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Silvical Characteristics of Sweetgum

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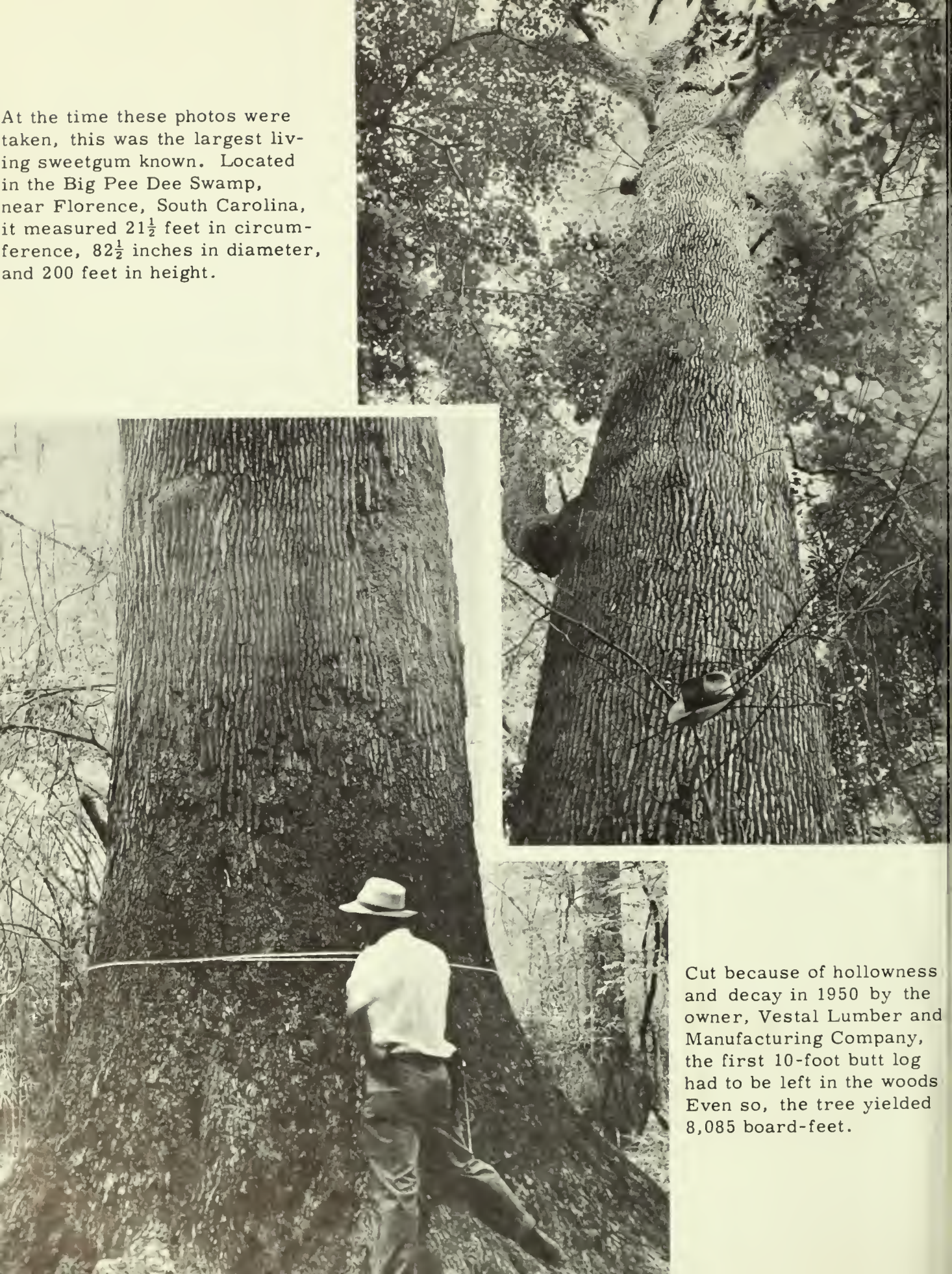
At the time these photos were taken, this was the largest living sweetgum known. Located in the Big Pee Dee Swamp, near Florence, South Carolina, it measured $21\frac{1}{2}$ feet in circumference, $82\frac{1}{2}$ inches in diameter, and 200 feet in height.



Cut because of hollowness and decay in 1950 by the owner, Vestal Lumber and Manufacturing Company, the first 10-foot butt log had to be left in the woods Even so, the tree yielded 8,085 board-feet.

SILVICAL CHARACTERISTICS OF SWEETGUM
(Liquidambar styraciflua L.)

by
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Sweetgum (Liquidambar styraciflua L.), also known as American sweetgum, bilstead (23), red gum, sap gum, starleaf gum, gum (1), sycamore gum, gumwood, sweetgum, and alligator tree (42), is highly valued both as a forest tree and as a shade tree. Its botanical range is shown in figure 1; however, the species is also planted as a shade tree in California and the Pacific Northwest (45). It is found naturally in the mountainous regions of Mexico and in scattered locations as far south as Honduras and Nicaragua (2). Occasional occurrence of the species in the swamp forests of Massachusetts may be an indication of the northward trend in its range (2).

Red gum was formerly the accepted common name for the species, but this name, as well as sap gum and gum, is now restricted to sweetgum lumber. In the lumber trade, the term sap gum applies to sapwood, and red gum applies to heartwood. The species is much used for lumber as well as for veneer and plywood. In 1948, the manufacturers of boxes, crates, furniture, and cabinets accounted for more than 90 percent of the sweetgum used in the wood products industry. Sweetgum pulp is also used in the making of fine grades of paper, corrugated board, and rayon (1). It can be used for any paper product that will tolerate a mixed hardwood pulp.

HABITAT CONDITIONS

Climate

According to Thornthwaite's classification (39), sweetgum grows in the humid climate of the eastern United States. The effect of climate on the growth of sweetgum within its commercial range is greatly modified by annual or periodic floods and the high water tables associated with bottomland sites.

Annual rainfall varies from 40 inches in the North to 60 inches in the South, and the growing season rainfall is 20 and 34 inches, respectively. There are 180 frost-free days in the northern part of the range and 320 in the southern part. Mean January temperatures are less than 30° F. in the North and about 50° in the South; minimum temperatures during the year are -5° in the North and 25° in the South. Maximum temperature during the year is about 100° for most of the range of sweetgum (44).

Edaphic and Physiographic

Sweetgum is very tolerant of different soils and sites but attains its best development on the rich, moist, alluvial clay and loam soils of river bottoms (6).

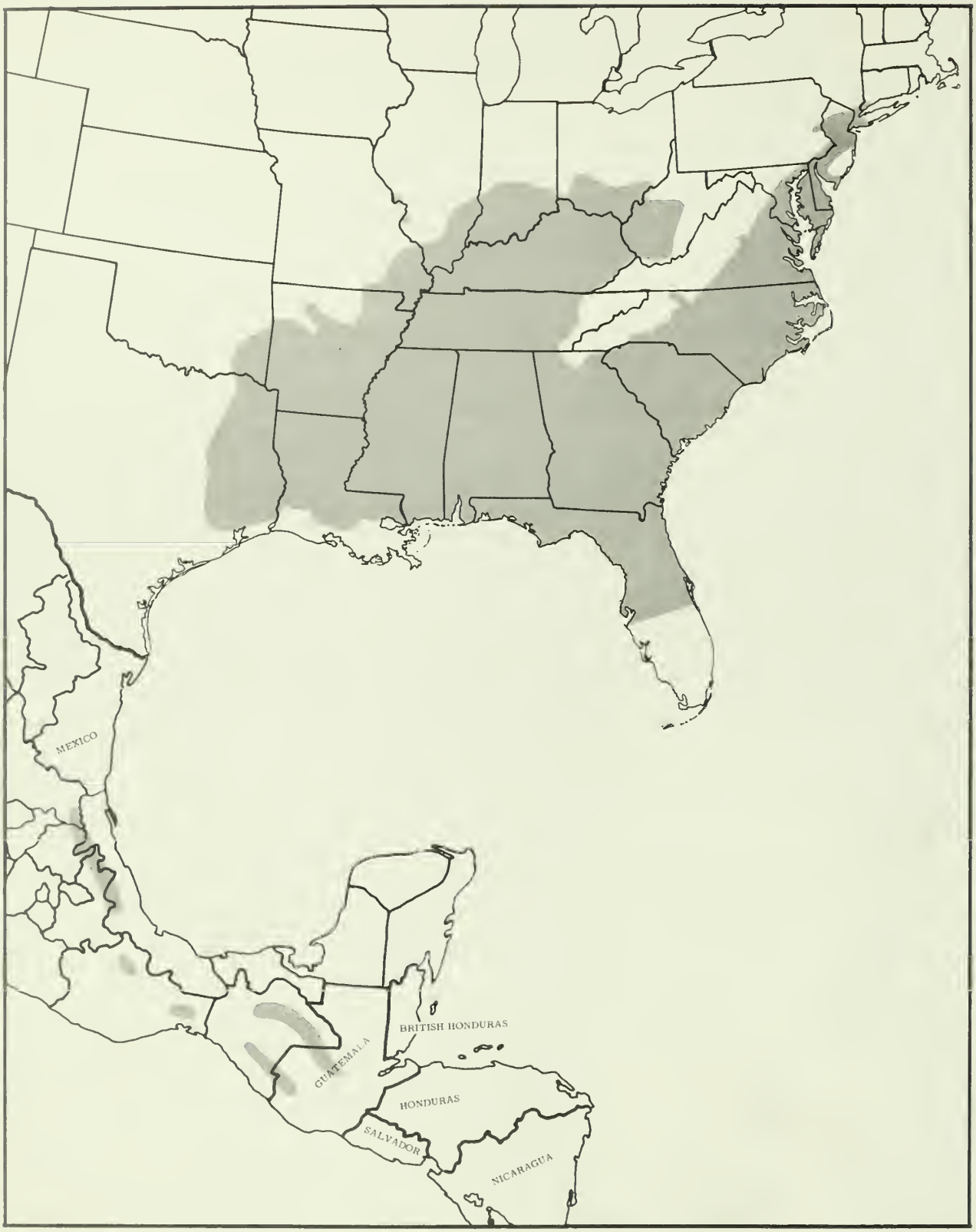

Figure 1.--Botanical range of sweetgum.

In Maryland, sweetgum is rarely found on well drained, sandy soils, usually being confined to heavy, moist soils. While it is common on clay or gravelly clay uplands, it grows poorly there. The best growth is restricted to alluvial swamps and to imperfectly and poorly drained soils having a high clay content (42).

Sweetgum is reported as an occasional dominant on the loessal soils along the east border of the Mississippi River alluvial plain. Dominant stands of sweetgum are often found on the relatively impervious planasols of the Illinoian till plain--including the very poorly drained Avonburg, Blanchester, and Clermont silt loams (2, 5).

Turner (43) related the occurrence of forest cover types (37) to topography and soil type in Arkansas. The cover types in which sweetgum is a major component were found primarily on the alluvial clay and loam soils of the river bottoms. The cover types in which sweetgum is listed as an associated species decrease in number with increasing elevation and are confined to loam soils.

On north slopes in the Ozark Mountains, sweetgum is a minor component of the stand and does not exert dominance; here it is always associated with soils derived from chert (34).

In the surcharge zone of reservoirs on the lower Tennessee River, sweetgum plantations attained their best growth on moist silty and sandy loams having a loose, deep surface soil and a permeable subsoil. The poorest growth was associated with sites having poorly drained, compact subsoils (36).

Height growth of 3-year-old sweetgum plantations in the Appalachian Valley varied from 0.41 to 0.60 foot per year on soils of dolomitic and limestone origin, respectively (28). In the same plantations, survival and growth of sweetgum was affected by soil type, soil profile, depth of A horizon, and consistency of A and B horizons. In general, the best sites for sweetgum were found to be those suitable for yellow-poplar (Liriodendron tulipifera), but sweetgum is not so demanding in site as yellow-poplar (29).

In the bottomlands, Braun (2) reports that sweetgum attains its best growth on low ridges. However, Chittenden (6) found growth slower on the ridges than in the glades of the Mississippi bottomlands. In the Mississippi Delta the species is most common "on silty clay or silty clay loam ridges and very moist but not too poorly drained silty clay flats in first bottoms" (33).

Except for the higher elevations in the Appalachians, there are apparently no altitudinal limitations on the occurrence of sweetgum in the eastern United States. In Mexico the species is found primarily at elevations that range from 3,500 to 6,500 feet, but its best development is on deep soils at elevations of 4,000 to 5,300 feet (30).

Biotic

In eastern North America, sweetgum is a predominant species in four forest cover types and an associated species in 24 additional ones. Of the cover types in which sweetgum is present, eight are found in the central forest region, while the rest are indigenous to the southern forest region. Considering all these cover types in both regions, we find five types on dry sites, three types on wet sites, and the remainder on fresh to moist sites (38).

Because of its wide distribution, adaptability to a variety of sites, and inconsistency in time of appearance in natural succession, there is considerable variation in the plant and animal associates of sweetgum. Over 65 tree species (2, 6, 31) and 30 shrub species (31) are associated with sweetgum. The principal tree species with which sweetgum is associated as a predominant species are shown in table 1 for four forest cover types.

Table 1.--Predominant and associated species of forest cover types in which sweetgum is an integral member (38)

Type	Predominant species	Associated species
Northern red oak-mockernut hickory-sweetgum	Northern red oak (Quercus rubra) Mockernut hickory (Carya tomentosa) Sweetgum	White oak (Quercus alba) White ash (Fraxinus americana) Blue ash (Fraxinus quadrangulata) Slippery elm (Ulmus rubra) September elm (Ulmus serotina) American elm (Ulmus americana) Blackgum (Nyssa sylvatica) American sycamore (Platanus occidentalis) Red maple (Acer rubrum) Silver maple (Acer saccharinum) Sugar maple (Acer saccharum) Black walnut (Juglans nigra) Honey locust (Gleditsia triacanthos) Black cherry (Prunus serotina)
Pin oak-sweetgum	Pin oak (Quercus palustris) Sweetgum	Red maple Elms (Ulmus spp.) Hickories (Carya spp.) Swamp white oak (Quercus bicolor) Bur oak (Quercus macrocarpa) Ash (Fraxinus spp.) River birch (Betula nigra) Hackberry (Celtis occidentalis)
Sweetgum-yellow-poplar	Sweetgum Yellow-poplar	Loblolly pine (Pinus taeda) Red maple White ash Green ash (Fraxinus pennsylvanica)
Sweetgum-Nuttall oak-willow oak	Sweetgum Nuttall oak (Quercus nuttallii) Willow oak (Quercus phellos) Water oak (Quercus nigra)	Sugarberry (Celtis laevigata) Green ash American elm Overcup oak (Quercus lyrata) Pecan (Carya illinoensis) Water hickory (Carya aquatica) Cedar elm (Ulmus crassifolia) Eastern cottonwood (Populus deltoides) Laurel oak (Quercus laurifolia) Red maple Honey locust Common persimmon (Diospyros virginiana)

Despite the wide range and abundance of sweetgum, it is utilized only to a small degree by wildlife. Ten species of birds and three species of mammals are reported as eating the seeds, bark, or wood. The eastern goldfinch (Spinus tristis) is the only bird that depends upon sweetgum seed for an appreciable part of its winter food. The seed also forms a small part of the fall diet of the eastern gray squirrel (Sciurus carolinensis). The bark and wood furnish 10 to 25 percent of the food for beaver (Castor canadensis) in the Southeast (25).

LIFE HISTORY

Seeding Habits

Flowering and fruiting.--Flower buds of sweetgum are extremely sensitive to cold, and they are often damaged by frost (42); the flowers appear from March to May, depending on latitude and weather. In the fall, the fruit turns yellow, and the seeds mature from September to November. Soon after maturity, the seed is disseminated by the wind, but the empty fruits often remain on the tree for the entire winter (45).

Seed production.--Seed production, which begins when the tree is 20 to 30 years old, remains abundant until about age 150. Fair seed crops are produced each year, with bumper crops every two or three years (42, 46).

Full sunlight and rich soil are conducive to optimum seed production, and under such conditions each fruit may average as high as 50 sound seed (42). However, under average conditions only 7 or 8 sound seeds are produced by each fruit, and 1 bushel of fruit will yield 12 ounces or approximately 60,000 seeds (46).

Seed dissemination.--The maximum recorded distance of seed dispersal is 600 feet, but ordinarily 96 percent of the seed lands within 200 feet of the point of release (14).

Vegetative Reproduction

Sweetgum is capable of sprouting until it is approximately 50 years of age (6). The season of cutting has no effect on the number of sprouts, but, for a given diameter of stump, the shortest sprouts develop on stumps of trees cut in May and August. No decline in sprout vigor occurs until the third generation following the cutting of successive generations of sprouts from the same stump (49).

Seedlings of sweetgum reach a height of 4.5 feet in 3 to 5 years, but sprouts often reach this height in 1 growing season. Duration of this rapid growth is unknown but 10-year-old sprouts frequently have the same size and appearance as 18- to 20-year-old seedlings in the same stand. The presence of "twins" in a 99-year-old stand would indicate that sweetgum sprouts are capable of developing into sawtimber (51).

Guttenberg (14) and Kaufert (20) have concluded that many of the old-field stands of sweetgum are of sprout origin. Many of these sprouts originate as root sprouts from cut trees.

The literature records no successful attempts at reproducing the species vegetatively by cuttings or aerial layers.

Seedling Development

Establishment.--Mineral soil is an ideal seedbed, but sod is not a serious hinderance to seed germination. When additional sweetgum reproduction is desired in partially cutover stands, exposed mineral soil and abundant direct sunlight are usually necessary. Lack of direct sunlight is probably the most limiting factor in the development of pure sweetgum stands on cutover timber land (42). Guttenberg (14) recommends that seed trees be spaced approximately 100 feet apart to assure adequate distribution of seed.

Sufficient moisture is especially important following germination, until the taproot of the seedling begins to develop (42). With watering conditions similar, potted seedlings of sweetgum were found to have a higher mortality in sandy soil than in clay or silt loam (48).

Early growth.--Root development varies with the site. A deep taproot and numerous horizontal rootlets usually develop early. However, in wet areas the root system is shallow and wide-spreading, with little or no taproot. On gravelly ridges and hillsides, sweetgum develops a particularly strong taproot and is very wind resistant (42).

Few measurements of early growth are available. Trenk (42) reports 5-year-old seedlings averaging 8.7 feet in height on an abandoned field adjacent to a swamp in Maryland. Seedlings in a Maryland nursery averaged 10 inches in height at the end of one growing season. On favorable sites in the lower Mississippi Valley, seedlings grow as much as 2 feet during the first year, both in the nursery and in the field.

Several sweetgum plantations have been established in the surcharge zones of reservoirs on the lower Tennessee River. Plantations in one reservoir were flooded with 2 to 4 feet of water from April through June with no apparent damage to the seedlings. Height growth of plantations on bottomland loam soils varied from 5.2 to 6.9 feet for a 5-year period. On upland sites the 5-year height growth of the plantations varied with the ground cover at time of planting (36):

Ground cover	Height growth (Feet)
Surface soil removed	3.6
Broomsedge and goldenrod	5.1
Areas reverting to woody cover	6.5

Sweetgum is a highly desirable species for planting on relatively acid strip-mine spoil banks in the Central States (11). The average height of 7-year-old sweetgum planted in pure stands was nearly 7 feet on a strip mine area in Indiana; in the same plantation, sweetgum planted in mixture with black locust and other hardwoods averaged over 10 feet in height.[1/]

In the Georgia Piedmont, sweetgum begins its radial growth 20 to 30 days after full leaf development, or about the third week in May. Fifty percent of the annual radial growth is completed within 40 to 49 days after radial growth (19) commences.

Sapling Stage to Maturity

Growth and yield.--Young sweetgums have long conical crowns that usually prune readily under forest conditions (6). The branches of young trees are at an acute angle to the stem (42). Mature trees have crowns that are round and spreading to ovate in shape, while the tops of overmature trees are usually broken or stag-headed (6). The species responds slowly to release, except while young, i.e., below 10 inches d.b.h. (33).

Maximum sizes attained by sweetgum in different parts of the country are:

Location	Height (Feet)	Diameter (Inches)
California (46)	50	--
Pacific Northwest (46)	80-120	--
Northeast (46)	50-75	--
Mississippi River bottom (6)	150	60
Maryland, well-drained uplands (42)	65	18-25
Maryland, river bottom (42)	110	36-42
Coastal Plain, swamp (9)	120	48

Because of the tree's tendency to fork at a definite stage in its development, the maximum length of clear stem for sweetgum in South Carolina was 58 feet. In South Carolina, forking occurred when the trees were approximately 16 inches d.b.h. In Missouri the maximum length of clear stem was 57 feet, but because of a lower growth rate, forking did not occur until the trees were much older and larger in d.b.h. than those in South Carolina (6). In Maryland, crowded stands of sweetgum virtually cease height growth at 65 to 70 years of age, at which time the crowns tend to flatten (42).

Sweetgum in a selectively logged, virgin "red gum ridge-oak" type in central Louisiana grew 1.57 inches in diameter during the 8 years prior to cutting. In the 8 years following cutting, diameter growth averaged 1.86 inches (8).

1/ Denuyl, Daniel, Tarbox, G. L., and Funk, David T. Growth of sweetgum planted on Indiana coal mine spoil banks. 1956. (Unpublished manuscript on file with the Department of Forestry, Purdue University, Lafayette, Indiana.)

Bull (4) reported the 10-year average diameter growth for overmature sweetgum as 1.9 inches. He concluded that the average growth for immature trees was probably 2.5 to 3.0 inches over a 10-year period. Vigorous sweetgum trees have a thick bark with distinct high ridges, while those of low vigor are characterized by a flatter and thinner bark. Ten-year diameter growth rates by vigor class are (15):

Vigor (Class)	Diameter growth (Inches)
High	3-4
Medium	2-3
Low	1-2

Forest resource data for the north Louisiana Delta showed the following growth rates for various diameter classes of sweetgum (50):

Diameter class (Inches)	Ten-year diameter growth (Inches)
6-12	2.12
14-18	2.18
20-28	2.02
30+	1.49

In the Mississippi Delta, pure stands of sweetgum average 6,000 to 8,000 board-feet per acre. Very good stands will have 15,000 to 20,000 board-feet per acre, with 30,000 to 40,000 on small selected areas. Ridges usually have lighter stands than the flats. In virgin stands of mixed bottomland hardwoods, sweetgum averages 5,000 to 6,000 board-feet per acre (33).

In the lower Piedmont of North Carolina, loblolly pine had 187 percent greater board-foot volume than sweetgum, when compared on a tree basis on all sites. There was no over-all difference in the site index curves of the two species. However, the site index of sweetgum was higher than the site index of loblolly pine on the bottomlands, while the reverse was true for all other sites.2/

Reaction to competition.--Winters and Osborne (51) point out that in pure stands on bottomland sites:

> "The young red gum tree is able to endure a certain amount of shade and stand crowding; hence the leaf and crown canopy of young stands is usually dense. With increased age, however, the trees become less able to endure competition. The most suppressed red gum trees die from crowding and the stands become more open. Following the natural decrease in the density of the crown canopy, sufficient sunlight reaches the ground to permit the development of an understory stand.... This understory is present in nearly all even-aged, second-growth, red gum stands more than 40 years old."

2/ Ralston, James. The relative productivity of loblolly pine and sweetgum on forest sites in the lower Piedmont of North Carolina. 40 pp. 1955. (Unpublished M.F. thesis, N.C. State College, Raleigh, N. C.)

Sweetgum is classified as intolerant by Zon and Graves (53). Their tolerance scales were modified by Toumey and Korstian (41), who classified sweetgum as intermediate in tolerance. Chittenden (6), who classified the species as intolerant, pointed out that it is nearly always a dominant or intermediate tree, and that seldom is an overtopped sweetgum found in the forest. Perhaps a better tolerance classification would be intermediate as a seedling or sapling, and intolerant in the larger sizes.

On poorly drained upland soils (Illinoian till plain) of southern Indiana, sweetgum, pin oak, and red maple are the principal species coming in first on old fields. These are followed next in succession by increased numbers of sugar maple, yellow-poplar, shagbark hickory, and black cherry. And finally a composition resembling the original old growth forest is developed by the prominence of beech, pin oak, and sweetgum along with white oak, black walnut, yellow-poplar, black cherry, and sugar maple (5).

In pure, upland southern pine stands of all ages, sweetgum seedlings or sprouts are usually present. The species is present as an understory tree in all but the youngest pine stands and only occasionally as a dominant tree in the older stands (31). Removal of the pine overstory results in rapid growth of the sweetgum (42). Sweetgum forms a small part of the total hardwood component of the pine stands; in the climax oak-hickory forest, it is also a very minor constituent (31).

The successional pattern of pure bottomland pine stands is similar to the upland pine stands, except that the rate of succession is considerably faster in bottomland stands, and sweetgum is represented by a greater number of stems in the pine overstory (31).

Speaking of bottomland hardwood succession, Oosting (31) says:

> "Red gum is recorded in every stand but its density as well as percent of total density vary widely and inconsistently. Ages of individuals within a stand have a wide range, and the time of appearance in the stand likewise varies considerably. All this should probably be expected, for red gum may be found in a great variety of habitats and conditions. In the bottoms it may appear as a pioneer tree, alone or with other species. Thereafter it maintains itself in competition and continues to reproduce for a surprising number of years....Of the species appearing early in bottomland succession it is least sensitive to environmental differences and best adapted to successful growth and competition under a variety of conditions. In spite of irregularities....it is unquestionably the most important pioneer tree in the establishment of the mixed hardwoods in bottomlands."

Principal enemies.--Fall frosts often kill the late summer shoot growth of sweetgum (42). Seedlings may be badly damaged by hogs, goats (6), or cattle. Rodents, particularly mice and rabbits, are reported to have caused considerable damage to young seedlings in sweetgum plantations in various localities (10, 22, 27, 36). In southern Illinois, rabbit injury varied from 9 percent on graded spoil banks to 82 percent on ungraded spoil banks at the end of 3 years (10).

Young sweetgum plantations in the Appalachian Valley of eastern Tennessee made good growth on the better sites, but field mice are so fond of this species and kill so many seedlings that its use in planting seems inadvisable except on good sites in rodent-free areas (27).

Sweetgum is very resistant to disease and insect attack, but it is highly susceptible to death or injury by fire. Summer fires damage understory sweetgum more than winter fires, as shown by a study of prescribed, annual burns in loblolly pine stands of the South Carolina coastal plain. One year after the third summer fire, 33 percent of the sweetgums were dead (24).

Fire scars on living trees may furnish entrance points for insects and fungi (6), although quite frequently basal wounds become covered with a gum exudation which prevents the entrance of fungi and insects. As long as the sapwood is not killed by fire, this protective layer of gum will form over it. However, with repeated fires, a tree is more apt to have some sapwood killed, and fungi and insects may become established. For example, in the lower delta of the Mississippi River, 42 percent of the sweetgum trees burned one time showed decay 8 years later; and 79 percent of the sweetgum trees burned repeatedly during an 8-year period showed decay (17).

The upward rate of the spread of decay in young fire-scarred sweetgum is approximately 1.2 inches per year in the Mississippi River Delta. A characteristic of this decay is that it is usually confined to the cylinder of wood extant at the time of scarring. In the same locale the rate of healing for fire-scarred sweetgums having a firm surface to heal over was 0.56 inch per year (17).

Kaufert (20) estimated that 90 to 95 percent of the decay in bottomland hardwoods was due to fire and that very little cull was due to fungi entering branch stubs or wounds on the upper stems. He also reported that 12 percent of the merchantable volume of a virgin sweetgum stand in Louisiana was left in the woods because of rot. Lentz (21) estimated that a tract of virgin sweetgum in the Mississippi Delta was deteriorating at the rate of one percent or more each year.

A check list of the fungus enemies of sweetgum includes many that are of secondary importance (47). The four most common decay organisms in the Mississippi River Delta are Fomes geotropus, Pleurotus ostreatus, Lentinus tigrinus, and Polyporus lucidus (17). Some relatively new and possibly serious diseases of sweetgum have been reported: bleeding necrosis of sweetgum (32), leader die-back or blight (12), and sweetgum blight (26). None of the causal agents for these diseases has been positively identified. Sweetgum blight is widely distributed (18), and has caused heavy mortality in several states. It has received intensive study in Maryland (52) and Mississippi (40), and may be related to soil properties affecting moisture supply (3).

Except for the leaf feeders, the insect enemies of sweetgum are capable of attacking only lumber or trees that are damaged, dead, or decadent. Of these insects the ones capable of attacking living tissue are the bark beetles,

which include Dryocoetes betulae, Dryocoetes liquidambarus, and Pityophthorus liquidambarus; the ambrosia beetles, which include the flatfooted ambrosia beetle (Platypus compositus) and the darkling beetles (Strongylium terminatum and Strongylium tenuiolle); and the leaf feeders, which include the forest tent caterpillar (Malacosoma disstria) and the luna moth (Tropaea luna) (7, 35).

SPECIAL FEATURES

Sweetgum is often characterized by corky, wing-like protrusions of bark on opposite sides of the twigs and branchlets. Between and within individuals, the amount of "winging" varies inconsistently and sometimes develops into a bark wartiness that persists for several years. Usually the protrusions fall off after the second or third year leaving a smooth branchlet (42).

Most sweetgum trees, especially those of low vigor, develop epicormic branches at some time during their development, but thinning stands lightly will help to prevent excessive epicormic branching (42). Harrar (16) found dormant and adventitious buds a major defect in sweetgum veneer logs.

The crushed leaves and twigs of sweetgum have a distinctly sweet and aromatic odor (42). When wounded or injured, sweetgum produces a gum called storax. A pathological product formed in the living wood and exuding from intercellular spaces (13), this gum commonly fills the cells adjacent to wounded areas and forms a dense, hard layer over the face of scars (17). Sweetgums are occasionally tapped for the commercial production of storax, which is used in adhesives, salves, incense, and perfume (1).

RACES AND HYBRIDS

Information on the races of sweetgum is lacking, and although another species, Liquidambar orientalis, is native to western Asia, no hybrids of sweetgum are known to exist.

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