December through May averages 100 to 110 mm (4 to 4.5 in) per month. It is hot and humid from June through September but slightly less so than in the north-central area. About 43 percent of the average annual rainfall of 1520 mm (60 in) occurs during this period of the year. October and November are the driest months, with rainfall averaging about 75 mm (3 in) per month. Temperature extremes of -17" and 42" C (2" and 107" F) have been recorded. Average temperature for January is 11" C (52" F) and 27" C (81° F) for July. A frost-free period of 265 days is normal (23).

Soils and Topography

Sand pine grows on well-drained to excessively drained, infertile, acid to strongly acid sandy soils of

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the order Entisols. This sand is of marine origin, much of which was deposited in terraces developed during the Pleistocene epoch.

Most Ocala sand pine grows in the division of Florida known as the Central Highlands. Elevations range from less than 6 m (20 ft) above sea level near Lake George to nearly 61 m (200 ft) in the highest areas of this region. Numerous lakes dot this area and are indicative of the presence of soluble limestone not far below the surface. Gentle rolling hills characterize the terrain. The major soils on which Ocala sand pine grows, in order of importance, are the Astatula, Paola, and St. Lucie series *(1).*

In west Florida, scattered stands of Choctawhatchee sand pine grow on the excessively drained soils of the Coastal Lowlands; however, the majority of such stands are in the division of Florida known as the Western Highlands (fig. 2) *(10).* Elevations range from near sea level to nearly 90 m (295 ft) above sea level. The terrain of this area is typified by long, gentle slopes and broad, nearly level ridgetops. Sloping to steep hillsides border most of the streams and small lakes of the area. The water level of the rivers, lakes, and intermittent ponds of the area fluctuates considerably according to the amount of rainfall and seepage from the surrounding deep, sandy soils. Soils common to this region include the Kershaw and Lakeland series.

Figure *2-Twenty-eight-year-old plantation of Choctawhatchee sand pine on Elgin Air Force Base in western Florida.*

Associated Forest Cover

The sand pine scrub of north-central Florida is one of the most distinctive plant communities of the State. Of particular interest is the sharpness of the boundaries with the adjacent sandhill vegetation which is dominated by longleaf pine *(Pinus palustris),* turkey oak ***(Quercus laevis),*** and pineland threeawn *(Aristida* ***stricta).*** Even-aged Ocala sand pine dominates the overstory, while the understory is composed almost entirely of evergreen shrubs 1.8 to 3.0 m (6 to 10 ft) tall. There is little or no herbaceous ground cover. Shrubs found in this understory include sand live oak ***(Quercus virginiana*** var. *geminata),* myrtle oak *(Q. myrtifolia),* Chapman oak *(Q.* ***chapmanii),*** rosemary ***(Ceratiola ericoides),*** tree lyonia ***(Lyonia ferruginea),*** scrub palmetto *(Sabal* ***etonia),*** saw-palmetto *(Serenoa repens),* silk bay *(Persea* ***borbonia*** var. *humilis),* gopher-apple *(Chrysobalanus* ***oblongifolius),*** and ground blueberry *(Vaccinium* ***myrsinites).*** Mats of lichens ***(Cladonia*** spp.) are often plentiful on the ground beneath the trees and shrubs *(14).*

The west Florida sand pine scrub is a distinct contrast to that of the north-central area. Here Choctawhatchee sand pine generally grows in uneven-aged stands and invades adjacent forested sites if protected from uncontrolled fire. The understory in these stands is quite sparse. Turkey oak, bluejack oak *(Q.* ***incana),*** sand post oak *(Q. stellata* var. *margaretta),* pineland threeawn, and prickly pear *(Opuntia* spp.) are the most common species of this understory.

Sand pine is the principal component of the forest cover type Sand Pine (Society of American Foresters Type 69) (12). It may also be found in several additional cover types such as Longleaf Pine (Type 70), Longleaf Pine-Scrub Oak (Type 71), and Slash Pine (Type *84).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Sand pine is monoecious. Flower buds are formed early in the summer but do not become visible until early autumn. The

Table l-Cone and seed characteristics of sand pine *(Pinus clausa)*

Characteristic	Choctawhatchee (var. *immuginata*)	Ocala (var. *clausa*)
Cones	Most cones open	Most cones remain closed
Number per liter	28	24
Number per bushel	1,000	830
Seed per cone	42	37
Sound seed		
Number per kilogram	25,447	21,410
Number per pound	56,100	47,200
Clean seed		
Weight per 35 liters of cones	0.27 kg	0.27 kg
Weight per bushel of cones	0.6 lb	0.6 lb
Dormancy	Mildly dormant	Nondormant
Germination		
No pretreatment	88%	94%
Stratified'	93%	96%
Peak, unstratified	17 days	10 days
Peak, stratified	11 days	9 days

'For stratification. seeds were placed in germination dishes containing a 1 to 2 mixture of moist sand and peat moss and refrigerated at 1° C (34' F) for 14 days.

time when staminate flowers ripen, as shown by pollen release, is one of the more reliable phenological events distinguishing the two varieties of sand pine. Ocala sand pine grows throughout most of the peninsula of Florida between latitude 26" and 30" N. At the southern end of its range it may start shedding pollen as early as mid-November but could start a month or more later in northern Florida. In plantations of Ocala in northwest Florida, pollen generally is shed from the last weeks of December through mid-January. By contrast, the Choctawhatchee variety of sand pine grows naturally only in northwest Florida, essentially within 1 degree of latitude. Pollen dissemination by this variety may start as early as the last week of December and end as late as mid-March but occurs most frequently from late January through February. There is little overlap in the periods when the two varieties shed pollen *(6)*. Conelet development is minimal during the first year but increases rapidly during the second year. Cones attain mature size by late summer.

Seed Production and Dissemination-Sand pine bears cones at an early age. It is not unusual to find mature cones on 5-year-old trees. Occasionally flowers, usually pistillate strobili, are produced by 9- to lo-month-old seedlings growing under nursery conditions. The two varieties of sand pine differ appreciably in cone production, cone size, seed size, and several other characteristics. An abundant crop of cones is produced by Ocala sand pine almost annually. Choctawhatchee cone crops of similar size are produced at 4- to 6-year intervals, with light crops in intervening years. Other differences of note are listed in table 1 *(2)*.

The majority of Ocala sand pine cones are serotinous: they remain closed when mature and require heat to open. Consequently, seed dispersal is minimal. The cones are very persistent and may accumulate in large numbers on a single tree. Viability of the seeds in such cones decreases with age; only 10 to 20 percent of the seeds in 5-year-old cones may be viable. Seeds from cones 2 or more years old have also been shown to be relatively dormant as compared to newer seeds (24).

Overly dense, unmanaged stands of the Ocala sand pines have developed following wildfire, which causes the cones to open and release large quantities of seeds *(11)*. Regeneration methods based on cone serotiny have had limited success. Stands to be regenerated are clearcut, the slash and residual vegetation are chopped, and mineral soil is exposed with site preparation equipment such as rolling drum choppers. Cones in close proximity to the soil open and release their seeds when exposed to high surface soil temperatures. Uniform distribution of seeds from treetops is difficult to attain, and poorly regenerated stands often result. Direct seeding at a rate of 0.56 to 1.12 kg/ha (0.5 to 1.0 lb/acre) after site preparation has been the most practical and successful regeneration method. This operation is most successful if the seeds are distributed from October through January and covered with about 6 mm (0.25 in) of soil shortly after being distributed *(16)*.

Seed dissemination of Choctawhatchee sand pine differs from that of Ocala sand pine. The majority of Choctawhatchee cones open when mature and most of the seeds are disseminated during September, October, and November. In western Florida the prevailing winds during the fall are from the west and northwest, and consequently seeds are distributed more evenly and to a greater distance on the eastern and southeastern sides of stands of seed-bearing age. It has been reported that along the western edge of a plantation, sand pine seedlings became established in the scrub oak-wiregrass cover for a distance of only 23 m (75 ft), or approximately 1.5 times average tree height (16.5 m or 54 ft at age 28). East of this plantation, reproduction was established in sufficient numbers to form a well-stocked stand for a distance of 38 m (125 ft). Occasional Choctawhatchee sand

pine seedlings were noted beyond the bounds of the sample area (105 m or 345 ft) in all but a northwesterly direction from the seed source (7).

Regeneration of this variety of sand pine may be accomplished quite simply. Cuttings can be timed to take advantage of its seed-dissemination characteristics, and as the seedlings can become established in competition with both understory and overstory vegetation, a natural system such as the shelterwood is a comparatively reliable and inexpensive regeneration method (5).

Seedling Development-Seedlings of the two varieties of sand pine differ markedly in their development, but germination of both is epigeal. Peak germination of Ocala seed occurs within 10 days after the seed is sown in the nursery, while Choctawhatchee seed requires 17 to 21 days. The Ocala seedlings grow more rapidly than Choctawhatchee and are often 38 to 46 cm (15 to 18 in) tall at the end of the growing season. Choctawhatchee seedlings usually attain an average height of about 25 to 38 cm (10 to 15 in) in the same period of time. This difference in rate of height growth may continue for 2 to 3 years after the seedlings have been transplanted to the field; however, average annual height growth of both varieties is essentially identical by the time the trees are 4 to 5 years old.

Maximum germination of seed distributed naturally or by direct seeding occurs from November through January for both varieties. Root development is rapid, and, as a result, seedling mortality is especially low when seedlings become established on bare areas during this period of the year. Germination from natural seed dispersal or direct seeding may occur at any time of the year, but few seeds disseminated during the summer months produce seedlings. High soil temperature may be a limiting factor. Surface soil temperatures as high as 72° C (162° F) have been observed in June and July on sandhill sites in Florida *(8,24)*.

Two flushes of growth are common during the first year of seedling development. The first occurs early in spring and the second usually in September and October. This growth characteristic is of special significance to the nurseryman. Sand pine seedlings, especially the Choctawhatchee variety, typically are only 10 to 13 cm (4 to 5 in) tall as late in the growing season as mid-August. Nothing need be done to stimulate such seedlings to attain plantable size as 1-O seedlings. The application of nitrogen at this time produces exceptionally large, often succulent seedlings that are difficult to plant and not well suited to the rigors of the sandhill environment *(4)*. Once established in the field, 3- to 4-year-old sand pines typically have three and occasionally four growth flushes during a single growing season. The fourth elongation generally occurs early in fall and is triggered by favorable soil moisture conditions.

Figure 3—*Open-grown Ocala sand pine.*

Birds, mammals, and insects cause the greatest losses of sand pine seeds and damage to newly germinated seedlings. The primary predators change with the season; losses attributed to migratory birds are greatest during spring and fall, while losses to insects and small mammals increase during the spring and summer as their numbers increase. Ants are more numerous and probably more destructive than all other insects. Birds and ants may be responsible for most seedling losses to predators *(8)*.

Vegetative Reproduction-Sand pine does not reproduce vegetatively. Seedlings of the Choctawhatchee variety do produce poorly developed basal branches. When 1- to 2-year-old seedlings are

injured or decapitated, one or more of these basal branches may elongate and replace the lost terminal.

Sand pine has been successfully grafted by several methods. Scion material from both sand pine varieties obtained from 20- to 60-year-old trees has been grafted successfully to potted slash, Ocala sand, and Choctawhatchee sand pine root stock as well as to root stocks of these same species growing in nursery beds. A wedge or cleft graft is commonly used *(3)*.

Sapling and Pole Stages to Maturity

Growth and Yield-Sand pine (fig. 3) varies in size from the unmerchantable scrub growing on the coastal sand dunes of Florida to trees that attain saw-log size on the better sites. Trees ranging from 51 to 66 cm (20 to 26 in) in d.b.h. and 23 to 26 m (75 to 85 ft) in height are found on the best sites but smaller sizes are more common. The largest sand pine in Florida, for example, is 63 cm (24.8 in) in d.b.h. and 31.4 (103 ft) tall.

Most of the volume of sand pine is currently being harvested for pulpwood, but the construction lumber market is a good potential outlet for some of the volume of sand pine. Formerly, tree size may have been a deterrent to its use for structural lumber, but improved sawmill equipment can now handle large volumes of small logs 15 to 25 cm (6 to 10 in) in diameter inside bark to produce lumber suitable for construction purposes. Both varieties have sufficient density for this use. Actually the density of Choctawhatchee is somewhat higher than that of Ocala. It could be put to structural uses similar to those of loblolly *(Pinus taeda)* and shortleaf *(P. echinata)* pines because the specific gravity of all three is in the same range *(22)*.

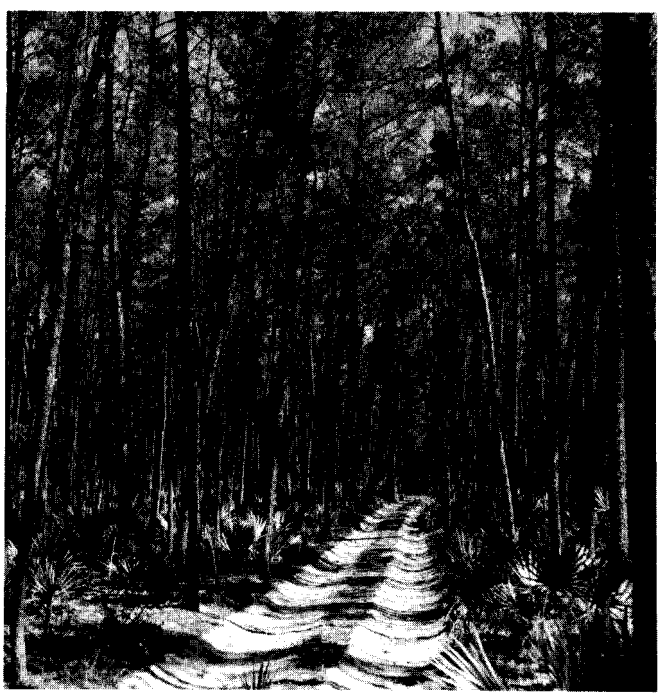

Figure 4—*Dense natural stand of 35- to IO-year-old Ocala sand pine on Ocala National Forest, FL.*

On the best sites, site index 24.4 m or 80 ft (age 50 years), the dominant trees in Ocala sand pine stands are expected to average 38 to 46 cm (15 to 18 in) in d.b.h. and 24 m (80 ft) in height. On average sites, site index 18.3 m or 60 ft, the dominant trees should average 25 to 30 cm (10 to 12 in) in d.b.h. and 18 m (60 ft) in height (fig. 4). The dominant stand on the poor sites, site index 15.2 m or 50 ft, is expected to average 18 to 23 cm (7 to 9 in) in d.b.h. and 15 m (50 ft) in height when mature.

In well-stocked natural stands of Ocala sand pine, yields of 126, 94, and 63 m^3/ha (20, 15, and 10 cords/acre) are predicted for high, average, and poor sites, respectively, at a rotation age of 40 to 45 years *(21)*. These stands tend to break up markedly when they are 50 to 60 years old. Yield tables or site index curves have not been prepared for Choctawhatchee sand pine but a limited amount of information is available. Well-stocked natural stands are expected to produce 210 m^3/ha (15,000 fbm/acre) of merchantable sawtimber plus 63 m^3/ha (10 cords/acre) of pulpwood *(5)*. Yields of Choctawhatchee plantations are expected to exceed the volumes reported above for Ocala sand pine. On the basis of data obtained from a very limited number of 25-year-old plantations, merchantable volumes for high, average, and poor sites, to a 7.6-cm (3-in) diameter outside bark, are anticipated to be 252, 189, and 126 m^3/ha (40, 30, and 20 cords/acre) for 25- to 30-year rotations.

Rooting Habit-Sand pine seedlings grown on very sandy sites develop a very fine root system with numerous laterals. The root system is somewhat coarser when the seedlings are grown on heavier textured soils; however, sand pine root systems are generally much finer and have greater development of lateral roots than is typical of other southern pines. Information is lacking on the rooting habit of sand pine older than seedlings.

Reaction to Competition-Sand pine has been rated as being moderately intolerant of shade and competition, but in its early establishment it is quite tolerant. Overall, it probably is most accurately classed as having intermediate tolerance to shade. Sand pine expresses very little dominance in its

usual growth pattern. Sand pine grows and persists in very dense stands of approximately 20,000 to 25,000 trees per hectare (8,000 to 10,000/acre). Seedlings of both varieties can be planted or will become established from seed in the scrub oak-wiregrass rough common to the Florida sandhills and eventually dominate the site. Natural pruning is very slow. Dead lateral branches may persist within a few feet of the ground until the trees are 20 to 25 years old.

Damaging Agents-Insects, disease, and fire play a significant role in the development of sand pine stands. Several species of insects attack and kill, deform, or cause growth losses of sand pine. Most of these pests, the majority of which also attack the other species of pine growing in Florida, are found throughout the range of sand pine.

Bark beetles, primarily Ips *(Ips **calligraphus*** and ***I. grandicollis)***, probably cause the greatest volume loss in sand pine, especially the Choctawhatchee variety. Generally, stress factors such as severe drought, lightning, fire, mechanical damage, or crowded stand conditions are associated with Ips beetle attacks.

The sand pine sawfly ***(Neodiprion pratti)*** is considered a potential cause of growth loss in sand pine. Plantations of both varieties of sand pine have been defoliated by this insect. Attacks are reported to be most severe along stand edges and in plantations with fewer than 750 trees per hectare (300/acre) (27). Outbreaks of the blackheaded pine sawfly (N. *excitans)* on sand pine, concurrent with localized outbreaks of this sawfly on loblolly pine in northwest peninsular Florida, have also been reported (26). The pitch-eating weevil ***(Pachylobius picivorus)*** and the pales weevil *(Hylobius **pales)*** could become important insect pests of sand pine, but future losses will depend on management practices.

Tip moths *(Rhyacionia* spp.), aphids, and scales have all been observed on sand pine but are not known to cause mortality or appreciable growth loss. These insects do cause a certain amount of deformity and discoloration of young trees and could cause significant losses where the objective of management is Christmas tree production. The southern pine coneworm ***(Dioryctria amatella)*** frequently damages twigs and cones, and if uncontrolled may cause substantial losses in seed orchards and seed production areas *(9)*.

Sand pine varies in its susceptibility to disease. Mushroom root rot caused by ***Clitocybe tabescens*** is found in natural stands of Ocala sand pine in central Florida and also has developed in Ocala plantations in northwest Florida and southern Georgia during the past 5 to 10 years *(18)*. As a result of this disease, a significant portion of many Ocala plantations may not reach merchantable size. The Choctawhatchee variety is considered resistant to this disease. ***Phytophthora cinnamomi*** is reported to be a virulent pathogen on seedlings of both the Ocala and Choctawhatchee varieties of sand pine, but there is no conclusive proof that this fungus is a pathogen of sand pine under field conditions. Heavy clay or poorly drained soils may support populations of l? ***cinnamomi.*** The areas of Florida and Georgia where planted sand pines have been killed by ***Clitocybe tabescens*** and where ***Phytophthora cinnamomi*** was later recovered were either shallow soils underlain by clay or were imperfectly drained sandy soils. Such soil conditions are not characteristic of a sand pine site. Eastern gall rust ***(Cronartium quercuum),*** which forms spherical galls mainly on twigs and branches of both sand pine varieties, is common but seldom a serious problem. Heart rot caused by ***Phellinus pini*** has been reported in sand pine but is usually not a problem until the stands are more than 40 years old *(19)*.

Fire is probably the principal enemy of sand pine, which is much less fire resistant than longleaf or slash pine. Hot ground fires which produce substantial needle scorch kill as readily as crown fires, yet sand pine can be burned under controlled conditions. This is especially true of Choctawhatchee variety, as its natural understory vegetation tends to be less flammable than that generally found in natural stands of the Ocala variety.

A unique combination of fuel and weather conditions appears to be responsible for the occasional blowup fires that occur in Ocala sand pine forests. The moisture content of sand pine needles is often lowest in March, and their resin and energy contents reach a yearly high from February through May. This condition is known as the "varnish stage" by those familiar with fire in Ocala stands. These fuel properties take on critical importance when they are combined with severe drought conditions and blustery spring weather characterized by unstable air masses, low relative humidity, and high winds.

The relation between Ocala sand pine and fire is somewhat of a paradox. Many acres of Ocala sand pine forest owe their existence to fire which releases seed from the serotinous cones. As a considerable volume of timber may be lost to such fires, however, this method of regeneration cannot be considered an acceptable form of management ***(11).***

Special Uses

Using sand pine for fuelwood or biomass plantations is feasible. Production levels comparable to

those attained by other biomass species can be produced in plantations established at spacings of 0.6 by 1 m (2 by 3 ft). Annual dry weight yields of 7.13 t/ha (3.18 tons/acre) have been produced on 17-year-old Choctawhatchee sand pine plantations *(17)*.

Some sand pines, especially the Choctawhatchee variety with its short, heavily foliated branches and dark green needles, are being grown for Christmas trees. Marketable trees 2 to 3 m (7 to 10 ft) tall can be produced in 4 to 5 years.

Genetics

The two geographic races of sand pine have been identified earlier in this paper.

Natural hybridization of sand pine has not been known to occur, but several successful attempts at artificial hybridization have been reported. The most encouraging of these efforts is a cross between Virginia pine *(P. virginiana)* and the Choctawhatchee variety of sand pine produced at the Institute of Forest Genetics at Placerville, CA, in 1953. Seedlings from this cross were planted in Charles County, MD. At age 10, 94 percent (47 trees) of the hybrid seedlings had survived, with an average height of 5.4 m (17.6 ft). Survival of the Virginia pine controls averaged 84 percent with an average height of 4.8 m (15.6 ft). These results indicate the feasibility of moving sand pine germ plasma into more northerly locations through hybridization with Virginia pine *(20)*.

Attempts to move sand pine north of its natural range without benefits of hybridization are also encouraging. Identical studies in the Georgia and South Carolina sandhills show that sand pines grow better than loblolly, longleaf, and slash pine (I? *elliottii)* on these deep, droughty, infertile sands. Heights at age 15 years averaged 10.8 m (35.4 ft) for Choctawhatchee sand pine, 10.0 m (32.8 ft) for Ocala sand pine, and 7.32 m (24.0 ft), 7.25 m (23.8 ft), and 6.9 m (22.6 ft) for slash pine, longleaf pine, and loblolly pine. Ice storms have caused the most serious damage to the Ocala plantings, but damage to the Choctawhatchee plantings from these same storms has been no greater than that done to longleaf and slash pine. The growth rate of Choctawhatchee sand pine included in these tests is comparable to that for plantations of this variety growing in northwest Florida *(13)*.

Several organizations have attempted a number of additional crosses with sand pine and other species of pine *(20)*. Slash pine x Ocala sand pine crosses were generally unsuccessful. Reported crosses in which the sand pine parent was not identified by variety included these:

P. taedu x *P. clausa*
P. clausa x *P. taeda*

P. banksiana x *P. clausa*
P. clausa x *P. banksiana*

P. rigida x *P. clausa*
P. clausa x *P. rigida*

P. pungens x *P. clausa*

I? pinaster x *I? clausa*
P. clausa x *P. pinaster*

P. echinata x *P. clausa*
P. clausa x *P. echinata*

P. virginiana X *I? clausa*
P. clausa x *P. virginiana*

P. thunbergii x *P. clausa*

P. clausa x *P. clausa*

With the exception of *F! virginiana* x *P. clausa* and *P. clausa x P. virginiana,* these crosses produced few sound seeds per cone. The ***P. virginiana x P.*** *clausa* cross produced an average of 13.1 sound seeds per cone, a yield that compares favorably with the results of many artificial intraspecific crosses. If such results are generally obtainable, mass production of this hybrid may be possible (20).

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