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Laurence C. Walker
Stephen F. Austin State University

Kenneth G. Watterson
Stephen F. Austin State University

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SILVICULTURE OF SOUTHERN BOTTOMLAND HARDWOODS

Laurence C. Walker
Kenneth G. Watterston

(Seventh of a Series on the Silviculture of Southern Forests)

School of Forestry
STEPHEN F. AUSTIN STATE UNIVERSITY
Nacogdoches, Texas

STEPHEN F. AUSTIN STATE UNIVERSITY
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Sponsored by the Conservation Foundation

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BOTTOMLAND REGIONS[1]

The potential of southern bottomland hardwood types is clear, for they, along with cypress, occupy about 37 million acres and comprise more than half of the hardwood stumpage in the South (Sternitzke, 1962). Although the Mississippi Delta, the broad flood plain of the Mississippi and its tributaries below the mouth of the Ohio, and the belts of hardwoods flanking the countless secondary waterways throughout the South are the principal areas of growth, the type is also found in swamps, bogs, ponds, and branch heads (Figure 1). Much of this land is inherently productive, capable of growing annually 500 board feet (Doyle) of high value wood per acre. Another ⅔ cord can be produced from topwood and small trees removed for cultural purposes.

Figure 1. *In addition to the flood plains of major rivers, swamps, [left] and creek and stream bottoms interspersed among pine sites [right] produce much hardwood timber.* U. S. Forest Service Photo.

Mississippi River Delta[2]

Hardwood silviculture in the Mississippi River Delta is primarily sawlog silviculture aimed at producing large, defect-free timber of high value for furniture, flooring, cooperage, lumber, veneer, and specialty products. The recently expanded market for pulpwood from

[1] Miller (1967) is an excellent bibliography dealing with southern hardwoods.
[2] Putnam (1951) and Putnam, Furnival, and McKnight (1960) are excellent references on the subject. Much of the material that follows, not otherwise cited, is from these sources.

deciduous trees in the lower part of the region is making intensive management of hardwood stands increasingly practical. Not only are growth rates of bottomland species excellent, reproduction is generally prolific and occurs naturally if sites are protected from grazing by wildlife and domestic stock, and from fire and disastrous flooding.

In the two years, 1916 and 1925, 85 percent of the bottoms north of the Red River were burned. While wildfire has left the forest with a high proportion of low-grade trees, culls, and undesirable species, mere presence of recent or incipient fire injury is not sufficient reason for intensive salvage operations. A single fire every 10 years prevents restocking of good trees and destroys the humus so that soils become puddled and dry to rock-like hardness. Regeneration is difficult to obtain where coarse, loose, sandy soils are at the surface or just below a thin veneer of fine material. In those soils, occurring between levees, the water table in summer is likely to be too deep to enable delivery of the moisture by capillarity through the sand. Other difficult sites are those with plastic clay, as on the low flats, and the hardpan and silty clay basins of the terraces. There, moisture and aeration are unfavorable and willow oak is generally the principal species present.

Soils and Physiography

Bottomlands, typically hardwood and cypress sites, have azonal soils too immature to have well-defined horizons. Forest sites and timber types are closely allied to and distinguished by topographic features (Table 1). First bottoms, major sites of relatively recent origin comprising the present main flood plain, are frequently flooded. The soils there are chiefly waxy clay and fine sandy loams, but may be coarser. Silt is relatively less important, impervious soils here being plastic clays. Terraces, or second bottoms, are older, higher areas which flood only occasionally and on which acidic silt loams and silty clay loams are major textural classes. Low areas may have impervious silty clay.

Table 1. *Southern bottomland forest types and their major characteristics [from Putnam, 1951].*

Type	Occurrence by site	General features	Common variations in type
Sweetgum-water oaks	In first bottoms except deep sloughs, swamps, fronts, and poorest flat sites. Also on on terrace flats.	Most widely distributed type. Second in quality, though nothing excels the best of this type. Produces high value factory lumber and veneer logs.	(a) **Predominately sweetgum:** on well-drained first bottom ridges and pervious silty clays on terrace flats. (b) **Predominantly water oaks:** on heavier soils on first bottom ridges and better drained flats on poorly drained flats on terraces Nuttall oak dominates on well-drained first bottom flats. Willow oak prevails on first bottom ridges and poorly drained terrace flats, i.e. pine oak flats; near the coast laurel oak takes over. (c) **Cedar elm-water oaks:** on poorly drained, impervious soils on low or indistinct first bottom ridges. of minor importance on impervious terrace soils.
White oaks-red oaks-other hardwoods	Best fine, sandy loam soils on first bottom ridges and all ridges on the terraces. Type extends on first bottom ridges to a few peculiar, well-drained soils other than sandy loam.	Highest value type, with best species and highest quality products. Second only to sweetgum water oaks type in area. Produces high-quality tight cooperage, factory lumber, veneer logs.	(a) **Predominantly white oaks:** on the most matured terrace soils. (b) **Pine-hardwood:** in very limited situations; most common with loblolly on terraces, but also with spruce pine on ridges in first bottoms of small streams of the Coastal Plains east of the Mississippi River.

		pulpwood make it valuable. Usual poor quality and form make it of little value away from fronts. With cottonwood, is characteristic of fronts of most major streams but commercially important only in lower Mississippi Valley.	
River front hardwoods	All front lands except deep sloughs and swamps.	Transition between cottonwood or willow and the sweetgum-water oaks type. Widely distributed but restricted in extent. Very rapid growth, moderately valuable products for factory lumber, veneer logs, and slack cooperage stock.	None.
Cypress-tupelo gum (Cypress-swamp blackgum)	Cypress-tupelo gum in very low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces. Cypress swamp blackgum in swamps of the Coastal Plains and river estuaries.	Widely distributed in small areas. Extensive areas on lower reaches and estuaries of major streams. Potentially highest value products but growth is slow and reproduction uncertain and difficult to secure.	(a) **Pure Cypress**; occurs scattered throughout the type. (b) **Pure tupelo gum** (or swamp blackgum): largely follows clearcutting of cypress.

Ridges, flats, sloughs, and swamps are secondary sites in both first and second bottoms. In second bottoms, sheet erosion has lessened their evidence. Ridges, high land 2 to 15 feet above flats, are the banks of former stream courses. Although rarely inundated, seasonal overflows have deposited coarser materials. Surface drainage is better than in other topographic classes.

Flats, lying between ridges, have poor surface soil drainage and, due to the high proportion of clay, internal drainage is also poor. Following floods or heavy seasonal rains, high flats are drained of free water within a few days after rivers or streams are again within their banks. Free water in low flats requires several weeks to subside. Sloughs are shallow depressions—usually filled-in stream courses—in which water collects during wet seasons; while swamps, except during droughts, are inundated for the greater part of every growing season. These alluvial swamps are distinguished from tidewater and land-locked Coastal Plain muck swamps by a fairly firm clay bottom, which sometimes is permanently flooded, in contrast to organic soils continuously under water.

Battures, lying between rivers and levees, usually have silty loam to sandy soils which are frequently inundated. The Mississippi River has some 2,000,000 acres of forested batture containing the fastest growing North American hardwoods, eastern cottonwood and black willow (Maisenhelder and Heavrin, 1956). Brakes denote cypress- and tupelo-covered lowlands or swamps.

Growth

Average values for diameter growth vary appreciably by species. For woods-run growing stock on all sites and without management, cottonwood is the fastest growing, exceeding 4 inches dbh in a 10-year period. Nuttall and willow oaks rank close seconds, averaging between 3½ and 4 inches (Bull, 1945) (Table 2). Baldcypress on those sites averages slightly less than 1 inch in a 10-year period. Under management, growth of cottonwood and cypress exceeds twice these amounts.

Overmature trees, as expected, grow slowly—only 75 percent as fast as mature stems; for example, an overmature virgin sweetgum-oak stand which, after a thinning removing one-half of the original volume (12.5 MBM per acre)—mostly in trees over 30 inches dbh—had an annual growth of less than 200 board feet per acre (Davis, 1935; 1935a). This is less than half that expected from well-managed stands.

In a one-year study in southern Louisiana, Eggler (1955) found cottonwood the fastest growing and red maple the slowest growing trees on a silty soil with good drainage and no flooding during the period of observation. Sycamore, black willow, and hackberry

Table 2. *Average 10-year dbh growth of the most common bottomland hardwoods of sawlog size [after Bull, 1945].*

Species (Local name in parentheses)	Probable dbh average [1]
	Inches
Eastern Cottonwood (cottonwood)	3.5-4.0
Nuttall Oak (red oak)	3.5-4.0
Willow Oak (red or pin oak)	3.5-4.0
American Elm (white or soft elm)	3.0-3.5
Honeylocust (locust)	3.0-3.5
Red Maple (maple)	3.0-3.5
Overcup Oak (white oak)	2.5-3.0
Sweetgum (sweet, red, or sap gum)	2.5-3.0
Green Ash (ash)	2.5-3.0
Sugarberry (hackberry)	2.0-2.5
Cedar Elm (rock elm)	2.0-2.5
Water Hickory (bitter pecan)	2.0-2.5

[1] These data apply only to well-formed dominant crop-trees in well-stocked stands.

followed cottonwood. Because radial growth in summer ceased while temperature was high and soil moisture adequate, drought cannot always be held responsible for growth cessation in midsummer. Continuous high summer temperatures or photoperiodism may also be important factors for the "march" of hardwood growth. While most radial growth is over by August 1, sycamore and water tupelo continued to grow until early November.

Radial growth is subject to over-estimation for bottomland gums in increment cores, due to failure to distinguish all rings. Burkle (1950) found over-estimation of 10 and 4 percent for blackgum and sweetgum. Maples, on the other hand, are under-estimated by 6 percent because of false rings.

Stand Rehabilitation

In initiating management, Putnam (1951a) shows that it is first necessary to determine which part of the growing stock to retain for the future. The rest of the forest is overburden: components of the stand whose immediate removal would tend to increase total returns from the stand during the next cycle, or components whose growing space might be made available to reproduction.

Most bottomland hardwood types may be managed as all-aged stands, but small areas might require even-aged stands. Individual tree quality is more important than species in choosing growing stock where quality difference is extreme. Diameter limit cutting must be forbidden, as it takes no account of growth rate and the value of individual trees.

Silvicultural practices depend upon basal area, merchantable volume, forest type, timber quality, markets, and results desired. Inevitably, the first treatment will be an improvement cut supplemented with a harvest of overmature stems, except in young stands where the supplemental treatment should be thinning from below. Some overburden—undesirable growing stock—should be deadened early (Putnam and Bull, 1940).

Overburden may include overmature and mature timber, undesirable immature stems, as well as culls and weeds. It usually comprises about half the volume in stands not previously managed. A typical Delta stand is described as having 2.5 MBF per acre of sawtimber in trees 12 inches dbh and over, three-fourths in trees more than 16 to 18 inches dbh. Forty percent is probably overburden and should be cut. One-third of the overburden might be expected to produce No. 2 logs; one-half, No. 3 logs; and the balance a few crossties. Only one-tenth of the overburden volume, amounting to an average of 2½ trees per acre, is likely to be in cull trees. For trees less than 12 inches dbh, stand volumes usually amount to about 3 cords per acre, one-half of which is overburden. If undesirable trees of the smallest sizes are not cut, they will die, unless left in an opening, before doing any harm. Ordinarily, overburden trees more than 6 inches dbh should be removed. Three-fourths of the volume in trees over 30 inches dbh is likely to be high quality, in contrast to 40 percent of the volume in smaller trees.

Generally, mature trees are 20 to 32 inches dbh. Occasionally stems up to 36 inches are still making sufficiently rapid growth to retain for high value products, such as face veneers.

Putnam (1951) describes silvicultural objectives, priority, and results for the first commercial improvement cuts in bottomland hardwood stands by stand classes based on volumes and tree sizes (Table 3).

Table 3. *Mixed-Stand Classes: Their characteristics and nature of the first commercial improvement cut* [*after Putnam, 1951*].

Stand class	Nature of stand and products	Cutting objectives and priority	Silvicultural results of the cut
I. **Heavy sawtimber** (8000 bd. ft. and more per acre)			
a. 50 percent or more of the volume in trees 23 inches dbh or larger.	Largest and best trees usually overmature. Products mostly factory and veneer logs.	Harvest of mature timber, salvage of overmature and damaged trees. High priority.	Sparse residual stand, often good in thrifty groups.
b. Less than 50 percent of the volume in trees 23 inches dbh or larger.	Skilled cutting especially desirable, as this class has best possibility of early formal management. Factory logs predominate, but great variety in size and utility of products within and between stands.	Normally stand improvement and release; occasionally salvage; secondarily harvest. Medium priority.	Good residual stand except where much timber is overmature and damaged.
II. **Medium sawtimber** (3500-8000 bd. ft. per acre)			
a. 50 percent or more of the volume in trees 23 inches dbh and larger			
1. Adequate supporting stand.	Large trees—mostly residual old growth; overstory often seriously obstructing promising second growth. Factory logs of many sizes but mostly of medium to poor quality.	Harvest, salvage, stand improvement release. High priority.	Fair to good residual stands, scattered or in groups.

Table 3 Cont.

2. Same as above, but without supporting stand.	Sawtimber overstory usually in very poor condition from same causes that damage or eliminate understory. Products largely factory logs of good size but medium to poor quality; also considerable tie-and timber-logs. Species composition often poor.	Harvest, salvage, stand improvement. High priority.	Sparse residual stand in need of regeneration.
b. Less than 50 percent of the volume in trees 23 inches dbh and larger; Supporting stand present.[1]	If undamaged, fair chance of sustained yield after first cut. Factory logs medium to poor in size and quality and often only a small majority of total. Tie-and timber-log volume large, sometimes a good amount of bolt stock and pulpwood.	Stand improvement, release, occasionally salvage. Low priority.	Good residual stand unless original stand had heavy early damage or sparse understory.
III. **Light sawtimber** (1500-3500 bd. ft. per acre) a. 50 percent or more of the volume in trees 23 inches dbh or larger.			
1. Adequate supporting stand.	Cut will usually be near minimum operable volume. Products range widely in size and quality, but sawtimber predominately, running half factory logs, half tie-and timber-logs. Very desirable to integrate sawtimber with other uses.	Harvest, salvage, stand improvement, release. High priority.	Good to sparse residual stand, depending on damage and development of supporting stand.

Table 3 Cont.

2. Same as above, but without supporting stand.	Stands mainly residual old growth following heavy cutting and repeated burning or grazing. Products chiefly sawlogs, about half factory and half tie-and timber-logs.	Harvest and salvage; stand improvement incidental. High priority.	Sparse residual stand needing reproduction.
b. Less than 50 percent of volume in trees 23 inches dbh or larger; Supporting stand present.	Only the best such stands are operable. Sawlogs; often runs strongly to tie-and timber-logs, but all products usually occur in substantial amounts. Integrated operation generally imperative.	Stand improvement, release, harvest, salvage. High priority.	Good residual stand.
IV. **Heavy pole stand** (more than 175 trees per acre) 5 to 11 inches dbh	Stand mainly even aged. Excellent chance of early formal management if not seriously damaged. Products almost entirely pulpwood and chemical wood, rarely piling or low-grade local-use sawlogs.	Thinning and stand improvement; occasional salvage. High priority.	Excellent young residual stand with great possibilities.
V. **Light pole stand** (less than 175 trees per acre 5-11 inches dbh)			
a. With supporting stand of saplings	One of the most common conditions. Products mainly low-grade cordwood and posts, occasionally traces of low-grade, local-use sawlogs.	Mainly stand improvement and release; occasional salvage. Medium priority.	Sparse residual stand but established reproduction has good future.
b. Without supporting stand of saplings	Same as above	Stand improvement, occasional salvage. Low priority.	Very sparse residual stand. Reproduction badly needed.

Table 3 Cont.

VI. **Saplings and seedlings** (at least 250 trees per acre)	Low-grade cordwood, traces of sawtimber, largely low-grade, local-use logs. Total too light for commercial operation	Release and stand improvement. Very low priority.	Reproduction promising.
VII. **Non-stocked** (all potentially productive conditions)	No produce, except perhaps some low-grade, local-use material	Elimination of undesirable seed source and clearing as site preparation.	Elimination of undesirable seed source

[1] Rarely a medium stand of sawtimber with less than 50 percent of volume in trees 23 inches dbh or larger may be encountered without a supporting stand of small trees. If it occurs, treat as "medium sawtimber (Large) without supporting stand" if the stand volume is in the upper range of its class; treat as "light sawtimber without supporting stand" if stand volume is in lower range of its class.

These early cuttings are to rehabilitate stands. Theoretically, the permissible cut in the ideal unevenaged stand on a good site simply serves to set the stand back to the condition in which it began the cycle (Tables 4 and 5).

Table 4. *Suggested optimum stocking of an uneven-aged bottomland hardwood stand on a good site*[1] *[after Putnam, 1951]*.

Dbh. (in.)	Midway of cycle or average stand		End of cycle: ready for cutting		Cut	
	Trees	Volume	Trees	Volume	Trees	Volume
	No./acre	Cords[2]/acre	No./acre	Cords[2]/acre	No./acre	Cords[2]/acre
4	20.0	0.3	30.0	0.4	12.75	0.2
6	13.0	.5	15.8	.6	5.28	.2
8	9.7	.7	12.2	.9	4.05	.3
10	7.6	1.0	9.0	1.2	2.02	.4
12	6.8	1.2	7.1	1.3	.10	(3)
Total	93.1	3.7	110.1	4.4	24.20	1.1
		Bd. Ft. Doyle		Bd. ft. Doyle		Bd. ft. Doyle
14	6.2	322	6.0	312	...	...
16	5.6	532	5.7	541	0.40	38
18	5.3	779	5.6	823	1.30	191
20	4.3	925	5.3	1139	2.10	451
22	3.2	944	4.3	1268	2.00	590
24	2.3	897	3.2	1248	1.60	724
26	1.6	816	2.3	1170	1.20	609
28	1.1	721	1.6	1048	.80	524
30	.80	656	1.1	902	.65	533
32	.45	452	.8	804	.53	532
34	.27	329	45	547	.34	408
36	.11	165	.27	392	.23	335
38	.04	64	.11	191	.10	163
40	.02	34	.04	76	.04	76
Total	31.29	7,636	36.79	10,498	11.31	5,211
All trees	124.39	...	146.89	...	35.51	...

[1] A cutting cycle of not less than 10 years is assumed.

[2] 128 cubic feet, gross, with 75 cu. ft. assumed as the net content of wood from 4-in. trees and 80 cu. ft. assumed from 6- to 12-inch trees. Topwood in sawtimber trees ignored.

[3] Negligible.

Table 5. *Hypothetical stocking and diameter distribution, with estimated development and yield per acre, for well-managed uneven-aged Southern Hardwoods on average or better sites*[1] *[From Putnam, et el. 1960]*

Dbh	After cutting; beginning of new cycle			End of cycle; ready for cutting			Cut		
	Trees	Basal Area	Volume[2]	Trees	Basal Area	Volume[2]	Trees	Basal Area	Volume[2]
Inches	No.	Sq. ft.	Cords	No.	Sq. ft.	Cords	No.	Sq. ft.	Cords
4------------	17.2	1.50	0.2	30.0	2.61	0.4	12.8	1.11	0.2
6------------	10.5	2.07	.4	15.8	3.10	.6	5.3	1.03	.2
8------------	8.2	2.86	.6	12.2	4.27	.9	4.0	1.41	.3
10------------	7.0	3.82	.8	9.0	4.92	1.2	2.0	1.10	.4
12------------	6.5	5.10	1.3	6.6	5.18	1.3	.1	.08	----
Total--------	75.4	15.93	3.3	121.6	21.14	4.4	46.2	5.21	1.1
			Bd. ft.[3]			Bd. ft.[3]			Bd. ft.[3]
14------------	6.0	6.41	312	6.0	6.41	312	.00	----	0
16------------	5.3	7.40	503	5.7	7.96	541	.40	.56	38
18------------	4.3	7.60	632	5.6	9.90	823	1.30	2.30	191
20------------	3.2	6.98	688	5.3	11.56	1139	2.10	4.58	451
22------------	2.3	6.07	678	4.3	11.35	1268	2.00	5.28	590
24------------	1.6	5.03	524	3.2	10.06	1248	1.60	5.03	724
26------------	1.1	4.06	561	2.3	8.48	1170	1.20	4.42	609
28------------	.8	3.42	524	1.6	6.84	1048	.80	3.42	524
30------------	.45	2.21	369	1.1	5.40	902	.65	3.19	533
32------------	.27	1.51	272	.8	4.47	804	.53	2.96	532
34------------	.11	.69	139	.45	2.83	547	.34	2.14	408
36------------	.04	.28	57	.27	1.91	392	.23	1.63	335
38------------	.02	.16	28	.11	.95	191	.10	.79	163
40------------	---	---	---	.04	.35	76	.04	.35	76
42------------	---	---	---	.02	.19	37	.02	.19	37

Table 5 Cont.

Total--------	25.49	51.82	5,287	36.80	88.66	10,498	11.31	36.84	5,211
All Trees--	100.89	67.75	---	158.40	109.80	---	57.51	42.05	---

[1] The cycle of development illustrated by this table will usually be completed in about 10 years, but may require 8 to 15 years, depending upon site quality.

[2] Saw-log volume includes all sound, reasonably straight stems to a 10-inch minimum top diameter, inside bark, at least 12 feet above the stump (Doyle).

Cordwood volume in tops of saw-log trees, not shown, is equivalent to about one cord per thousand board feet log scale or 40 percent of the total cubic volume of such trees.

[3] Doyle rule.

It should be noted that there is no fixed rotation age: growth rate, condition, and product value determine that for individual trees.

When a stand averaging 105 square feet per acre basal area in all trees received an improvement cut that removed 25 square feet in trees 18 inches dbh and above, the pre-harvest volume of 3 MBF per acre in trees this large was reduced by one-half. Trees released by this operation, which reduced the effective competition by more than one-half, increased in diameter at a rate 26 percent above that of the 10-year period before harvest. However, removal of only one-third of the competition from other trees effected no change in growth rate and, in contrast, where little or no release was accomplished, growth diminished by 17 percent (Johnson, 1950). Best response to release in sawtimber stands is likely to be in trees less than 18 inches dbh. Thus, in initial improvement cuts, one-half of the effective competition with desirable growing stock should be removed and more than three-fourths of the competition to intermediates and codominants. Low value species (overcup oak, bitter pecan, hackberry-elm-ash, and sweetgum-water oak types), on poorer sites or abused good sites, should be converted through cutting to more favorable species. Preharvest weeding is needed for all pure and evenaged types except cypress-tupelo. Oaks and white ash respond to release to a greater degree than green ash, hackberry, and honey locust (Davis, 1935).

Epicormic Branching

Drastic thinning encourages epicormic sprouting, an important cause of quality reduction. Branching is most frequent in stands with basal areas below 75 square feet/acre; for the most common species it is inversely related to the product of tree dbh and stand basal area (Hedlund, 1964). Thinning from below removes trees most likely to put on epicormic branches when released, the intermediate, suppressed and injured ones. Thinning can usually wait until after stands have adjusted to removal of undesirable stems in initial cuts of the overburden, when light and frequent harvests on cycles of 10 years or less are suggested. Dominant and codominant trees, particularly yellow poplar, exhibit less epicormic branching when left as border trees around openings than do trees of lower crown classes or other species (Smith, 1965).

Coastal Plain Alluvial Valleys

Virgin timber in many of the Coastal Plain bottoms of the Southeast was cut between 1920 and 1950, taking the best stems and leaving areas ripe for weed trees and brush invasion. Stands of less than 5 MBF, mostly in low value species and low grade stems, are therefore common.

Heavy initial cuts to place such stands under management amount to 3 MBF per acre and light cuts to about 2 MBF, removing about 75 to 25 stems per acre to release valuable trees. Subsequent harvests on 10-year cycles are lighter. Annual growth of such stands may range from 200 to 1000 board feet per acre, depending upon recent cutting practices. A reasonable average for some of the more favorable bottoms, like the Tombigbee and Savannah Rivers, is 500 board feet per acre, exceptional stems growing as much as one inch in diameter each year.

Piedmont Alluvial Valleys

The forest types of the Piedmont alluvial valleys are similar to those of the Delta Bottomland Hardwood region. Included are river birch, sycamore, sugarberry, and green ash in the riverfronts; black willow, green ash, boxelder, and the bottomland oaks throughout the wider bottoms. Yellow-poplar is encouraged in the bottoms of the Piedmont Province. There, it may be underplanted in stands of inferior broadleaf trees on better sites, provided release is prompt when establishment is assured (Freeze, 1951).

Sweetgum and sycamore are also favored for alluvial valleys and bottoms of the Piedmont Province. These species are not detrimentally affected by dormant season flooding. Evenaged silvicultural techniques, perhaps by seed-tree cuttings are generally recommended.

Site Index

Site potential is very high on alluvial soils. Where site indices are above 90 for loblolly pine, yellow-poplar, along with sweetgum, has greater height growth than other hardwoods and loblolly pine. Yellow-poplar and sweetgum, therefore, are preferred on the better sites while loblolly pine is favored on land below SI 90. Shortleaf pine at any point on the scale is inferior to yellow-poplar, sweetgum, and northern red oak. The oaks have lower growth rates than yellow-poplar and sweetgum except on the poorest sites. No difference is reported for site indices of black, southern red, or scarlet oaks (Nelson and Beaufait, 1956) (Figure 2).

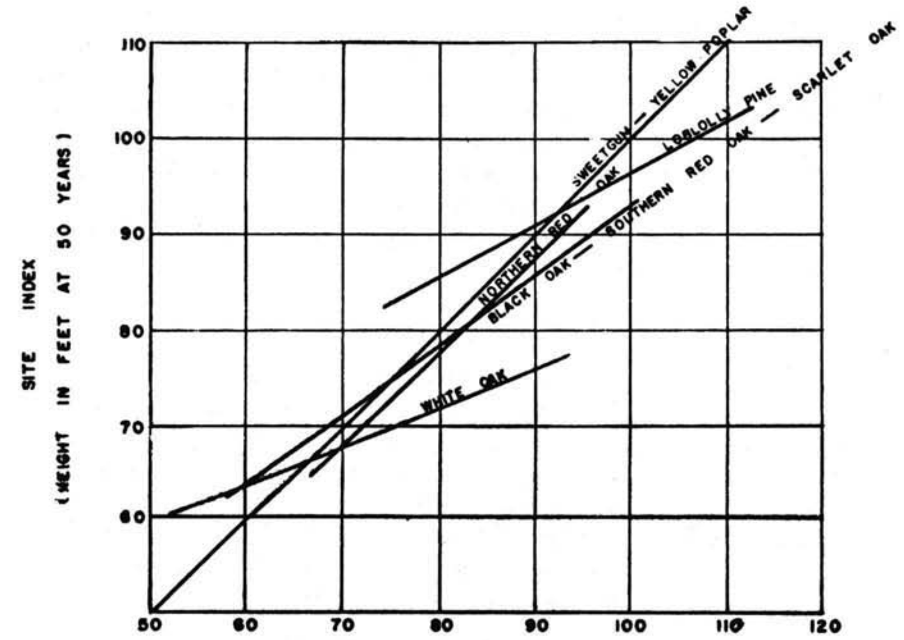


Figure 2. *Comparison of site indices for several species on the same land in Georgia Piedmont.* From Nelson and Beaufait, 1956.

INJURIOUS AGENTS [1]

Decay

Fire-caused Rot [2]

Virtually all decay in bottomland hardwoods is attributed to fire; and all fire-wounded trees, regardless of species, will contain rot (Kaufert, 1933). Fires make wounds into which rots enter and destroy desirable trees, especially in seedling and sapling stages. Undesirable species are frequently the most fire resistant and, hence, a site may be transformed by a single fire. Although injuries as small as one inch in diameter will sometimes admit rot fungi which subsequently destroy butt logs, wounds less than 2 inches in width are generally not important points of infection (Toole and McKnight, 1956). Up to 4 years may be required for rot to reach the heartwood but, once there, spread is rapid—as fast as 2 feet in 10 years. Thus, butt logs are often totally destroyed in the 15 to 20 years required for fire scars to heal. High temperature and humidity encourage spread of decay. Gruschow and Trousdell (1959) show volume deductions by species in North Carolina ranging from 4 percent for yellow-poplar and white oak to 38 percent for red maple. Incidence of rot ranged from 16 percent for yellow-poplar to 57 percent for red maple.

Ground fires are most injurious to immature trees, due to the poorer insulation of the cambium by the bark of younger stems. Some young trees with tight, smooth bark, such as hackberry, hickories, and red oak, are more severely scarred than those with rough, corky bark like sweetgum and white oak, but the difference is slight.

Future value of a tree, in respect to rot, depends on the (1) extent of rot, (2) part of tree doty, (3) probability of breakage, and (4) degrade from stain and associated insects. Fire-damaged trees which should be removed in salvage cuts and subsequent harvests are those where (1) bark is charred to a height of more than 6 feet above the stump or (2) char extends around more than one-half of the tree's circumference and reaches more than 2½ feet above the stump (Toole and McKnight, 1956). Trees with greater external injury probably will rot rapidly or die.

Increment Boring

A controversial subject is the effect of increment boring in forest trees. Toole and Gammage (1959) report that some rot does enter such wounds of bottomland hardwoods, preceded by stain-causing

[1] Agents injuring certain species are discussed in appropriate sections.

[2] See Toole (1959) for details on decay after fire injury and Lockard, Putnam and Carpenter (1950) for illustrations to aid in evaluating log defects.

fungi. They note, however, that most stain at borer holes is physiological in origin—reaction of chemicals in the wood to the entrance of air and contact with the steel tool. While increment borer holes callus rapidly, vertical discoloring may extend a foot in 2 years. Horizontal spread is negligible. Borer holes should be only as deep as necessary and made as low to the ground as possible.

Beavers

Beaver damage in bottoms is an increasing source of butt-log decay. As with fire damage, partial girdling by beavers results in a wound subject to attack by decay-causing fungi. Toole and Krinard (1967) indicate that decay may be as deep as 2 inches after 6 years in ash and 8 years in sweetgum. Wounds extending more than one-quarter of the way around the circumference indicate a strong probability of mortality within 10 years and such trees should be removed in salvage cuts along with trees containing deep rots or low vigor.

Insects

Table 6 presents the important insects which damage living bottomland trees.

Tent Caterpillar

The forest tent caterpillar defoliates tupelos, blackgum, sweetgum, willow oak, overcup oak, and river birch in southern bottomlands. Larvae spin cocoons in early May; moths are in flight 2 weeks later. By June, defoliated trees may put on new leaves, but this crop will be smaller and less abundant than normal. Fortunately, it is believed fungus, virus, or fly parasites may stop outbreaks, but not before many trees are killed (SFES, 1960).

Table 6. *Key to important insect damage in living southern hardwood and cypress trees* [after Morris, 1955].

Type of damage	Tree species	Economic importance
HOLES		
Grub damage. Large holes and long tunnels anywhere in tree trunks.	Most oaks. Especially overcup, willow, Nuttall, laurel, and water oak. Also black oak and white oak on dry sites.	Most important oak defect in all forests. Worst on poor sites and when trees are low in vigor. Largely responsible for the poor reputation of overcup oak.
Grub damage. Usually clustered in lower tree trunks.	Cottonwood.	Important. Clustered holes may weaken young trees so that they break off. Holes degrade wood for lumber and pulpwood.
Spotworm. A very small hole filled with dust and often surrounded by a narrow zone of brown-stained wood.	Overcup oak, willow oak, and Nuttall oak.	Of great importance in some areas. Can reduce otherwise FAS lumber to Sound Wormy grade.
Flag or spot worm. Attacks living trees repeatedly.	Soft maple and post oak.	Degrades veneer and lumber.
Ambrosia beetle "worms" bore into weakened and damaged trees. The small, round, open holes become surrounded by dark sap-stained areas.	Oaks, sweetgum, bitter pecan, ash, and American elm	Minor in living trees. Attack indicates low vigor, dead cambium, or that tree is dying. (Serious in old logs and fresh-cut lumber.)
BARK SCARS		
Bark scarrer damage. A patch of inner bark is killed and the wood surface is stained. When overgrown, appears as a stained area with ingrown bark. Often occurs throughout a log.	Overcup oak, laurel oak, willow oak, water oak, Nuttall oak, and on poor sites, cherrybark oak. Blackgum, hickory, and yellow-poplar. Black oak and white oak on high, dry sites.	Second only to grub damage in most bottomland oaks, and sometimes worse. Especially bad in overcup oak. Reduces black and tupelo gum veneer to core stock grade.
ABNORMAL GROWTH		
Ridges of abnormal wood and ingrown bark that develop from bark lesions.	Sweetgum.	Cause a lumber defect similar to a small catface or large bark scar. Serious degrade over limited areas.
Ribbed swelling in the trunk near the ground.	Sycamore	Abnormal wood growth and ingrown bark cause a lumber degrade.
GALLS		
Galls that girdle oak twigs and kill the leaves and buds.	Willow oak, southern red oak, and water oak.	Kills trees in 2 or 3 years. Locally important. Nearly 20 million board feet of

Table 6 Cont.

		willow oak died in one area a few years ago. Serious damage now occurring in other areas.
DEFOLIATION		
Defoliation by tent caterpillars	Sweetgum, pecan, hackberry, and hickories.	Serious, especially if defoliation is repeated 2 years or more. Gum trees are dying after 3 years of defoliation on 60,000 acres north of Mobile, Ala. Also causing mortality in Calcasieu River bottoms of southwest Louisiana.
Defoliation	Cypress	Periodic defoliation slows growth and weakens trees.
Defoliation	Cottonwood and willow	Periodic buildups serious. May injure young cottonwood in plantations and nurseries. Extensive plantation threatened at Scott, Mississippi.
Partial to complete defoliation.	Nuttall oak, cherrybark oak, southern red oak, and overcup oak.	Weakens trees and slows growth. Repeated attacks may cause death. Damage not fully evaluated.
Reddening of foliage in cypress. Partial defoliation.	Cypress	Importance not known. Growth is reduced, and weakened trees may be damaged by other agencies.

Grazing

Grazing of domestic livestock must be excluded from all bottomland hardwood forests. Cattle trample reproduction, browse valuable stems, and compact the soil. The soft floor of many bottomland forests, especially border areas of reeds and swamps where one quickly sinks to the knees in soft, loose organic matter, discourages cattle. Perhaps too, the impalatability of swamp herbs further inhibits grazing, as cattle seem reluctant to graze the swamps except during the famine or extremely droughty seasons (Hall and Penfound, 1943).

Competition

All competing vegetation except annual herbs must be eliminated if preferred species are to grow adequately. Dominance of free-to-grow stems among most bottomland species is then quickly asserted.

Fire promotes buckvine and honeysuckle sprouting, encouraging its spread. These serious pests are prevalent in sites occupied by stands which are sufficiently sparse to permit light to penetrate the canopy, especially on heavy, slack-water soils. As drastic thinning encourages the spread of vines, caution should be exercised in opening up stands where invasion has begun until reproduction has an even start. Sprays such as 2,4-D and 2,4,5-T give incomplete control as they do not prevent germination of seed in the duff (Bruner, 1967). However, vines are seldom a serious threat where stands are reasonably stocked.

Windthrow

Windthrow is important in sites with pervious soils which, in spite of deep tap roots, afford poor support when saturated. On areas with impervious substrata, wind removes trees with defective root systems and those which lean from a "root-sprung" condition.

The increase in soil moisture following heavy cuttings, consequently raising the danger of windfall, encourages conservative harvesting. The rise of ground water after clearcutting, converting flats and sloughs to brushy swamps, is particularly devastating where soils are too shallow for establishment of deep tap roots on potential seed trees.

Flooding Effects

Absorption, transpiration, water movement, temperature, chemicals and organic matter in the water, microbes, algae, and the soil physical and chemical properties all probably affect the tolerance of trees to submergence. These factors, in turn, influence the amount of free oxygen available to plants under saturated soil conditions. It is this oxygen deficiency or carbon dioxide toxicity which detrimentally influences seed germination, seedling survival, and tree growth.

Germination

Free oxygen is considered the limiting factor in the germination of bottomland hardwood seeds in flooded sites. Except for siltation, which covers seeds too deeply, flooding bottomlands for up to one month does not appear to reduce germinative capacity (Hosner, 1957). Observations suggest that even if bottomland tree seed were to germinate while immersed in water in actual field conditions, eventual establishment of the seedling would be most unlikely unless the immersing waters receded before the seedling perished from other causes (DuBarry, 1963). Consequently, the normal amount of flooding is not a major cause of selective regeneration among species until after germination, except possibly in swamps. But, in long-inundated areas, production of great quantities of seeds are essential to offset the hazards of submergence. Red maple, silver maple, sycamore, and elm germinate only after flooding subsides, but germination percentages for those species are probably higher as a result of short flooding. Drainage is necessary for germination of tupelo and blackgum.

The amount of light reaching the forest floor also influences germination of bottomland hardwood seeds. Germination is more favorable for river birch, sycamore, and American elm under conditions of full sunlight than under crown canopies. In contrast, red maple, winged elm, and alder germinate best under low light intensity (McDermott, 1953). That may account for these less desirable species, with deciduous holly and dogwood, outnumbering favorable species in some flooded bottoms where litter is deep and ground vegetation dense. (New ground that is regenerated with cottonwood and subsequently invaded by weed trees is an exception to this generality.)

Reproduction of desirable species is initially adequate on all sites not currently flooded, but it is best where litter is shallow or absent; the ground cover light, or absent; and the overstory sparse. In one case, elm was the most abundant of all species where litter was deep or ground cover dense, while hickories and some oaks were more prolific on heavier soils with high moisture-holding capacity. This, however, could be due to the greater frequency of seed-producing stems of those species on such sites (Hosner and Minckler, 1960).

Survival and Growth

Trees in southern bottomlands depend for survival upon their ability to withstand and recover from periodic and more-or-less permanent flooding. Species vary appreciably in their ability to do so. Up to 16 weeks of soil saturation from the time of planting does not significantly affect survival, date of bud-break, or initiation of height growth of sycamore, sweetgum, and Nuttall oak seedlings. But when soil temperatures were rapidly increasing in mid-April, saturation for more than 10 to 12 weeks severly reduced height, root, and stem-diameter growth (Bonner, 1966). Willow, cottonwood, and green ash may survive much more than a month of inundation. Hosner and Boyce (1962) classified seedling tolerance to water saturated soil as follows: Tolerant - green ash, pumpkin ash, water tupelo, willow; Intermediate - eastern cottonwood, boxelder, red maple, silver maple, pin oak, sycamore; Intolerant - cherrybark oak, Shumard oak, American elm, willow oak, sweetgum, hackberry, sugarberry.

Although chlorosis and reduction in height growth occur, adventitious roots permit rapid recovery after drainage (Hosner, 1959, 1960). Sycamore develops a brisk red chlorosis indicative of a break down of chlorophyll in leaf cells, but color is regained upon removal of the water. The oaks—pin, Shumard, and cherrybark,—and hackberry, red maple, sweetgum, and American elm did not respond to drainage after long periods of inundation in southern Illinois. Height growth does not occur while seedlings are submerged but, for some flood-tolerant species, elongation takes place if a few leaves are above water. Lentz (1928) noted that if saplings are taller than high water levels, lower branches die, and growth is retarded in direct proportion to the amount of crown loss. Usually no damage occurs to oaks, sweetgum, hickories, ash or elm if crowns are entirely out of water; but exceptions are reported, as when trees up to 24 inches dbh died, perhaps as a result of siltation, after a severe flood (Lentz, 1929). Where floods deposit silt or sand to depths as shallow as ½ foot, all species except cottonwood and willow, regardless of size, will probably die (SFES, 1933). Ability to develop adventitious roots just under the new level of the soil sourface enables cottonwoods and willows to survive.

Although red maple exhibited less tolerance to flooding than did silver maple in controlled experiments, the former is considered the more hydric of the two species. Silver maple did not endure even 1 week of complete inundation in other tests (Hosner, 1958). There is evidence that growth of green ash in lower bottoms is favored by severe floods. Trees in second or higher bottoms do not react to flooding in this manner (SFES, 1935). McAlpine (1961) finds green ash seedlings very tolerant of inundation, but black walnut, white ash, and red mulberry do not survive frequent flooding (Maisenhelder, 1957).

Three-week old cottonwood, willow, sweetgum, ash, and boxelder seedlings about 3 inches tall survived under a foot of water for one week during the growing season. Some chlorosis of foliage occurred and leaves died, but recovery followed drainage. Ash, sweetgum, and boxelder survived over 2 weeks of this treatment (Hosner, 1958). In the New Orleans battures, growth of pecan and hackberry was excellent during floods in which water was maintained at a depth of 4 to 7 feet for long periods of time (Bonck and Penfound, 1944). Neither species is considered a hydrophyte.

McDermott (1954) subjected river birch, American elm, red maple, and alder to saturated soil just after the first true leaves formed in the spring. Soil temperature was abnormally high in contrast to expected natural conditions. Birch and maple recovered rapidly from sustained saturation, and elm recovered slowly (Tables 7 and 8). This suggests that elm is somewhat less hydric than the other species tested, although succession in nature is usually from an alder-willow type to a maple-elm-ash association, a transition most likely occurring in very wet to moderately wet habitats. Intermediate timber types in succession may be sweetgum-yellow-poplar, pure birch, pure sycamore, or boxelder.

Table 7. *Mean height growth of seedlings subjected to treatment of 32 days saturation compared to mean height growth of control seedlings 52 days later* [*after McDermott,* 1954).

Species	No saturation	Saturation
River birch	24.67	15.78 (*)
Red maple	20.30	10.76 (*)
Sycamore	14.84	12.30 (*)
American elm	17.57	11.25 (*)
Winged elm	15.11	6.18 (*)
Alder	6.50	6.30 (ns)

(*) Difference from check significantly negative at 5 percent probability level, thus reduced growth.
(ns) No significant difference in growth response at 5 percent probability level.

Table 8. *Relative degree of recovery after most injurious treatment compared to recovery after most favorable treatment* [*after McDermott, 1954*].

Species	Treatment	Days	Recovery Rate
River Birch	Most favorable Most injurious	0 16	Very rapid to stunted growth responses
Red Maple	Most favorable Most injurious	0 32	Very rapid to stunted growth responses
Sycamore	Most favorable Most injurious	1 32	Rapid to slightly stunted growth responses
American elm	Most favorable Most injurious	0 32	Moderate to some stunted growth responses
Winged elm	Most favorable Most injurious	1 32	Moderate to stunted growth responses
Alder	Most favorable Most injurious	32 0	Some saturation growth promoting

While flooding during dormant seasons is not injurious to yellow-poplar, growing season inundation of newly planted seedlings for even 3 or 4 days kills all trees (McAlpine, 1959b, 1961). Short-term floods of less than 2 days apparently are not damaging. Injured stems may appear healthy for a month or so before leaves wilt and trees die. Sudden wilting does not always follow the recession of flood waters: symptoms of injury may be delayed 6 weeks. When 3-year-old seedlings were continuously flooded during the growing season, all leaves died within 2 weeks (Kramer, 1951). Before death, they became epinastic, a state in which more vigorous growth of the upper surface of unfolding leaves caused downward curvature of leaves and twigs.

In studies of tolerance of many woody plants to flooding during the growing season over an 8-year period, it was noted that chances

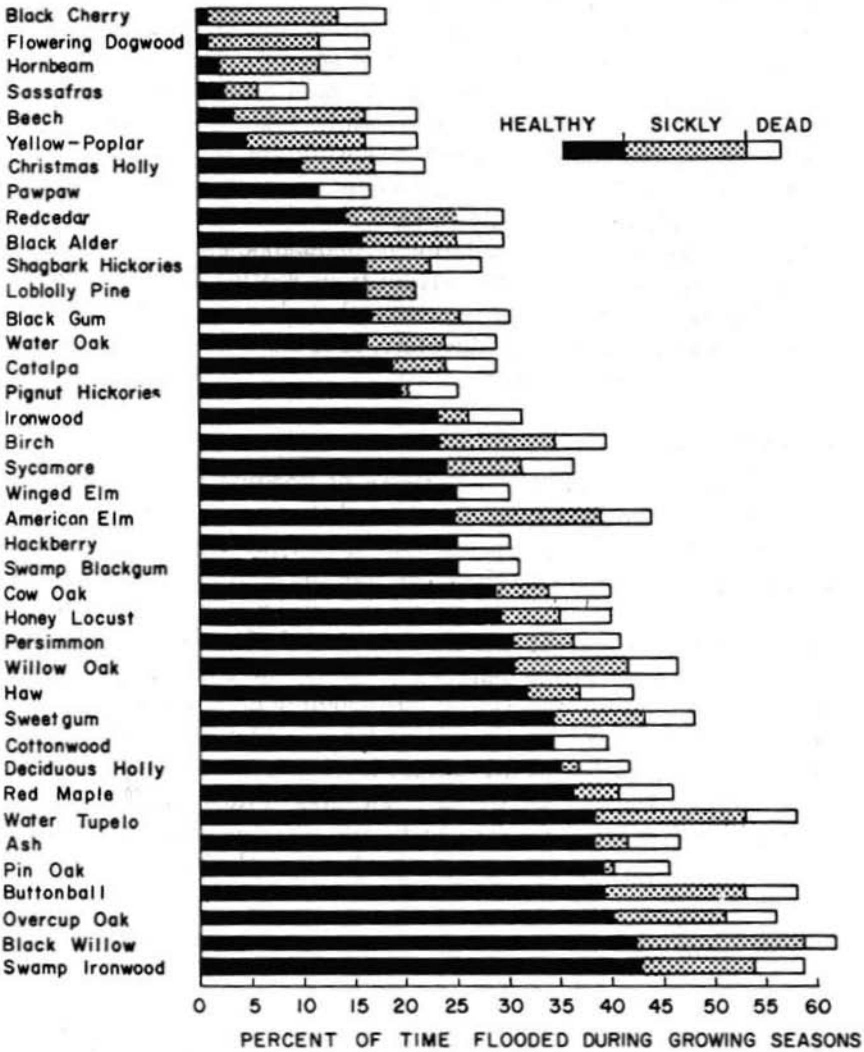


Figure 3. *Tolerance of 3-inch dbh and larger woody species to flooding during the growing season.* After Hall and Smith, 1955.

for survival are better if tops are above water, provided the species have some tolerance for high water (Hall and Smith, 1955). This tolerance varies from 2 days for black cherry and dogwood to 42 days for black willow and swamp ironwood (Figure 3). All woody plants were killed where root crowns were periodically flooded for more than half of the growing season.

McAlpine (1959b) reasoned that in ponded areas exposed to sunlight after rain a temperature rise increases respiration and the activity of micro-organisms, resulting in oxygen deficiency and carbon dioxide toxicity. Hopkins, Specht, and Hendricks (1950) found that root growth (of a number of species) stopped when free oxygen reached 0.5 percent in the gas around roots, but top growth then continued, accompanied by possibly toxic accumulations of iron. Those workers further noted that while the rate of transfer of solutes from root to shoot is independent of aerobic mechanisms of roots, flooding might stop downward movement of carbohydrates and auxins. Thus, the accumulation of plant foods and hormones at the water line may account for adventitious rooting of flooded trees. Sprouting from root collars indicates that death of roots has not preceded death of tops and, therefore, root-kill by flooding was not responsible for tree necrosis.

Transpiration

Parker (1950), studying the effects of flooding on transpiration and survival of various species, assumed that injury to roots caused a decrease in water absorption and, subsequently, transpiration. When oaks were flooded for one month in July, transpiration decreased. However, upon drainage, stomatal water loss returned to 60 percent of the normal rate within a month. Northern red, white, and swamp chestnut oaks behaved similarly, there being no evidence that those species are superior in withstanding high water during the growing season. For overcup oak, under water for 4 weeks, drainage restored transpiration to its normal level (Figure 4). Overcup oaks produced new leaves after the first few days of flooding. The sudden decrease in transpiration rate just after flooding begins suggests that soil moisture limits nutrient and water absorption.

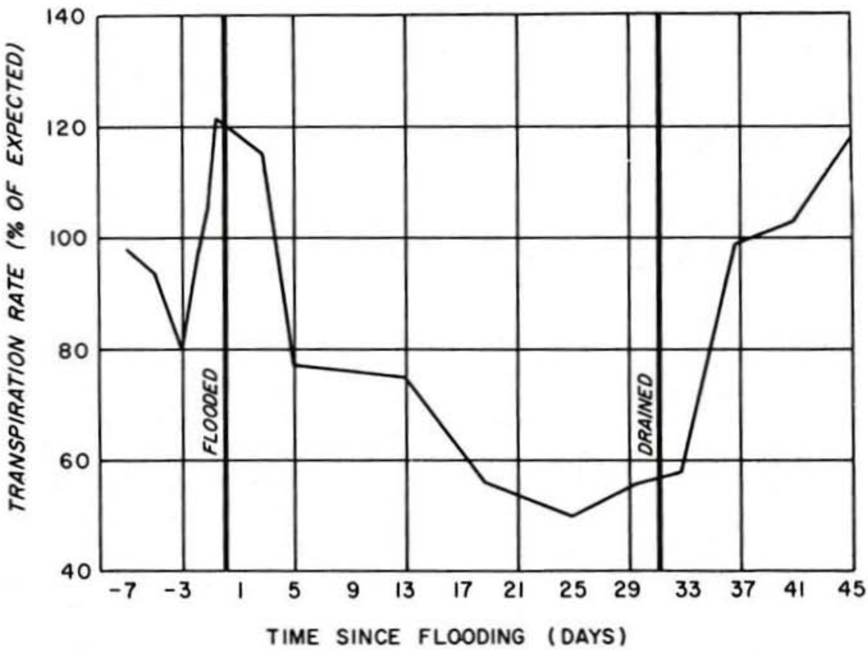


Figure 4. *Transpiration of overcup oak seedlings in soil flooded in the spring for about 4 weeks.* From Parker, 1950.

COTTONWOOD [1]

Cottonwood occurs on new-formed land built up by floods, in borrow pits, and in old-fields subject to flooding. New land is formed as the meandering of a river cuts its bank and deposits on a "point-bar" downstream the soil caved away. Succeeding floods deposit coarser sediments near the bank of the river, building high, well-drained ridges or natural levees.

Cottonwood has great ability to recover from inundation. Roots die when soil is soaked for over a month, but extensive adventitious roots quickly develop from dormant buds on the mainstem. Some height growth is lost, but the slightly chlorotic foliage regains color and continues growth after inundation ceases (Hosner, 1959). Even when cottonwoods have been completely submerged during the growing season, damage is slight (Lentz, 1928), and if the flood is so severe as to deposit as much as 3 feet of silt or sand on the bottom, a new root system develops—in one case 4 feet above the original (SFES, 1933).

An exception to the concensus of opinion for the high water tolerance of cottonwood is found when newly planted stock, especially cuttings, are flooded. In the greenhouse work of Hosner (1958), it was indicated that 16 days is the limit beyond which the species can not survive complete inundation. Earlier, Hosner (1957) found the species not only capable of withstanding a month of high water, but seed germinated after being under water 4 days. Flooding for a month did not reduce germinative capacity, perhaps because of the high water temperatures—up to 93° F.

Growth

Fully stocked unmanaged stands on good sites produce 10.7 MBF per acre (Doyle rule) in 25 years and 27.5 MBF in 35 years with no accounting of salvage mortality, the latter equal to 785 board feet per acre per year (Maisenhelder, 1960). When they mature at about 45 years of age, there will then be about 32 trees per acre with 30 MBF. Some stands continue rapid growth for longer periods. Natural stands on better sites often grow ⅔ to 1 inch dbh and 4 to 5 feet in height each year, up to age 25. Trees in plantations do better, first-year height growth from cuttings sometimes averaging 13.5 feet. Well-stocked natural stands in the Mississippi Valley may contain cottonwoods averaging 20 inches dbh and 120 feet tall at 35 years, at which time growth begins to decline. Plantations at age 14 have 232 trees 9 inches dbh and averaging 82 feet tall with a basal area of about 100 square feet per acre (Wylie, 1961).

[1] See Applequist (1959b) for **A Selected Bibliography on Cottonwood**, and Farmer and McKnight, (1967) for **Populus: A Bibliography of World Literature, 1854-1963.**

Release stimulates growth if residual trees are of good vigor, even when 30 inches dbh. Released trees on good batture sites which had grown 3.2 inches dbh in the 10 years preceding release increased diameter growth by 50 percent during the next decade (Maisenhelder, 1960).

Site Index

Broadfoot (1960) has developed two techniques for estimating capability of mid-south soils to grow cottonwood. The first is based upon soil texture and internal drainage in the surface 2 feet and an ocular estimate of the inherent moisture condition of the soil (Table 9). In distinguishing texture, clays, both buckshot and gumbo, are fine; sandy soils are coarse; and the remainder are medium. Exceptionally dry and excessively drained sand ridges are not included in the classification, since those should not be in cottonwood. The soils are internally well-drained if no distinct gray or reddish brown mottling occurs within 2 feet of the surface. Otherwise, drainage is poor. They are inherently dry if the site is on a slope or ridge, enabling floodwaters or heavy rains to drain off. If the sites are subject to flooding, classification is moist.

Table 9. *Field key for estimating cottonwood site index* [*from Broadfoot, 1960*].

Soil-site description	Site index (30 years)
I. Fine texture	
A. Good internal drainage	
1. Inherently moist	110-119
2. Inherently dry	100-109
B. Poor internal drainage	
1. Inherently moist	90-99
2. Inherently dry	89
II. Medium texture	
A. Good internal drainage	
1. Inherently moist	120
2. Inherently dry	110-119
B. Poor internal drainage	
1. Inherently moist	100-109
2. Inherently dry	90-99

Broadfoot's (1960) second method requires identification of soil series. With either technique, the site index curves of Figure 5 are applicable.

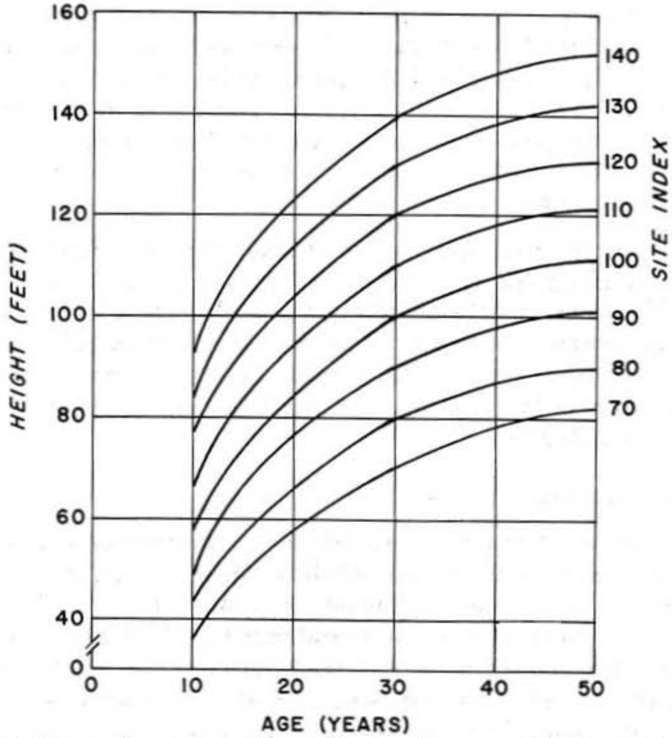
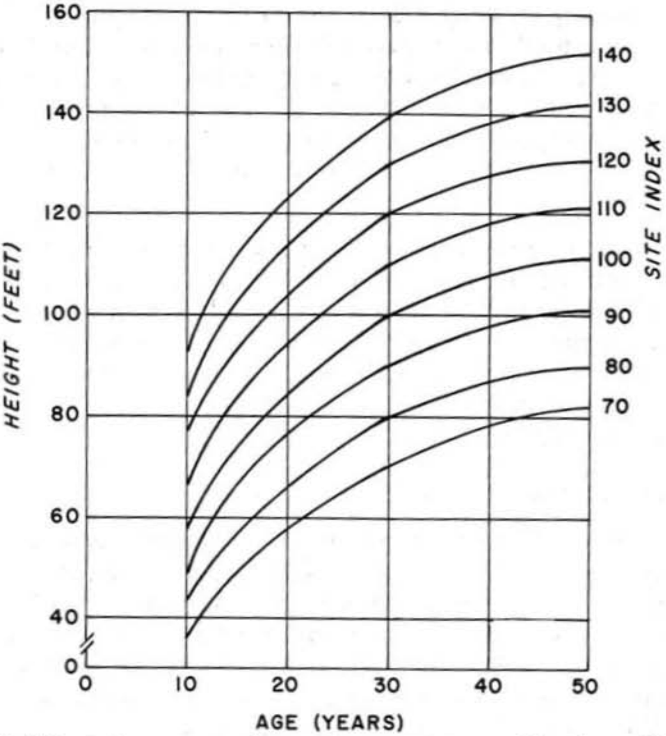


Figure 5. *Site index curves for eastern cottonwood in the mid-south, based upon an age of* 30 *years.* From Broadfoot, 1960.

Natural Regeneration

The life cycle of cottonwood begins in late February or early March when male and female flowers occur on separate trees as young as 10 years of age. Cottonwood seeds, produced annually, mature and fall between April and July, but for some it is as late as mid-August. A freeze after flower buds begin to open will destroy the seed crop. Seeds are carried by wind and water; short floods are apparently beneficial for germination. The annual floods which water the land deposit a fresh layer of silt in which the cottony seed settle out in white masses to germinate. Favorable soil moisture conditions must prevail, for seeds remain viable under dry conditions only a few days.

As many as ½ million seedlings per acre appear. They are delicate the first few weeks, many being lost to hard, blowing rains and hot sun. Reproduction may occur initially on any site, but it is adequate only on open areas of mineral soil exposed to direct sunlight for a greater part of the day, such as old fields, sand bars, and other river deposits subjected to frequent showers or flooding. Sites must be nearly devoid of litter and ground cover for establishment of reproduction. Once started, early dominance is asserted, so that undersirable species are seldom a problem after establishment. Except on very wet areas, cottonwood, if seeded-in with black willow,



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Prior to the final harvest, intermediate cuts maintain optimum growth and enable establishment of succeeding types. The type should be clearcut with expectation of replacement by other species, such as sycamore, sweetgum, and ash which are usually present in the understory. Clearcutting may be by groups or strips if regeneration is desired, but the normal succession of mixed types is usually satisfactory.

Site Preparation

Cottonwood has been regenerated by clearing or deadening the overstory and then cutting shallow strips or trenches into the ground with a bulldozer (Johnson and Burkhardt, 1961; Johnson, 1965). The amount of available soil moisture is thus increased, and the mineral soil is exposed. Two seed trees per acre seem adequate to regenerate river front stands with as many as 2 million seedlings per acre. Treatments less intense than bulldozing appear inadequate and, by this technique, height growth has exceeded 1 inch per day during the first growing season.

Artificial Regeneration

Cottonwood is the only typical hardwood of Southern bottomlands for which planting techniques have been developed and commercial planting is underway on a substantial scale (McKnight and Biesterfeldt, 1968). In abandoned fields and where repeated fire, grazing, and overcutting have prevented reproduction establishment, planting cutover cottonwood areas may be desirable; nursery seedlings, wildlings, and cuttings have been successfully used.

In abandoned fields where row cropping has removed the moisture-holding organic matter and where planting of cottonwood cuttings is frequently prescribed, the species starts slowly and grows poorly. Vigorous trees may die suddenly in midsummer when free water is no longer present. This common condition occurs when total soil moisture falls below 30 percent, all of which is unavailable to plants. When bottomland clays reach the wilting point, the soil still feels moist to the touch.

Confronted with this situation, one might (1) restore organic matter before planting by turning under several cover crops; (2) prepare the site to control the moisture competing weeds, vines, and shrubs by disking or bulldozing just prior to planting; (3) use a subsoil plow to break through the plow sole; or (4) irrigate until trees are firmly established. In any case, 1 to 3 cultivations during the first growing season are essential in order for young trees to outgrow competition. The investment in site preparation and cultivation is made up in reduced cost of subsequent operations (McKnight and Biesterfeldt, 1968). Disks or rotary mowers are appropriate.

Contrary to popular belief, cottonwood can be successfully grown from seed in the nursery to produce 2½ ft. seedlings in one growing season. The costs of growing seedlings has been low and seedlings (especially large vigorous ones) have an advantage over cuttings when planted in the field when heavy vegetative competition is a factor. Cuttings still seem to the best recommendation when combined with intensive culture, such as cultivation (Rudolph and Lemmien, 1961).

Cottonwood does best on moist, well-drained, fine sandy loam or silty soils in the battures; but heavier clays or gentle slopes bordering swamps and sloughs are acceptable. Heavy clay "buckshot" soils, recognized by the absence of trees and sparce grass stands in dry summers, are not recommended because they dry out and crack under the moisture stress of typical droughty summers. Ridges of coarse sand and swampy areas, where backwater is likely to submerge seedlings for several days, are also unsuitable planting chances.

Poorly drained, but not flooded, Coastal Plains sites in Georgia were found to be poor planting areas for cottonwood (Jones, 1959). Both survival and growth, under cultivated and uncultivated conditions, were highly inferior to either slash or loblolly pines on the same site. This may be an isolated case on soil which is neither alluvial or colluvial; but again, the few plantations outside of the Delta are not sufficient for evaluating the species throughout the South. Upon removal of all vegetation, the ground should be left level to facilitate later machine cultivation. Fall tillage is preferred, thus avoiding puddling of soil which occurs when winter rains accompany cultivation. Site preparation may be done on 10-foot wide strips with the debris windrowed between.

Tree spacing ranging from 6 x 10 to 12 x 12 feet is used, depending on the survival potential. Maisenhelder (1960) recommends 10 x 10 feet on sites where at least three-fourths of the seedlings or cuttings can be expected to survive, even in droughty seasons. McKnigh and Biesterfeldt (1968) recommend 12 x 12 feet in order for most trees to reach merchantable size by the first thinning. Less productive land should have more trees planted. Seedling stock recommended is 1-0.

Planting is satisfactory anytime between the first severe frost and the opening of buds in spring. February is preferred for the Delta region; at that time, even the higher sites are usually wet, and drying winds, high water, and rabbits have less time to take their toll before spring growth. Replanting failed spots of less than 1/8 acre is not advised, as the replacements are suppressed by survivors of the initial planting.

Hybrid poplars and cottonwood clones differ in resistance to leaf rust of *Melamspora* spp. but, thus far, none has been found resistant to insect attack (Maisenhelder, 1961). Some hybrids have especially good survival rates and early height growth. Cottonwood clones are not especially different in these respects.

Seedlings

For swamps and low flats, seedlings should be cut back to 18 to 24 inches above ground at planting time; and to 4 inches for ridges and high flats, assuming planting is to be done before buds open.

Wildings, 2 years old, 4 to 7 feet tall, and with 10-inch roots make satisfactory stock. In an early study, first-year results were better for wildlings than cuttings (Bull and Putnam, 1941).

Cuttings

Cuttings, growing more than 16 feet in the first growing season at the rate of an inch a day, are especially effective for propagating cottonwood forests. The recommended length of vegetative cuttings is 20 inches for ridges and flats which are not severely flooded. (Permanently inundated areas should not be reforested with cuttings). Bundles of cuttings, set butt end down in a 2- to 3-inch layer of moist sand on wooden duckboard, are stored at 40° F. with circulating air. As rooting ability decreases with age, new growth from 1- to 3-year-old trees is used (Capel and Coffman, 1966). Diameter of the stock should exceed 3/8 inch (Allen and McComb, 1956; Maisenhelder, 1960), and lateral branches should be pruned flush. For swamps and low flats, cuttings are inserted 1 foot or deeper into the soil. Kaszkurewicz (1964) found increased survival with plantings as deep as 6 feet in all soils.

Best survival and rooting occurs in light sandy soils with high soil moisture, but unsaturated ground. Mortality of cuttings may be due either to inadequate rooting, to vegetative competition, or to careless handling. To control competition, cultivation is essential the first year. Later, when growth is no longer inhibited by grass because either the roots obtain nourishment below those of the grass, or when there are more tree roots, cultivation may not be needed. Turning under the sod improves rooting through areation enhancement as well as through nutrient cycling. Sod, however, is uncommon, and overhead competition for light is an equally important reason for cultivating. Planting in plowed furrows does not always improve growth (Figure 6).

Figure 6. *Trees grown from stem cuttings of Mississippi Delta cottonwood on a Piedmont bottomland site. Left, age 2; right, age 6; survival was 88 percent* U. S. Forest Service Photos .

Greenhouse rooting is readily accomplished, particularly on cuttings collected just prior to foliation in the spring (Farmer, 1966a). Immersing the basal 2 inches of stock in an indoleacetic or indolen-butyric acid (100 mg/liter) solution for 24 hours increases rooting (Allen and McComb, 1956). Gibberellic acid, the growth regulator, has given excellent growth responses when a 1 percent solution was applied to seedlings (Nelson, 1957; McAlpine, 1957; Farmer, 1966).

Fertilization

There is evidence of favorable responses of cottonwood cuttings to applications of about 4 ounces per tree of a 5-10-10 fertilizer formulation applied following planting on plowed and disked sites. Extra cultivation must accompany fertilization to control the weeds which otherwise are severe competitors for soil moisture. Because of this competition, fertilizer probably will be most beneficial after the first year. Ammonium nitrate, at the rate of 2 ounces per tree distributed at planting time in a ring on the surface of the ground at least 6 inches away from cuttings, probably stimulates growth in the absence of competing vegetation (Maisenhelder, 1960). Martin and Carter (1967) increased the size and yield of cuttings in the nursery with nitrogen fertilization.

hardwoods to survive complete inundation for more than a month. The maximum duration capacity was not determined, but after a month, black willow leaves were chlorotic if not dead. Upon drainage, recovery was quick and growth vigorous.

Drought

A sharp line of demarcation has been found between healthy and drought-stricken stands of black willow growing in stratified alluvial soils characterized by 2½ feet of heavy clay overlying deep fine sand. Tree roots extended only 3 inches into the normally saturated sand. Upon desiccation, these trees readily succumbed, as the sands rapidly carried away water which would have been stored had the lower horizon been of more finely textured clay. In an adjacent stand with clay soil 6 feet deep, survival was not seriously affected by drought (Beaufait, 1955).

The critical nature both of soil water and the length of periods between rains were cited by Broadfoot (1953), who found the floor of hardwood forests—typical of those for black willow and cottonwood—capable of losing 95 percent of the moisture held at field capacity within 5 days following light showers.

Trees of the genus *Salix* readily become dormant, even losing leaves, when the wilting point is reached for soil moisture, but they rapidly regain vigor and put out new foliage when water is supplied.

OAKS

Vigor Classes

For bottomland red oaks, bark is considered a more reliable factor for evaluating vigor of individual trees than site characteristics, age, or root system. Crowns furnish additional evidence of vigor. Guttenberg and Putnam (1951) developed three vigor classes based on these characteristics for Nuttall, willow, water, and cherrybark oaks of the Delta and other overflow bottoms (Table 10) (Figure 8). Burkle and Guttenberg (1952) include merchantable white oaks at least 16 inches dbh in these vigor classes.

For high vigor, growth exceeds 4 inches dbh for a 10-year period, medium vigor growth is between 3 and 4 inches, and low vigor trees have less than 3 inches dbh growth. As delays of 4 to 5 years may occur before the bark reflects either improvement or decline in vigor or growth rate, occasional checking with an increment borer is advisable. Observations of crown characteristics in the spring may underestimate the quality of overcup oak because it leafs out later than do most other oaks.

Site Index

Beaufait (1956) reported that exchangeable potassium in river bottom soils is inversely proportional to site index for willow oak (Table 11). Actually, the potassium content is a symptom of site potential. It is directly related to the colloidal content of the soil, for the minute particles provide an ideal surface area to which exchangeable potassium cations leached from higher ground are absorbed. When the colloidal content is exceedingly high, pore spaces are filled, aeration and drainage consequently inhibited, and growth reduced.

Beaufait (1956) also determined the influence of soil and topography on willow oak sites outside of the Delta region using exchangeable potassium (Table 12). As he found the site index to

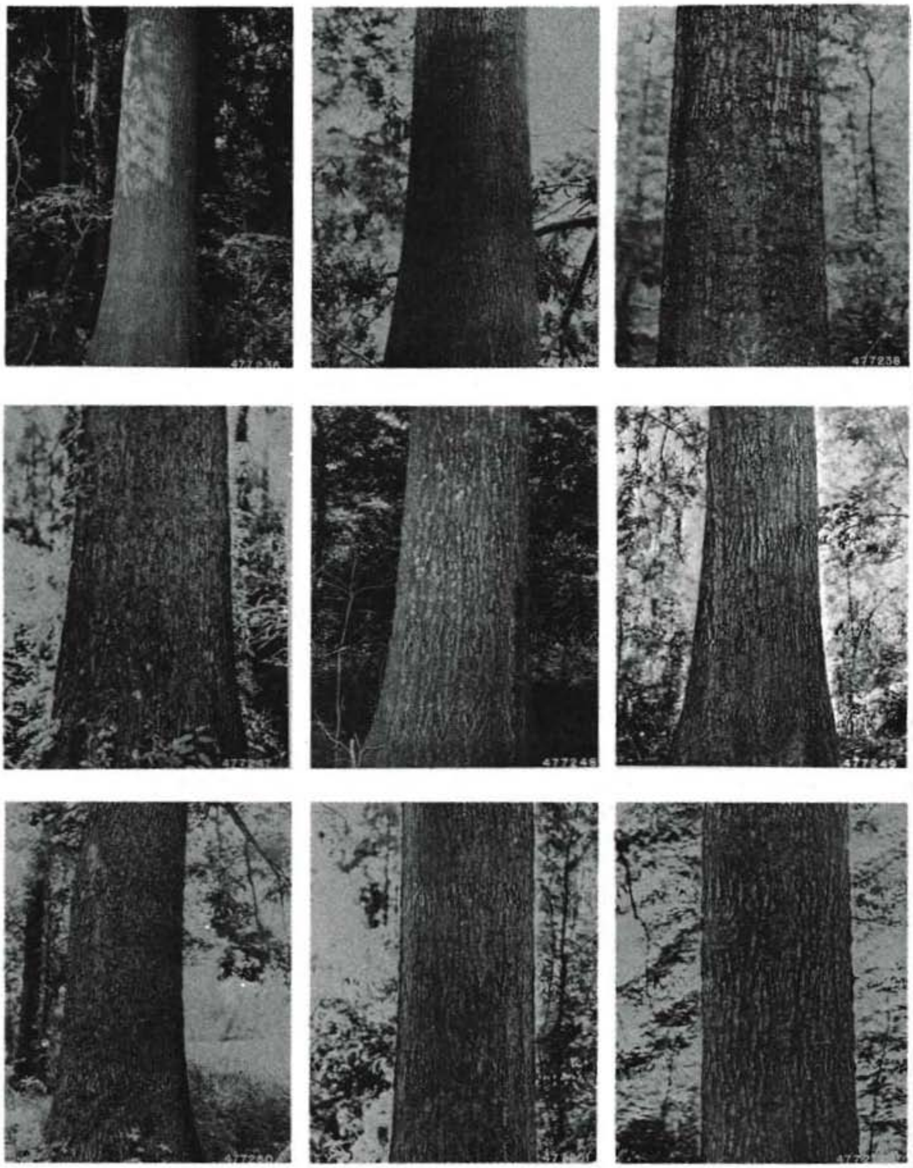

Figure 8. *Bark of Nuttall oak, upper, willow oak, middle, and cherry bark oak, lower, showing left to right, high, medium, and poor vigor classes.* From Guttenberg and Putnam, 1951.

Table 10. *Crown and bark characteristics of red and white oaks by vigor class [from Burkle and Guttenberg, 1952].*

High vigor	Medium vigor	Low vigor
	RED OAKS	
Bark: Bark thickness and color of the inner and outer bark, varies with the species. In general, the bark is healthy, fully normal in color, relatively thin and smooth, but with shallow fissures exposing fleshy, lighter colored inner bark that contrasts markedly with dark outer bark. The bark is the most conclusive indicator	**Bark**: Compared with high vigor, fissures less wide, inner bark duller and generally less conspicuous. Overall, bark is somewhat rougher and darker.	**Bark**: Dark, thick, narrowly fissured. Little or no live tissue exposed in fissures.
Crown: ¾ or more fully formed and without close competition. Full and thrifty. Profuse, long, upward-reaching young branches and twigs, light-colored and lustrous. No dying leaders or dead stubs in upper crown. Foliage abundant and lustrous.	**Crown**: ½ or more well-formed, with abundant foliage, and without close competition. Some crowns may be entirely free of competition,but twigs will be thicker and fewer, and foliage scantier, than in high vigor crowns.	**Crown**: Small and poorly formed, or open thinly foliated.
Crown quality and vigor more important than length or volume, except that a high ratio of crown length to stem length is significant.		
	WHITE OAKS	
Bark: Thick, dark-gray with distinct, long fissures. Ridges flat with few cross breaks running from fissure to fissure.	**Bark**: Thinner. Gray. Fissures shorter and less distinct; ridges somewhat scaly; cross breaks more common.	**Bark**: Thin. Ash-gray. Fissures short and obscure, ridges scaly, and cross breaks abundant.
Crown: ¾ or more fully formed and without close competition. Full and thrifty, branches small, silvery, and ascending. No dying leaders or dead stubs in upper crown.	**Crown**: ½ or more fully formed and without close competition. Notably less full than those of high vigor trees. Branches darker, less ascending in aspect.	**Crown**: Small and poorly formed or open. Thinly foliated.

Table 11. *Site index for willow oaks decreases with availability of potassium in river bottom soils of the Mississippi Delta* [*after Beaufait, 1956*].

Available Potassium* lbs/ac	Site Index
100	83-95
200	78-93
300	69-86
400	60-78

*Determined by quick-test of the surface six inches.

Figure 9. *Willow oak on good* [*left*] *and poor* [*right*] *sites. Merchantable height and log quality decrease as total height at a given age diminishes* From Beaufait, 1956 .

vary with stand density, the tabular data are adjusted to a standard basal area of 110 square feet per acre for all trees 6 inches dbh and larger. Broadfoot (1964) evaluates willow oak sites on the basis of clay content in the 36- to 48-inch layer, depth to mottling, inherent moisture condition, and presence or absence of a hard pan. Site index increases with decreasing clay content and increasing depth to mottling on inherently dry sites without a pan. Wet conditions or the presence of a hardpan results in decreased growth.

Table 12. *Average total height of dominant willow oak at age 50 years on non-delta sites [from Beaufait, 1956].*

Available K per acre in 0-6 inch Layer (lbs.)	Topographic class			
	High ridge or front	Low ridge	High flat	Low flat
	Feet			
100	95	92	89	87
200	90	87	84	82
300	82	79	76	74
400	73	70	68	65
500	64	61	59	56

Water oak sites are classified by the amount of sodium present in a 4-foot depth, thickness of topsoil, and presence or absence of a hardpan (Broadfoot, 1963). Increased sodium content indicates high colloidal content and reduced growth. Highest site indices are obtained on deep soils without a pan and with low colloidal content.

Site index for cherrybark oak increases with increased drainage and thickness of topsoil (Broadfoot, 1961).

Natural Regeneration

Natural reproduction of water oak generally occurs in dense patches in temporary shallow pools of water beneath closed canopies. Drainage is advisable as standing or moving water prevents establishment of reproduction whenever it submerges seedlings for more than several weeks during the growing season. If submergence takes place prior to the growing season, seedlings remain dormant longer than usual in th spring and do not begin growth until after water recedes. Regeneration usually fails if floods during the growing season occur too frequently for seedlings to have a chance between periods of high water to grow above the average depth of flooding.

Mesic oak seedlings rarely survive the low soil aeration conditions of inundation. In an extreme case, where soil was saturated for 38 days, leaves of cherrybark and pin oak seedlings became chlorotic and roots died. Roots were not replaced through adventitious buds, and those formed after excess water drained were weakly developed. Growth was not resumed following drainage (Hosner, 1959).

White, cherrybark, and pin oaks do not survive and, therefore, are not found on sites frequently flooded (Maisenhelder, 1957; Yeager, 1949). Cutting for those species should be gaged to seed-years, since rodents consume seeds stored in the duff. Gaps in seed production of 6 to 8 years are not uncommon.

Hosner and Minckler (1960) noted that in the upper reaches of the Delta, pin oak reproduction increases as overstories become heavier until basal areas reach 100 square feet per acre. Openings, therefore, will retard regeneration of that species and permit entrance of more desirable broadleaf trees. Seedlings should be released from overhead shade, but release of water oaks which only sparsely make up advanced regeneration may be delayed for a miximum of 3 years. On the other hand, large openings seem necessary for regeneration of cherrybark and Shumard oaks (Hook and Stubbs, 1965).

Artificial Regeneration

Planting

Nuttal, cow, and overcup oaks do best when planted on well-drained soil. Those species, however, survive in swampy or poorly drained sites, provided (1) water recedes below tops before the growing season begins and (2) trees grow sufficiently tall the first year to avoid being overtopped by brush in succeeding years. Nuttall and overcup delay growing until water recedes

A 30-year-old mixed oak plantation on a well-drained terrace not subject to flooding produced a basal area of 134 square feet per acre and about 0.8 cord per acre per year. The best growth on the site was for water oak; live and cow oaks were less productive; and the site was too dry for Nuttall oak (Kaszkurewicz and Burns, 1960).

Creek bottom terraces recently abandoned from agriculture make excellent cherrybark oak sites. Seedlings survive well and average almost 3 feet per year height growth for the first 9 years (Applequist, 1959). Cherrybark oak prunes naturally but has some crook injury casued by the hickory twig girdler which, however, is overgrown by vigorous stems.

Direct Seeding

Direct seeding shows promise for reproducing cherrybark and Shumard oaks under certain site conditions. Terraces are superior to bottoms as flooding damage is less severe (Table 13). and cherrybark oak requires the better sites, regardless of flooding chances.

Acorn weevils and filbert worms destroy many bottomland oak seeds. But because unsound seeds float in water and exhibit insect entrance holes, they are readily culled by flotation and hand inspection. For cow oak, and perhaps for other oaks, a single dark spot on the acorn shell is sufficient indication of an opening made by an egg-laying beetle, the weevil larvae of which feed on the meat. For Shumard and cherrybark oaks, a light tan circular cup scar is indicative of sound seed. Dull brown cup scars mean defective seed (Lotti, 1959) (Figure 10).

Table 13. *Average third-year survival and height growth of direct seeded oaks by site condition, Santee Experimental Forest [from SEFES, 1959].*

Species	Cleared terraces		Released first bottoms [1]	
	Survival Percent	Total Height Inches	Survival Percent	Total Height Inches
Cherrybark oak	23	23	5	13
Shumard oak	37	30	6	28
Average	30	27	6	20

[1] Released after one growing season.

Although visual observation and hand selection make seed treatment with chemicals unnecessary, weevils are killed by fumigation for 4 hours in a tight container with 1 ounce of methyl bromide for each 25 cubic feet of tank volume. Soaking in hot water at 120° F. for 30 to 45 minutes is also an effective weevilcide (Lottie, 1959).

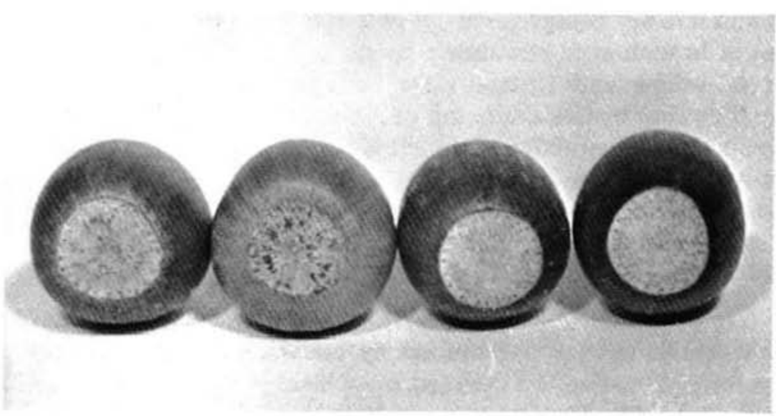

Figure 10. *Shumard oak acorns. Those with light colored cup scar [two on right] are sound, and those with dull coloration [two on left] show evidence of weeviling or rot.* From SEFES Annual Report, 1959

Pruning

Willow oak pruning wounds require 2 to 3 years to heal, live-branch wounds healing faster than those caused by the removal of dead branches (Johnson, 1961). Rot and insect infestation are rare in live-branch wounds, but may occur on one-fifth of the dead-branch wounds. Most rot is confined to the cores of knots. Epicormic branches which develop following pruning may make the practice uneconomical.

Injurious Agents

Disease

Fire wounds are the most important cause of cull in bottomland red oaks. In order to determine the amount of decay behind old scars and to estimate rot expected from new wounds, Toole and Furnival (1957) developed graphic means applicable to a number of common fungi: *Polyporus, Corticium, Stereum, Poria, and Fomes.* In practice, extent of rot is estimated from the length of hollow by probing with a stick or judging the height of butt bulge (Figure 11). Rot generally extends 2 feet above the top of the hollow or 3½ feet above the bulge. One applicable rule for deducting volume lost through butt rot is to reduce the merchantable length of a stem by the length of rot, then reduce dbh by 1 inch for each 6-foot length of rot. This calculation, however, is not applicable to decay scars more than 50 years old.

Heart rot caused by *Poria spiculosa* is extensive in the Delta, probably infecting more than one percent of the water and willow oaks and hickory (Toole, 1954). Small, roughly circular cankers with traces of branch stub remaining in the usually depressed center on boles of willow and Nuttall oaks indicate presence of the brown decay. Fruiting bodies are found only on dead wood in contract with the ground. Well established infections exhibit brown fungus matter when the suspected branch tree is cut into. When *P. spiculosa* cankers occur on the first log, that log is a total cull. The length of the rot, increasing about 10 inches each year, is discernable from the age of the canker, using Toole's (1954) relationship (Figure 12).

Age can be readily determined by counting rings on the callus tissue formed around the infected branch trace. Early harvest in the hope of salvaging logs above the butt section is recommended.

Polyporus hispidus is also a cause of cull in bottomland oaks: red, willow. Nuttall, and cherrybark. The fungus results in elongated, swollen areas surrounding dead depressions or cankers which, upon recurrent killing of bark and cambium and renewed callus folds, give spindle-shaped swellings. Yellowish-brown to rusty-red conks 2

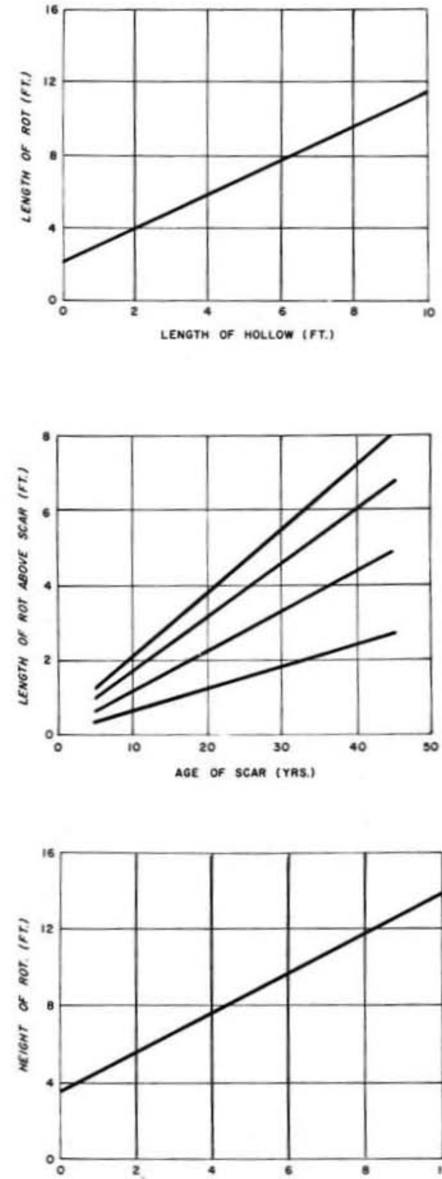

Figure 11. *Extent of heart rot in red oaks is related to length of hollow [a[, age of scar [b], and height of butt bulge [c]. For scar age, the relation concerns the extent of rot above the original scar height for four values calcualted by subtracting two from original scar width and dividing by stump diameter at the time of wounding. Hence, if stump diameter was 12 inches when a fire occurred and the original scar width was 8 inches, then the length of heart rot above the scar height for a 20-year-old scar is about 2¼ feet.* From Toole, 1959

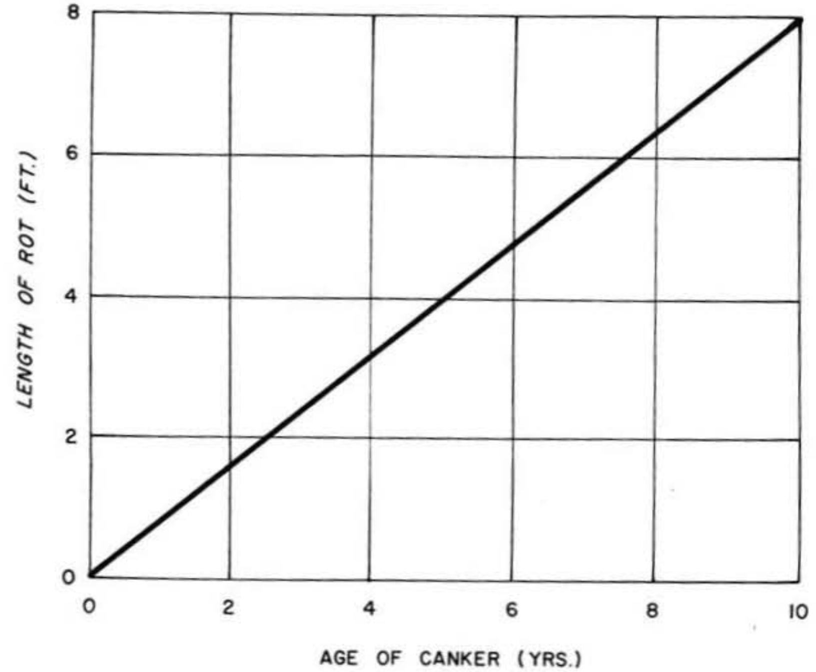

Figure 12. *Relation between length of heart rot and age of poria spiculosa cankers on willow oak. The rot increases in length about 0.8 foot each year.* After Toole, 1954

inches or more in width, spongy, hairy, and without a stalk, occur on surfaces of well-developed cankers in fall or winter. Drying to a rigid black mass, the conks fall to the ground by spring. Infection by the fungus entering through dead branch stubs gives rise to white or pale yellow soft rot in the wood and death of the cambium. Canker length, which rot length exceeds by about 30 inches, increases ½ foot per year (Toole, 1956) (Figure 13). Infected trees should be promptly salvaged since they quickly become culls. Other canker-forming fungi attacking souther hardwoods are *Poria laevigata* (Bottomland red oaks and *Irpex mollis* (red oaks). Canker fungi enter through stubs of dead branches, working down the heartwood and also spreading from the point of entry to kill the cambium. *Irpex* cankers are irregular in shape and with a number of sunken areas. Creamy white conks and white fungus material often occur at the base of the sunken area, the fruiting bodies varying greatly in size and having short, jagged teeth on the lower surface (Toole, 1959).

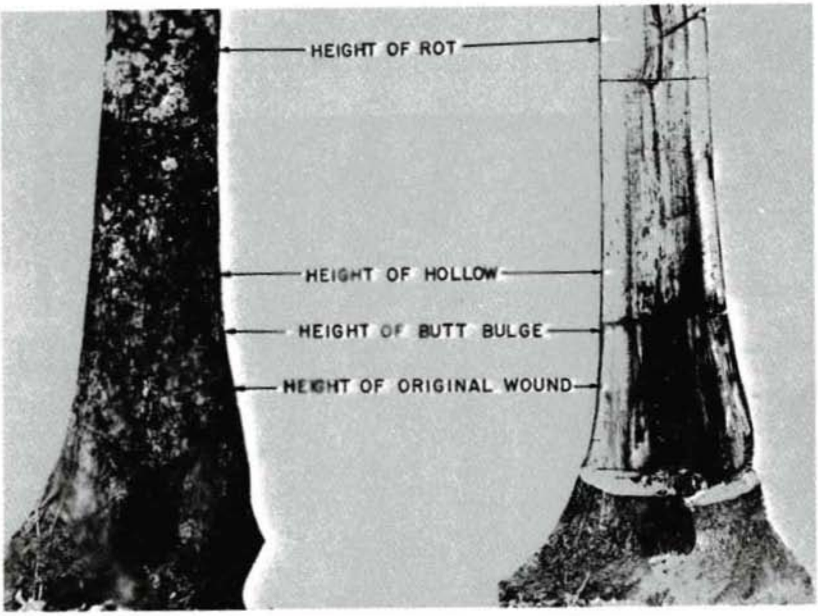

Figure 14. *Fire-scarred Nuttal oak, wounded* 16 *years previously.* From Toole and Furnival, 1957 .

Wood Quality

Southern hardwoods in general, especially oaks, are hard and heavy because of ample moisture and long growing seasons—a corollary of rapid growth. Low specific gravity wood, however, accompanied by slow growth, is found in overcup oaks growing in backwater areas annually flooded for long periods (Paul and Marts, 1934).

SWEETGUM

Within the Coastal Plain, second-growth sweetgum in fully-stocked, relatively pure stands on alluvial soils is frequently evenaged, becoming established over an 8- to 10-year period. Although many pure stands of virgin gum occur, such stands are in contrast to the species' gregarious association in primeval forests, especially on the better-drained, silty clay sites.

Seed-tree cuts should be used for regeneration of evenaged stands. Retaining too many seed trees permits enroachment of undesirable shade-tolerant species. Maintenance of approximately 70 square feet of basal area in evenaged stands seems to yield maximum cubic foot growth (Johnson, 1968).

Coppice is a common form of natural reproduction of sweetgum forests. Early growth of sprouts is considerably faster than that of seedlings, reaching breast height in a singly year in contrast to 3 to 5 years for seedlings. Sprouts 10 years old, therefore, may equal the height of 15-year-old saplings grown from seed.

Vigor Classes

Vigor classes based on bark and crowns have been derived for sweetgum by Guttenberg and Putnam (1951). High vigor trees exceed 3 inches dbh growth in 10 years, medium vigor grow between 2 and 3 inches, and low vigor trees have less than a 2-inch increment during the period (Table 14). These vigor classes apply only to trees 16 inches dbh or greater, and not to culls.

Table 14. *Bark and crown characteristics of sweetgum, by vigor class [from Guttenberg and Putnam, 1951].*

High vigor	Medium vigor	Low vigor
Bark: Light ash-gray, corky, thick, with pronounced rounded ridges. Bottoms of fissures display streak of very light inner bark.	**Bark**: Gray, thick, somewhat corky (or at least with ridges slightly rounded), and free of scales or plates. Bottoms of fissures narrow, only occasionally displaying thin streak of inner bark.	**Bark**: Compared with medium vigor, darker, thinner, flatter. No display of inner bark. May be scaly.
Crown: ¾ or more without close competition. Full and healthy, composed preponderantly of small ascending leaders and twigs. Foliage abundand and lustrous. Other things being equal, high ratio of crown lenght to stem length indicates high vigor.	**Crown**: ½ or more well formed and without close competition. Some crowns are small because of competition, but have preponderance of small twigs and abundant foliage; others are large but are heavy-limbed with thin foliage. Foliage always of good color.. Little sign of dry-topping.	**Crown**: Compared with medium vigor, smaller, or more preponderantly heavy-limbed and with thinner foliage. Foliage may be pale Some trees may be stag-headed or dry-topped.

Simplified marking rules for intermediate and unevenaged or mixed management of sweetgum on a 10-year cutting cycle require that low vigor trees, regardless of diameter, be cut as soon as financially mature, that is, when growth rate fails to meet a specified interest rate. All sweetgum 22 inches dbh and over that show no promise of developing better than a grade No. 3 butt log fall into this class. Where one of two trees must be selected, the one with the greatest potential for higher value is retained (Guttenberg and Putnam, 1951).

Vigor classes, along with age, aid the marker in determining which trees are financially mature (Table 15). For sweetgum, low vigor trees do not grow at a 3 percent interest rate, while high vigor trees may attain 4 percent if they are less than 26 to 29 inches dbh. Medium vigor stems are usually under 22 to 25 inches.

Table 15. *Merchantable gross board-foot volume* [*Scribner*] *per acre, classified by site and stand-age* [*after Winters and Osborne, 1935*].

Age at breast height	merchantable trees	Average breast-high diameter of merchantable trees	Basal area of merchantable trees	Volume per acre
Years	Number	Inches	Sq. Ft.	Bd. Ft.
		POOR SITE - (SITE INDEX 80)		
40	7	14.6	7	400
50	30	14.8	33	2,000
60	49	15.1	57	4,070
70	62	15.4	75	6,280
80	71	15.9	88	8,430
90	77	16.5	98	10,540
		MEDIUM SITE - (SITE INDEX 100)		
40	44	14.8	58	4,260
50	64	15.4	91	8,180
60	76	16.1	115	12,400
70	86	17.0	133	16,510
80	93	17.8	146	20,460
90	97	18.6	156	24,120
100	99	19.3	163	27,360
		GOOD SITE - (SITE INDEX 120)		
30	42	14.7	47	3,430
40	75	15.4	101	9,850
50	89	16.3	136	16,710
60	97	17.4	161	23,620
70	103	18.5	179	30,120
80	107	19.6	190	35,940

Site Index

Best sites are those with the following combination of characteristics; medium-texture soil, between sand and clay; moderate to good internal drainage, as is evidenced by the absence of mottling; no hardpan within the upper 2 feet; and soil inherently moist. Dry slopes and ridges, a hardpan in the upper 2 feet, and poor drainage noted by the mottling hues of red, yellow, and blue indicate lower site indices. Hence, sweetgum sites may be evaluated by the (1) clay content of the soil and the correlated amount of exchangeable potassium, (2) surface drainage and hardpan presence, and (3) soil series (Broadfoot and Krinard, 1959).

Table 16. *Height of sweetgum at age 50 years, as determined from clay and potassium contents at 36- to 48-inch soil depth [after Broadfoot and Krinard, 1959].*

Clay	Exchangeable potassium, in pounds per acre					
(Percent)	0	100	200	300	400	500
	Feet					
10	97	100	104	108	112	116
20	93	96	100	104	107	111
30	89	92	95	99	103	106
40	85	88	91	95	98	102
50	82	85	87	91	94	97
60	78	81	84	87	90	93
70	75	77	80	83	86	89
80	71	74	77	79	82	85

Site index increases with increasing exchangeable potassium, provided the clay content remains constant (in contrast to Beaufait's (1956) report for willow oak), and decreases with increasing clay content for any given quantity of exchangeable potassium (Broadfoot and Krinard, 1959). Reduced growth with higher clay content is probably a reflection of lower aeration and lessened permeability for soil moisture and root extension. Better growth with higher exchangeable potassium is, in turn, an indication of the response of the species to the overall nutritional status of the soil, but especially to this cation of unknown function in the chlorophyll of green plants.

Use of surface drainage and hardpan as a method of indicating sweetgum site potential is apparently limited to the flood plain of the Mississippi River, as Broadfoot and Krinard (1959) were unable to find this relationship in adjacent loessial and Coastal Plain alluvial soils (Table 17). Surface soil texture alone, ranging from the extremes of buckshot and gumbo clay, is not obviously influential in growth responses but, as evidenced from Table 18, is necessary for using the key which relates site index to drainage and hardpan occurence. Although site index may be estimated by soil series, in site indices, average 104 on recent natural levee soils and 90 on slack water soils; there is, however, a wide range within series. On Delta and adjacent uplands, for which the table was derived, the range is from 71 to 121.

Table 17. *Site index of sweetgum by soils [after Broadfoot and Krinard, 1959].*

Soils	Site Index
Soils of recent natural	105-109
Soils of old natural	85-103
Soils of slack-water areas	83- 87
Bottomland soils from loess	94-105
Bottoms from mixed loess and Coastal material	95-100
Alluvial soils with Permian Red Bed influence	90
Soils from Coastal Plain alluvium	85- 95
Terrace soils	70-110
Soils developed in loess	80- 85

Table 18. *Site index for sweetgum for soils derived from alluvium on the Mississippi river flood plain*[1] *[after Broadfoot and Krinard, 1959].*

Soil-site description	Site index
I. Fine texture (clay, including buckshot and gumbo)	
A. Moderate to good internal drainage (no mottling)	100
B. Moderate to poor internal drainage (mottling)	
1. Without pan in upper 2 feet	
a. inherently moist (subject to flooding)	85
b. inherenlty dry (slope, ridge)	95
2. With pan in upper two feet	70
II. Medium texture (between clays and sands)	
A. Moderate to good internal drainage (no mottling)	
1. Without pan is upper two feet	
a. inherently moist (subject to flooding)	110
b. inherently dry (slope, ridge)	105
2. With pan in upper two feet	75
III. Coarse texture (sandy soils)	
A. Moderate to good internal drainage (no mottling)	
a. inherently moist (subject to flooding)	100
b. inherently dry (slope, ridge) (not a sweetgum site)	----

[1]Key not applicable to soils outside the Mississippi River flood plain--as loess and Coastal Plain alluvium. Sites not indexed are either nonexistent or are not recommended for sweetgum.

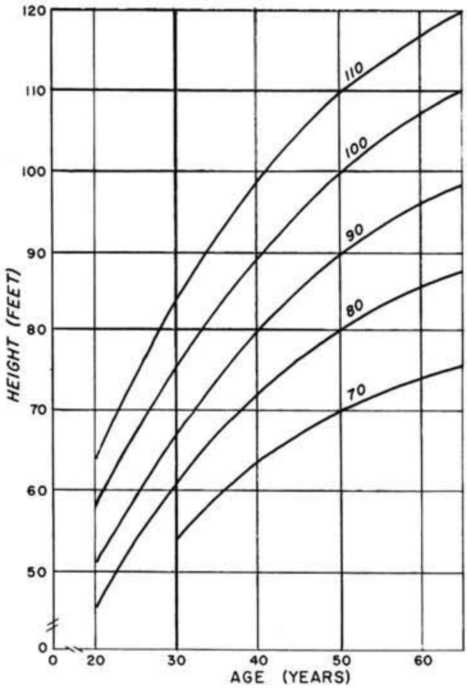

Figure 15. *Site index curves for sweetgum.* From Broadfoot and Krinard, 1959.

Injurious Agents

Disease

Sweetgum in the bottoms is seriously affected by a blight which may be associated with abnormal climatic and consequent soil-moisture conditions. No transmissible virus or infective principle is known for the malady which was first noted in 1950, a drought year. The first visible indication appears in late summer when leaves on some branches prematurely develop fall coloration. Crowns then thin gradually from the top down. Some buds do not open; others produce small chlorotic leaves, and death to the tree comes a year or more after symptoms first appear. Sometimes dieback is arrested, and trees appear healthy except for the dead top. As much as 90 percent of the fine feeder roots in the soil surface layers are dead on blighted trees, while larger roots remain healthy in appearance (Toole, 1954, 1959a). A cut into the wood of diseased branches often reveals irregular tan or dark brown streaks in the white sapwood. Damage seems greatest where sweetgum is off-site, since the blight in bottomlands is more severe on slack water soils and least on natural levees. If the malady is primarily a matter of water shortage, dense and old stands will be expected to suffer most because of their great demand for moisture (Figure 16).

Figure 16. *Blight damage to tree and root of sweetgum in the Mississippi Delta.* From Toole, 1959.

At deeper levels of the soil Toole and Broadfoot (1959) found an accumulation of sodium and potassium salts in amounts sufficient to reduce available water following years of low rainfall. They further observed an inverse relation to bulk density; loose soils which drain readily and retain less water are most susceptible to blight. Hence, the disease is twice as prevalent on upland as on bottomland sites (Toole, 1959a).

No control for the blight is known. Trees with more than 10 percent of the fine branches dead should be salvaged unless there is evidence that dieback has ceased. The species should not be favored for sawtimber on heavy, slack-water bottomland soils and on rolling upland sites except loessial bluffs. Sweetgum, however, can be grown on such soils for small products.

A lesion occurring in patches of the cambium tissue is casued by an unknown fungus. Although trees are not killed, lumber is degraded as bark is encased within the stems and bumps and ridges of callus tissue that forms over the lesions. Damage is reported to be most common in 10- to 20-year-old stands, principally in the lower 8 feet of trunk (SFES, 1960), but small veneer timber is occasionally seriously degraded (Figure 17).

Figure 17. *Sweetgum lesions. The inactive lesion on the left has ridge formation and overgrown patches of dead cambium. At right is a young lesion.* From Toole, 1959.

Fire

Light ground fires seldom kill sweetgum after it is 30 to 40 years old, but serious basal wounds result. At that age, defects affect 25 to 40 percent of the volume. Younger trees, 10 to 15 years of age, are frequently killed by fires of moderate intensity (Winters and Osborne, 1935).

Apparently the cambium of sweetgum can be heated to the lethal temperature of 140° F. about twice as fast as can southern pine and cypress stems of the same bark thickness (SFES, 1960). This accounts for the ability of fire to kill sweetgum in hardwood control operations and also points up the necessity for fire exclusion in the management of the species.

WATER TUPELO

Water tupelo, or tupelo gum, and black willow behave similarly in the forest. Both survive on swampy and poorly drained land, provided water recedes by the time the growing season begins and first-year height growth is above the growing season water level on the succeeding year. Under continuous inundation from winter on, water tupelo seedlings and young saplings will maintain dormancy into July and then proceed to grow normally.

A virgin unevenaged stand averaging 200 years composed predominantly of water tupelo stems about 16 inches in diameter above the butt swell had a basal area of 230 square feet per acre. Basal areas in primeval water tupelo forests frequently were twice that of old-growth timber on uplands. Because of butt swell, dbh is meaningless; the stand mentioned above would have had a basal area of almost 1000 square feet per acre. Second-growth, too, is stongly affected by taper, equivalent to over 150 square feet per acre basal area.

Water usually covers the swamp floor throught the winter, spring, and even until midsummer, stimulating production of swollen butts or "Bottlenecks". Butt-swell increases with wetness of the site, tree size, and age. Only cypress has greater butt-swell. (Trees of the genus *Fraxinus* have some swelling at their bases [SFES, 1934], and yellow-poplar seedlings, if alive after 6 weeks of submergence, will be buttressed (Kramer, 1951).)

In shallow areas, baldcypress and swamp tupelo accompany water tupelo. In deeper swamps, swamp tupelo is absent, indicating that depth of water is a limiting factor in the distribution of dominant arborescent species. Swamp tupelo, but not water tupelo, occurs in the Okefenokee Swamp and in deep bogs of Louisiana and Tennessee (Mattoon, 1941). Their occurrence there reflects the secondary distinctions within the Coastal Plain muck swamps small estuaries, and small piney woods tributary stream bottoms. In those locales, water tupelo, if present, inhabits the fresh, moving water sites along drainage courses and alluvial swamps, while swamp tupelo is found in the relatively stagnant muck swamps. The two meet along the margins of live water in swamps, in some minor stream bottoms on their respectively preferred sites, and in the smallest estuaries. Standing water in water tupelo swamps is generally deeper, though of shorter duration, than that in the swamp tupelo sites.

In the Delta area, seedlings of water tupelo on the swamp floor numbered only 80 per acre, but where soil was exposed for 2 to 4 inches above the water level, 1300 seedlings per acre were counted (Penfound and Hall, 1939). It seems, therefore, that slight, temporary drainage, if possible to control, may be helpful in reproducing the type, and that a seed-tree cut, anticipating evenaged stands, would be appropriate. A two-cut modified shelterwood—the initial harvest to provide for seed fall, seedbed preparation, and germination—is suggested. Final harvest would await establishment of a satisfactory stand.[1]

Following cutting, it is possible that in some situations high water will be retained for a considerably longer period, unless drained, for water consumed in transpiration by these large trees far exceeds that of evaporation in the openings exposed to sunlight after cutting. On the other hand, almost all feeder roots of swamp tupelo, but not water tupelo, in hydric plant communities are in the organic matter on the soil surface, consisting perhaps of eight to 12 layers of leaves below which is decaying material to a depth of 1 foot. Drastic and sudden drainage could be catastrophic, as this zone dries out readily.

Seed Viability Under Water

Water tupelo seeds retain viability for up to 14 months of submergence (Applequist, 1959a). This is significant, for southern swamps supporting this species are typically flooded throughout the winter and spring months, and occasionally remaining under water for an entire year. Thus, water tupelo seeds germinate but the seeds of other trees, such as baldcypress, which tolerate less than a year of inundation, are destroyed. Sites flooded only for relatively short periods, therefore, are necessary for establishment of the cypress-tupelo type in swamps. Seeds have been known to germinate and survive afloat for a significant period.

Thinning

Hypothetical stocking and yields of pure evenaged tupelo stands, showing development from the pole class onward, are given in Table 19. Expected yields from well-stocked stands can be estimated from the last column, provided diameter growth rates are known. The table, which assumes the stands are well-managed, fully stocked, and occur on at least average sites, suggest that between one-half and one-third of the basal area of trees averaging 10 inches be removed in thinning, while among the largest trees—above 30 inches—only one-fourth of the basal area need be taken. Cutting cycles for thinnings or stand improvement will be between 8 and 15 years, depending upon (1) size of trees retained after thinning, (2) site index, and (3) purity of the stand. Average tree size, rather than stand age, determines the end of a growth period. Usually 10 years

[1]Shelterwood is a misnomer, as shelter is not required for the young seedlings.

Table 19. *Hypothetical stocking and estimated development and yields per acre, for well-managed even-aged Tupelos at end of successive growth periods on average or better sites*[1] [*After Putnam, Furnival and McKnight, 1960*]

Average diameter above bottleneck			Average basal area			Average number of trees		
All trees Inches	Leave trees Inches	Cut trees Inches	All trees Sq. ft.	leave trees Sq. ft.	Cut trees Sq. Ft.	Total No.	Leave trees No.	Cut trees No.
10	10.75	8.95	141.3	79.5	61.8	259	146	113
14	14.80	12.45	155.8	101.6	54.2	146	95	51
18	18.85	15.95	167.9	118.4	49.5	95	67	28
22	22.85	19.55	176.8	131.1	45.7	67	50	17
26	26.80	23.50	183.3	139.5	43.8	50	38	12
30	30.70	27.35	185.5	143.2	42.3	38	29	9
34	34.60	31.60	183.7	142.9	40.8	29	23	6
38	38.50	36.30	178.7	136.2	42.5	23	17	5
42	-----	42.00	166.2	-----	166.2	17	--	17

Average sawtimber volumes			Sawtimber cumulative yields[2]
Total Bd. Ft.[3]	Leave trees Bd. Ft.[3]	Cut trees Bd. Ft.[3]	Bd. Ft.[3]
------	------	------	------
3,335	3,335	------	3,335
8,970	7,935	1,035	8,970
13,800	11,615	2,185	14,835
17,796	15,042	2,754	21,016
21,246	17,940	3,306	27,220
24,587	21,016	3,571	33,867
27,945	23,794	4,151	40,796
31,280	-----	31,280	48,282

[1] Duration of each growth period will vary with size of residual growing stock (leave trees), site, species composition, and, for first cycle, on time lapse pending reproduction. End of each period is signaled by attainment of specified average size.

[2] Includes all sound, reasonably straight sawlong stems to a 10-inch minimum top diameter, inside bark, at least 12 feet above the stump.

[3] Doyle rule.

Sycamore is relatively easy to reproduce by vegetative cuttings on appropriate sites in Coastal Plain, Piedmont, and other bottoms. Typical cottonwood sites and some friable and loose soils too dry for cottonwood are also suitable for conversion to this species.

Site Index

Early height growth of sycamore is very rapid, tapering off at about age 30. For that reason, the curves derived by Briscoe and Ferrill (1958) are based on an age of 35 years, rather than the conventional 50-year standard (Figure 19). The stands along Louisiana rivers used in formulating these curves were on soils ranging from loamy sand to heavy clay loam. Surface drainage varied from poor to very good.

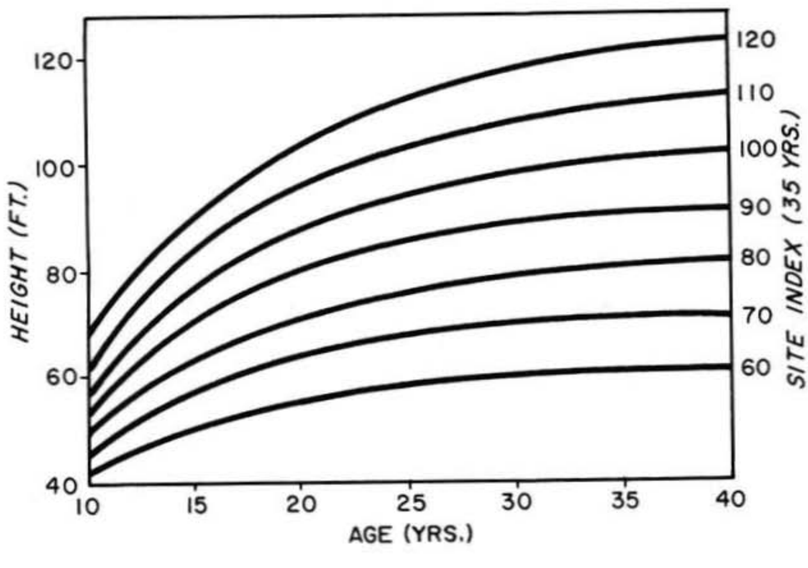

Figure 18. *Site Index curves for American sycamore in southeastern Louisiana, based upon age 35.* from Briscoe and Ferrill, 1958.

Regeneration

Propagation by Cuttings

Cuttings from 1-year-old sprouts taken from nursery-grown stock initiated an adequate root system and grew well. Butt cuttings, about ½ inch in diameter at the small end, are trimmed to 20 inches when removed from parent seedlings and stored in moist sawdust until planting time.

Rough, cutover land is prepared by double furrowing prior to winter planting at 9 x 9 foot spacing. Stocks are inserted in the ground with 4 inches extending above the surface. Cultivation during the latter part of the first season is essential for weed control. Late spring and midsummer cultivation is also recommended, particularly if rainfall is appreciably below normal.

Planting

Autumn planting appears preferable because roots develop throughout the winter, thus providing for good height growth the following spring and a hedge against drought. Planting should not precede the earliest killing frost and the onset of dormancy, nor should it be done prior to the end of the autumn drought expected in some sections. Sixty-five percent survival and an average first-year height growth of 5 feet was obtained by Nelson and Martindale (1957).

Fertilizer as a side-dressing, using 1½ ounces of 8-8-8 formulation in each of two dibble holes 1 foot deep and 4 inches from the stem on opposite sides, significantly improves growth (Huppuch, 1960). Fertilizer should not be placed in planting holes, even when a layer of sand separates the base of the cutting from the salt, as burning of tissues results. Water standing after rain in double furrows aids survival and probably reduces the chance of fertilizer burn by dissolving and diluting the material, as fertilized stems not furrowed showed poor survival.

In addition to nutritional amendments, seedling growth has been improved by growth regulator application. Gibberellic acid, in one instance, stimulated height growth (Nelson, 1957).

Practically any condition of temperature and light intensity of seedbeds under sycamore stands is expected to favor germination of American elm seed to the exclusion of sycamore establishment. Hence, to this Brunk and Hansbrough (1960) attribute the successional sequence of elm in sycamore forests of the midsouth's bottomlands. McDermott (1954a), finding sycamore seedlings at least as tolerant as elm, believed that the ecological tranistion to elm was not due to light but to some other factor associated with the seedbed. Perhaps temperature of the soil, which is generally exposed, is the other factor. However, if sycamore is as tolerant as elm, it would be but for a brief period following germination.

Successful regeneration also requires subsequent removal of undesirable hardwoods and vines. Cleanings will be needed to remove invading boxelder, soft elm, hackberry, and sweet pecan, especially.

Thinning

Degrade from epicormic branching may be related to residual density after thinning. In relatively dense unmanaged stands with basal area exceeding 130 square feet per acre, most sycamores are free of epicormic branching. Such stands may probably be safely reduced to 80 square feet per acre, but heavier thinning results in considerable branch development.

YELLOW-POPLAR

Yellow-poplar, though generally not thought of as a Coastal Plain bottomland species, exists there. This anomalous status may be explained by two illustrations, both emphasizing the importance of site identification and discrimination. For example, when poorly drained but not flooded Coastal Plain sites were planted to yellow-poplar, survival and growth, under cultivated and uncultivated conditions, were highly inferior to either slash or loblolly pine on the same site (Jones, 1959). Survival and growth were better, though still not satisfactory, in uncultivated sites than in cultivated areas, possibly due to hacking of roots in plowed areas. On the other hand, yellow-poplar may grow 14 feet in 4 years in bottoms and 9 feet on lower slopes, but be unsatisfactory at higher elevations. In the Piedmont province, too, it is more appropriately encouraged in the bottoms than elsewhere (Schomader, 1957). On loessal sites planted yellow-poplar has shown as much as twice the growth in young stands as other species (Johnson and Krinard, 1961).

The species may be underplanted in stands of inferior broadleaf trees on better sites but, in that case, should be promptly released when establishment is assured (Freese, 1951a). Evenaged silvicultural techniques, perhaps by seed-tree cuttings, are generally recommended.

Fertilization

While coves and bottoms in the Piedmont are not deficient—in the usual sense of the word—in nutrient elements for this species, growth was stimulated by applications of up to 1000 pounds per acre of diammonium phosphate during the first spring after planting. The optimum rate appears, by interpolation, to be about 750 pounds per acre (McAlpine, 1959a). Beyond this, there is some increase in growth, but the amount diminishes. First-year height growth was 1.7 feet for 750 pound rates as against 0.5 feet for unfertilized trees. Three-year growth responses were similar, but it is believed that future growth will be more markedly affected by the high-rate applications, early vigor being influential in subsequent growth. Survival of seedlings, however, is not influenced by applications of nitrogen and phosphorus (McAlpine, 1959a; Ike, 1962).

Flooding

While flooding during dormant seasons is not injurious to yellow-poplar, growing season inundation of seedlings for even 3 to 4 days kills all tress (McAlpine, 1961). Short-term floods of less than 2 days may do no damage. Injured stems appear healthy for a month or so before leaves wilt and death follows (McAlpine, 1959). When 3-year-old seedlings were continuously flooded during the growing season, all leaves died within a week or two. Before death, they became epinastic, a state in which more vigorous growth of the upper surface of unfolding leaves causes downward curvature of leaves and twigs (Kramer, 1951). Saplings and small pole-size trees have also been killed by growing season inundation merely above the root collar.

McAlpine (1959) reasoned that a temperature rise in ponded areas exposed to sunlight after rain ceases, increases respiration and, at the same time, the activity of microorganisms. An oxygen deficiency and carbon dioxide toxicity results. Hopkins, Specht, and Hendricks (1950) found that root growth of all of a number of species tested stopped when free oxygen reached 0.5 percent in the gas around roots, but top growth then continued, accompanied by possibly toxic accumulations of iron. Those workers further noted that while the rate of transfer of solutes from root to shoot is independent of aerobic mechanisms of roots, flooding might stop downward movement of carbohydrates and auxins, and that the accumulation of plant foods and hormones at the water line may account for adventitious rooting of flooded trees. Some sprouting from root collars indicates that death of roots does not precede death of top, and therefore, root-kill by flooding was not responsible for tree necrosis.

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bitter	*lecontai*
Persimmon	*Diospyros virginiana*
Pine	*Pinus*
loblolly	*taeda*
longleaf	*palustris*
shortleaf	*echinata*
slash	*elliottii*
Redcedar, eastern	*Juniperus virginiana*
Sassafras	*Sassafras albidum*
Sugarberry	*Cletis laevigata*
Sweetgum	*Liquidambar styraciflua*
Sycamore	*Plantanus occidentalis*
Tupelo-gum	*Nyssa aquatica*
Tupelo, swamp	*Nyssa sylvatica* var. *biflora*
water	*aquatica*
Walnut, black	*Juglans nigra*
Willow, black	*Salix nigra*
Yellow-poplar	*Liriodendron tulipifera*

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