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Yellow-Poplar: Characteristics and Management

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This reference tool and field guide for foresters and other land managers includes a synthesis of information on the characteristics of yellow-poplar with guidelines for managing the species. It is based on research conducted by many individuals in State and Federal forestry organizations and in universities throughout the Eastern United States. This handbook describes distribution, uses, biological and environmental features, regeneration methods, stand management opportunities, and growth and yield estimates.

Key Words: Site, regeneration, stand management, growth, yield, cultural practices, ***Liriodendron tulipifera.***

Contents

Introduction

Yellow-poplar is one of the top commercial hardwood species in the United States because of its availability, rapid growth, large size, excellent form, early natural pruning, and the good working quality of the wood. Botanically an ancient tree, yellow-poplar dates back to Cretaceous times some 70 million years ago when there were 16 species of the genus *Liriodendron* in North America. During the ice age, 15 species disappeared. But since *Liriodendron tulipifera* L. inhabited the Deep South, it survived (Southern Hardwood Producers, Inc. 1941). The only other *Liriodendron* species in the world, *L. chinensis* Sarg. of central China, resembles our yellow-poplar (Sargent 1933). Artifacts from Cretaceous deposits in the Southeastern United States show the distinctive yellow-poplar leaf in a silhouette that resembles a tulip, the same leaf form that characterizes our present-day species (fig. 1).

The species has been variously named by its users and admirers at different times and in diverse places. In the lumber trade it has been known as whitewood, white-poplar, white-tree, blue poplar, hickory poplar, cucumbertree, basswood, sap poplar, canary yellow-wood, tulipwood, and soft yellow-poplar. Based on its appearance and use it has been called saddle-tree, saddle-bag, old wife's shirt-tree, and canoewood (Graves 1910, Hough 1910, Sudworth 1927, USDA Forest Service 1965). The most commonly used names at present are yellow-poplar, tulip-poplar, and tuliptree.

The mature yellow-poplar has a striking appearance. In forest stands its trunk is straight, tall, and clear of lateral branches for a considerable distance up the bole (fig. 2). It is among the tallest of all broadleaf trees in the Eastern United States. On the best sites, old-growth trees grow to nearly 200 feet high and 8 to 12 feet in diameter. But usually they reach between 80 and 120 feet at maturity, with a straight trunk 2 to 5 feet in diameter, and are conspicuously free of branches for the first 60 to 100 feet above ground level (Little and others 1962, Sargent 1933) (fig. 3). Age at natural death is usually about 200 to 250 years (Little and others 1962), although some trees may live up to 500 years (Newell 1972).

The value of yellow-poplar was quickly recognized by the early settlers because its wood proved easy to work and serviceable. From past use as interior finish for houses, containers and utensils, carriage bodies, shingles, clapboards, and saddle frames to present-day use as cabinet wood, corestock, and veneers in furniture manufacturing its value has remained undiminished. In 1963 it was second only to oak in lumber production among the hardwoods, was third in hardwood veneer-log production, and made up 9 percent of the volume of all hardwoods (Vick 1973). Besides having good commercial value as wood, it has been cultivated as an ornamental since 1663 (Querengasser 1961), and several distinctive varieties exist (Sudworth 1927). It also has value as a honey tree (McCarthy 1933).

Because of its widespread occurrence in the Eastern United States and its importance to the wood-using industries, forest scientists have studied yellow-poplar intensively. Information on the characteristics and management of yellow-poplar is scattered through hundreds of articles in many publications.

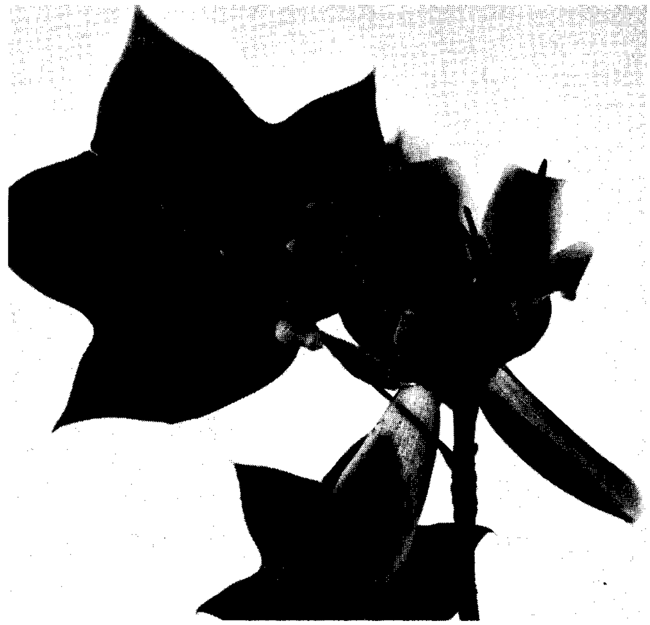

Figure 1.-Yellow-poplar has a distinctive leaf which is tuliplike in silhouette. It also has a tulip-shaped flower. F-490885

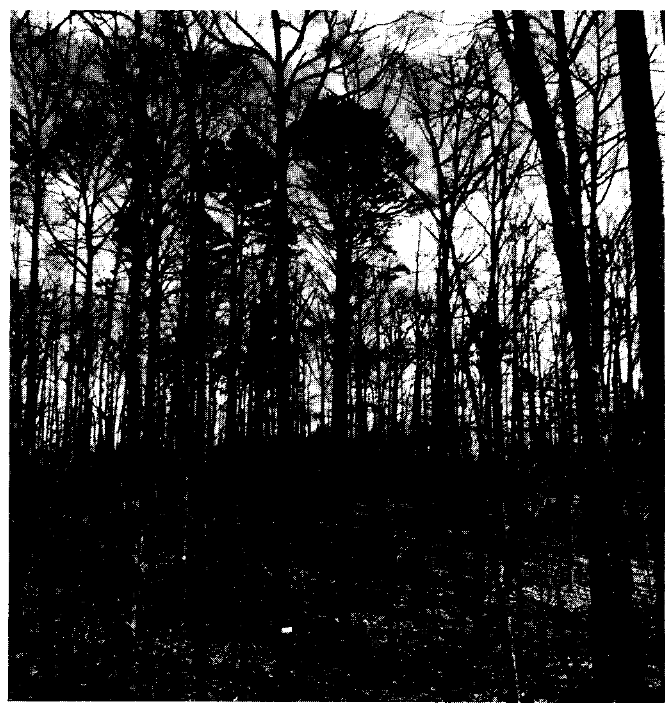

Figure 2.-In forest stands, yellow-poplar has a straight, tall, columnarlike bole clear of lateral branches to a considerable height. The 21-inch d.b.h. "plus" tree shown here and designated by a stripe on the trunk is 63 years old, 103 feet tall, and is clear of limbs for 59 feet. It was found in Iredell County, North Carolina. F-486187

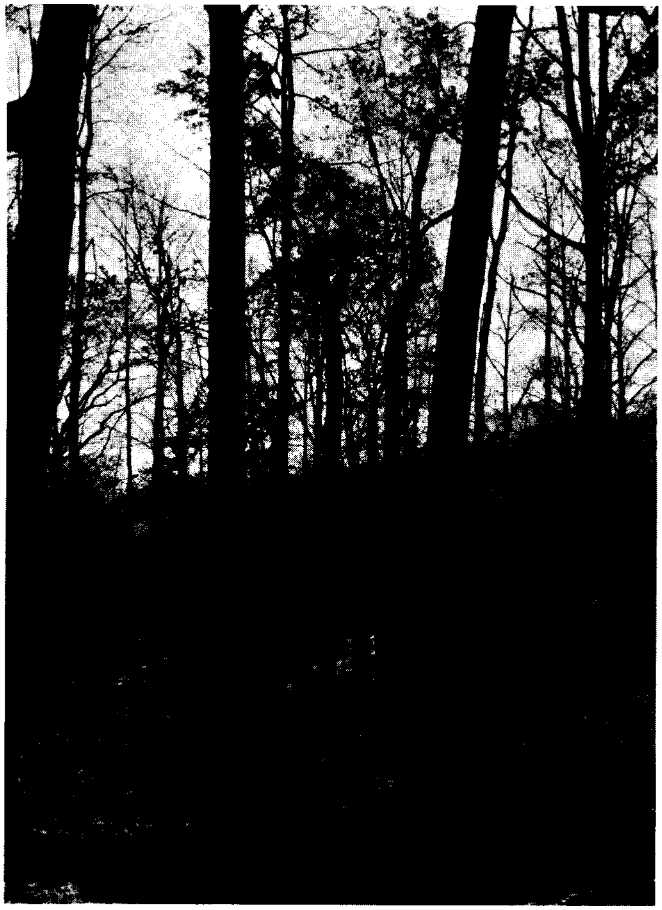

Figure 3.-A virgin stand of old-growth yellow-poplar growing in Union County, Georgia, in 1931. F-256718

Much new knowledge has accumulated since Olson (1969) summarized the available information on silvical characteristics of the species and since McCarthy's (1933) management recommendations were published more than 40 years ago.

This paper summarizes the accumulated information on the characteristics of yellow-poplar and presents guidelines for managing the species. It is intended to serve as a reference tool and field guide for foresters and other land managers responsible for prescribing and supervising management of this valuable resource.

Distribution of Growing Stock

The botanical range of yellow-poplar encompasses practically the entire Eastern United States. The species ranges from southern New England, west through southern Ontario and Michigan, south to Louisiana, then east to north-central Florida (fig. 4). Yellow-poplar is not uniformly distributed over its botanical range. Boyce and McClure (1975) divided the range into Timber Production Provinces on the basis of physiographic features and showed the distribution of yellow-poplar growing stock in 1974 (table 1).

The Mountain province (fig. **4),** where the species attains its best development, contains 44 percent of the total yellow-poplar growing stock in the Eastern United States; this volume represents about 13 percent of the hardwood growing stock in the province. The adjacent Piedmont province contains an additional 29 percent of the total yellow-poplar in the Eastern United States. Again, yellow-poplar makes up about 13 percent of all hardwood growing stock in the Piedmont (Boyce and McClure 1975). Together, the Mountain and Piedmont provinces contain nearly three-fourths of all yellow-poplar growing stock, but they collectively represent considerably less than one-half the area of commercial forest within the botanical range of the species.

Table 1.—***The area of commercial forest, the volume of all hardwood and yellow-poplar growing stock, and the proportion of hardwoods in yellow-poplar by four Timber Production Provinces, 1974***[1]

Timber production province	Area of commercial forest	Volume of growing stock: All hardwoods	Volume of growing stock: Yellow-poplar	Proportion of hardwoods in yellow-poplar
	Thousand acres	Million cubic feet		Percent
Mountain	48,704	31,362	4,137	13.2
Piedmont	36,459	21,110	2,760	13.1
Interior	23,294	13,064	781	6.0
Coastal Plain	62,562	28,117	1,417	5.0
All provinces	171,019	93,653	9,095	9.7
Outside of provinces	199,424	108,748	273	0.2
Total	**370.443**	**202.401**	**9.368**	**4.6**

[1] Adjusted from 1970 data, Forest Resource Report No. 20 (USDA Forest Service 1973a), to include inventories completed since 1970. Source: Boyce and McClure (1975).

The Coastal Plain, largest of the provinces, with 62 million acres of commercial forest land, contains 16 percent of the total yellow-poplar growing stock. But yellow-poplar accounts for only **5** percent of its hardwood growing stock.

Of the remaining 11 percent of yellow-poplar, 8 percent is found in the Interior province and 3 percent in its residual botanical range.

Figure 4.-Natural range of yellow-poplar (shaded) with Timber Production Province boundaries following county lines and coinciding with Forest Survey units. (Boyce and McClure 1975)

Current Growth and Removals

A relatively large surplus of periodic annual growth over removals and mortality continues to add to the already large growing stock base (table 2). Periodic annual growth as a percentage of growing stock is nearly constant among the four provinces. Likewise, mortality as percentage of growing stock varies but little among provinces. However, removals are not proportional to growing-stock levels. In the Piedmont, removal percentages are decidedly higher than in any other province, amounting to 74 percent of growth; removals plus mortality take out 78 percent of growth. In the Interior and Coastal Plain, removals plus mortality account for 45 and 52 percent of growth, respectively. In the Mountain province, removals plus mortality equal 32 percent of growth.

Distribution of Growing Stock by Size Class

In 1970 about 34 percent of growing-stock volume was smaller than sawtimber size (table 3). Nearly 58 percent of the volume was in trees that ranged from 11 to 21 inches in diameter at breast height (d.b.h.), with only 8 percent in trees over 21 inches d.b.h.

Sawtimber board-foot volume was more concentrated within small diameter classes since 63 percent occurred in the 11- to 17-inch d.b.h. range. Only about 12 percent of board-foot volume was in classes over 21 inches d.b.h.

Table 2.-Volume ***and proportion of the growing stock volume in periodic annual growth, removals, and mortality for yellow-poplar in four Timber Production Provinces***[1]

Timber production province	Volume			Proportion of growing stock		
	Periodic annual growth	Removals	Mortality	Periodic annual growth	Removals	Mortality
	Million cubic feet			Percent		
Mountain	225.4	63.3	8.3	5.4	1.5	0.2
Piedmont	133.0	97.9	5.6	4.8	3.5	0.2
Interior	40.5	16.5	1.6	5.2	2.1	0.2
Coastal Plain	81.9	38.3	4.4	5.8	2.7	0.3
Total	480.8	216.0	19.9	5.3	2.4	0.2

[1]Source: Boyce and McClure (1975).

Table **3.—*Stocking of yellow-poplar on commercial timberland in the East, by diameter class, 1970***[1]

Diameter class	Net volume of growing stock	Net volume of sawtimber
Inches	**Million cubic feet**	**Million board feet**[2]
5.0 to 7.0	699	—
7.0 to 9.0	992	—
9.0 to 11.0	1,250	0
11.0 to 13.0	1,360	5,251
13.0 to 15.0	1,324	5,750
15.0 to 17.0	1,052	4,933
17.0 to 19.0	739	3,557
19.0 to 21.0	462	2,242
21.0 to 29.0	590	2,947
29.0 +	94	410
Total	**8,562**	**25,090**

[1]Source: USDA Forest Service (1973a).
[2]Int. 1/4-inch rule.

Products

Yellow-poplar is an extremely versatile wood with a multitude of uses. It is straight-grained with medium even texture, moderate in weight and stiffness. Its specific gravity is low compared to other hardwoods, and in this respect it is comparable to softwoods. The wood seasons easily with low volumetric shrinkage and little defect development. It rates high in ability to stay in place, has excellent gluing qualities, and rates excellent for both painting and staining. The wood is moderately soft and susceptible to indentation or marring. It is relatively low in strength but compares favorably with several softwoods as stud material for walls. Machining properties are average; it can,be easily turned, bored, and planed but is poor in shaping and sanding characteristics. However, it is easily worked with hand tools, so it was a favorite of early-day settlers.

Neither the heartwood nor sapwood are particularly durable under conditions favorable to decay, but despite this characteristic yellow-poplar was used extensively and with apparent success as logs in cabins, as structural members, and as siding.

The wood can be treated by chemical, semichemical, or ground-wood processes to yield short-fibered pulp. Various low grades of wrapping papers, printing papers, container boards, and insulating boards are made from the pulp (Vick 1973).

The list of uses is lengthy-one compilation totaled more than 80, not including pulpwood, veneer, and particleboard (Core 1978). The most important recent uses have been as lumber for hidden furniture parts and core stock, as rotary-cut veneer for crossbands in construction of furniture parts, as plywood for items such as backs and interior parts, and as pulpwood (Core 1978, Smith 1978).

Because of availability of the wood, considerable attention is being given to its use as structural framing material and for veneers in structural plywood as a substitute for increasingly scarce softwoods. Yellow-poplar has physical properties quite comparable to those of many softwoods; therefore, these new uses are technically feasible and acceptable to the building trades (Koch 1978, Schick 1978).

Characteristics Critical to Management of the Species

Occurrence by Forest Types

Yellow-poplar is a component of 16 forest cover types (USDA Forest Service 1965), a major species in 4, and a minor species in the other 12:

Type No.	Type (Major Component)
57	Yellow-poplar
58	Yellow-poplar-hemlock
59	Yellow-poplar-white oak-northern red oak
87	Sweetgum-yellow-poplar
	Minor component
21	White pine
22	White pine-hemlock
51	White pine-chestnut oak
52	White oak-red oak-hickory
53	White oak
55	Northern red oak
60	Beech-sugar maple
64	Sassafras-persimmon
81	Loblolly pine
82	Loblolly pine-hardwood
90	Beech-southern magnolia
91	Swamp chestnut oak-cherrybark oak

On bottomlands and better drained soils of the Coastal Plain, yellow-poplar occurs in mixture with tupelos, baldcypress, oaks, red maple, sweetgum, and loblolly pine. In the Piedmont, associated species include oaks, sweetgum, blackgum, red maple, loblolly pine, shortleaf pine, Virginia pine, hickories, flowering dogwood, sourwood, and redcedar.

At lower elevations in the Appalachian Mountains, yellow-poplar is found with black locust; eastern white pine; eastern hemlock; hickories; white oak and other oaks; black walnut; shortleaf, pitch, and Virginia pines; flowering dogwood; sourwood; sweet birch; blackgum; basswood; and Carolina silverbell. At higher elevations, associated species include northern red oak, white ash, black cherry, cucumbertree, yellow buckeye, American beech, sugar maple, and yellow birch. Trees associated with yellow-poplar in nonmountainous areas of the North and Midwest include white oak, black oak, northern red oak, white ash, beech, sugar maple, blackgum, flowering dogwood, and hickories. (See appendix 5.)

Pure stands of yellow-poplar occupy only a small percentage of the total land within the natural range of the species, but pure stands are usually on the kind of productive sites that include some of the most valuable timber-producing forests in eastern North America (Olson 1969). It has been repeatedly observed in the Southern Appalachians that the percentage of yellow-poplar increases noticeably with increasing quality of the site. Where yellow-poplar occurs in pure or nearly pure stands on sites of medium or lower quality, it likely originated on abandoned old-field sites.

Natural Variation

Many traits of yellow-poplar vary significantly among individual trees, among stands, and between geographic sources.

These variations are of interest to forest managers and users of wood products, because they can be exploited through silvicultural practices and through selection and breeding programs (Dorman 1966; McKnight and Bonner 1961).

Varying degrees of genetic control have been demonstrated for wood and tree properties such as specific gravity and fiber length; straightness; branch angle; natural pruning ability; leaf, fruit, and seed characteristics; disease resistance; growth of seedlings; and length of growing season (Kellison 1967, 1968; Sluder 1964; Taylor 1964; Thor 1965, 1975, 1976; Thorbjornsen 1961; Wilcox and Taft 1969). For other important traits, such as the tendency to produce epicormic sprouts, evidence exists that the trait is strongly inherited, but the evidence is not conclusive (Della-Bianca 1972, Wahlenberg 1950a).

Vaartaja (1961) has demonstrated the existence of photoperiodic ecotypes of yellow-poplar. Under very long days (3-hour dark periods) the northernmost source (Michigan) grew best, and the southernmost source (Georgia) grew least. With 6- to 12-hour dark periods, the converse resulted. At all photoperiods, the Indiana source was intermediate. The most consistent difference among geographic seed sources has appeared in dormancy relationships (Farmer and others 1967, Funk 1958, Limstrom 1955, Sluder 1960, Webb 1970). In an experiment near Asheville, North Carolina, growth initiation of seedlings from 16 geographic sources ranging from Mississippi to Michigan and New York was highly correlated with conditions at the site of the mother tree; height-growth cessation was correlated with date of first killing frost of the source (Sluder 1960). In general, the more northern sources began to grow later and ceased earlier than the more southern sources. Noting a similar dormancy pattern, Funk (1958) found that damage from spring frost in a 3-year-old plantation in Ohio was generally related to latitude of seed source and planting site. Trees from the four southernmost locations suffered more extensive dieback than those from the three more northern sources. Funk (1958) emphasized the desirability of using locally produced yellow-poplar seed in forest planting. In a study of four geographic sources ranging from central Mississippi to Sewanee, Tennessee, trees from more southerly sources foliated earlier than those from northern areas (Farmer and others 1967).

Few studies are old enough to permit good comparisons of volume differences for different seed sources, but significant differences in early height growth have been reported (Farmer and others 1967; Kellison 1968; Limstrom and Finn 1956; Sluder 1960; Thor 1975, 1976).

While most geographic differences are associated with latitude of source, environmental differences associated with altitude are also important. In North Carolina, Kellison (1967) demonstrated a clinal pattern of variation from coast to mountain for several seed and leaf characteristics. There was also a clinal pattern of variation in height growth for seedlings in an upper Coastal Plain nursery; height growth decreased from coast to mountains for seedlings from those locations (Kellison 1968). Thor (1975, 1976) found differences in height and diameter after 15 years for different altitudinal sources from Tennessee and adjoining States when outplanted in Tennessee. In general, the high-altitude sources performed most poorly. However, the test was limited in scope, so generalizations about altitudinal effects must be weighed with caution.

At least one distinct ecotype of yellow-poplar has been confirmed. The first evidence came from a plantation near

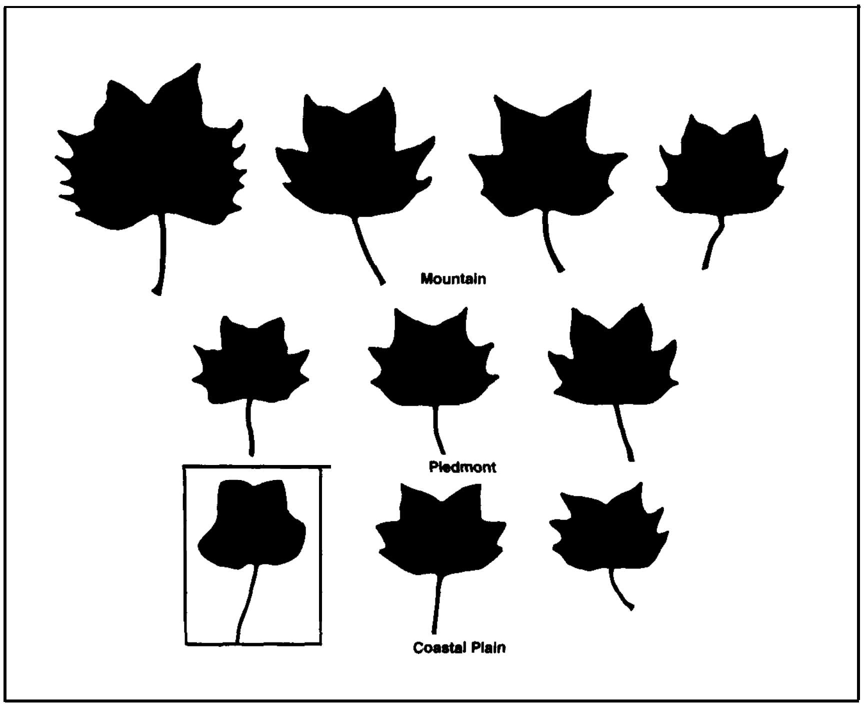

Figure S.-A comparison of variation in yellow-poplar leaf morphology among Mountain, Piedmont, and Coastal Plain provinces. The inset leaf is representative of the southern coastal deep-peat ecotype with rounded lobes and copperish-red leaves. (Adapted from Kellison 1967)

Charleston, South Carolina; trees from a Coastal Plain source in eastern North Carolina were twice as tall 3 years after outplanting as those from a Mountain source in western North Carolina (Lotti 1955). Later, Kellison (1968) found that trees from the Coastal Plain source of North Carolina performed poorly in comparison to upland sources when planted at a Piedmont location, but were far superior to upland sources when planted on organic soils of the Coastal Plain where a pH of 4 is seldom exceeded. The Coastal Plain yellow-poplar ecotype has a distinctive leaf pattern and color-rounded lobes and copperish-red leaves (fig. 5). It is apparently adapted to highly acidic, water-saturated organic soils of the Coastal Plain, and can withstand periodic inundation without harm. Schultz and Kormanik (1975) showed that Coastal

in yellow-poplar is very sensitive to soil moisture stress in comparison to upland sources. In an upland clone, overdry root weights varied less than 6 grams between ramets grown under drying cycles of 1 and 15 atmospheres of soil moisture tension. The swamp ecotype, however, showed a 75-gram difference in root weight under similar levels of moisture tension. The Coastal Plain ecotype is apparently not restricted to North Carolina. Sources with the distinctive leaf characteristics have been found as far south as Florida (Kellison 1968).

No single seed source has been found that is adapted to geographical extremes, but neither have local sources always produced best growth. Distant seed sources and individual trees have performed well in some cases; however, local sources have proved themselves to be in phase with their environment and have efficiently used the growing season available to them (Webb 1970). Current recommendations for seed collection would include selecting seed from a source where climatic and edaphic factors are similar to the proposed outplanting site, with altitude as well as latitude considered. Kellison (1968) recommended that North Carolina be divided into four zones for collection of yellow-poplar seed: (1) lower Coastal Plain (organic soils), (2) upper Coastal Plain (mineral soils), (3) Piedmont, and (4) Mountains. Limstrom (1965) and Rudolf (1956) have set up seed collection zones for the Central States based on climatic and geographic conditions supplemented by provenance research.

Table 4.—*Insects that affect yellow-poplar*[1]

Parts affected	Common name	Scientific name	Importance: Major	Importance: Minor
Foliage	—	***Abgrallaspis (= Aspidiotus) townsendi*** (Cockerell)		X
	Polyphemus moth	***Antheraea (=Telea) polyphemus*** (Cramer)		X
	Tuliptree silk moth	***Callosamia angulifera*** Walker		X
	Promethea moth	***Callosamia promethea*** (Drury)		X
	Flatheaded appletree borer	***Chrysobothris femorata*** (Oliver)		X
	Tuliptree beauty	***Epimecis virginaria*** (Cramer)		X
	European fruit lecanium	***Lecanium corni*** Bouché		X
	Tuliptree aphid	***Macrosiphum liriodendri*** (Monell)		X
	Yellow-poplar weevil	***Odontopus (= Prionomerus) calceatus*** (Say)	X	
	—	***Paralobesia liriodendrana*** (Kearfott)		X
	—	***Phyllocnistis liriodendrella*** Clemens		X
	Tulip tent maker moth	***Polychrosis liriodendrana*** Kearfott		X
	Tulip gall fly	***Thecodiplosis liriodendri*** Osten Sacken	X	
Stems	Coconut scale	***Aspidiotus destructor*** Signoret		X
	—	***Aspidiotus ulmi*** Johns		X
	Willow scurfy scale	***Chionaspis salicisnigrae*** (Walsh)	X	
	Periodical cicada	***Magicicada septendecim*** (Linnaeus)		X
	Harper scale	***Neopinnaspis harperi*** McKenzie		X
	Walnut scale	***Quadraspidiotus (=Aspidiotus) juglansregiae*** (Comstock)		X
	Tuliptree scale	***Toumeyella liriodendri*** (Gmelin)	X	
Trunk	—	***Ambrosiodmus tachygraphus*** (Zimmerman)		X
	Pear blight beetle	***Anisandrus pyri*** (Peck)		X
	—	***Buprestis rufipes*** (Oliver)		X
	Flatheaded sycamore-heartwood borer	***Chalcophorella campestris (Say)***		X
	Flatheaded appletree borer	***Chrysobothris femorata*** (Oliver)		X
	Columbian timber beetle	***Corthylus columbianus*** Hopkins	X	
	Oak-bark scaler	***Encyclops caerulea*** Say		X
	Sapwood timberworm	***Hylecoetus lugubris*** Say		X
	Melandryid bark borer	***Orchesia castanea*** Melsheimer		X
	Ambrosia beetle	***Xyleborus saxeseni*** Ratzeburg)		X
Roots	Root-collar borer	***Euzophera ostricolorella*** Hulst	X	

[1]Source: Adapted from Anderson (1975), Baker (1972), Brimley (1938), Burns (1970), Craighead (1950), and Johnson and Lyon (1976).

Principal Enemies and Damaging Agents

Yellow-poplar is unusually free from damage by pests in comparison to many other commercially important species. There are, however, a number of agents that can damage or kill yellow-poplar throughout its life span.

Insects

Yellow-poplar is attacked by a variety of insects (table 4). However, only four species are considered to have significant economic impact.

The tuliptree scale, a sucking insect, damages yellow-poplar by removing much phloem sap. It feeds on twigs less than one-half inch in diameter and on adventitious twigs and callus tissue. It can be found on yellow-poplars of any size, but it damages seedlings and saplings most severely. Scale attack often kills the leader and results in a crook where a lateral branch takes over apical dominance. When the leader and upper laterals are killed, the tree may become bushy and be overtopped by its competitors. The most subtle expression of damage is a loss of vigor. Symptoms become visible when the lower branches of open-grown yellow-poplars blacken and die and the foliage of the upper crown becomes thin and sparse. The leaves and trunk develop a black, sooty mold, which thrives on honeydew (Burns 1970). Parasites and predators generally are effective control agents of the scale.

The yellow-poplar weevil is a small, blackish beetle that feeds on buds and foliage. Before budbreak, the weevils attack the swelling buds and make puncturelike feeding marks. As the leaves unfold and enlarge, the insects feed upon them too. After pupation, newly emerged weevils feed on foliage. Their feeding produces numerous chlorotic spots that give a burned appearance to severely attacked trees. No control measure is effective other than using chemical sprays to control adults. Parasitism in immature stages has occurred at rates up to 50 percent, but has not prevented large population buildups. From 1960 to 1967, excluding 1963 and 1966, yellow-poplar was attacked by the weevil over large areas in Appalachia and the Ohio River Valley (Burns 1970, Burns and Gibson 1968).

The root-collar borer is a moth larva. It bores in the phloem tissue at the base of yellow-poplar trees in a zone 2 feet above soil line to 2 inches below it (Hay 1958). Most attacks are on trees that are pole-size or larger. Borer attacks are generally not severely damaging to trees; however, they provide entry points for rots, other pathogens, and carpenter ants. Trees infested with root-collar borer have shown considerable dieback and mortality (Hay 1958, Schuder and Giese 1962). No control measure is known, although small-scale insecticide tests have been made (Burns 1970).

Attacks by the Columbian timber beetle do not kill the host tree, but defects caused by attacks may seriously degrade the wood. Most attacks are on the lowest 6 feet of the bole (Burns 1970). In yellow-poplar, the defect is known as "calico poplar" and consists of black-stained burrows and discolored wood extending for a foot or more above and below the attack point. No satisfactory control measures for this insect are known.

Diseases

Fire scars, logging damage, animal and bird damage, top breakage, dying limbs, and decaying parent stumps of sprout-origin stems all provide entry for decay-causing fungi (table 5). Probably the most common type of decay associated with sprouts and with basal wounding of trees by fire or logging is a soft, spongy, white or gray rot caused by the fungus *Armillaria mellea* (Byler and True 1966, McCarthy 1933, True 1962, True and Tryon 1966).

In a West Virginia study, 92 percent of trees that had their tops broken by a snowstorm showed active decay 4 years later. Most of the decay was a soft, spongy, white heartwood rot caused by snow-break rot *Collybia velutipes* (Roth 1941). In some cases, rot was found to have penetrated the tree boles by as much as 72 inches. However, the extent of ultimate spread and damage was unknown. Rot extended down the stem three times faster than up the stem, and there was about twice the amount of discoloration as there was rot (Roth 1941).

Yellow-poplar is also subject to heartrot in the main stem through disease conduction by dead branches. In one study, 20 percent of dead tree branches examined were entry points for heartrot; the larger the branch the greater was the chance of its having heartrot (Toole 1961). The extent of rot was as much as 109 inches in large branch wounds, and the rate of spread was much faster downward than upward. When branch wounds are large, associated rots can have major damaging effects.

Several fungal species have been associated with stem cankers on yellow-poplar; in some cases the trees died. Species of the genus *Nectria* have been associated with a yellow-poplar canker in the Southeast (Nelson 1940). Incidence of the disease and mortality from it were greatest on low-vigor, overtopped trees. On vigorous trees, cankers healed quickly and apparently had little effect on tree viability.

Large stem canker *Fusarium solani* was isolated from cankered yellow-poplars in Ohio and was shown to cause characteristic cankers through pathogenicity studies (Dochinger and Seliskar 1962a, 1962b). Some mortality resulted during a period of drought, but large stem canker is apparently not a virulent pathogen and causes damage only when the host is weakened by unfavorable environmental factors.

Dieback and associated stem canker of yellow-poplar saplings were reported by Toole and Huckenpahler (1954) to have resulted in considerable mortality in some stands. A fungus of the genus *Myxosporium* was associated with dead bark of infected trees and was shown to cause canker formation after experimental inoculations. Dieback symptoms identical to symptoms found on yellow-poplars in Mississippi were reported by Johnson and others (1957) for scattered areas throughout the South. Symptoms included chlorosis of leaves, sparse crown, trunk and branch cankers, and epicormic sprouting. Several fungal species were consistently isolated from cankered trees, but there was uncertainty about the causative agent. The severity and extent of infection is greater in upland sites than in bottomland sites. All canker-forming diseases reported for yellow-poplar appear to be confined to, or most severe on, trees of low vigor due to drought, poor site, or competition.

A nursery root-rot disease caused by *Cylindrocladium scoparium* causes root and stem lesions (Kelman and Gooding 1965, Kelman and others 1959). It is frequently lethal in nursery beds, and when infected seedlings are outplanted, it results in low survival and poor growth. Extensive root damage and mortality in a 27-year-old yellow-poplar plantation was reported by Ross (1967).

Yellow-poplar logs, especially when cut in warm seasons, are subject to rapid deterioration because of attacks of wood-staining fungi which feed largely on the starch and sugars in the green sapwood and penetrate deeply while the wood is moist. The most common and most rapid-staining species is *Ceratocystis pluriannulata.* Other wood-staining species common in yellow-poplar logs and boards are *Ceratocystis coerulescens* and *Graphium rigidum.* The deterioration in grade that results from staining is frequently great because of the large proportion of sapwood in second-growth yellow-poplar. Prompt use of the logs reduces stain losses.

Table 5.—*Diseases that affect yellow-polar*[1]

Parts affected	Common name	Scientific name	Importance: Major	Importance: Minor
Foliage	Sooty mold	***Capnodium elongatum*** Berk. & Desm.		X
	Tar spot	***Ectostroma (Xyloma) liriodendri*** Kunze ex Fr.		X
	—	***Erysiphe liriodendri*** Schw.		X
	Powdery mildew	***Erysiphe polygoni*** DC.	X	
	—	***Fumago vagans*** Fr.		X
	Anthracnose	***Gloeosporium liriodendri*** E. & E.		X
	—	***Phyllactinia guttata*** (Fr.) Lev.		X
	Leaf spot	***Phyllosticta liriodendrica*** Cke.		X
Stems	Dieback	***Botryosphaeria ribis (Dothiorella gregaria)*** (Tod. ex Fr.) Gross. & Dug.		X
	Sapstreak	***Ceratocystis coerulescens (Endoconidiophora virescens)*** (Münch) Bak.	X	
	Senescent stem canker	***Cytospora leucostoma*** var. ***magnoliae*** D. Sacc.		X
	Large stem canker	***Fusarium solani*** (Mart.) App. & Wr. em Snyd. & Hans.	X	
	Sooty blotch	***Gloeodes pomigena*** (Schw.) Colby		X
	Dieback	***Myxosporium*** spp.		X
	Canker	***Nectria magnoliae*** Lohm. & Hept.	X	
	Verticillium wilt	***Verticillium albo-atrum*** Reinke & Berth.	X	
Trunk	Shoestring fungus	***Armillaria mellea*** Vahl. ex Fr.	X	
	Heartwood rot	***Fomes applanatus*** (Pers. ex S. F. Gray) Gill		X
		Fomes connatus (Weinm. ex Fr.) Gill		X
		Fomes everhartii (Ell. & Cell.) Schr. & Spauld.		X
		Fomes robiniophilus (Murr.) Lloyd		X
		Hydnum erinaceus Fr.	X	
		Hypholoma spp.	X	
	Butt and heartrot	***Pleurotus ostreatus*** (Jacq. ex Fr.) Kumm.	X	
		Polyporus graveolens (Schw.) Fr.		X
		Polyporus sulphureus Bull. ex Fr.		X
		Polyporus zonalis Berk.		X
Roots	Shoestring fungus	***Armillaria mellea*** Vahl. ex Fr.		X
	Root rot	***Phymatatrichum omnivorum*** (Shear) Dugg.		X
Seedling	Root rot	***Cylindrocladium scoparium*** Morg.	X	
	Blight	***Rhizoctonia solani*** Kuehn		X
Sprouts	Shoestring fungus	***Armillaria mellea*** Vahl. ex Fr.		X
	Snow-break rot	***Collybia velutipes*** (Curt.) Fr.	X	
	Stump-sprout rot	***Phialophora*** spp.	X	
Stains	—	***Ceratocystis coerulescens*** (Munch) Bak.	X	
	—	***Ceratocystis multiannulata*** (Hedg. & Davids.) Hunt		X
	—	***Ceratocystis pluriannulata*** (Hedg.) C. Mor.	X	
	—	***Graphium rigidum*** (Pers.) Sacc.		X
	—	***Lasiosphaeria pezicula*** (B. & C.) Sacc.		X

[1]Source: Adapted from Hepting (1971).

Fire

Because yellow-poplar seedlings and saplings have thin bark, they are extremely susceptible to fire damage. Even a light ground fire is usually enough to kill tops of small stems up to 1 inch in diameter. These stems may resprout after fire, but fire can reduce yellow-poplar on a site (McGee 1979, 1980). The bark does not burn readily, and when it becomes thick enough to insulate the cambium (about one-half inch), yellow-poplar becomes extremely fire resistant (McCarthy 1933). Damage to larger trees results from old fire-caused wounds that permit fungi to attack the heartwood. Of 94 decayed yellow-poplar trees examined in western North Carolina, 59 had healed-over fire scars, 34 had open fire scars, and 1 tree had an open lightning scar (McCarthy 1933). Cull deduction due to fire was 15.9 percent. In the Appalachian region from 1924 through 1928, the most common wounds on yellow-poplar standing timber were caused by fire (45.3 percent) and lightning (0.7 percent) (Hepting and Hedgcock 1937).

Climate

Sleet and glaze storms occur occasionally throughout most of the natural range of yellow-poplar (Olson 1969). Damage done by glaze storms varies with tree size, nature of the stand, and attendant climatic factors such as wind or calm. Where heavy ice formation or accumulation of wet, heavy snow is accompanied by strong winds, entire stands may be decimated. Saplings or poles with slender boles are particularly susceptible to breakage. Damage may be severe from glaze storms that follow thinnings in formerly dense stands (Carvell and others 1957, McCarthy 1933).

More commonly, glaze results in only partial crown loss. Such top damage may result in a permanent bole crook, in entry of decay-causing fungi into the trunk, and in loss of growth (Carve11 and others 1957, McCarthy 1933, Roth 1941). Many stands, particularly at higher elevations, contain numerous trees with a definite crook at a common height, which suggests glaze damage. Some stands show evidence of two or more glaze storms. Through stem analysis, Carvell and others (1957) traced breakage in a West Virginia yellow-poplar stand to a winter for which meteorological records showed frequent glaze storms. They also found that the percentage of damaged trees increased with the intensity of thinning. Stands in which less than 30 percent of the volume was removed had least damage. Isolated tree crowns resulting from heavy thinnings are very susceptible to glaze damage.

Yellow-poplar has shown unusual ability to recover from ice damage if crown loss is not complete. In a 50-year-old stand thinned at age 43, a winter glaze storm resulted in severe crown breakage (Della-Bianca and Beck 1977). Crown loss averaged 39 percent, with some trees losing as much as 90 percent of their crown. Poststorm loss in diameter growth was about 35 percent, and represents a 1:1 ratio for percentage of crown loss to loss in diameter growth rate. A concurrent study of litter production in the stand showed that the amount of foliage produced the following growing season was 90 percent of its prestorm weight, indicating rapid recovery of live crown (fig. 6).

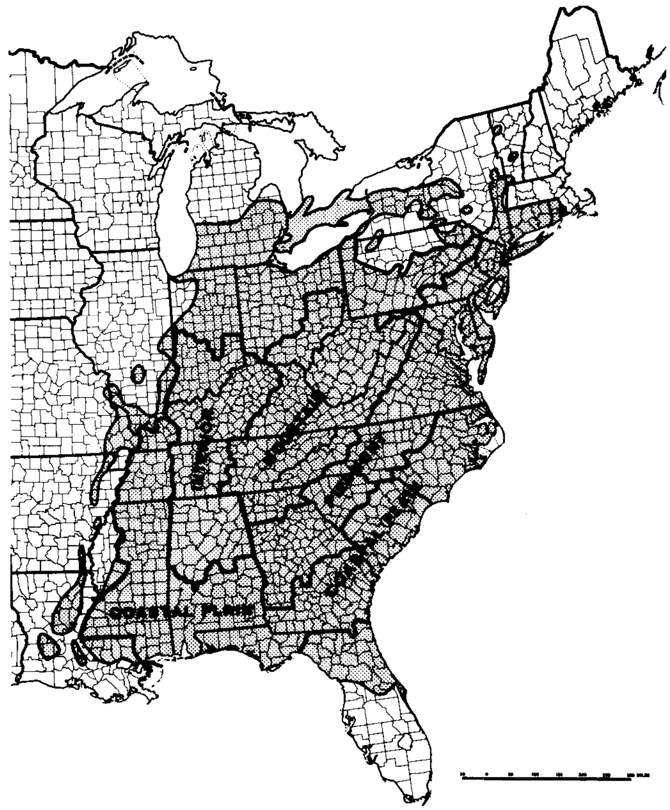

Figure 6.-After glaze damage, yellow-poplar recovers its leaf-production capacity rapidly by profuse epicormic sprouting along surviving stub and live branches. (Della-Bianca and Beck 1977) F-529649

Frost, and particularly frost pockets, can have significant impact on early growth and development of yellow-poplar (Olson 1969). Tryon and True (1964) rated yellow-poplar as among the Appalachian species most susceptible to frost damage. In one instance, newly formed yellow-poplar foliage was killed by a freeze in late May of 1961 at elevations above 3,400 feet along Rich Mountain in east-central West Virginia. Yellow-poplar diameter growth for 1961 was 64 percent less than the prefreeze 5-year average (Tryon and True 1968). Frost damage in a 3-year-old plantation in Ohio was associated with seed sources (Funk 1958). Funk emphasized the desirability of using locally produced seed in forest planting and avoiding sites with poor air drainage and lower-slope frost pockets. Older trees are also damaged to some extent by such conditions. After a late spring frost in a 20-year-old plantation, leaf mortality varied from 5 to 100 percent for individual trees (White and Finn 1964). Such a leaf loss usually has only a slight impact on growth because new leaves are soon regenerated. Frost may also cause bole damage in the form of shake-a separation of growth rings resulting in cull. A weather-induced defect called blister shake, related to frost shake, that occurred in 30-year-old yellow-poplar trees in West Virginia has been described by Tryon and True (1952).

Flooding can kill yellow-poplar. Hall and others (1946) classified yellow-poplar as intolerant to flooding because it will not survive continuous flooding 1 foot deep for one growing season. A study done in 1958 near Oxford, Mississippi, showed that all yellow-poplars flooded continuously for as long as 19 days died, and those flooded for as long as 10 days were damaged (Williston 1959). A 4-year-old plantation in Georgia subjected to only 3 or 4 days of continuous flooding suffered considerable damage and mortality (McAlpine 1959a). Hook and Brown (1973) found roots of yellow-poplar seedlings rapidly deteriorated under flooding and no new roots were regenerated.

Animal Damage

Twigs and foliage of yellow-poplar are succulent and often heavily browsed by livestock and deer in preference to other tree species. Seedlings are often grazed to the ground, and small saplings trimmed back or straddled and severely damaged (Olson 1969). Where deer are overabundant, as in western Pennsylvania, yellow-poplar regeneration can be totally prevented by continual deer browsing of seedlings (McCarthy 1933).

Cattle eat the current growth of yellow-poplar, especially when they are concentrated in small enclosures (McCarthy 1933). In a grazing study in a North Carolina woodlot, Sluder (1958) found that during the first year cattle browsed all yellow-poplar in reach. By the end of the third growing season, coves and lower slopes were particularly bare of ground vegetation, and a browse line was evident. After nine growing seasons, yellow-poplar in the 3- to 9-inch diameter class had 50 percent less radial growth on grazed plots than on ungrazed plots, presumably because severe soil compaction and erosion had developed on the grazed plots.

In a study of simulated browsing over a 5-year period in western North Carolina (Harlow and Halls 1972), yellow-poplar seedlings whose terminal and lateral twigs were clipped in summer were significantly shorter in height, had smaller stem diameter, and had shorter twigs than those clipped in winter. Also, mortality was greater and dry-weight production was less. Harlow and Halls (1972) concluded that yellow-poplar seedlings are only slightly affected by browsing of lateral branches either in summer or winter. However, terminal browsing in summer caused seedling mortality of 40 percent or more. In the Southeast, woody twigs are eaten most during the growing season (Cushwa and others 1970), so heavy browsing could result in severe growth reduction and high mortality. But harvesting on fertile sites produces so much regeneration that moderate browsing can be tolerated (Della-Bianca and Johnson 1965, Harlow and Downing 1970).

Rabbits and other rodents eat bark and buds of small yellow-poplars and can cause extensive damage. Also, regeneration can be hampered by seed predation because yellow-poplar seed is part of wildlife diets. Quail, purple finch, cardinals, cottontail rabbit, red squirrel, gray squirrel, and white-footed mice are some of the birds and animals that eat yellow-poplar seed (Olson 1969). On forested sites of the Cumberland Plateau, screen protection of seed spots tripled yellow-poplar seedling establishment (Russell 1973). Similar results were experienced in North Carolina (Sluder and Rodenbach 1964). Considerable lumber degrade from “bird peck” is periodically caused by the common sapsucker.

Vines

Vines can be extremely damaging to yellow-poplar. Japanese honeysuckle, kudzu, and climbing bittersweet have been known to harm yellow-poplar in isolated cases. However, the most widespread damage results from wild grapevines. Throughout the Appalachians, grapevines are becoming a serious problem on good sites that have been regenerated naturally by clearcutting.

Wild grapes reproduce by both seeds and sprouts. In mature stands, grapevines that are cut or broken during a harvest operation sprout and grow vigorously in the resulting full sunlight. Such sprouts may grow as much as 15 feet in the first year (Trimble 1973b). Uncut vines also root-layer prolifically when they come into contact with the soil. Because of their rapid growth, vines grow up with the developing stand and spread from tree to tree. Numerous grapevines of seedling origin develop from seed that may remain viable in the forest floor for up to 6 years (Smith and Lamson 1975). There were as many as 70,000 grape seedlings per acre at the end of the first growing season after clearcutting on a good site in West Virginia (Trimble and Tryon 1974). However, seedling-origin vines are not as serious a threat as sprout-origin vines because they grow more slowly and suffer considerable mortality. After 5 years, of the initial 70,000 grape seedlings, 195 per acre survived. Of these, only 139 per acre were climbing into tree crowns of selected crop trees.

Grapevines can completely occupy sizable areas of regenerating stands. For example, in a 5-year-old sapling stand, which regenerated after a clearcutting in the Southern Appalachians, grapevines completely covered areas up to one-quarter acre in size (McGee and Hooper 1970). Seventeen percent of the 50-acre area was covered by masses of grapevines to the exclusion of any trees (fig. 7). Areas completely smothered by grapevines are very obvious, but perhaps even greater damage may eventually result from vines that become an integral part of the developing stand without engulfing it.

Smith and Lamson (1975) reported that six 12- to 15-year-old stands on good to excellent sites had an average of about 700 vines per acre intertwined with the developing tree crowns. Nearly 70 percent of the saplings had vines in their crowns. On poorer quality sites, vines were less of a problem. On areas with a medium site index for yellow-poplar, there were only 16 vines per acre, and they were affecting less than 3 percent of the tree crowns.

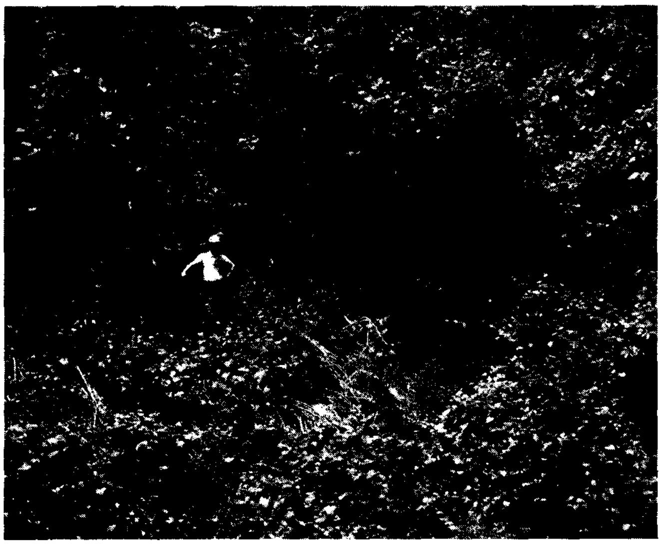

Figure 7.-A naturally regenerated 5-year-old cleaicut in which grapevines have completely excluded trees from patches as large as one-quarter acre. F-52%53

Figure I.--Grapevines smothering S-year-old yellow-poplar saplings by breaking limbs and tops, twisting and bending the main stem, and restricting photosynthesis by intercepting needed sunlight. Vines become established in saplings soon after clearcutting. F-529654

Grapevines damage young trees by breaking limbs and tops, twisting and bending the main steam, and intercepting solar radiation (fig. 8). The result is reduced growth, malformation of stem and crown, and sometimes death of the tree. Grapevines also worsen winter storm damage in some areas by furnishing increased surface area for accumulation of ice and snow.

Site Requirements

Climate

Because of its wide geographic distribution, yellow-poplar grows under a variety of climatic conditions. Low-temperature extremes range from severe winters in southern New England and upper New York with a mean January temperature of 19°F to almost frost-free winters in central Florida with a mean January temperature of 61 "F. Average July temperature ranges from 69°F in the northern sector to 81 °F in the southern (USDA 1941). The average number of days without killing frost ranges from 150 to over 310 days within the range of yellow-poplar. Rainfall ranges from 30 inches in the Midwest to more than 80 inches in some areas of the Southern Appalachians (USDA Forest Service 1965).

Effects of temperature and moisture extremes are tempered somewhat by local topography. At the northern end of its range, yellow-poplar is usually found in valleys and stream bottoms at elevations below 1,000 feet. But in the Southern Appalachians, it may grow on a variety of sites, including stream bottoms, coves, and moist slopes up to an elevation of about 4,500 feet. Toward the southern limit of its range, where high temperatures and soil moisture probably become limiting, the species is usually confined to moist but well-drained streambottoms.

Optimum development of yellow-poplar occurs where rainfall is well distributed over a long growing season (USDA Forest Service 1965). But in West Virginia, rainfall affected diameter growth during the early growing season more than during the total growing season (Tryon and Meyers 1952).

Soils and Topography

Yellow-poplar thrives on soil types with various physical properties, chemical compositions, and parent materials. Exceptionally good growth has been observed on alluvial soils bordering streams; on loam soils of mountain coves; on talus slopes below cliffs and bluffs; and on well-watered, gravelly soils (McCarthy 1933). In general, where yellow-poplar occurs naturally and grows well, the soils are moderately moist, well drained, and loose textured; it rarely does well in very wet or very dry conditions.

Studies in locations as varied as the Coastal Plain of New Jersey, the Central States, the Great Appalachian Valley, the Piedmont of the Carolinas and Virginia, the Cumberland Plateau, and the mountains of north Georgia have isolated soil features that are measures of effective rooting depth and moisture-supplying capacity, and that are the most important determinants of growth (Auten 1937a, 1937b, 1945; Coile 1948; Czapowskyj 1962; Della-Bianca and Olson 1961; Gilmore and others 1968; Hebb 1962; Hocker 1953; Ike and Huppuch 1968; McCarthy 1933; Metz 1947; Minckler 1941a, 1941b; Munn and Vimmerstedt 1980; Phillips 1966; Schomaker 1958; Smalley 1964; Tryon and others 1960). These variables are in quantitative terms such as relative content of sand, silt, and clay; depth of humus accumulation; organic matter content of

Figure 9.-Taking volumetric soil samples from the A, horizon of a Piedmont forest soil. F-486080

Figure 10.—A freshly opened yellow-poplar flower. The anthers are unopened, and the light-colored, succulent stigmas are receptive to pollen. (Sluder 1966) F-52%72

various horizons of the soil profile; percent moisture retention; available water; and depth to impermeable layers (fig. 9).

The same studies also stressed that topographic features plus latitude and elevation-which partially determine the amount of incoming solar radiation, rate of evaporation, or otherwise influence moisture-supplying capacity of soil-are important variables in assessing site suitability for yellow-poplar growth. The best growth is usually on north and east aspects, on lower slopes, in sheltered coves, and on gentle concave slopes. Yellow-poplar growth is usually poor on narrow ridges and upper slopes, on south to west aspects, and on steep convex slopes.

Low levels of soil nutrients-most frequently nitrogen, but also phosphorus and potassium-have occasionally been linked to slow growth of yellow-poplar (Chapman 1935, Czapowskyj 1962, Gilmore and others 1968, Mitchell and Chandler 1939, Schomaker and Rudolph 1964). However, soil physical properties far overshadow chemical properties in determining distribution and growth of yellow-poplar.

Natural Regeneration

Seed Production

Yellow-poplar trees usually produce their first flowers between ages 15 and 20 (Little and others 1962). Flowering occurs from April to June, depending on location and weather conditions (USDA Forest Service 1965). The singly occurring, perfect flower is tuliplike in form and size, 1% to 2 inches wide, with six petals that are a light yellowish green at the margin with a deep orange band at the center; the flower lasts only a week or two (McCarthy 1933, Vick 1973) (fig. 10). The length of the flowering period for each tree varies from 2 to 6 weeks depending on the size and age of the tree and number of flowers per tree (Taft 1962). Pollination must occur soon after the flowers open and while the stigmas are light colored and succulent; brown stigmas are no'longer receptive to pollen (Sluder 1966). Normally the receptive period is only 12 to 24 daylight hours long (Boyce and Kaeiser 1961).

At maturity, stigmas and pollen grains are mucilagenous (sticky). The sticky pollen masses adhere to insects and are brushed onto the hairy reflexed stigmas as the insect passes by (Boyce and Kaeiser 1961). Flies (Muscidae), beetles (Coleoptera), honeybees (*Apis* sp.), and bumblebees (*Bombus* sp.)-in decreasing order of abundance-were observed on opened flowers (Wright 1953). However, uncontrolled insect pollinations do not result in effective pollination of all stigmas, and a great deal of selfing occurs (Boyce and Kaeiser 1961). According to Taft (1966), bees should be an integral part of all yellow-poplar seed orchards.

Higher percentages of filled seed result from cross-pollination (Boyce and Kaeiser 1961, Carpenter and Guard 1950) and crosses among widely separated trees (Boyce and Kaeiser 1961). Only about 10 percent of most open-pollinated samaras contain a viable seed, but since each samara has the potential for two seeds, actual viability is seldom more than 5 percent

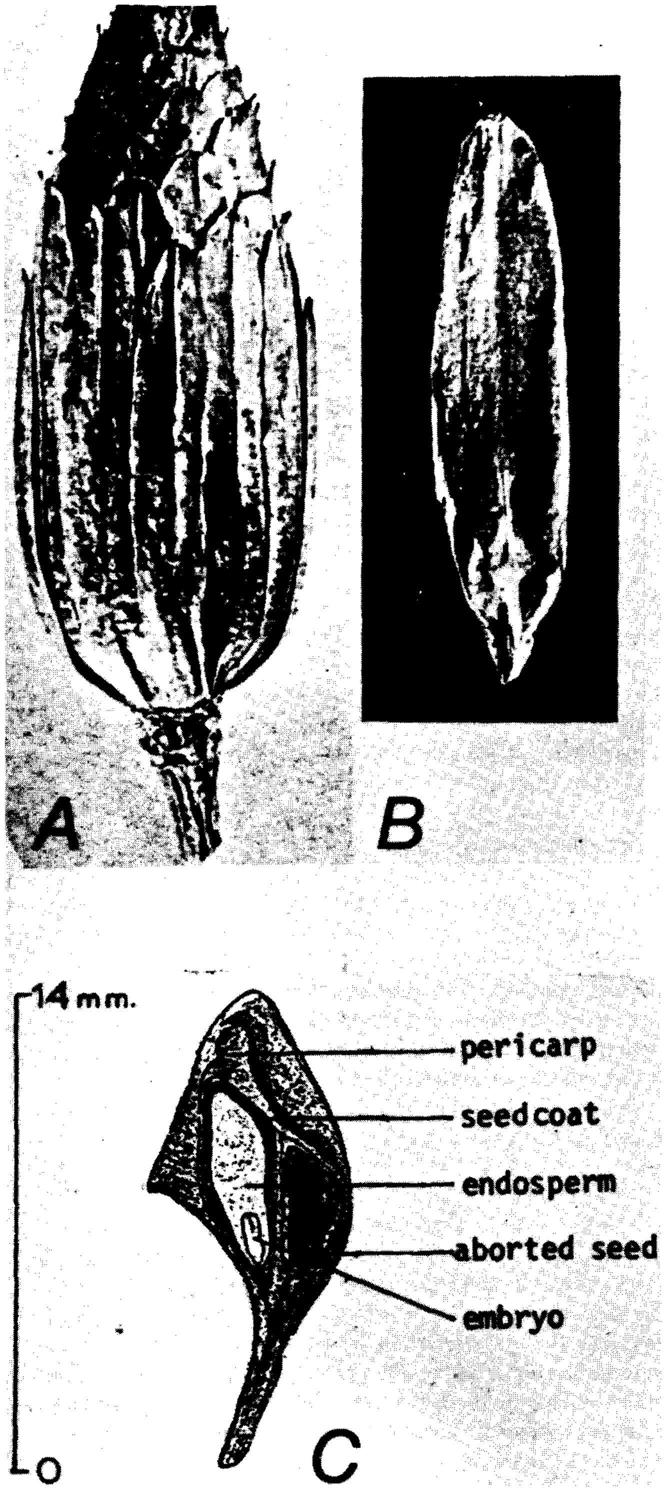

Figure **11.**—***Liriodendron tulipifera,*** yellow-poplar: A, Cone; ***B,*** single samara, 2X: ***C,*** longitudinal section through a embryo of a samara, 4X. (USDA Forest Service 1974)

(Thor 1976). Seed viability varies greatly between trees, but individuals regularly produce seeds of a given viability (Limstrom 1959, Wean and Guard 1940). In Indiana, the percentage of filled seed for trees 15 inches or less in diameter was one-third more than that for larger trees (Guard and Wean 1941). Seed from the upper two-thirds of the crown were filled 4 percent more than seed from the lower third. Also, trees in closed stands had about the same percentage of filled seed as did trees in open stands, and seed quality was nearly the same on fertile and poor soil. By controlled cross-pollination of yellow-poplar, Carpenter and Guard (1950) obtained up to 90 percent filled seed per cone; the highest percentage of filled seed for an open-pollinated tree was 34.8. Also, cross-pollinated seedlings tended to be more vigorous than seedlings obtained from open pollination.

Yellow-poplar fruit is a conelike aggregate of many winged carpels or samaras borne on a central stalk (fig. 11). About 80 samaras are produced in each fruit, each bearing two seeds, one usually aborted (Carve11 and Korstian 1955, Kellison 1967, USDA Forest Service 1965). The cones turn from green to light brown as they ripen and mature from early August in the north to late October in the south (USDA Forest Service 1974). In Indiana, samaras are morphologically mature between mid-August and mid-September, but seed should not be gathered until the first week in September (Guard 1943). In the Piedmont of North Carolina, seedfall begins in mid-October and reaches its peak in early November (Carve11 and Korstian 1955). High seedfall occurs during dry periods with high temperatures, with periods of heavy rainfall resulting in low rates of seed dissemination. Viable seed is disseminated from mid-October to mid-March; the percentage of viability is about equal throughout the seedfall period.

Dissemination

Yellow-poplar is a prolific seeder, and large crops are produced almost annually. Seed bearing may continue ‘for more than 200 years. In North Carolina, a IO-inch tree produced 750 cones with 7,500 sound seeds, and a 20-inch tree produced 3,250 cones with 29,000 sound seeds (Carve11 and Korstian 1955).

Seedfall per acre is characteristically heavy. A study in North Carolina showed that a fall of 300,000 seeds or more per acre is not uncommon (Carve11 and Korstian 1955). In West Virginia and in southern Indiana some 500,000 seeds were produced per acre per year (Engle 1960, Tryon and Carve11 1960). Whipple (1968) reported a seedfall of more than 600,000 seeds per acre within one chain of a good seed tree in the upper Coastal Plain of Alabama. Measurement of the 1966 seed crop in 19 stands in the Southern Appalachians showed an average of 1.5 million seeds per acre.’

The individual winged samaras may be scattered by the wind to distances equal to four or five times the height of a tree (McCarthy 1933). In southern Indiana, a seedfall pattern was shown to be oval with the center north of the seed tree (Engle

‘Olson, David F., Jr. 1967. Data filed, Southeastern Forest Experiment Station (SE-I 102), Asheville, N.C.

1960). Prevailing south and southwest winds occasionally carried seeds over 600 feet. Distribution of filled seed was satisfactory, 1,000 to 10,000 seeds per acre; seeds were distributed up to three chains from a good seed tree in the direction of the prevailing wind and 1.5 chains in all others directions (Whipple 1968). Dissemination of sound seed was unsatisfactory for seedling establishment where seed-producing trees were more than four chains apart in the direction of the prevailing wind or three chains apart in other directions. Directions and distances of dispersal vary with prevailing winds and topography, but seed dispersal is generally adequate.

Not only is yellow-poplar a prolific seed producer, but its seeds retain their viability in the forest floor for 4 to 7 years (Clark and Boyce 1964, Herr and Carve11 1975, Sander and Clark 1971).[2] Many seeds on the forest floor are capable of producing seedlings when suitable environmental conditions exist. In West Virginia, a study in three 40-year-old stands with 41 to 190 yellow-poplar trees per acre showed from 97,080 to 192,000 sound seeds per acre in the forest floor (Herr and Carve11 1975). These seeds produced between 56,000 and 77,000 seedlings per acre when transferred to an open area and kept well watered.

Seedling Establishment

Yellow-poplar seed must overwinter under natural conditions or be stratified under controlled conditions to overcome internal dormancy. Under controlled conditions, stratification in moist sand within a temperature range of 32 ° to 50 °F for 70 to 90 days resulted in satisfactory germination (Carpenter and Guard 1950, Chadwick 1935). However, seedling yield increases with increasing stratification time.

In an experiment simulating natural field conditions, Clark and Boyce (1964) showed that stratification for one winter does not break dormancy of all seeds, but after two winters of stratification most viable yellow-poplar seeds germinate. Limstrom (1958) found that seeds stratified 1 or 3 years produced more seedlings over 6 inches tall than unstratified seeds when all seeds were sown the same fall. Williams and Mony (1962) also found that seedling yield increased with increased stratification time. Filled seeds that produced seedlings ranged from lo-percent germination for fall-sown fresh seeds to 55 percent for seeds stratified for 3 years.

Germinating yellow-poplar seedlings need a suitable seedbed and adequate moisture to survive and become established. Yellow-poplar regeneration will develop better on the surface of the soil A horizon or on well-decomposed organic matter (H layer) than on undecomposed organic matter or on the surface of the soil B horizon (Boyce and Parry 1958). Tryon and Carve11 (1960) found that in West Virginia a tightly matted humus layer tended to keep seedlings from germinating. In the same locality, where there was little humus and only sparse herbaceous cover, newly germinated yellow-poplar seedlings were abundant. In the North Carolina Piedmont, Carve11 and Korstian (1955) reported that the number of yellow-poplar seedlings becoming established was greatest where little or no litter was present on the soil surface. A southern Illinois study (Minckler and Jensen 1959) showed that on moist sites, both in cut openings and under forest canopies, yellow-poplar seedlings became established most easily where litter depth was less than 1 inch. Clark and Boyce (1964) observed that some seeds germinate in forest litter without a mineral seedbed, but the yellow-poplar seedlings rarely live more than one growing season. In Maryland, McCarthy (1933) found that a spring surface fire in a moist bottomland destroyed the litter layer and the yellow-poplar seed from the previous fall. However, up to eight times more yellow-poplar seedlings became established on the burned bottomland than on unburned bottomland. McCarthy assumed the seedlings in the burn germinated from an earlier seed crop buried beneath the more inflammable top litter.

Logging operations also bring dormant seeds in forest litter into contact with mineral soil, thereby triggering germination. Seeds that fall at the time of cutting can also reach mineral soil and hasten the germination-establishment process. Sims (1932) reported that for 4 years, areas that were either clearcut and burned or uncut but burned had more yellow-poplar seedlings than unburned areas in the Southern Appalachian Mountains.

After germination, yellow-poplar seedlings develop a strong taproot rapidly. The taproot can grow to about 27 inches long in the first growing season. Two weeks or less after germination, the uppermost strong lateral roots are nearly as long as and, in some cases, longer than the taproot (Tourney 1929). Despite rapid root development, the first few years after germination are critical ones for seedling establishment. Excessive drying, flooding, frost heaving, and vegetative competition may harm seedlings at this early stage. Rapid and deep root penetration is critical to survival in droughty times, and a loose, easily penetrated soil enhances the chance for survival.

In a study in Connecticut in which different mulches were used to induce variation in soil temperature, seedlings grew faster in warm soil than in cool soil. Soil temperatures up to 97 °F aided seedling growth when moisture was adequate. And seedlings mulched with black polyethylene grew taller and survived better than hay-mulched and unmulched seedlings in the Cheshire fine sandy loam (Stephens 1965). In Alabama, bared soil with high evaporation rates and high surface soil temperatures in conjunction with two prolonged droughts was associated with high lst-year seedling mortality (Whipple 1968). Abundant soil moisture well distributed throughout the growing season in well-drained, fertile soils is certainly a key to successful yellow-poplar establishment.

Clark (1963) found that yellow-poplar seedlings infected with endotrophic mycorrhizal fungi grew much faster than seedlings grown without mycorrhizae. Anything that reduced or eliminated the naturally occurring fungi would slow seedling development.

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[2] See also Olson, David F., and Tim W. Jarrett. 1970. A study of yellow-poplar seed viability as affected by length of time on the ground. 11p. Southeastern Forest Experiment Station (SE-I 102), Asheville, N.C. (Closed study files.)

Figure 12.-The 2-year-old regeneration in this **clearcut** shows the results of yellow-poplar's prolific stump-sprouting after second-growth stands are harvested. F-529650

Kozlowski (1949) found that yellow-poplar reached maximum or near-maximum photosynthetic efficiency at relatively low light intensities. In West Virginia, Tryon and Carve11 **(1960),** investigating why yellow-poplar seedlings did poorly under an overstory canopy, found that the amount of sunlight reaching the forest floor in June amounted to 1.33 percent; where herbaceous cover existed, it was only 0.13 percent.

After the first growing season, vegetative competition (including intraspecies competition), rather than climatic and edaphic factors, may become the most important factor affecting survival. Scarified areas in northern Alabama that were bare in spring and early summer were partially covered with sprouts, forbs, grasses, and vines by late summer and early fall (Whipple 1968). Vines were less of a threat to yellow-poplar seedlings on scarified areas than on undisturbed areas because they were prostrate on scarified areas; on undisturbed areas, vines were more dense and covered all levels of other vegetation. Little (1967) recommended special measures to eliminate Japanese honeysuckle from regeneration areas in the Coastal Plain and Piedmont sections of New Jersey and Maryland. He also noted that herbaceous cover did not severely limit establishment, survival, and growth of yellow-poplar seedlings. Sims (1932) found that after logging and burning in a creek bottom in the southern Appalachians, severe competition from ferns was the most obvious cause of death of yellow-poplar seedlings. McCarthy (1933) regarded sprout growth of other tree species after pulpwood cutting to be the most serious threat to yellow-poplar seedling establishment and development.

Sprout Reproduction

Yellow-poplar of the age and size currently harvested in second-growth stands produces stump sprouts prolifically (fig. 12). Wendel(1975) found that 97 percent of the yellow-poplar stumps on two harvested areas in West Virginia produced sprouts. Trees ranging from 6 to 22 inches in diameter produced an average of 42 sprouts per stump 1 year after harvest. True (1953) reported an average of 21 sprouts on l-year-old yellow-poplar stumps ranging from 6 to 26 inches in diameter. The percentage of stumps sprouting and the number of sprouts per stump decreased with increasing size of stump. More than 95 percent of the 6-inch stumps sprouted, but only 40 percent of the **26-** to 30-inch stumps did. Sprouts per stump decreased from 31 for 6-inch stumps to 8 for 26-inch stumps.

Yellow-poplar sprouts arise chiefly from preexisting dormant buds situated near the base of dead or dying stems, or near the soil line on stumps. Sprouts may develop as high up as 12 to 15 inches on high stumps, but more than 80 percent arise at or below the soil line (True 1953). Their position on the stump is important to subsequent development. Sprouts arising from roots, or from the stump below groundline, usually lack a heartwood connection because the roots and belowground portions of the stump do not normally contain heartwood. The sapwood tissues separate heartwood columns of stump and sprout and may prevent heartrot fungi that enter the stump from spreading to the heartwood of the sprout (True and Tryon 1966).

The initial growth rate of yellow-poplar sprouts far exceeds that of young seedlings (Renshaw and Doolittle 1958) (fig. 13). In western North Carolina, the dominant sprout on each of 60 stumps on a good site grew an average of 4.7 feet per year over the first 6 years (Beck 1977). At age 24, these sprouts averaged 80 feet tall and 9.6 inches d.b.h. In West Virginia, the dominant stem of each sprout clump grew at 2.9 feet per year for 11 years on a medium-quality site for yellow-poplar (Wendel 1975).

McCarthy (1933) suggested that yellow-poplar sprouts are poor risks for future crop trees because of poor survival. However, recent studies show very good survival for stump sprouts. Of stumps with sprouts at age 6, nearly 90 percent had one or more sprouts intact at age 24 in western North Carolina (Beck 1977). Wendel (1975) reported that 91 percent of stumps with sprouts 1 year after cutting still had one or more viable sprouts 9 years later.

Sprout clumps of yellow-poplar, unlike those of white oak, have shown outstanding ability to thin themselves naturally. Sprout clumps dropped from an average of 6.4 stems at age 6 to only 2.1 stems at age 24. It was estimated that 65 percent of the sprout clumps would be reduced to only one stem, 25 percent would retain two stems of about equal size, and the remaining 10 percent would have three or four codominant stems per parent stump-all with the potential to produce sawtimber trees of good quality (Beck 1977, Wendel 1975).

Butt rot from the parent stump and from dying ancillary stems occurs in some sprout-origin trees. Incidence of rot is

Figure 13.-An outstanding example of a yellow-poplar sprout. This 5-year-old tree is 5 inches d.b.h., 35 feet tall, and is growing in a 'IO-acre clearcut in the Southern Appalachians. F-529655

greater in sprouts originating higher on the stump and on sprouts from large stumps (Beck 1977; True and Tryon 1966). In one study, however, about 50 percent of the sprout clumps produced at least one stem with minimal risk of butt rot (Beck 1977). Most of the stems with butt rot had attained pulpwood or even small sawlog size at age 24. Although they are poor risks as future crop trees, such sprouts can be removed in early thinnings. Wendel (1975) concluded that 85 percent of the sprout clumps of his study produced at least one stem that was well anchored and vigorous, had a well-developed crown, and had ample clear length. Although some stump sprouts may not be desirable, the many good sprouts add considerably to the ability of yellow-poplar to reproduce itself.

Determining Site Quality

Proper classification of site quality is critical for management of yellow-poplar, a site-sensitive species. Quality of the site will dictate to a large extent species composition; the ease of obtaining regeneration; cultural practices likely to be needed; and, ultimately, growth and yield of the stand.

There are several ways of recognizing site capacity for yellow-poplar: tree size at a given age, soil properties, topographic features, and the presence of vegetative types that are indicators of site quality.

Site Index

The most direct and commonly used technique for classifying site quality is to use the tree itself as an indicator. Site index, or height of the dominant stand at index age 50, has proved a good indicator of relative site productivity for yellow-poplar. The species is particularly suited to this technique because it normally has a single, well-defined central leader. So, height measurement is easy and precise. Intolerant of shade, yellow-poplar commonly grows in even-aged stands and does not tend to move up in crown position. It either stays in the overstory throughout its life or eventually dies

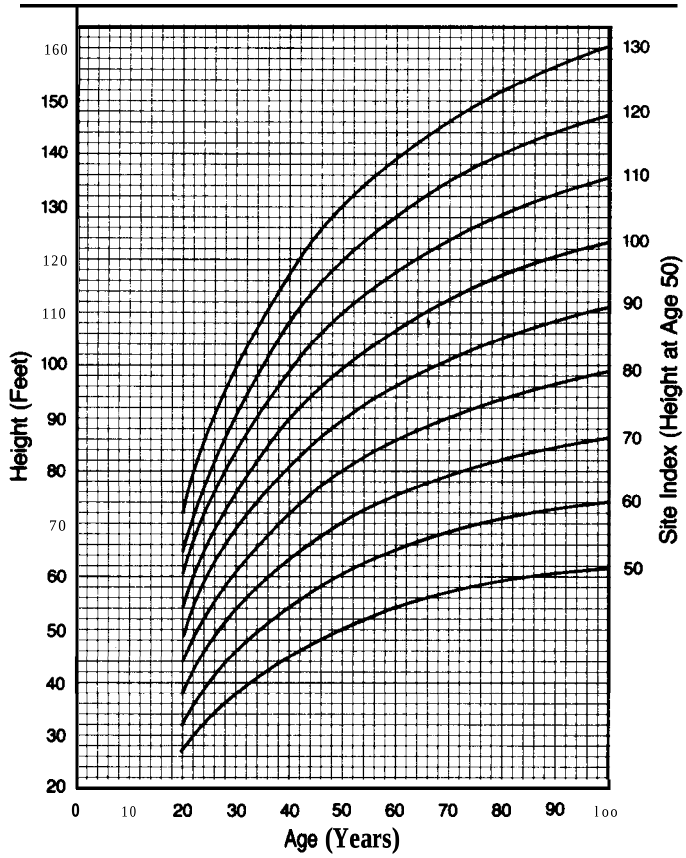

Figure 14.—Site index curves at an index age 50 for yellow-poplar in the Southern Appalachian Mountains. (Adapted **from Beck 1962)**

out. Thus, its height at a given age reflects the quality of the site rather than some effect of competing trees.

Four sets of site-index curves are currently used for yellow-poplar:

Southern Appalachian curves.—The site-index curves in figure 14 (Beck 1962) are for a stand age of 20 to 100 years and site range of 50 to 130 feet at 50 years. These curves are based on a sample of stands in north Georgia and western North Carolina, and on measurements of about 25 dominant and codominant trees per acre. Site index can be calculated by entering height and age in figure 14, or from the equation:

$$\log_{10} \text{site index} = \log_{10} \text{height} - 9.158\ (1/50 - 1/\text{age}).$$

Suggested area of use for these curves is the Mountain province, especially south of West Virginia.

Central Appalachian curves.—Schlaegel and others (1969) developed site-index curves (fig. 15) from stands in West Virginia. The site-index curves cover an age range from 20 to 80 years and sites ranging from 60 to 110 feet at age 50. The estimating equation is:

$$\log_{10} \text{site index} = \log_{10} \text{height} - 7.716\ (1/50 - 1/\text{age}).$$

These curves approximate the site-index values of the Southern Appalachian curves (Beck 1962) over most of the age range. Except at extreme ages (below 20 years, or over 80), the two sets of curves give estimates within one 10-point site class.

Piedmont curves.—Site-index curves in figure 16 are based on sample stands from the Piedmont of the two Carolinas and Virginia (Beck 1962). The equation is:

$$\log_{10} \text{site index} = \log_{10} \text{height} - 6.503\ (1/50 - 1/\text{age}).$$

Regionwide curves.—McCarthy's (1933) site-index curves (fig. 17) were developed from stands distributed over most of the range of yellow-poplar. They are restricted to an age range of 10 to 50 years because of a lack of older stands at the time they were prepared. These curves are essentially similar to the Piedmont curves by Beck (1962) in figure 16 and can be substituted for them.

It should be noted for all the site curves presented that estimates for stands less than 20 years old are subject to substantial error due to the variability of growth in early years. In applying the curves, care should be taken to pick trees that come from the dominant and codominant crown classes that show no signs of suppression or crown breakage, and that appear to have maintained their position in the canopy throughout their life. The sampling intensity for site-index

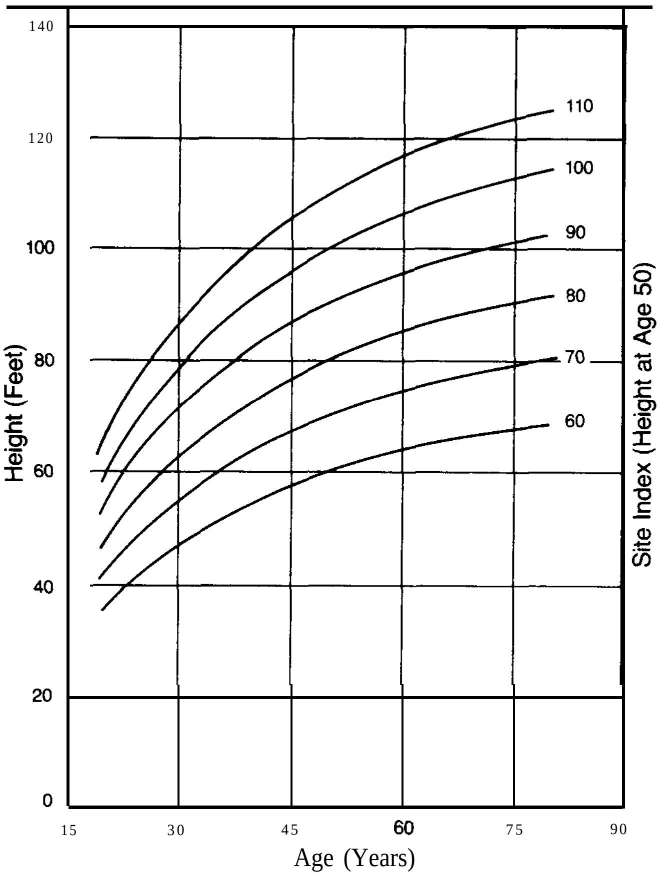

Figure 15.—Site-index curves for West Virginia yellow-poplar. (Adapted from Schlaegel and others 1969)

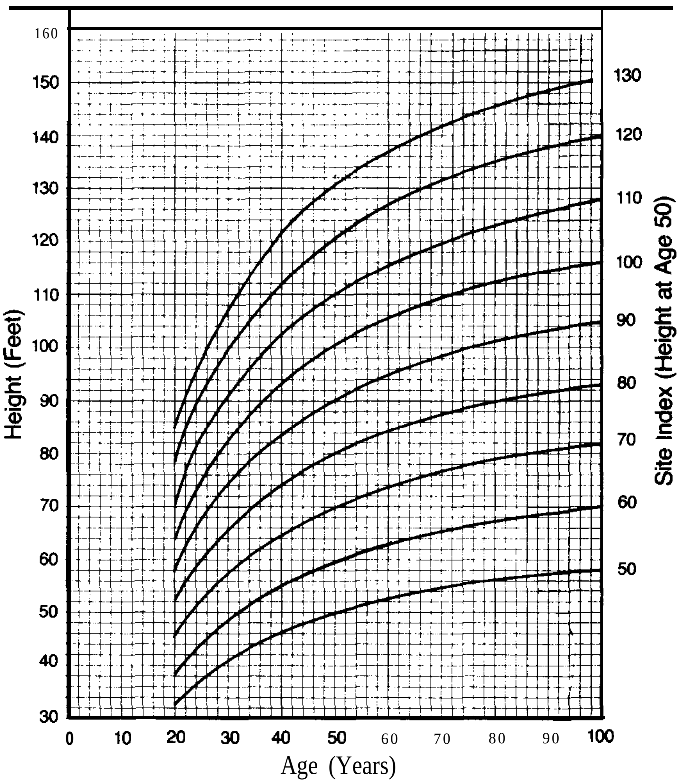

Figure 16.—Site-index curves at index age 50 for yellow-poplar in the Piedmont of Virginia and the Carolinas. (Adapted from Beck 1962)

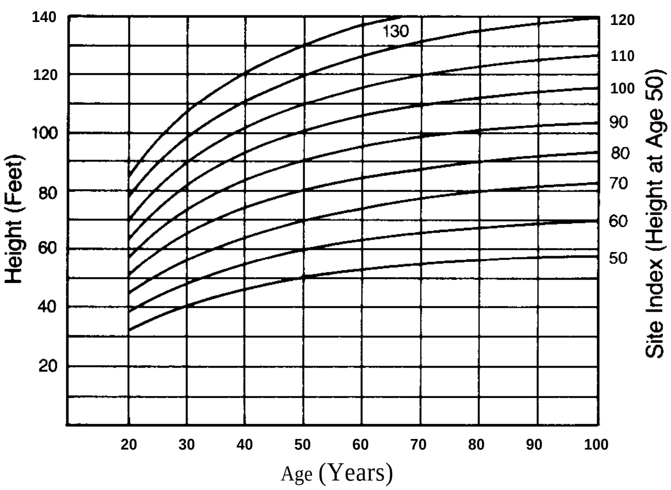

Figure 17.-Height in feet of average dominant and codominant trees, by site index at 50 years, in Coastal Plain and Piedmont areas, in natural range outside Mountain areas. (Adapted from McCarthy 1933)

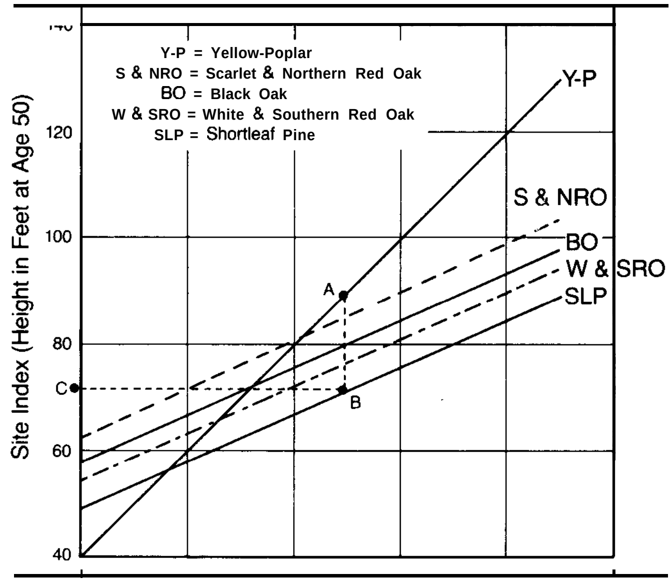

Figure l&-Site-index comparisons for important timber species in the Virginia-Carolinas Piedmont. For example, on land that is site index 90 for yellow-poplar (A), read down to (B) and across to (C) to find that this same land averages about 72 feet for shortleaf pine. (Adapted from Olson and Della-Bianca 1959)

estimates should approximate 25 sample trees per acre. The ability to estimate site index to one point or less, by using the equations, should not create a false sense of accuracy for the estimates. Categorization into lo-foot site classes is probably the best that can be expected of any of the site curves except at ages very close to index age.

Species Comparisons

Several studies have compared the relative height growth rates of yellow-poplar and other species when grown together in mixed stands. These studies generally make is possible to estimate site quality of other tree species when site index of yellow-poplar is known. Table 6 shows the geographic areas and the tree species for which species comparisons have been developed.

A common finding for most of these studies is that yellow-poplar grows faster than its associates on good sites, and slower than its associates on poorer sites. For example, Olson and Della-Bianca (1959) showed that in the North Carolina Piedmont, on sites above 81 for yellow-poplar, yellow-poplar outgrows all associated species, whereas on sites progressively poorer than 81, it rapidly falls behind all its associates, and at site index 57 and below, it has the lowest site index of any Piedmont tree species (fig. 18). Nelson and Beaufait (1957) showed similar trends in the Georgia Piedmont except for sweetgum, which was able to keep up with yellow-poplar

Table 6.—*Tree species comparisons by site index for selected areas within the range of yellow-poplar*

Region	Tree species compared'	Presentation method	Variable	Reference
Southern Appalachian Mountains	YP, WP, VP, SLP, PP, wo, 00	Graph Equations	Site index*	Doolittle (1958)
North Carolina—Lower Piedmont	YP-LP	Equation	Site index	Hocker (1953)
Durham, North Carolina	YP, LP	Equation	Site index	Metz (1947)
Georgia-Piedmont	YP-SG, NRO, SO, BO, SRO, WO, LP	Graph	Site index	Nelson and Beaufait (1957)
Virginia and Carolinas—Piedmont Uplands	YP, NRO-SO, BO, WO-SRO, SLP	Graph Equations	Site index	Olson and Della-Bianca (1959)
Middle Tennessee and northern Alabama—Cumberland Plateau and Highland Rim	YP, LP, VP	Table	Height in feet Diameter in inches	Smalley and Pierce (1972)

'BO = black oak; LP = loblolly pine; 00 = other oaks; NRO = horthern red oak; PP = pitch pine; SLP = shortleaf pine; SO = scarlet oak; SRO = southern red oak; VP = Virginia pine; WO = white oak; WP = eastern white pine; YP = yellow-poplar.

'Site index (height in feet of dominant and codominant trees at age 50).

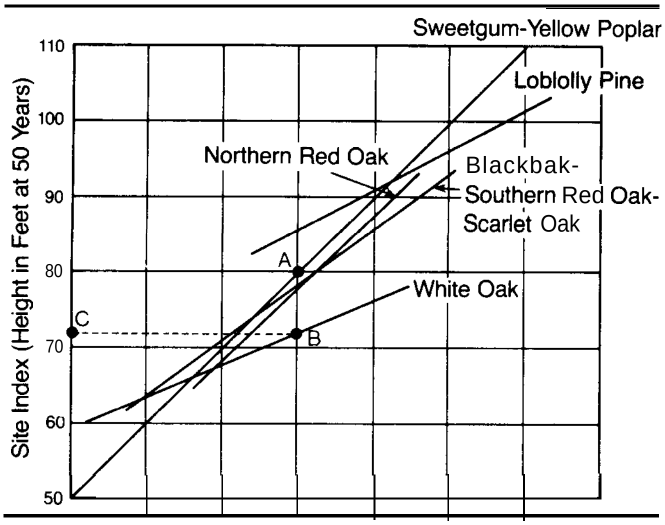

Figure 19.-Comparison of site indexes for several different species on the same land in the Georgia Piedmont. For example, on land that is site index 80 for yellow-poplar (A), read down to (B) and across to (C) to find that this same land averages about 72 for white oak. (Adapted from Nelson and Beaufait 1957)

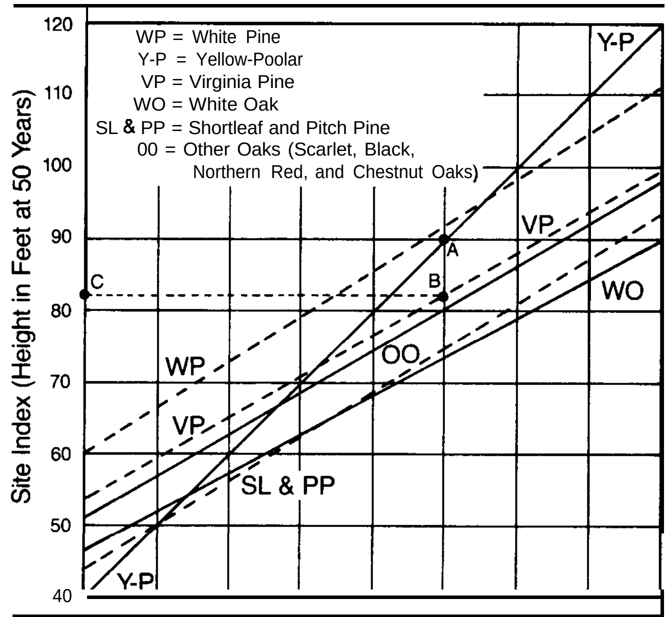

Figure 20.-A comparison of site indexes for 10 timber species on the same land in the Southern Appalachians. For example, on land that is site index 90 for yellow-poplar (A), read down to (B) and across to (C) to find that this same land averages about site 82 for Virginia pine. (Adapted from Doolittle 1958)

across the full range of sites (fig. 19). In the mountains of western North Carolina, eastern white pine comes closest to matching growth of yellow-poplar (fig. 20), but even white pine falls behind on sites better than site 96 for yellow-poplar (Doolittle 1958).

Site Classification from Soils and Topography

At times, estimates of site quality may be desired where no suitable stands exist for direct estimation of site index, e.g., a recently cutover area. Many attempts have been made to develop schemes for estimating site productivity for yellow-poplar from characteristics of the soil and topography. Most such attempts have used correlations of site index with essentially permanent features of soil and topography. Table 7 summarizes the area or region of application and the major soil and topographic features found useful in estimating site index with soil-site equations. Appendix 1 lists these equations.

As noted earlier, most of the features found to be related to site index measure the amount of root space and those factors that influence or reflect the soil-moisture supply. Soils must have an effective depth (depth to tight subsoil, or a poorly drained layer) of 24 inches or more to be classified as superior sites for yellow-poplar. Topographic positions that reflect moisture relationships-and to some extent soil depth—were consistently isolated as important variables. In only one case were standard soil series of any use for estimating site quality (Ike and Huppuch 1968); more commonly, a given soil series was likely to encompass a wide range in site index and to be of no use (Della-Bianca and Wells 1967; Van Lear and Hosner 1967).

These procedures were developed from lands that were in a forested condition with trees suitable for site-index estimation. They can be applied most reliably to forested areas or to areas recently cutover. It is not always clear if the correlations demonstrated are cause or effect. For example, A, horizon depth has been isolated as a significant variable in several cases. However, Coile (1952) observed that an A, horizon can develop as a result of the presence of yellow-poplar. Auten (1937a, 1937b) found that yellow-poplar will grow rapidly in the complete absence of an A, horizon provided the soil has good physical properties and is well drained.

The above estimation techniques are only considered applicable to geographic areas and types of sites from which they were developed.

Establishing Natural Regeneration

Seed

The successful regeneration of yellow-poplar by natural means requires either trees capable of producing stump sprouts or the combination of adequate seed, a seedbed of exposed mineral soil, and direct sunlight (Olson 1969).

Adequate seed is seldom a problem on sites capable of growing yellow-poplar if even a few seed-producing trees are available. Preparatory cuts to encourage seed production or to leave trees specifically to produce seed are not needed. Likewise, there is seldom need to make provisions for obtain-

Table 7.—*Significant factors for yellow-poplar soil-site estimations*

Location	Soil variables	Topographic and other variables	Source
Fred Russ Forest Cassopolis, Michigan	Fine clay in A, and A, horizons Maximum water-holding capacity of A_2 horizon Soil moisture at 6-inch depth	Growing season precipitation Air temperature Relative humidity Surface soil temperature Light intensity Evaporation rate	Shipman and Rudolph (1954)
Fred Russ Forest Cassopolis, Michigan		Foliage nitrogen Foliage phosphorus	Schomaker and Rudolph (1964)
Dobbs Memorial Forest Terre Haute, Indiana	Thickness of A, horizon Depth to tight subsoil Depth to mottling		Tryon and others (1960)
Dixon Springs, Agricultural Center Dixon Springs, Illinois	Depth of incorporated organic matter Depth of fragipan		Gilmore and others (1968)
Tar Hollow State Forest Ross County, Ohio	Lime test index pH of A horizon Exchangeable calcium of A horizon Depth to B_2 horizon	Aspect Slope position	Munn and Vimmerstedt (1980)
Central States	Thickness of A, horizon Depth to tight subsoil Color of surface soil Color of subsoil Subsoil drainage Subsoil mottling	Steepness Aspect	Auten (1945)
New Jersey Coastal Plain	Percent clay in A horizon Available water in root zone Hydraulic conductivity of B horizon Bulk density of C horizon Percent organic matter in A horizon Exchangeable potassium in A horizon		Czapowskyj (1962)
New Jersey Coastal Plain	Percent clay in subsoil Depth to tight subsoil Depth to mottling	Slope position	Phillips (1966)
Durham, North Carolina (Alluvial soils)	Thickness of A horizon Imbibitional water value		Metz (1947)
Lower North Carolina Piedmont	Thickness of A horizon		Hocker (1953)
Piedmont Uplands— Virginia and Carolinas	Percent organic matter in A, horizon Thickness of A_1 horizon Thickness of total A horizon Percent sand in A, horizon	Slope position Latitude	Della-Bianca and Olson (1961)
Georgia Blue Ridge Mountains	Soil series	Slope position Elevation above sea level Basal area Sheltered cove or ridge site	Ike and Huppuch (1968)
Flat Top Experimental Forest Birmingham, Alabama	Total soil moisture in percent	Slope position	Schomaker (1958)
Flat Top Experimental Forest Birmingham, Alabama	Available water in soil profile Soil depth	Slope position Aspect	Smalley (1969)
Ames Plantation Grand Junction, Tennessee	Depth to mottling	Slope position Aspect	Hebb (1962)

ing seed from surrounding stands or to plan harvests to take advantage of good seed years, as is the case with some other species. High production of seed on an annual basis and long viability in the forest floor provide more than adequate seed when proper conditions are created for germination and growth (Herr and Carve11 1975).

Mineral Soil

Scarification and fire, which put seeds into contact with mineral soil, increase the number of seedlings significantly as compared to undisturbed forest floor (Engle and Williams 1957, Little 1967, Sims 1932, Whipple 1968, Williams and Mony 1962). Under normal conditions, however, the site disturbance caused by logging the mature stand is the only seedbed preparation needed to provide enough yellow-poplar seedlings for a new stand. In Indiana, 1 year after cutting, there were 4,000 yellow-poplar seedlings per acre on a plot that was clearcut, and 4,800 per acre on partially cut plots (Sander and Clark 1971). In western North Carolina, more than 50,000 seedlings per acre followed both clearcuts and partial cuts that removed as little as one-third of the basal area. Occasionally, sites with deep accumulations of litter may require some seedbed treatment; this is likely to be needed only on the drier sites dominated by oaks or beech. In such cases, both disking and burning are effective (Little 1967, Shearin and others 1972). Treatment by disking or burning has also been recommended for sites with few seeds in the forest floor, especially if the floor is covered with dense herbaceous growth (Little 1967).

Light

To admit sunlight to the forest floor, any harvest cut to establish even-aged stands can be used, or patch cuts can be used in selection forests. On good sites in Ohio, Kentucky, Indiana, and Illinois, harvest cuts ranging from removal of 35 percent of the basal area to complete clearcuts, where all trees 1 inch and larger were removed, resulted in establishment of many seedlings (Sander and Clark 1971). The heavier the cut, the more seedlings, but even the lighter cuts had enough seedings to establish a new stand; after 2 years, the lightest partial cut had nearly 1,200 seedlings per acre. On good sites in the Southern Appalachians, cuts ranging from removal of 30 to 100 percent of basal area resulted in establishment of 2,000 to 12,000 seedlings per acre (McGee 1975). How many seedlings were established seemed to be more closely related to the quality of the site than to the intensity of the cut.

Although partial cutting (two- or three-cut shelterwood method) can be used to establish regeneration, height growth is severely limited by the remaining overstory. In an Indiana study, yellow-poplar in clearcuts was nearly twice as tall after 5 years as seedlings in a shelterwood cut (Sander and Clark 1971). In western North Carolina, seedlings in a clearcut were three times as tall after 12 years as those in partial cuts (McGee 1975). Rapid height growth does not begin until the overstory is removed. Where other management considerations mandate the use of the shelterwood system, the understory treatment should be done at the time of the first removal cut, and the residual overstory should not remain longer than 5 years after initial seedling establishment.

Size of the opening has a significant effect on growth of reproduction after establishment. Four years after cutting, Smith (1963) found that yellow-poplar in 1/2-acre openings were taller than those in either 1/4-acre or l/lo-acre openings. Ten years after cutting in West Virginia, yellow-poplar height growth increased as opening size increased, averaging 17 feet in 100-foot openings (0.18 acre) to about 28 feet in 250-foot openings (1.127 acres). Diameter growth showed a similar trend, averaging 2.5 and 3.3 inches in IOO-foot and 250-foot openings, respectively (Smith 1977b). All openings, regardless of size, are bordered by a zone where growth of reproduction is retarded (fig. 21); this zone may extend from 10 to 30 feet from the boles of surrounding trees. Thus, the percentage of the area in the restrictive zone increases greatly for openings smaller than about one-half acre (fig. 22). Sander and Clark (1971) recommend that for best growth of reproduction, the minimum-size circular opening should be not less than one-half acre; 1 acre is probably better (Little 1967). Openings of any other shape will have a higher percentage of the total area in the border zone. So, the minimum size of rectangular openings should be about 1 acre for best results.

The minimum-size opening that can be used to regenerate yellow-poplar is fairly small. Abundant yellow-poplar reproduction has been established in openings as small as one-eighth

Figure 21.-Five years after cutting, reproduction seedlings next to the old stand (right edge of photo) are much shorter than those in the center of this 1/8-acre opening.(Sander and Clark 1971) F-520661

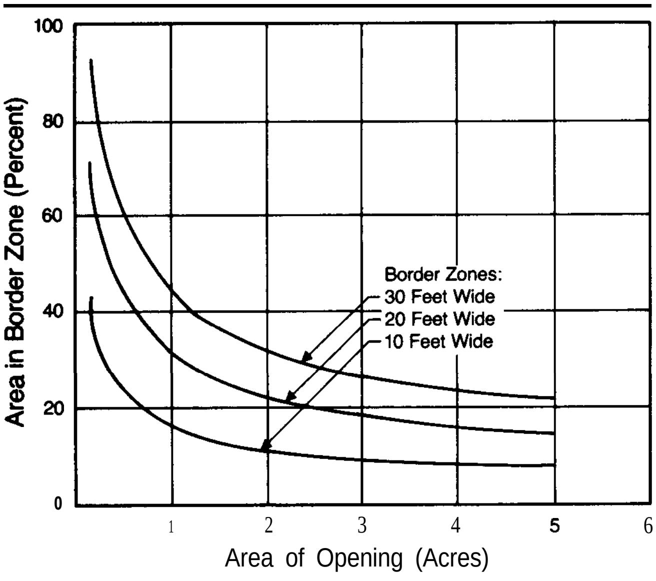

Figure 22.-Relationship between the total area of circular openings and the percentage of area of the opening contained in border zones 10 to 30 feet wide. (Sander and Clark 1971)

of an acre (83-foot-diameter openings). In an Ohio study, there was little difference in number of seedlings in openings ranging from 1/8 to 5 acres (Sander and Clark 1971). Similar results were reported in Illinois and Kentucky for openings ranging from 1/20 to 4 acres.

Season

Season of logging, while not critical, does have some effect on establishment and growth of yellow-poplar seedlings. It has been reported from studies in West Virginia, Ohio, and Indiana that summer logging produced fewer seedlings than logging at other times of the year (Sander and Clark 1971; Trimble and Tryon 1969). Apparently, in summer-logged stands most of the seeds did not germinate until the following year, and these small seedlings were not as able to compete with the rank vegetation that started the previous year. Nevertheless, cuttings in summer months have usually produced enough seedlings where a good seed source was previously present. If seed supply in the litter layer is expected to be scarce, logging in fall, winter, or early spring might be advantageous.

Competition

Treatment of stems left after commercial logging is usually essential for the best development of well-distributed yellow-poplar reproduction. Some stands that have carried high stocking up to the time of the final harvest cut may have relatively few unmerchantable stems where a good pulpwood market is available. But, in the typical case, numerous stems of the more tolerant understory species such as flowering dogwood, red maple, and American hornbeam will be left after commercial logging. Studies in the Southern Appalachians have shown that 300 or more stems per acre from 1 to 4 inches in diameter are left after logging. This residual material can have a significant impact on growth of yellow-poplar, especially seedlings. In Indiana, on a medium-quality site, 18-year-old yellow-poplar that had been completely released by cutting all woody vegetation over 5 feet tall averaged 25 feet tall and 2.7 inches in d.b.h. Trees of the same age in an area where only trees 6 inches d.b.h. and over were cut or killed (residual basal area in smaller trees was 17 square feet per acre) were only 15 feet tall and 1.1. inches d.b.h. In another area with 40 square feet of residual nonmerchantable material per acre, the 18-year-old yellow-poplar were only 6 feet tall and 0.5 inches d.b.h. (Williams 1976).

Cull and unmerchantable stems may be controlled before, during, or after the commercial logging operation. A range of techniques is available, from cutting down unmerchantable stems with saws, to chemical control by injection or basal spray, to mechanically knocking down leftover material with bulldozer blades. Burning is also a viable option. Complete elimination of competing vegetation is not necessary. Cutting it back, or effecting topkill is usually sufficient to provide time for yellow-poplar seedlings to become dominant, if they are not near yellow-poplar sprouts. Where yellow-poplar sprouts are abundant and desirable, less control of competing vegetation is needed because of the fast growth of sprouts.

Establishing Artificial Regeneration

Although yellow-poplar has never been planted on a large-scale basis, it is biologically and technically feasible to do so with procedures widely used for other species (fig. 23). Russell's (1977) key planting requirements are: (1) selection of suitable sites, (2) adequate control of competing vegetation, especially the first few years after planting, and (3) use of the best planting technology, which includes high-quality seedlings, careful stock handling, and choice of appropriate seasons and methods of planting. Boyette (1970) attributed widespread failure of planted yellow-poplar in North Carolina to neglect of these requirements.

Site Selection

Improper site selection has probably caused more yellow-poplar failures than all other planting errors combined (Russell 1977). Abandoned fields and pastures-although enticing planting opportunities-have proved to be particularly poor sites for planting yellow-poplar. Adverse conditions commonly found on these sites include severe erosion, soil compaction and loss of soil structure, depleted nutrient capital, lack of appropriate soil micro-organisms, and heavy sod or weed growth (Boyette 1970, Clark 1964, Clark and Losche 1969, Gilmore and others 1968, McCarthy 1933, Russell 1977).

It is relatively easy to determine those sites that are definitely unsuitable and those that are obviously excellent. Protected coves and lower slopes with northerly aspects and deep, friable soils that are moist but well drained, are obviously suitable. Ridgetops and southerly aspects with shallow, droughty soils

Figure 23.-A fast-growing 21-year-old yellow-poplar plantation in the Georgia Piedmont near Athens. The plantation was established in a slight mesic depression near a ridgetop. (McAlpine 1959b) F-529673

are obviously not suitable. Between these extremes, site evaluation is more difficult and involves more risk. However, judicious use of available guides should enable the planter to take acceptable risks. On forested areas with suitable stands, site-index curves and species-comparison formulas offer a good means of site assessment. On cutover areas, the soil-site-index information for selected areas is helpful. While not foolproof, indicator species offer good insight into site capability-particularly the presence of adverse conditions. For example, Boyette (1970) found that where yellow-poplar plantings in North Carolina failed because of poor drainage, tag alder was frequently present. Plants commonly found on depleted fields and pastures were Virginia pine, broom-sedge (*Andropogon virginicus*), plantain (*Plantago rugelii*), and reindeer moss (*Cladonia rangiferina*).

Site Preparation

Because yellow-poplar seedlings grow fast, they can outstrip most competing vegetation on cutover sites. However, seedlings will not persist for long in the understory, or if overtopped by faster growing sprouts. Opinions on optimum intensity of competition control are frequently in conflict, and the conflicts may arise from the great variation in competition from site to site. The nature of competing vegetation may be influenced by past treatment but is largely controlled by the inherent quality of the site. Competition is more severe on fertile soils of high moisture-supplying capacity than on less fertile, drier soils. The need for site preparation will vary accordingly.

On sites of intermediate quality in central Tennessee and northern Alabama, yellow-poplar has performed reasonably well without complete elimination of competing vegetation (Russell 1977). Where the understory was sparse, killing the overstory hardwoods by girdling, frill girdling, or injecting with a herbicide was all that was needed to insure survival and growth of planted yellow-poplar. A study on the Cumberland Plateau illustrates the results that are possible on average sites with minimum site preparation (McGee 1977). Where only trees over 6 d.b.h. were killed (as in competition control for commercial logging of pulpwood and saw logs), planted yellow-poplar averaged 12 feet in height and 0.8 inches in diameter after 10 years. When all hardwoods over 2 inches d.b.h. were injected, planted yellow-poplar averaged 25 feet in height and 2.3 inches in diameter. Injecting all hardwoods before planting, with followup treatment the next year wherever necessary, boosted yellow-poplar IO-year heights to 31 feet, and diameters to 3.2 inches. Survival was unaffected by treatment, averaging about 75 percent. Even though complete control of competing hardwoods improved growth somewhat, the much less intensive and less costly treatment, injecting all hardwoods over 2 inches d.b.h., provided 122 trees per acre, 4 inches d.b.h. and larger, at 10 years of age-an adequate number of crop trees for management.

On more productive sites where competing vegetation is dense and resurgent sprout growth is likely to be rapid, a more nearly complete control by mechanical or chemical means is likely to be needed. Basal spraying, injection, cutting and treating stumps with herbicides, and mist blowing have all been used effectively. Mechanical site-preparation techniques suitable for establishing pine on good sites should prove effective for yellow-poplar.

On good sites, weed control may also be beneficial, if not essential. On well-drained alluvial sites in Georgia that were clearcut, sheared, and disked, chemical control'of invading herbaceous weeds markedly increased early growth of planted yellow-poplar (Fitzgerald and Selden 1975). After three growing seasons, sapling height averaged 8.1 feet on the chemically treated plots but only 5.5 feet on the untreated plots. Survival was no different on treated and untreated plots. On the Cumberland Plateau in Tennessee, postplanting weed control improved growth of yellow-poplar on sites of average quality (Russell 1977). Fifth-year heights averaged 11.1 feet on sites where weeds were mowed for 2 years and 7.9 feet where no mowing was done. While most studies of herbaceous weed control in yellow-poplar plantings show that it will boost early growth, they have not shown that herbaceous weed control is essential to insure successful plantation establishment.

Planting Technology

Even if the chosen site is capable of growing yellow-poplar and has been properly prepared, close attention to planting technology (seedling quality, stock handling, and the planting operation) is still essential for success.

Quality of planting stock includes both its genetic makeup and morphological characteristics. Given the wide geographic and altitudinal range of yellow-poplar, indiscriminate movement of seed from place to place could prove disastrous. While local seed sources have not always shown the best growth, they are well enough adapted to local environment to minimize risk of a complete failure from bad weather. No widely adapted sources have been shown to exist. Nor is our knowledge complete enough to recommend movement from one specific place to another. Unless the superiority of a specific nonlocal source is based on research or experience, it is advisable to obtain seed from reasonably near the planting site in areas where environmental factors are similar.

Seedling size indicates physiological vigor, and it has long been accepted that large hardwood seedlings perform better initially than small seedlings (Limstrom and others 1955, McElwee 1970, Rodenbach and Olson 1960). Moreover, the detrimental effects of planting substandard seedlings may persist for many years (Funk and others 1974). Most yellow-poplar planting is done with 1-O bare-root stock (fig. 24). According to published guides for the Central States (Limstrom 1963), seedlings with 1/8- to 3/8-inch diameter stems at the ground line are acceptable; those with a 5/16-inch diameter are preferred (fig. 25). Seedlings within this range have also performed satisfactorily in many trials on a wide variety of sites in central Tennessee and northern Alabama (Russell and others 1970). The current trend in the South is to plant even larger hardwood seedlings; a 3/8-inch root-collar diameter is often considered the minimum acceptable size (McElwee 1970). In West Virginia, 4-year-old yellow-poplar seedlings have been recommended for planting sites dominated by tall-growing herbaceous weeds (Carve11 1966a).

Figure 24.-Yellow-poplar planting is generally done with 1-O bare-root planting stock of the size shown here. Survival is poor with smaller seedlings.
F-486193

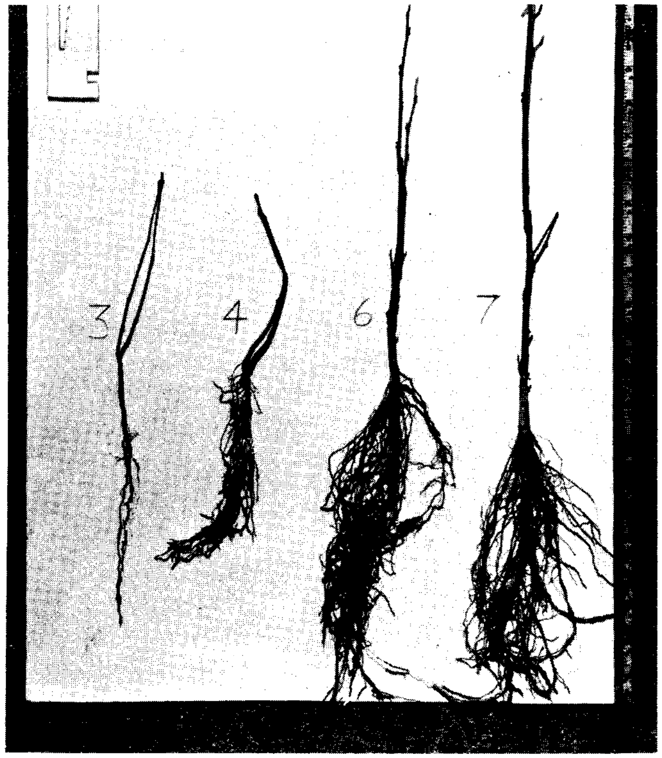

Figure 25.—Yellow-poplar seedlings with stems of about l/Cinch diameter and larger at ground line (6 and 7) are acceptable for planting. Smaller seedlings (3 and 4) generally die after outplanting.
F-486154

Seedlings within this range have also performed satisfactorily in many trials on a wide variety of sites in central Tennessee and northern Alabama (Russell and others 1970). The current trend in the South is to plant even larger hardwood seedlings; a 3/8-inch root-collar diameter is often considered the minimum acceptable size (McElwee 1970). In West Virginia, 4-year-old yeliow-poplar seedlings have been recommended for planting sites dominated by tall-growing herbaceous weeds (Carvell 1966a).

Roots and shoots are often pruned in the nursery to reduce costs of packing and shipping. Root pruning also tends to increase branching of root mass (Sluder 1964; Thor 1965) and may improve both initial survival and growth (Limstrom and others 1955, Sterling and Lane 1975). Roots should not be pruned without also clipping tops; to fail to clip tops too may reduce first-year growth. Preferably, seedlings should be root-pruned before they become dormant and top-clipped when they are dormant. Seedlings that have not been pruned at the nursery can be pruned in the field for ease in handling and planting. Overlong roots should be cut back to about 10 inches; tops can be clipped to 12 to 18 inches.

Yellow-poplar seedlings require considerably more care in handling and planting than hardier species, such as the pines. Allowing seedlings to dry out, heat, or freeze during shipment, storage, or planting may be an especially serious cause of poor initial survival (Russell and others 1970). Seedlings can be kept in bales for a few weeks in a cool, shaded place. They can be heeled in for a longer time but should be planted before new leaves unfold. Refrigeration at about 36°F is best for long-term storage (Limstrom 1963). At Sewanee, Tennessee, seedlings were kept dormant and in good condition in cold storage for almost 6 months (Russell 1977). During cold storage, bales must be turned occasionally and watered as needed.

The choice of hand or machine methods for planting depends on what is available and what can be done most economically. Either method can be successfully used. For hand planting in stony soils, the KBC planting bar proved better than the standard wedge-shaped bar, and it makes a slightly wider and deeper slit that more readily accepts the yellow-poplar root system. As with any bare-root planting stock, care should be taken to straighten out roots and to press soil firmly around them.

Optimum planting dates vary, depending on local climate. Seedlings planted in fall or early winter may be injured by frost heaving in some regions, particularly on heavy soils or where intensive mechanical site preparation has removed all cover. In general, spring planting is preferable.

Spacing

Data on long-term plantation yield are too scanty to make good spacing recommendations. McCarthy (1933) recommended spacing between 7 by 7 and 10 by 10 feet, but the criteria for his recommendation are not known.

Rudolph and others (1965) tried spacings of 8 by 8, 10 by 10, 12 by 12, and 14 by 14 feet. After evaluating the plantation spacings at age 22, they recommended the two close spacings on the basis of better potential merchantable height and quality of yellow-poplar. Their results were somewhat- confounded because of the formation of multiple stems after topkill and sunscald. Among the 100 largest trees per acre (which were considered the most important for the future development of the plantation), neither height nor diameter differed much. Only the 14- by 14-foot spacing had significantly less potential merchantable stemwood because the widely spaced trees tended to fork and become "wolf" trees. If market and other management constraints will allow thinning at a young age, higher quality might be achieved by plantings with approximate spacings of 8 by 8 to 10 by 10 feet. If early thinnings are not possible, planting at 12 by 12 feet should result in trees of acceptable quality and enable the stand to reach a larger mean diameter before thinning is necessary.

Establishing Stands by Direct Seeding

Direct seeding of yellow-poplar has been attempted only on a very limited, experimental basis, and with mostly negative results. In a test of spot seeding, Korstian and MacKinney (1931) covered 75 seeds per spot with one-eighth inch of soil on a wide variety of sites. After 4 years, only 40 percent of the spots contained one or more seedlings. Those seedlings were very small-averaging about 0.1 foot in height. Seedlings had sprouted on nearly 90 percent of the spots, but many died.

Sluder and Rodenbach (1964) found that spring-planted, stratified seed, covered with one-eighth inch of soil, and protected by screens gave best results. Even this treatment resulted in only about nine seedlings per 100 seeds planted, and 84 percent stocking after 1 year. Fall planting on the surface of prepared spots, with no screening, resulted in less than one seedling per 10,000 seed, and less than 1 percent stocking of seed spots. Seed predators were mostly responsible for the low rate of establishment. At present no effective repellent is known. Protection must come from expensive screening techniques, or from sowing very large numbers of seeds per acre (Russell 1973).

In a test of broadcast seeding, Clark (1958) spread stratified seed in February at the rate of 120,000 seeds per acre. He estimated that on the average, direct seeding produced about 800 seedlings per acre after the first year, or less than 1 seedling per 100 seed. There was no difference in the stocking of yellow-poplar seedlings on disked and undisked areas. However, one-third of the undisked area was scarified during logging with negligible effects on the final results.

Best results with direct seeding can apparently be obtained where stratified seed are sown in the spring with a light soil covering and protected from seed predators. Even then, very large numbers of seed must be sown. Under the best conditions, one can expect only about 10 percent of the seed to produce seedlings, and subsequent losses are generally high because of frost heaving, vegetative competition, and other adverse factors.

At present, direct seeding does not present an attractive alternative to planting when artificial means are chosen to establish yellow-poplar.

Managing Established Stands

Once established on a suitable site, yellow-poplars originating as seedlings or as sprouts grow rapidly in height. It is not uncommon for seedlings to grow 10 to 18 feet in 5 years (McCarthy 1933). Sprouts may be 25 or more feet tall in 5 years. Rapid height growth may continue for 25 to 30 years before slowing down appreciably. Doolittle (1958) has shown that in the Southern Appalachians on land of site index 95 and above, yellow-poplar has faster height growth than any associated species up to 50 years of age. On lands from site index 75 to 95, yellow-poplar outgrows all its associates except white pine. Below site index 75, other species have better height growth than yellow-poplar. If not interfered with by overtopping trees from a previous stand, yellow-poplar will take and hold its place in the dominant crown canopy of the developing stand. Recent observations indicate that yellow-poplar is increasing in acreage after a variety of cutting methods.

When growing in mostly pure stands, yellow-poplar expresses dominance well, and seldom, if ever, stagnates because of excessive stand density. Because of yellow-poplar growth characteristics, yellow-poplar stands can develop and produce considerable quantities of large, high-quality products with no intermediate stand management (Appendix 3, tables 25-42).

However, even at advanced ages, unmanaged stands typically contain many trees of less than merchantable size for saw and veneer logs-the most valuable yellow-poplar raw products (fig. 26). In some stands, the volume in small trees can be considerable. For example, on a site 100 at age 70, the average unmanaged stand has 40 to 50 percent of its trees in sizes less than minimum sawtimber size of 11 inches d.b.h. These trees account for 12 to 15 percent of stand volume. The remaining volume is in trees 11 to 18 inches d.b.h. Only about 20 to 25 percent of stand volume is in trees large enough to classify as grade A with a No. 1 butt log under current grading standards (Beck and Della-Bianca 1970). Also, during the course of stand development, some volume is lost to mortality, much of which is in trees too small to be merchantable. However, on the better sites, much usable wood will be lost to mortality as a result of overcrowding (Della-Bianca 1975a).

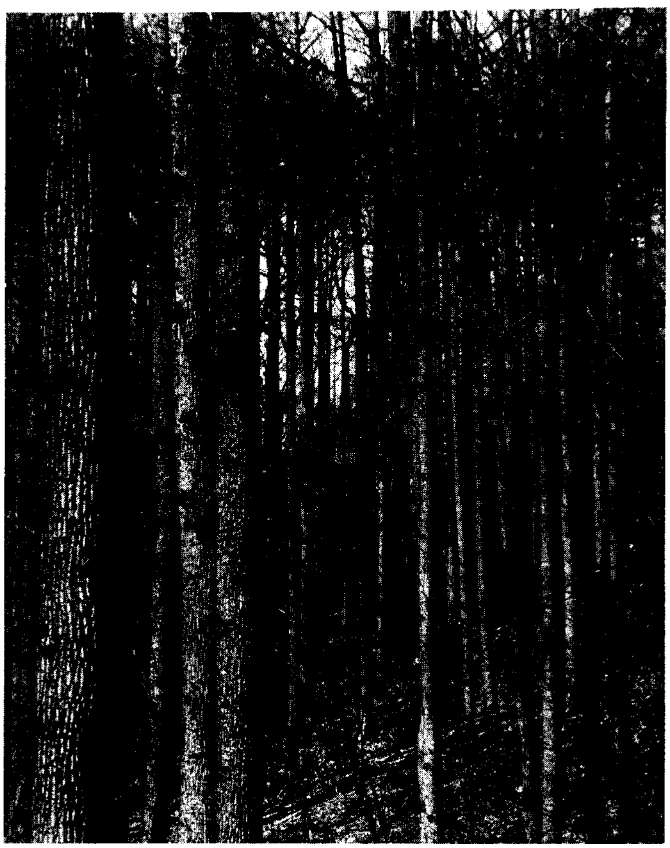

Figure **26.—Unmanaged** mature yellow-poplar stands contain a large volume of pulpwood-size trees which early thinning eliminates. Thinning concentrates growth on the much more valuable saw log and veneer trees. Thinnings also minimize mortality. **F-529651**

With a premium on large, high-quality trees, it is desirable to use cultural practices to redirect the wood growth, which otherwise would accumulate on small trees or would be lost to mortality, into fewer but larger trees. Commercial thinning that adjusts the growing stock is the best management technique now available.

Seedling-Sapling Stands

The seedling-sapling stage of stand development is dynamic, with rapid changes in size and number of trees. Rates of height and diameter growth are greater during this early stage than at any other time. Differentiation in size and crown classes becomes apparent as the trees struggle for survival. A seedling stand of 50,000 stems per acre may be reduced by natural mortality to less than 300 trees per acre in the main canopy by age 20 to 30 (fig. 27). In this early stage, on sites favorable to yellow-poplar, there is usually a variety of associated plant species that originated from seed, seedling-sprouts, or stump sprouts.

Figure 27.-Dense seedling stands of yellow-poplar with 50,000 stems or more per acre are generally reduced by natural mortality to under 300 stems per acre when the stands are between 20 and 30 years old. **F-529656**

A casual observer of young stands may feel that some cultural work must be done if an acceptable stand is to finally emerge. At this stage, however, no commercial uses for thinnings are likely and any cultural work will be costly. The best guide for prescribing cultural treatments at this early stage of stand development is to be reasonably certain that treatment is needed and then to minimize the amount of cultural work done. Other management objectives such as making wildlife browse available, changing species composition, and increasing water yield may dictate the early use of cultural practices, but costs should be prorated among all benefits.

Precommercial treatment is profitable only if it increases the stand value by increasing the possible number of saw logs or veneer bolts to be expected. If a timber owner's objective is to grow trees to 20 inches d.b.h., 50 or fewer trees per acre will be in the stand at final harvest. Because we cannot pick the final crop trees with certainty in this early stage, more than 50 will be needed to allow for possible mortality of some stems and to assure that enough high-quality trees will be available for the future selection. But exactly how many more is debatable. Roach and Gingrich (1968) suggested 200 well-spaced saplings per acre. Others suggest that 109 trees per acre-spaced 20 by 20 feet-will be sufficient (Lamson and Smith 1978, McGee 1977, Trimble 1973b).

Undisturbed stands of yellow-poplar show that it is unlikely that more than 200 trees per acre, suitable in vigor and crown position to consider as future crop trees, can be carried to the pole stage. Therefore, the release of more than about 200 trees in the seedling-sapling stage, will cause early competition among released trees. It makes little sense to spend money releasing trees that will die or be cut for small, low-value products at the first commercial thinning.

In seedling-sapling stands where yellow-poplar is competing with other trees of the same age and size, there appears to be little to be gained from crop-tree release by precommercial thinning. The dominants and codominants do not need it, and the lesser crown classes will require more than one release. If a decision is made to thin in very young seedling-sapling stands, the thinning should be one of a planned series. The effects of a single thinning in such stands last only a few years—probably not more than 6 to 8—and will be obscured over the course of a rotation if not repeated (Della-Bianca 1969, 1971). Studies of weeding or thinning in seedling-sapling stands have also shown that response to thinning of yellow-poplar depends on crown class and vigor of the individuals. Releasing dominant and codominant saplings has resulted in slight improvement in diameter growth but often causes a reduction in height growth in comparison to unreleased trees (Allen and Marquis 1970; Downs 1942, 1946; Lamson and Smith 1978; Trimble 1973b). Release has also proved to have little effect on survival or in helping dominant and codominant trees to maintain their crown positions (Lamson and Smith 1978, Trimble 1973b). Intermediates of good vigor have sometimes shown positive response to release in both height and diameter growth. But it appears that more than one release will be necessary for intermediates to become a permanent part of the stand (Downs 1942). When released to a dominant position, intermediates regress rapidly in crown status. In one study, none of the released intermediates was considered a potential crop tree 5 years later without further release (Lamson and Smith 1978). Poor-vigor intermediates and suppressed trees should not be considered for release because of their general lack of response (Downs 1942, 1946).

When yellow-poplars of seedling origin are overtopped by residual trees or faster growing sprout regeneration, cultural work in seedling-sapling stands may be needed. This condition exists where residual trees are left from the harvest cut and yellow-poplar seedlings are developing underneath them, or where rapidly growing sprouts of competing species are overtopping new yellow-poplar seedlings. As defined here, overtopping refers to the physical position and not low vigor. In one case, overtopped yellow-poplar seedlings responded well to release from residuals and height and diameter growth greatly improved (Williams 1976). In another case, 3-year-old seedlings responded to release from overtopping sprouts of locust (Beck and McGee 1974). This kind of release should be done before seedlings lose vigor. Selectively killing overtopping trees with herbicides is the best way to prevent sprouting. Otherwise, sprouts from cut trees may overtop the seedlings again in a few years. If herbicides are used in young stands, careful selection of chemicals and application methods should be made to prevent damage to crop trees.

If grapevines are present before logging on good Appalachian sites and are not controlled, their density will increase considerably after cutting. The problem is most noticeable in large clearcuts, but serious grapevine problems may occur in canopy openings as small as 50 feet in diameter (Smith and Lamson 1975).

A grapevine problem in sapling stands can be largely avoided by cutting vines in mature stands from 3 to 5 years before the harvest cut (Smith and Lamson 1975; Trimble and Tryon 1974, 1976a, 1976b). Trimble and Tryon (174) found that severed vines sprout prolifically, but in closed stands sprouts begin to die. After 4 years, they found that all vines that resprouted had died along with the cut stumps. Apparently grapevine sprouts are too intolerant of shade to survive under the canopy of a well-stocked stand. Smith and Lamson (1975) reported that cutting grapevines in mature hardwood stands in West Virginia required about 2/3 man-hour per acre on steep slopes. Such costs would seem worthwhile to prevent future tree damage and even higher control costs.

Because grape seeds have long-term viability in the forest floor, preharvest cutting of grapevines will not completely eliminate vines from the new stand. However, seedling grapevines are potentially much less damaging than sprouts from mature vines. Grapevines that become established in young stands can be controlled by cutting at ground level when canopies close or when stands are 15 to 20 feet tall at about 8 to 10 years of age.

Stumps of cut vines will sprout heavily, but in a closed sapling stand sprouts will not be vigorous enough to climb back into trees. Sprouts will usually die within a few years. Trimble and Tryon (1976a, 1976b) recommend cutting all grapevines in the stand, not just vines in crop trees. If left uncut, vines in noncrop trees can and often do cross over into crowns of crop trees. Costs of cutting vines averaged about 3-1/4 man-hours per acre in sapling stands with densities ranging from 40 to 1,100 (average 500) vines per acre (Smith and McCay 1979).

Thinning Pole and Sawtimber Stands

By the time yellow-poplar stands are 20 to 25 years old, the peak rates of growth and mortality are past, and the crown canopy has closed. Some trees will continue to grow larger at the expense of others, and some mortality will continue to occur. But the major result of continued crowding as the stand matures will be a reduction in crown size and consequent slowing of diameter growth for all trees.

Thinnings that salvage suppressed trees, improve growth of residual trees, increase the yield of high-value timber products, and shorten rotations are the essence of intermediate stand management (fig. 28). The four important aspects of thinning in pole and immature sawtimber stands are: (1) growth of individual trees, (2) cubic-foot and board-foot growth, (3) effect on bole and wood quality, and (4) thinning regime.

Individual tree response.-A number of studies have reported response of yellow-poplar to thinning. Holsoe (1951) found that yellow-poplar responded immediately to crown release afforded by removing adjacent trees. Trees released during the growing season increased diameter growth during that same season; the heavier the release, the greater the thinning response. Wahlenberg (1952) also found that yellow-poplar stands respond quickly to thinning with the degree of response proportional to thinning intensity. Moderately thinned stands exceeded average diameter growth of unthinned stands by 0.2 inch in 10 years. Heavily thinned stands exceeded growth of unthinned stands by 0.5 inch in the same period. In West Virginia, Carve11 (1964) found combined improvement cuts and thinnings resulted in 2.9 inches diameter growth in 11 years compared to only 2.1 inches in unthinned stands. Shearin and others (1970) found that trees released very heavily in a seed-tree cut grew nearly three times as fast as unreleased trees. They concluded that yellow-poplar will respond to release over a wide range of diameter and age classes. In New Jersey, in an 18-year-old stand of mixed yellow-poplar, oak, ash, and red maple heavily thinned to a residual basal area of 35 square feet per acre, the mean stand diameter increased 2.5 inches in 15 years compared to only 1.8 inches in an unthinned stand. Yellow-poplar showed a markedly stronger growth response to thinning than did its associates (Tepper and Bamford 1959).

In a large, long-term study of the effect of stand density on growth, Beck and Della-Bianca (1975) found that yellow-poplar responded to thinning over a wide range of site quality, stand age, and tree sizes. As shown in figure **29A,** rate of diameter growth after thinning varied directly with residual basal area (appendix 4, table 43).

In a given even-aged stand, trees of all sizes and crown classes respond to thinning, but not to the same degree. Trees of intermediate crown class had a greater percentage increase in diameter growth than codominants. In turn, codominants had greater percentage increase than dominants (Beck and Della-Bianca 1975; Holsoe 1951; Wahlenberg 1952). However, even though percentage increase was less for large trees because of a lesser need for release, the large trees maintained a faster absolute rate of diameter growth than did smaller trees.

The net result of numerous thinning experiments is that individual yellow-poplar trees have an aptitude to utilize space quickly and to accelerate diameter increment. The heavier the thinning and the lower the residual density, the greater will be the individual tree response with increased diameter growth. Response will occur across a wide range of sites and stand ages, even in stands as old as 80 years that have never been previously thinned. Thinnings should be made from below in order to leave the biggest and best trees. However, smaller trees in the stand such as those intermediate in crown class

Figure 28.-A 35-year-old natural yellow-poplar stand on site 104 land in the Pisgah National Forest in northwestern North Carolina. The residual stand shown contains 64 trees per acre and 42 square feet of basal area per acre. Basal area growth for the first 5 years after thinning was 2.7 square feet per acre per year. F-529652

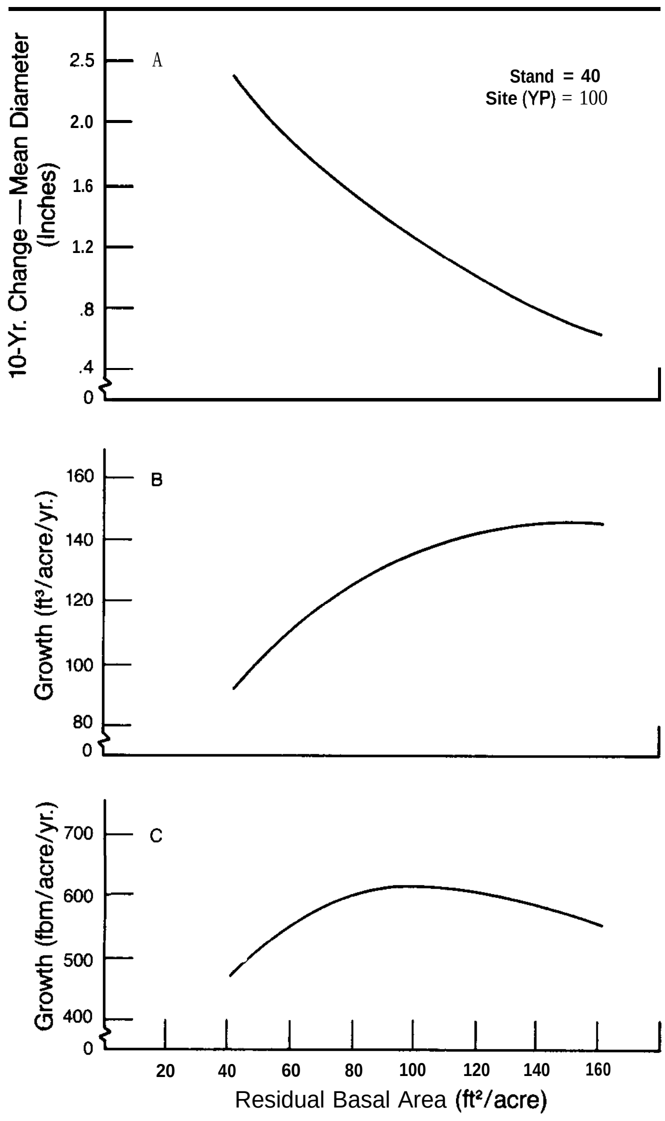

Figure 29.-Yellow-poplar responds to thinning over a wide range of site quality, stand age, and residual tree size and densities. The IO-year change in mean diameter (A) shows a strong inverse relationship with increasing residual basal area. Cubic-foot growth (B) varies directly with increasing residual basal area and culminates only at or near maximum residual density. Maximum board-foot growth (C) culminates when residual basal areas are equivalent to site index of the yellow-poplar stand.

will respond well if they are left to meet some quality or spacing need.

Cubic-foot growth.-Although individual tree growth is increased markedly by thinning to very low densities, total cubic-foot volume growth per acre will be reduced because the stand does not fully occupy the site after heavy thinning. In fact, even light commercial thinnings can reduce total cubic-foot growth and yield. In one study, the greatest cubic-foot growth rate was attained at the highest residual densities (Beck and Della-Bianca 1972) (fig. 29B); the only exception was in older stands on the poorest sites. In that case, there were maximum densities beyond which growth actually decreased. It should be noted that for all age-site combinations, cubic-foot growth was near a maximum over a relatively wide range of densities.

Board-foot growth.-Board-foot volume growth reaches a maximum rate at densities well below those which maximize cubic-foot growth (fig. 29C). Optimum density for board-foot growth varies with site quality and stand age, with maximum rates occurring at higher residual densities on the better sites. It is noteworthy that for a given site and age, board-foot growth varies little over a wide range of basal area diversities. For example, on land with site index 100 and trees at age 40, 98 percent of the maximum board-foot growth rate can be obtained at basal areas between 80 and 130 square feet per acre. At lower densities, volume is accumulated on fewer but larger trees. Thus, there is considerable leeway in manipulating stocking levels to achieve diameter growth and quality goals without sacrificing volume growth.

Bole and wood quality.-Successful efforts to produce desired quantities of wood are wasted if the quality of the bole and wood becomes undesirable through subsequent growth patterns or logging damage. Obvious aspects of bole and wood quality affected by thinning are degree of limbiness of the lower bole and changes in wood properties associated with varying rates of diameter growth.

When trees grown in dense stands are exposed to increased sunlight, epicormic branches may arise on main stems below the crown subsequent to normal crown development. If epicormic branches occur, they can be a source of degrade in lumber and veneer. Thus, sprouting as a result of thinning can lower monetary returns from increased tree size. However, sprouts are a relatively minor problem in yellow-poplar compared to other hardwood species.

In one of the earliest studies of epicormic sproutmg, Jemison and Schumacher (1948) found that cutting in 150-year-old stands increased epicormics, with the most sprouts developing in the most heavily cut stands. However, most of the epicormic sprouts were confined to upper logs and there was little reduction in lumber value. Wahlenberg (1950a) found that thinning young, second-growth stands stimulated sprouting; severity was related to degree of release. Again, sprouts were mostly confined to upper logs and to trees in the subordinate crown classes. Wahlenberg suggested that epicormic sprouts arise to restore loss of the lower crown which is suffered by crowded trees, and they are more likely to arise in the thin-barked sections of the bale.

Smith (1965), in a study of sprouting on yellow-poplar trees left adjacent to clearcut openings, reported that most sprouting occurred on upper logs and on low vigor trees in the suppressed and intermediate crown classes. He concluded that there was only a trace of degrade in the butt log of the yellow-poplars even from this drastic exposure. Della-Bianca (1972) confirmed that this is a minor problem. He found no relation between number of new sprouts and degree of thinning or residual basal area after examining trees in 34 thinned stands. He found that long sprouts present at time of thinning will increase in size and could result in increased degrade of the trees. This study, along with others, suggested that sprouting is under strong genetic control. Some trees sprout profusely before thinning and afterwards, and others without epicormic sprouts before thinning maintain a clear bole even after heavy release.

All the studies that have been done on sprouting suggest that within the normal range of thinning in pole and sawtimber stands, epicormic sprouting should not be a serious or even minor cause of timber degrade. Vigorous dominant and codominant trees, which are most likely to be the crop trees left after thinning, show little tendency to sprout. Most of the sprouts that do develop will be on upper logs which are already of low grade because of small size and presence of prethinning epicormic sprouts. Individual trees that are inherently likely to sprout often do so before thinning and can be removed during cultural operations. Kormanik[3] suggests that sprouting, even on the lower bole, may be more prolific in young sapling stands. At this stage, bark is thin and succulent, and buds are not buried nearly as deeply as on older trees. In lightly thinned stands, crown spread soon re-forms a closed canopy in young sapling to pole-size stands. Consequently, sprouts on the lower bole are not likely to persist, and blemishes in the wood will be confined to a small core.

Regulation of growing space by thinning not only changes rate of diameter growth but may also affect various wood properties. Several studies have attempted to relate rate of diameter growth, expressed as ring width or number of rings per inch, to specific gravity, fiber length, and other wood properties of yellow-poplar. Specific gravity has been the most studied feature because of its relationship to fiber yield per unit volume, strength properties, amount of shrinkage, surface hardness, and other properties which determine suitability of wood for various uses.

As for other diffuse-pore species, rate of diameter growth has shown little or no practical effect on specific gravity and fiber length (Erickson 1949, Paul and Norton 1936, Sluder 1972, Taylor 1977, Thor and Core 1977, van Eck and Woessner 1964, Wooten and others 1973). In general, slow growth produces lower specific gravity than does fast growth. However, the range in specific gravity is rather small over a very wide range in growth rates. Increased rates of radial growth due to thinning will result in wood of slightly higher specific gravity, harder surface qualities, and more strength. However, there is little the forest manager can do through thinning to either markedly improve or degrade wood quality.

Thinning regime.-Many management objectives can be met in yellow-poplar stands by manipulating the timing of thinnings and the density of residual stands. Maximum sustained growth of individual trees, greatest yield of high-quality material, and shortest rotation can be achieved by thinnings that are begun early and repeated at 5- to 15-year intervals. The first commercial thinnings may be feasible when yellow-poplar stands are 15 to 20 years old, especially on high site-quality land. Such thinnings will typically remove 8 to IO cords per acre in trees over 4.5 inches d.b.h. (table 8).

Because of rapid basal-area growth rates in young stands, sites will again be fully occupied in 10 to 15 years, even after heavy thinning. Again, individual growth rates will diminish, and some mortality will occur. If first thinnings are light, second thinnings will be needed even sooner to avoid slowing of individual tree growth rates.

Second and subsequent thinnings should leave higher residual basal areas than the first thinning, and thinning intervals should be lengthened because basal-area growth rates slow appreciably as stand age increases. Table 8 shows recommended ranges of residual basal area by age and site for use when the thinning objective is to grow large, high-quality trees. As a rule of thumb, board-foot volume growth is maximized by that residual basal area which approximates stand site index in value in yellow-poplar stands 40 years and older. Lower levels of basal area shown in table 8 will produce 95 percent or more of maximum possible board-foot growth. If short rotations or very fast diameter growth of individuals are desired, one should thin to levels approximating the low end of the range.

Table ***L-Recommended residual basal areas to maximize board-foot growth and accelerate diameter growth of yellow-poplar'***

Age	Site Index 80	90	100	110	120
	ft²/acre				
25	—	45-65[2]	50-75	55-80	60-85
30	45-60	50-70	55-80	60-90	65-95
35	50-70	55-80	60-90	65-100	70-105
40	55-80	60-90	65-100	70-110	75-115
45	60-85	65-95	70-105	75-115	80-120
50	65-90	70-100	75-110	80-120	85-125
55	70-90	75-100	80-110	85-120	90-125
60	70-90	75-100	80-110	85-120	90-125

'Includes all trees 5 inches d.b.h. and larger.
Source: Beck and Della-Bianca (1975).
'Residual basal area at upper end of range will maximize board-foot growth after thinning. Basal area at the lower end of range will produce approximately 95 percent or more of potential board-foot growth while concurrently accelerating rate of diameter growth.

Tables and figures in appendix 4, and accompanying equations, can be used to project stand growth and yield for a variety of residual densities and to establish thinning regimes that will meet desired management objectives.

Fertilization

Yellow-poplar seedlings respond to fertilization under field conditions and in the greenhouse. The most consistent and greatest response has been to nitrogen, with additional response

'Personal correspondence from Paul P. Kormanik. USDA Forest Service, Southeastern Forest Experiment Station, Athens, Georgia, April 29, 1976.

to phosphorous in the presence of added nitrogen. The best response has been on the poorest sites where need is apparently greatest. Fertilization has most often improved height growth with a lesser effect on diameter growth. All fertilization effects have been relatively short lived; generally, the major growth effect occurs within the first 3 to 5 years after application.

Greenhouse studies have shown that growth in height and gain in weight of seedlings was positively related to both nutrient and foliar concentrations of N, P, and Ca (Chapman 1933, Finn 1966, Ike 1968, Madgwick 1971). The nutrient studies also showed that there are optimum solution concentrations of N, and consequently, foliar nutrient concentrations that give maximum growth. For example, Chapman (1933) applied N in the form of ammonium nitrate at rates of 0 to 400 pounds per acre. Maximum gain in weight of seedlings occurred at 100 pounds per acre; weight gain decreased above and below that level. Madgwick (1971) too showed that there was an optimum concentration of nitrogen, with slower growth rates above and below the optimum.

In field studies, seedlings have responded strikingly to additions of N and to some extent to P and K. In one case, diammonium phosphate (20-52-o) was applied at the rates of 0, 250, 500, and 1,000 pounds per acre on a well-drained bottomland site known to be low in N, P, and K by agricultural standards (Broadfoot and Ike 1968; Ike 1962; McAlpine 1959b, 1959c). After 4 years the seedlings given 250 pounds per acre were only slightly taller than unfertilized seedlings. But the seedlings fertilized at the rate of 500 and 1,000 pounds per acre were 2 and 2.5 times as tall as controls, respectively. The most heavily fertilized seedings were 10.2 feet tall compared to 4.1 feet tall for unfertilized controls. Broadfoot and Ike (1968) determined that N was the key element for increased growth in this study. Trees fertilized with N plus P grew only slightly faster than those given N alone. In the Tennessee Valley, seedlings given N at the rate of 300 pounds per acre were 40 percent taller than controls after 5 years and only 16 percent taller after 9 years; seedlings given 600 pounds per acre were 70 percent taller than controls after 5 years and only 43 percent taller after 9 years (Buckley and Farmer 1974; Farmer and others 1970). On an old-field site in West Virginia, seedlings given 500 pounds N per acre were 43 percent taller (2.1 vs. 1.5 feet) than controls after 2 years. Seedlings fertilized less heavily grew less well.

Probably the best demonstration of growth response to heavy applications of N was reported by van de Werken and Warmbrod (1969). They applied N at the rates of 0, 60, and 120 pounds per acre every year for 8 years to small yellow-poplars (initially 8 to 10 feet tall). Trees receiving heaviest application of N (a total of 960 pounds per acre) were 24.4 feet tall and 5.4 inches in diameter after 8 years compared to 14.3 feet and 2.2 inches for controls. Trees that received a total of 480 pounds N per acre over the I-year period were intermediate in size within the limits of the above figures.

Growth response of seedlings has varied with site; the best response occurred on the poorest sites. In one study, application of 13-13-13 at 1,000 pounds per acre gave a 25-percent increase in 5-year height growth on a moderately eroded upland soil. On a severely eroded site, the same treatment gave a 40-percent increase in height growth (Baker and Blackmon 1977; Blackmon and Broadfoot 1970). Buckner and Maki (1977) reported that height of fertilized seedlings after 7 years was 90 percent greater than that of controls on a good old-field site. But on a somewhat better cutover site, height of fertilized seedlings was only 42 percent greater than controls. Francis (1977) reported even more striking differences in response to the application of 150 pounds N and 100 pounds P per acre on the Cumberland Plateau. Fertilized seedlings grew 28 times more in height than did controls on an undisturbed Hartsells soil. But on an adjacent plot with the topsoil removed to the B horizon, fertilized seedlings grew 6.1 times more than controls in the first year.

Despite all the evidence on response to fertilization, there are no good guidelines as to when, where, and how to fertilize yellow-poplar seedlings. Ike (1968) proposed some guides based on foliar analysis as to when a response to nitrogen might be expected. But, just how much response to nitrogen might be expected in a given case, or what other elements might be needed, is unknown. Methods of application have received little attention. But in most of the experimental trials, broadcast application was used with apparent success.

It has been suggested that fertilization of seedlings might aid in getting yellow-poplar established and into a better competitive position. However, the long-term effect of fertilization on yield of yellow-poplar and its attendant economic impact is at best nebulous.

Pole- and sawtimber-size stands of yellow-poplar have shown positive growth response to fertilization across a variety of sites. However, the economic returns are questionable. As was the case with seedlings, older stands have responded most vigorously and consistently to nitrogen applied at high rates. Application of a balanced fertilizer (336 pounds per acre N, 73 pounds per acre P, and 139 pounds per acre K) to a 20-year-old plantation on a nutrient-deficient site in Michigan resulted in 100 percent more height growth, 85 percent more diameter growth, and 200 percent more volume growth per acre over a 5-year period than on adjacent unfertilized areas (Finn and White 1966). Nitrogen and potassium without phosphorous gave results almost as good. But nitrogen alone was nearly as effective in promoting growth. Fertilization of pole-size stands in New York (Mitchell 1971; Mitchell and Chandler 1939) on glacial tills known to be low in nitrogen resulted in positive response to N but no response to P and K. Radial growth of yellow-poplar was increased by more than 100 percent by adding N at the rate of 300 to 800 pounds per acre; the effect lasted from 6 to 8 years.

Applying 300 pounds per acre N to a series of 20- to 75-year-old stands in the Tennessee Valley resulted in a doubling of basal-area increment over a 5-year period (Farmer and others 1970). When 66 pounds per acre P, were added to the 300 pounds per acre N, the basal-area growth rate increased by 2.5 times over that of unfertilized trees. Most of the growth response occurred the first 3 years after the application. Buckner (1972) found that both diameter and height growth in mature stands could be increased significantly by a heavy application of fertilizer. First-year diameter growth was almost doubled, and height growth was increased by 60 percent after applying fertilizer. After the third growing season, however, there was no detectable effect of fertilizer on growth. In West Virginia, on a good yellow-poplar site, 600 pounds per acre N-applied as urea 2 successive years at 300 pounds per year-increased average annual and 7-year cumulative basal-area growth of yellow-poplar by 36 percent over unfertilized controls (Auchmoody and Smith 1977; Lamson 1978). Seven-year volume growth after the urea application was estimated as increased by almost 30 percent-from 175 cubic feet per acre to 228. In the Tennessee Valley, sawtimber ıds receiving 300 pounds per acre N had a board-foot volume increase of 5.2 percent per year over controls for a 5-year period (Farmer and others 1978). Comparable unfertilized stands increased in board-foot volume by 4.2 percent per year.

In one study where combinations of several elements. were tested at varying rates of application, the results failed to define optimum combinations or rates of application (Vimmerstedt and Osmund 1970). However, heavy application of nitrogen gave the greatest and most consistent response.

Although the effects of nitrogen on growth of sawtimber stands are substantial, profitability is questionable. In one case in which an economic analysis was attempted, negative returns resulted from fertilizing mature sawtimber stands toward the end of their rotation (Farmer and others 1978). Based on a cost of $86 per acre to apply 300 pounds of nitrogen per acre, $60 per thousand board feet stumpage, and an alternative investment rate of 7% per 5 years, Farmer and others (1978) found that value increment would have to be increased two to three times more than the actual value increase in order for fertilization to become profitable. They concluded that the amount of increase in volume and value growth rates required to economically justify fertilization was probably unobtainable by current techniques.

Summary

Yellow-poplar has long been and remains one of the most important eastern hardwoods. It is widespread geographically and constitutes a large and increasing growing stock on many of our more productive sites. The wood is extremely versatile. It continues to be in demand in the furniture and millwork industries. Also, the dwindling supply of softwoods for construction-grade lumber and plywood is opening an even greater potential market for the species.

Unlike some commercially important timber species, yellow-poplar is relatively free from insect and disease pests.

Because of its seed-production characteristics and its sprouting ability, yellow-poplar is readily regenerated by natural means. On suitable sites where yellow-poplar is present, harvest of the mature stand by clearcutting, shelterwood, or small patch clearcuts will usually be sufficient to insure establishment of yellow-poplar regeneration. Sometimes, however, it may be necessary to use manual, chemical, or mechanical means to control competing vegetation left after the commercial cut. Clearcutting areas of 1 acre or more is probably the most efficient and economical means to establish yellow-poplar regeneration. Once established, its rapid early height growth allows yellow-poplar to compete successfully with associated species on good sites. In fact, because of yellow-poplar's aggressive regenerative ability, many sites occupied by other species-particularly the oaks-are currently being preempted by yellow-poplar.

With proper site selection and meticulous care in stock handling, yellow-poplar can be successfully planted with standard machine and hand-planting techniques widely used for many softwood species.

Usually little cultural care is required when yellow-poplar is in the seedling-sapling stage. An exception is the need to control grapevines on fertile mountain sites where grapevines often severely suppress yellow-poplar growth in young stands.

Yellow-poplar stands can grow to maturity and produce acceptable yields and quality logs with minimal management effort. At the same time, they are extremely responsive to management—particularly density control by thinning. Board-foot volume production of yellow-poplar stands is maximized by basal-area stocking that approximates site index. But total growth and yield remain relatively constant over a wide range of densities. Thus, yellow-poplar growth can be redistributed by light, frequent thinnings, or by heavier thinnings at longer intervals.

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1. Yellow-Poplar Soil-Site Equations by Location

Fred Russ Forest
Cassopolis, Michigan — Schomaker and Rudolph (1964)

For a 27-year-old yellow-poplar plantation:
Total tree height, in feet = 4.9
+ 28.1 (percent nitrogen, ovendry leaf weight)
Total tree height, in feet = 10.1
+ 223.3 (percent phosphorus, ovendry leaf weight)

Dobbs Memorial Forest
Terre Haute, Indiana — Tryon and others (1960)

For a 14-year-old yellow-poplar plantation:
Total height, in feet = 3.48
+ 2.33 (thickness A, horizon, in inches)
$r = 0.76$ $Sy.x_1 = 4.59$
Total height, in feet = -5.90
+ 1.61 (depth to tight subsoil, in inches)
$r = 0.63$ $Sy.x_2 = 5.47$
Total height, in feet = 5.54
+ 1.50 (depth to mottling, in inches)
$r = 0.63$ $Sy.x_3 = 5.47$

Dixon Springs Agricultural Center
Dixon Springs, Illinois — Gilmore and others (1968)

For an 18-year-old yellow-poplar plantation:
No equation given, but variation in height (100 trees) was significantly correlated with depth to fragipan ($r = 0.90$) and depth of organic matter ($r = 0.81$).

Tar Hollow State Forest
Ross County, Ohio — Munn and Vimmerstedt (1980)

Log (height), in meters = 1.51
− 6.72 (l/age, in years)
+ 0.00037 (corrected aspect, in degrees = minor angle from southwest)
+ 0.11 [log (slope position = distance from plot to ridge/slope length)]
+ 0.0048 (depth to B_2 horizon, in centimeters)
$R^2 = 0.65$ Standard error of estimate = 0.03 meter

Central States
(Southeastern Ohio, southern Indiana and Illinois, Kentucky, and Tennessee) — A uten (1945)

Height of stand, in feet = 23.06
+ 1.125 (stand age, in years)
+ 2.62 (thickness of A_1 horizon, in inches)
$R^2 = 0.70$ Standard error of estimate = 12.12 feet

New Jersey Coastal Plain — Czapowskyj'(l962)

Average height dominant and codominant yellow-poplars, in feet = 48.85
+ 1.13 (average age at breast height, in years)
+ 0.35 (clay in A horizon, in percent)
− 0.82 (hydraulic conductivity of B horizon, in inches/hour)
+ 0.68 (total available water in root zone, in inches)
− 9.70 (bulk density of C horizon, in grams/cubic centimeter)
$R^2 = 0.87$

New Jersey Coastal Plain — Phillips (1966)

Site index, in feet = 88.1
+ 0.739 (depth to mottling, in inches)
− 0.686 (depth to mottling, in inches)^3/1,000
+ 0.555 (percent clay in subsoil)
− 0.140 (percent clay in subsoil)^3/1,000
+ 3.558 (1) For poor bottomland sites
(2) For mid- and upper portions of stream-cut slopes and occasional upland sites
(3) For good bottomland sites and lower 25 percent of stream-cut slopes
− 1.288 (36 inches minus depth to tight subsoil, in inches)
− 18.374 (0) If tight subsoil is less than 36 inches from the soil surface
(1) If tight subsoil is 36 inches or more from the soil surface
$R^2 = 0.67$ Standard error of estimate ± 5.5 feet

Durham, North Carolina — Metz (1947)

For yellow-poplar on alluvial soils:
Site index, in feet = 110.11
− 101.0/(thickness of A horizon, in inches)
− 1.98 (imbibitional water value)

North Carolina-Lower Piedmont — Hocker (1953

Site index, in feet = 74.88
+ 0.7163 (thickness of A horizon, in inches)

Virginia and Carolinas—
Piedmont Uplands — Della-Bianca and Olson (1961)

Logarithm of total height = 0.42027
− 6.02173/(total age, in years)
+ 0.00098 (slope position, percent distance from ridge = 0 to stream = 100)
+ 0.00146 (percent organic matter in A_1 horizon × thickness of A, horizon, in inches)
+ 0.40356/(thickness of total A horizon, in inches)
+ 0.00011 (percent sand in A_2 horizon × thickness of total A horizon, in inches)
+ 0.04114 (latitude, in degrees and hundredths)
$R^2 = 56.5$

Georgia Blue Ridge Mountains — Ike and Huppuch (1968)

Logarithm of total height = 1.92943
- 7.65069/(total age, in years)
+ 0.00027 (elevation, feet above sea level to nearest 20 feet)
+ 0.00032 (slope position, percent distance from ridge = 0 to stream = 100)
+ 0.00044 (basal area, square feet per acre to nearest 20 square feet)

If sheltered cove site, ***add 0.02889*** to A = 1.92943
If ridge site, ***subtract 0.02889*** from A
If Tusquittee soil, ***add 0.02666*** to A
If Burton soil, ***add 0.05332*** to A
R^2 = 0.71 Standard error of Y = 0.04080

Flat Top Experimental Forest
Birmingham, Alabama — Schomaker (1958)

For 2-year-old yellow-poplar plantation:
Total tree height, in feet = - 1.73
+ 0.26 (soil moisture, in percent ovendry weight)
Correlation coefficient = 0.823

Ames Plantation
Grand Junction, Tennessee — Hebb (1962)

Site index, in feet = 41.2
+ 5.3 (slope position)
1 Ridge
2 Upper slope
3 Middle slope
4 Lower slope
5 Terrace
6 Bottom
+ 2.3 (aspect)
1 South
2 Southwest
3 Southeast
4 West
5 No slope
6 East
7 Northwest
8 Northeast
9 North
+ 0.2 (depth to mottling, in inches)

2. Tree Volume and Weight Tables for Yellow-Poplar

Volume Tables

Tables 9-13 for tree volume are based on measurements of 336 trees felled in the mountains of Georgia, North Carolina, Tennessee, and Virginia (Beck 1963, 1964). The sample trees ranged from 1 to 30 inches d.b.h. and from 10 to 138 feet in total height. Equations for volume computations are:

Total cubic-foot volume outside bark =
$0.0025\ D^2H - 0.0028$ (table 9).
Cubic-foot volume outside bark to 4-inch top (o.b.) =
$0.0024\ D^2H - 0.6417$ (table 10).
Cubic-foot volume outside bark to 8-inch top (o.b.) =
$0.0024\ D^2H - 5.3000$.
Cubic-foot volume inside bark to 4-inch top (o.b.) =
$0.0020\ D^2H - 0.6837$ (table 11).
Cubic-foot volume inside bark to 8-inch top (o.b.) =
$0.0020\ D^2H - 5.1000$.
Board-foot : cubic-foot ratio =
$6.1670 + 8.4641\ D/H - 249.2550\ {}^1/H$ (table 12).

Where D is diameter at breast height in inches and H is total tree height in feet.

The equations for 4- and 8-inch top-diameter limits are related by constant values. Therefore, volume o.b. and i.b. to I-inch top may be obtained by subtracting constant values from tables 10 and 11, respectively. Board-foot volumes in table 13 were obtained by applying the ratios from table 12 to cubic volume (o.b.) for 8-inch top.

Table *9.-Total cubic-foot volumes for natural* ***yellow-poplar***[1]

D.b.h. (inches)	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135
	Total tree height (feet) — *Cubic feet*																								
1	0.03	0.05	0.06	0.07																					
2	0.15	0.20	0.25	0.30	0.35	0.40																			
3			0.56	0.67	0.78	0.90	1.01																		
4				1.2	1.4	1.6	1.8	2.0	2.2	2.4															
5					2.2	2.5	2.8	3.1	3.4	3.8	4.1	4.4													
6							4.0	4.5	5.0	5.4	5.8	6.3	6.8	7.2											
7							5.5	6.1	6.7	7.4	8.0	8.6	9.2	9.8	10.4	11.0	11.6	12.2							
8								8.0	8.8	9.6	10.4	11.2	12.0	12.8	13.6	14.4	15.2	16.0	16.8						
9									11.1	12.2	13.2	14.2	15.2	16.2	17.2	18.2	19.2	20.2	21.2						
10										15.0	16.2	17.5	18.8	20.0	21.2	22.5	23.8	25.0	26.2	21.5					
11											19.7	21.2	22.7	24.2	25.7	21.2	28.7	30.2	31.8	33.3	34.8	36.3			
12											23.4	25.2	27.0	28.8	30.6	32.4	34.2	36.0	37.8	39.6	41.4	43.2			
13											27.5	29.6	31.7	33.8	35.9	38.0	40.1	42.2	44.4	46.5	48.6	50.7	52.8	54.9	
14											31.8	34.3	36.8	39.2	41.6	44.1	46.6	49.0	51.4	53.9	56.4	58.8	61.2	63.7	
15												39.4	42.2	45.0	47.8	50.6	53.4	56.2	59.1	61.9	64.7	67.5	70.3	73.1	
16												44.8	48.0	51.2	54.4	57.6	60.8	64.0	67.2	70.4	73.6	76.8	80.0	83.2	
17														57.8	61.4	65.0	68.6	72.2	75.9	79.5	83.1	86.1	90.3	93.9	
18														64.8	68.8	72.9	77.0	81.0	85.0	89.1	93.2	97.2	101.2	105.3	109.4
19															76.7	81.2	85.7	90.2	94.8	99.3	103.8	108.3	112.8	117.3	121.8
20															85.0	90.0	95.0	100.0	105.0	110.0	115.0	120.0	125.0	130.0	135.0
21																	104.7	110.2	115.8	121.3	126.8	132.3	137.8	143.3	148.8
22																	115.0	121.0	127.0	133.1	139.2	145.2	151.2	157.3	163.4
23																		132.2	138.9	145.5	152.1	158.7	165.3	171.9	178.5
24																		144.0	151.2	158.4	165.6	112.8	180.0	187.2	194.4
25																		156.2	164.1	171.9	179.7	187.5	195.3	203.1	210.9
26																		169.0	177.4	185.9	194.4	202.8	211.2	219.7	228.2
27																			191.4	200.5	209.6	218.7	227.8	236.9	
28																				215.6	225.4	235.2	245.0	254.8	
29																					241.8	252.3	262.8	273.3	
30																					258.8	270.0	281.2	292.5	

[1] Includes wood and bark of entire stem from ground level to tree tip. Stump volume computed as a cylinder 1 foot high with a diameter equal to that at its top. Source: Beck (1963). Blocked-m area indicates range of data.

Table *l&-Merchantable cubic-foot volume outside bark (top diameter, 4 inches outside bark)'*

D.b.h. (inches)	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135
	Total tree height (feet) — *Cubic feet*																				
5	1.5	1.8	2.1	2.4	2.1	3.0	3.3	3.6													
6			3.2	3.7	4.1	4.5	5.0	5.4	5.8	6.3											
7			4.6	5.2	5.8	6.4	7.0	7.6	8.2	8.8	9.4	9.9	10.5	11.1							
8				7.0	7.8	8.6	9.3	10.1	10.9	11.6	12.4	13.2	14.0	14.7	15.5						
9					10.0	11.0	12.0	13.0	13.9	14.9	15.9	16.8	17.8	18.8	19.8						
10						13.8	15.0	16.2	17.4	18.6	19.8	21.0	22.2	23.4	24.6	25.8					
11							18.2	19.7	21.1	22.6	24.0	25.5	27.0	28.4	29.9	31.3	32.8	34.2			
12							21.8	23.6	25.3	27.0	28.7	30.5	32.2	33.9	35.6	37.4	39.1	40.8			
13							25.7	27.8	29.8	31.8	33.8	35.9	37.9	39.9	42.0	44.0	46.0	48.0	50.1	52.1	
14							29.9	32.3	34.6	37.0	39.3	41.1	44.0	46.4	48.8	51.1	53.4	55.8	58.2	60.5	
15								37.2	39.9	42.6	45.3	48.0	50.1	53.4	56. I	58.8	61.5	64.2	66.9	69.6	
16								42.4	45.4	48.5	51.6	54.7	57.7	60.8	63.9	66.9	70.0	73.1	76.2	79.2	
17								41.9	51.4	54.8	58.3	61.8	65.2	68.7	72.2	75.6	79.1	82.6	86.1	89.5	
18										61.6	65.4	69.3	73.2	77.1	81.0	84.9	88.8	92.7	96.6	loo.4	104.3
19										68.7	73.0	17.3	81.7	86.0	90.3	94.7	99.0	103.3	107.7	112.0	116.3
20											81.0	85.8	90.6	95.4	100.2	105.0	109.8	114.6	119.4	124.2	129.0
21													99.9	105.2	11.05	115.8	121.1	126.4	131.7	137.0	142.4
22													109.7	115.5	121.3	127.1	132.9	138.8	144.6	150.4	156.2
23														126.3	132.7	139.0	145.4	151.7	158.1	164.4	170.8
24														137.6	144.5	151.4	158.3	165.2	172.2	179.1	186.0
25														149.4	156.9	164.4	171.9	179.4	186.9	194.4	201.9
26														161.6	169.7	177.8	185.9	194.0	202.2	210.3	218.4
27															183.1	191.8	200.6	209.3	218.1	226.8	
28																206.3	215.7	225.2	234.6	244.0	
29																	231.5	241.6	251.7	261.8	
30																	247.8	258.6	269.4	280.2	

To obtain cubic-foot volume outside bark to an B-inch (o.b.) top diameter in trees larger than 1 1 inches d.b.h., subtract 4.7 cubic feet from tabular values. Source: Beck (1963). Blocked-m area Indicates range of oata.

Table *Il.-Merchantable cubic-foot volume inside bark (top diameter, 4 inches outside bark)'*

D.b.h. (inches)	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135
	Total tree height (feet) — Cubic feet																				
5	1 . 1	1.3	1.6	1.8	2.1	2.3	2.6	2.8													
6			2.6	2.9	3.3	3.6	4.0	4.4	4.7	5 . 1											
7			3.7	4.2	4.7	5.2	5.7	6.2	6.8	7.2	7.6	8.1	8.6	9.1							
8				5.7	6.4	7.0	7.6	8.3	8.9	9.6	10.2	10.8	11.5	12.1	12.8						
9					8.2	9.0	9.8	10.7	11.5	12.3	13.1	13.9	14.7	15.5	16.3						
IO						11.3	12.3	13.3	14.3	15.3	16.3	17.3	18.3	19.3	20.3	21.3					
11							15.0	16.3	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4			
12							18.0	19.5	20.9	22.4	23.8	25.2	26.7	28.1	29.6	31.0	32.4	33.9			
13							21.3	23.0	24.7	26.4	28.0	29.7	31.4	33.1	34.8	36.5	38.2	39.9	41.6	43.3	
14							24.8	26.8	28.7	30.7	32.6	34.6	36.6	38.5	40.5	42.4	44.4	46.4	48.3	50.3	
15								30.8	33.1	35.3	37.6	39.8	42. I	44.3	46.6	48.8	51.1	53.3	55.6	57.8	
16								35.2	37.7	40.3	42.8	45.4	48.0	50.5	53.1	55.6	58.2	60.8	63.3	65.9	
17								39.8	42.7	45.6	48.4	51.3	54.2	57.1	60.0	62.9	65.8	68.7	71.6	74.5	
18										51.2	54.4	57.6	60.9	64.1	67.4	70.6	73.8	77.1	80.3	83.6	86.8
19										57.1	60.7	64.3	67.9	71.5	75.1	78.7	82.4	86.0	89.6	93.2	96.8
20											67.3	71.3	75.3	79.3	83.3	87.3	91.3	95.3	99.3	103.3	107.3
21													83.1	87.5	91.9	96.3	100.8	105.2	109.6	114.0	118.4
22													91.3	96.1	101.0	105.8	110.6	115.5	120.3	125.2	130.0
23														105.1	110.4	115.7	121.0	126.3	131.6	136.9	142.2
24														114.5	120.3	126.0	131.8	137.6	143.3	149.1	154.8
25														124.3	130.6	136.8	143.1	149.3	155.6	161.8	168.1
26														134.5	141.3	148.0	154.8	161.6	168.3	175.1	181.8
27														145.1	152.4	159.7	167.0	174.3	181.6	188.9	
28																171.8	179.6	187.5	195.3	203.2	
29																	192.8	201.2	209.6	218.0	
30																	206.3	215.3	224.3	233.3	

'To obtain cubic-foot volume inside bark to an 8-inch (o.b.) top diameter in trees larger than 1 I inches d.b.h., subtract 4.4 cubic feet from tabular values. Source: Beck (1963). Blocked-m area indicates range of data

Table 12.—*Ratio of International IN-inch board-foot volume to cubic-foot volume' for Southern Appalachian yellow-poplar (top diameter, 8 inches outside bark)*

D.b.h. (inches)	65	70	75	80	85	90	95	loo	105	110	115	120	125	130	135	140
	Total tree height (feet) — Ratio															
11	3.76	3.94	4.09	4.22	4.33	4.43	4.52	4.60	4.68	4.75	4.81	4.87				
12	3.89	4.06	4.20	4.32	4.43	4.53	4.61	4.69	4.76	4.82	4.88	4.94				
13	4.02	4.18	4.31	4.43	4.53	4.62	4.70	4.77	4.84	4.90	4.96	5.01	5.05	5.10		
14	4.16	4.30	4.42	4.53	4.63	4.71	4.79	4.86	4.92	4.98	5.03	5.08	5.12	5 16		
I5		4.42	4.54	4.64	4.73	4.81	4.88	4.94	5.00	5.05	5.10	5.15	5.19	5.23		
16		4.54	4.65	4.74	4.83	4.90	4.97	5.03	5.08	5.13	5.18	5.22	5.26	5.29		
17		4.66	4.76	4.85	4.93	5.00	5.06	5.11	5.16	5.21	5.25	5.29	5.32	5.36		
18				4.96	5.03	5.09	5.15	5.20	5.24	5.29	5.32	5.36	5.39	5.42	5.45	
															5.51	5.54
19				5.06	5.13	5.28	5.34	5.38	5.42	5.46	5.40	5.50	5.46	5.59	5.57	
21							5.41	5.45	5.49	5.52	5.55	5.57	5.59	5.62	5.64	
22							5.50	5.54	5.57	5.59	5.62	5.64	5.66	5.68	5.70	
23								5.62	5.65	5.67	5.69	5.71	5.73	5.75	5.76	
24								5.70	5.73	5.75	5.77	5.78	5.80	5.81	5.82	
25								5.79	5.81	5.82	5.84	5.85	5.87	5.88	5.89	
26								5.87	5.89	5.90	5.91	5.92	5.93	5.94	5.95	
27									5.97	5.98	5.99	5.99	6.00	6.01		
28										6.05	6.06	6.06	6.07	6.07		
29											6.13	6.13	6.14	6.14		
30											6.21	6.21	6.21	6.21		

'Ratio of board-foot volume to cubic-foot volume (o.b.) in the saw-log portion of the stem. Source: Beck (1964). Blocked-in area indicates range of data

Table 13.-*International I/l-inch board-foot volumes for Southern Appalachian yellow-poplar*[1] *(top diameter, 8 inches outside bark)*

D.b.h. (inches)	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
	Board feet															
11	51	59	67	76	84	92	101	109	118	127	135	144				
12	67	77	87	97	107	117	127	137	147	158	168	179				
13	85	97	108	120	132	144	156	168	180	193	205	217	229	242		
14	105	119	133	146	161	174	189	203	217	231	245	260	274	288		
15		144	160	176	192	208	224	241	257	273	290	306	323	339		
16		171	190	208	227	245	264	282	301	320	339	357	376	394		
17		202	222	243	264	286	307	327	348	370	391	412	433	455		
18				282	306	329	353	377	400	424	448	472	495	519	543	
19				324	351	376	404	429	456	482	509	536	562	589	615	643
20					399	428	458	487	516	546	575	604	634	663	692	
21							515	548	581	613	646	678	710	743	776	
22							578	614	650	685	721	756	792	828	864	
23								684	723	762	801	840	879	919	957	
24								758	801	844	887	928	972	I.013	1,057	
25								838	884	929	976	1,022	I.070	1,115	I.162	
26								921	972	I.022	1,071	1,121	1,171	1,221	1,272	
27									I.065	1,119	I.173	1,226	1,280	1,335		
28										1,220	1,279	1,336	1,395	1,453		
29											1.390	1,452	1,517	1,578		
30											I.510	1,577	1,644	1,711		

[1]Derived from board-foot:cubic-foot ratios. Source: Beck (1964). Blocked-m area indicates range of data

Weight **Tables**

Tables 14 and 15, respectively, give green weight of total tree wood and bark, and for total tree wood only. Green weight of total tree bark can be obtained by subtraction. Tables 16-21 give dry weight of yellow-poplar trees by component parts. Tables 14-21 are based on a sample of 39 trees

Table 14.-*Predicted weight of total tree wood and bark for yellow-poplar trees*[1]

D.b.h. (inches)	40	50	60	70	80	90	100	110	120	130	140
	Total tree height (feet)[2]										
	Pounds GREEN)										
6	218	270	321	373	424						
7	293	363	432	501	570	638					
8	378	469	559	648	737	825	913				
9		588	701	812	924	1,034	1,145	1,254			
10			858	995	1,131	1,266	1,401	1,536	1,670		
11			1,030	1,195	1,358	1,521	1,683	1,844	2,005		
12			1,218	1,412	1,605	1,798	1,989	2,180	2,370	2,559	
13			1,420	1,647	1,872	2,097	2,320	2,542	2,764	2,985	
14				1,899	2,159	2,417	2,675	2,931	3,187	3,442	3,696
15				2,168	2,465	2,760	3,054	3,347	3,639	3,929	4,219
16				2,454	2,790	3,124	3,457	3,789	4,119	4,448	4,776
17				2,757	3,135	3,510	3,884	4,257	4,628	4,998	5,366
18				3,077	3,499	3,918	4,335	4,751	5,165	5,578	5,989
19					3,882	4,347	4,810	5,271	5,730	6,188	6,645
20					4,284	4,797	5,308	5,817	6,324	6,829	7,333
21					4,705	5,268	5,830	6,388	6,945	7,501	8,054
22					5,145	5,761	6,375	6,986	7,595	8,202	8,807
23						6,275	6,943	7,609	8,272	8,933	9,592
24						6,809	7,534	8,257	8,977	9,694	10,410
25						7,365	8,149	8,931	9,709	10,485	11,259
26							8,787	9,630	10,469	11,306	12,140
27							9,448	10,354	11,256	12,156	13,053
28							10,132	11,103	12,071	13,036	13,998

[1]Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).

[2]Includes l-foot stump allowance.

[3]$\text{Log}_{10}\ Y = -0.69614 + 0.96067\ \text{Log}_{10}(D^2Th)$; Y = total tree wood and bark green weight (pounds), D = diameter at breast height (inches), Th = total tree height (feet).

in western North Carolina ranging from 6 to 28 inches d.b.h. (Clark and Schroeder 1977).

Tables 22-24 show green weight of residues left after utilization of the sawtimber portion of the stem (Clark and others 1974). Moisture content of the sawlog portion of the main stem averaged 98 percent. Therefore, dry weight of chippable residue and sawdust can be obtained by multiplying 0.505 times values in tables 22 and 23. Bark moisture content averaged 114 percent. Multiplying 0.467 times values in table 24 gives dry weight of bark residue.

The variation in specific gravity among yellow-poplar trees in the Southern Appalachians is discussed by Sluder (1972) (fig. 30).

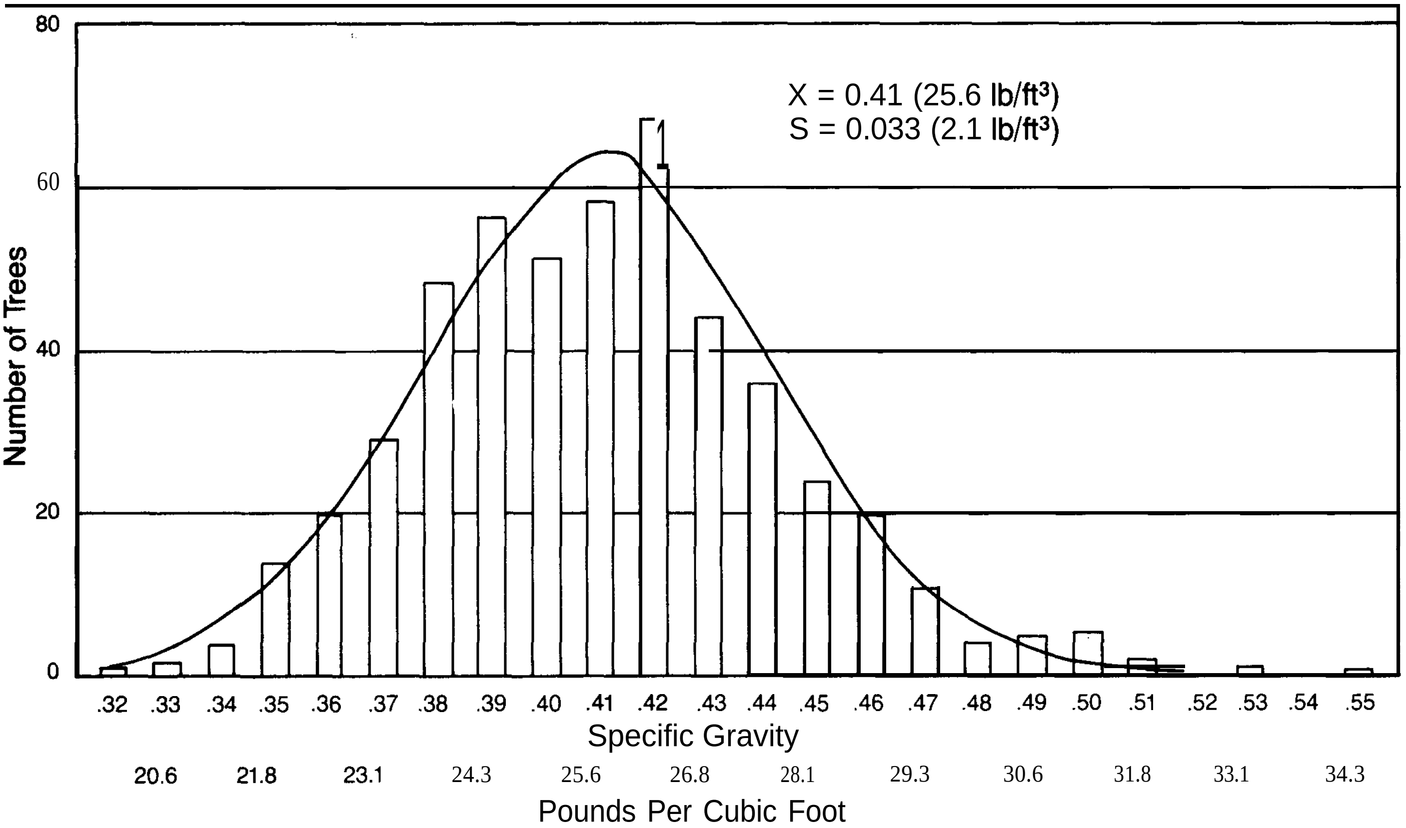

Figure W.-Frequency distribution of specific gravities of the 500 trees on the basis of rings 21 through 30. (Sluder 1972)

Table 15.—*Predicted weight of total tree excluding bark for yellow-poplar trees*[1]

D.b.h. (inches)	Total tree height (feet)[2] 40	50	60	70	80	90	100	110	120	130	140
						Pounds *GREEN*[3]					
6	173	215	257	299	340						
7	234	291	347	403	459	515					
8	303	377	450	523	595	668	740				
9		474	566	657	749	840	930	1,021			
10			695	807	919	1,031	1,142	1,253	1,363		
11			836	972	1,106	1,241	1,375	1,508	1,641		
12			990	1,151	1,310	1,469	1,628	1,786	1,944	2,101	
13			1,157	1,345	1,531	1,717	1,902	2,087	2,272	2,456	
14				1,553	1,769	1,983	2,197	2,411	2,624	2,836	3,048
15				1,776	2,023	2,268	2,513	2,757	3,001	3,244	3,486
16				2,014	2,293	2,572	2,849	3,126	3,402	3,678	3,953
17				2,266	2,581	2,894	3,206	3,518	3,828	4,138	4,448
18				2,533	2,884	3,234	3,583	3,931	4,279	4,625	4,971
19					3,204	3,593	3,981	4,368	4,753	5,138	5,522
20					3,540	3,970	4,399	4,826	5,252	5,678	6,102
21					3,893	4,365	4,837	5,306	5,775	6,243	6,710
22					4,262	4,779	5,295	5,809	6,322	6,834	7,345
23						5,211	5,773	6,334	6,893	7,452	8,009
24						5,661	6,271	6,881	7,489	8,095	8,700
25						6,128	6,790	7,450	8,130	8,764	9,419
26							7,328	8,040	8,751	9,459	10,166
27							7,887	8,653	9,417	10,180	10,941
28							8,465	9,287	10,103	10,926	11,743

[1]Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).
[2]Includes 1-foot stump allowance.
[3]$\text{Log}_{10} Y = -0.83371 + 0.97283 \text{ Log}_{10}(D^2Th)$; Y = total tree green weight (pounds) excluding bark, D = diameter at breast height (inches), Th = total tree height (feet).

Table 16.—*Predicted weight of total tree wood and bark for yellow-poplar trees*[1]

D.b.h. (inches)	Total tree height (feet)[2] 40	50	60	70	80	90	100	110	120	130	140
						Pounds DRY)					
6	93	116	140	163	187						
7	127	159	191	223	255	287					
8	166	208	250	292	334	376	418				
9		263	317	370	423	477	530	584			
10			392	458	524	590	656	722	788		
11			475	555	635	715	795	875	956		
12			566	661	757	852	948	1,044	1,139	1,235	
13			665	777	889	1,002	1,114	1,227	1,339	1,452	
14				903	1,033	1,163	1,294	1,425	1,555	1,686	1,817
15				1,038	1,187	1,337	1,487	1,638	1,788	1,939	2.089
16				1,182	1,353	1,523	1,694	1,866	2,037	2,208	2,380
17				1,336	1,529	1,722	1,915	2,109	2,302	2,496	2,690
18				1,499	1,716	1,932	2,149	2,366	2,584	2,801	3,019
19					1,914	2,155	2,397	2,639	2,882	3,124	3,367
20					2,123	2,391	2,659	2,928	3,196	3,465	3,735
21					2,342	2,638	2,934	3,231	3,527	3,824	4,121
22					2,573	2,898	3,223	3,549	3,875	4,201	4,527
23						3,170	3,526	3,882	4,239	4,595	4,952
24						3,455	3,842	4,230	4,619	5,008	5,397
25						3,751	4,172	4,594	5,016	5,438	5,860
26							4,516	4,973	5,429	5,886	6,343
27							4,874	5,366	5,859	6,352	6,846
28							5,245	5,775	6,306	6,836	7,367

[1]Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).
[2]Includes 1-foot stump allowance.
[3]$\text{Log}_{10} Y = -1.22162 + 1.00963 \text{ Log}_{10}(D^2Th)$; Y = total tree wood and bark ovendry weight (pounds), D = diameter at breast height (inches), Th = total tree height (feet).

Table *Il.-Predicted weight of total tree excluding bark for yellow-poplar trees'*

D.b.h. (inches)	Total tree height (feet)* 40	50	60	70	80	90	100	110	120	130	140
	Pounds DRY[3]										
6	77	97	117	136	156						
7	106	133	159	186	213	240					
8	139	174	209	244	280	315	351				
9		221	265	310	355	400	445	490			
10			329	384	440	495	551	607	663		
11			398	466	533	601	669	736	804		
12			475	556	636	717	798	879	959	1,041	
13			559	654	748	843	938	1,033	1,128	1,224	
14				759	870	980	1,090	1,201	1,311	1,422	1,533
15				873	1,000	1,127	1,254	1,381	1,508	1,636	1,763
16				9%	1,140	1,284	1,429	1,574	1,719	1,864	2,009
17				1,126	1,289	1,452	1,616	1,780	1,944	2,108	2,272
18				1,264	1,447	1,630	1,814	1,998	2,182	2,367	2,551
19					1,615	1,819	2,024	2,229	2,435	2,641	2,847
20					1,791	2,019	2,246	2,474	2,702	2,930	3,158
21					1,978	2,228	2,479	2,731	2,983	3,235	3.487
22					2,173	2,449	2,725	3,001	3,277	3,554	3,831
23						2,679	2,981	3,284	3,586	3,889	4,193
24						2,921	3,250	3,579	3.909	4,240	4,570
25						3,173	3,530	3,888	4,247	4,605	4,965
26							3,822	4,210	4,598	4,986	5,375
27							4,126	4,544	4,963	5,383	5,802
28							4,442	4,892	5,343	5,794	6,246

'Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).

'Includes l-foot stump allowance.

[3] $\log_{10} Y = -1.31186 + 1.01330 \log_{10}(D^2Th)$; Y = weight (pounds, ovendry) all aboveground wood excluding bark, D = diameter at breast height (inches), Th = total tree height (feet).

Table *U.-Predicted weight of wood and bark in main stem to 8-inch d. i. b. merchantable top for yellow-poplar trees*[1]

D.b.h. (inches)	Total tree height (feet)' 60	70	80	90	100	110	120	130	140
	Pounds DRY'								
12	365	435	506	579	653	728	804	881	
13	438	522	608	695	784	874	965	1,057	
14		168	720	823	928	1,035	1,143	1.252	1,362
15		723	842	963	1 086	1,211	1,337	1,465	1,595
16		838	976	1,116	1 . 2 5 9	1,403	1,550	1,698	1,847
17		962	1,121	1,282	1,445	1,611	1,779	1,949	2,121
18		1,096	1,277	1,460	1,647	1.836	2,027	2,221	2,417
19			1,444	1,652	1,863	2,077	2,293	2,513	2,734
20			1,623	1,857	2,094	2,334	2,578	2,824	3,073
21			1,815	2,075	2,340	2,609	2,881	3,157	3,435
22			2,018	2,308	2,602	2,901	3,204	3,510	3,820
23				2,554	2,880	3,211	3,546	3,885	4,228
24				2,814	3,174	3,538	3,907	4,281	4 ., 6 5 9
25				3,089	3,484	3,884	4,289	4,699	5,113
26					3,810	4,247	4,690	5,139	5,592
27					4,152	4,629	5,112	5,601	6,094
28					4,511	5,029	5,554	6,085	6,622

'Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).

[2] Includes l-foot stump allowance.

[3] $\log_{10} Y = -1.92791 + 1.14055 \log_{10}(D^2Th)$; Y = weight (pounds, ovendry) wood and bark in main stem to 8-inch d.i.b. merchantable top, D = diameter at breast height (inches), Th = total tree height.

Table 19.—*Predicted weight of wood excluding bark in main stem to g-inch d.i. b. merchantable top for yellow-poplar trees*'

D.b.h. (inches)	Total tree height (feet)[2]								
	60	70	80	90	100	110	120	130	140
					Pounds *DRY*[3]				
12	303	362	423	484	547	611	676	742	
13	365	436	509	583	659	736	814	893	
14		517	604	692	782	873	966	1,060	1,155
15		607	709	812	917	1,025	1,133	1,243	1,355
16		705	823	943	1,065	1,190	1,316	1,444	1,573
17		811	947	1,085	1,226	1,369	1,514	1,661	1,810
18		926	1,081	1,239	1,399	1,563	1,728	1,896	2,066
19			1,225	1,404	1,586	1,771	1,959	2,149	2,342
20			1,379	1,581	1,786	1,995	2,206	2,420	2,637
21			1,544	1,770	2,000	2,233	2,470	2,710	2,952
22			1,720	1,971	2,227	2,487	2,751	3,018	3,288
23				2,185	2,469	2,757	3,049	3,345	3,645
24				2,412	2,724	3,042	3,365	3,691	4,022
25				2,651	2,994	3,344	3,698	4,057	4,421
26					3,279	3,662	4,050	4,443	4,841
27					3,579	3,996	4,420	4,849	5,283
28					[redacted]	[redacted]	,808	5,275	5,748

[1]Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).
'Includes l-foot stump allowance
'Log,, Y = – 2.07644 + 1.15782 $Log_{10}(D^2Th)$; Y = weight (pounds, ovendry) wood excluding bark in main stem to I-inch d.i.b. merchantable top, D = diameter at breast height (inches), Th = total tree height (feet).

Table *20.-Predicted weight of wood and bark in branches for yellow-poplar trees'*

D.b.h. (inches)	Total tree height (feet))										
	40	50	60	70	80	90	100	110	120	130	140
						Pounds *DRY*[3]					
6	12	14	17	19	21						
7	15	19	22	25	28	31					
8	19	24	28	32	36	40	43				
9		29	34	39	44	49	53	58			
10			41	47	53	59	64	70	76		
11			49	56	63	69	76	83	89		
12			57	65	73	81	89	97	104	112	
13			65	75	84	93	102	111	120	129	
14				85	96	106	116	127	137	147	157
15				96	108	120	132	143	155	166	177
16				108	121	134	147	160	173	186	198
17				120	135	150	164	178	193	207	221
18				132	149	165	181	197	213	229	244
19					164	182	200	217	234	252	269
20					179	199	219	238	257	275	294
21					196	217	238	259	280	300	320
22					212	236	258	281	304	326	348
23						255	280	304	328	352	376
24						275	301	328	354	380	405
25						295	324	352	380	408	436
26							347	377	408	437	467
27							371	403	436	467	499
28							395	430	464	498	532

'Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).
'Includes l-foot stump allowance.
[3]Log_{10} Y = – 1.71827 + 0.88172 Log,, (D^2Th); Y = weight (pounds, ovendry) wood and bark in branches, D = diameter at breast height (inches), Th = total tree height (feet).

Table 21.—*Predicted weight of wood excluding bark in branches for yellow-poplar trees*[1]

D.b.h. (inches)	40	50	60	70	80	90	100	110	120	130	140
	Total tree height (feet)[2]										
	Pounds DRY[3]										
6	9	11	13	15	17						
7	12	15	17	20	22	25					
8	15	19	22	25	28	31	34				
9		23	27	31	35	38	42	46			
10			32	37	41	46	50	55	59		
11			38	44	49	54	59	64	69		
12			44	51	57	63	69	75	81	87	
13			51	58	65	72	79	86	93	99	
14				66	74	82	90	98	105	113	121
15				75	84	93	102	110	119	127	136
16				83	94	104	114	123	133	142	152
17				93	104	115	126	137	148	158	169
18				102	115	127	139	151	163	175	186
19					126	140	153	166	179	192	205
20					138	153	167	181	196	210	224
21					150	166	182	197	213	228	243
22					162	180	197	214	231	247	264
23						194	213	231	249	267	285
24						209	229	249	268	288	307
25						225	246	267	288	309	329
26							263	286	308	330	352
27							281	305	329	353	376
28							299	325	351	376	401

[1] Blocked-in area indicates range of data. Source: Clark and Schroeder (1977).
[2] Includes 1-foot stump allowance.
[3] $\text{Log}_{10} Y = -1.76294 + 0.86612 \text{ Log}_{10}(D^2Th)$; Y = weight (pounds, ovendry) wood excluding bark in branches, D = diameter at breast height (inches), Th = total tree height (feet).

Table 22.—*Green weight of **chippable** residue from yellow-poplar saw-log merchantable stem to d-inch d.i. b. top*[1,2]

D.b.h. (inches)	1-1/2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	6-1/2
	Merchantable tree height (number of 16-foot logs)[3]										
	Pounds										
12	278	308	337	367	397	426	456				
13	294	329	364	398	433	468	503	537			
14	311	352	392	432	473	513	553	594	634		
15	330	376	423	469	515	561	608	654	700	746	
16		403	455	508	561	613	666	718	771	824	876
17		431	490	550	609	668	728	787	847	906	965
18		460	527	594	660	727	793	860	927	993	1,060
19			566	640	714	789	863	937	1,011	1,086	1,160
20			607	689	772	854	936	1,018	1,100	1,183	1,265
21			650	741	832	922	1,013	1,104	1,194	1,285	1,376
22			696	795	895	994	1,094	1,193	1,293	1,392	1,492
23				852	961	1,069	1,178	1,287	1,396	1,504	1,613
24				911	1,029	1,148	1,266	1,385	1,503	1,621	1,740
25				973	1,101	1,230	1,358	1,487	1,615	1,744	1,872
26					1,176	1,315	1,454	1,593	1,732	1,871	2,010
27					1,253	1,403	1,553	1,703	1,853	2,003	2,153
28					1,334	1,495	1,656	1,818	1,979	2,140	2,301
29						1,590	1,763	1,936	2,109	2,282	2,455
30						1,689	1,874	2,059	2,244	2,429	2,614

[1] Blocked-in area indicates the range of data. Source: Clark and others (1974).
[2] Includes a 1-foot stump allowance.
[3] $Y = 185.56929 + 0.02570 D^2Mh$; Y = weight (pounds) chippable residue from saw-log merchantable stem to 8-inch d.i.b. top, D = diameter at breast height (inches), Mh = merchantable tree height (feet).

Table **23.**—*Green weight of sawdust from yellow-poplar saw-log merchantable stem to B-inch d.i.b. top’* [2]

D.b.h. (inches)	Merchantable tree height (number of ldfoot logs)’										
	1-1/2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	6-1/2
	Pounds										
12	107	131	154	178	202	226	250				
13	120	148	176	204	232	260	288	316			
14	134	166	199	231	264	296	328	361	393		
15	149	186	223	260	298	335	372	410	447	484	
16		207	250	292	334	377	419	462	504	546	589
17		230	278	325	373	421	469	517	565	613	661
18		254	307	361	415	468	522	576	629	683	737
19			339	398	458	518	578	638	698	757	817
20			372	438	504	571	637	703	769	836	902
21			407	480	553	626	699	772	845	918	991
22			443	523	604	684	764	844	924	1,004	1,085
23				569	657	744	832	920	1,007	1,095	1,182
24				617	712	808	903	998	1,094	1,189	1,285
25				666	770	873	977	1,081	1,184	1,288	1,391
26					830	942	1,054	1,166	1,278	1,390	1,502
27					893	1,013	1,134	1,255	1,376	1,497	1,617
28					958	1,088	1,217	1,347	1,477	1,607	1,737
29						1,164	1,304	1,443	1,582	1,722	1,861
30						1,244	1,393	1,542	1,691	1,840	1,989

‘Blocked-in area indicates the range of data. Source: Clark and others (1974).
*Includes a l-foot stump allowance.
[3] $Y = 32.15269 + 0.02071 D^2Mh$; Y = weight (pounds) sawdust from saw-log merchantable stem to 8-inch d.i.b. top, D = diameter at breast height (inches), Mh = merchantable tree height (feet).

Table 24.—*Green weight of bark residue from yellow-poplar saw-log merchantable stem to 8-inch d.i. b. top’* [2]

D.b.h. (inches)	Merchantable tree height (number of 16-foot logs)[3]										
	1-1/2	2	2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	6-1/2
	Pounds										
12	167	193	219	245	271	297	323				
13	181	212	242	273	303	334	364	394			
14	196	232	267	302	338	373	408	444	479		
15	213	253	294	334	375	416	456	497	537	578	
16		276	322	369	415	461	507	553	600	646	692
17		301	353	405	457	509	562	614	666	718	770
18		327	385	444	502	561	619	678	736	794	853
19			420	485	550	615	680	745	810	875	941
20			456	528	600	672	744	816	889	961	1,033
21			494	573	653	732	812	891	971	1,050	1,130
22			533	621	708	795	883	970	1,057	1,144	1,232
23				670	766	861	957	1,052	1,147	1,243	1,338
24				722	826	930	1,034	1,138	1,242	1,346	1,450
25				776	889	1,002	1,115	1,227	1,340	1,453	1,566
26					955	1,077	1,199	1,321	1,442	1,564	1,686
27					1,023	1,154	1,286	1,417	1,549	1,680	1,812
28					1,094	1,235	1,376	1,518	1,659	1,801	1,942
29						1,318	1,470	1,622	1,774	1,925	2,077
30						1,405	1,567	1,730	1,892	2,054	2,217

[1] Blocked-in area indicates the range of data. Source: Clark and others (1974).
‘Includes a l-foot stump allowance.
[3] $Y = 85.79319 + 0.02255 D^2Mh$; Y = weight (pounds) bark residue from saw-log merchantable stem to 8-inch d.i.b. top, D = diameter at breast height (inches), Mh = merchantable tree height (feet).

3. Yields of Unthinned Yellow-Poplar Stands

The diameter distribution and volume yield for natural, unthinned stands are based on measurements of stands in the mountains of Virginia, North Carolina, and Georgia, and represent a wide range of ages, site indexes, and stocking levels.

Derivation of the diameter distributions in tables 25-29 are fully described by McGee and Della-Bianca (1967). Tree heights by diameter classes in tables 30-34 and yields by age, site index, and number of trees per acre in tables 35-38 are described more fully by Beck and Della-Bianca (1970).

Stand volumes by age, site index, and basal area stocking tables 39-42, previously unpublished, were derived from the above described data set. Equations for the stand volume estimates in tables 39-42 are:

Table 39

$$\text{Log (TCFV)} = 2.06259 - 0.39144\ \mathbf{100/S} - 0.08332\ \mathbf{100/A} + 1.05298\ \mathbf{Log_{10}}\ \text{BA}$$

$R^2 = 0.99$
Std. Error = 0.0182

Table 40

$$\text{Log}\ \mathbf{(100{*}OBV/TCFV)} = 1.80258 + 0.03718\ \mathbf{S/100} + 0.02370\ \mathbf{BA/100} - 0.01059\ \mathbf{100/A} + 0.08605\ (\text{Log}_{10}\ \text{BA})$$

$R^2 = 0.92$
Std. Error = 0.0032.

Table 41

$$\text{Log}\ \mathbf{(100{*}IBV/TCFV)} = 1.66607 + 0.04826\ \mathbf{S/100} - 0.03151\ \mathbf{BA/100} - 0.01373\ \mathbf{100/A} + 0.11400\ \text{Log}_{10}\ \text{BA}$$

$R^2 = 0.92$
Std. Error = 0.0042

Table 42

$$\text{Log (BFV/TCFV)} = 0.45860 + 1.80497\ \mathbf{S/100} - 0.59978\ \mathbf{100/A} - 1.17960\ \mathbf{A{*}S/10{,}000}$$

$R^2 = 0.86$
Std. Error = 0.1313

Where TCFV = Total cubic-foot volume of wood and bark
OBV = Cubic-foot volume of wood and bark to 4-inch top diameter
IBV = Cubic-foot volume of wood only to **4-inch** top diameter
BFV = International **1/4-inch** board-foot volume
s = Site index (feet)
A = Stand age (years)
BA = Stand basal area (square feet/acre)

In tables 30-34, derived by the equation footnoted in each table, the following abbreviations apply:

- Log = Common logarithm
- H_c = Average height of dominant and codominant trees, in feet
- H = Total height in feet of a tree of diameter D in inches
- Dmax = Maximum diameter occurring in the stand
- T = Number of trees per acre
- A = Age of stand in years
- S = Site index

Table **25.—*Diameter*** *dktributions for pure natural yellow-poplar stands by age and stand density per acre on site index 90'*

Total trees (No.)	Basal area (ft²)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Number of trees per diameter class (inches)																									
Age *20*																											
100	33	15	21	19	16	12	9	5	3																		
150	38	48	37	25	17	11	7	4	1																		
200	43	95	47	26	15	9	5	2	1																		
250	48	145	53	26	14	7	4	1	—																		
300	54	194	57	26	13	6	3	1	—																		
350	61	242	61	26	12	6	2	1	—																		
Age *30*																											
100	51	3	8	13	14	15	14	12	10	7	4																
150	61	12	23	25	24	21	17	13	9	5	1																
200	70	29	39	36	30	24	18	13	8	3	—																
250	77	51	56	46	35	26	18	11	6	1	—																
300	84	77	72	54	39	27	17	10	4	—	—																
350	90	105	87	62	42	28	17	8	1	—	—																
Age *40*																											
50	44	—	—	1	2	4	5	6	6	7	7	6	4	2													
100	67	1	4	8	10	12	12	12	12	11	9	6	3	—													
150	82	5	14	18	20	20	18	16	14	11	8	5	1	—													
200	91	14	27	30	29	26	22	19	15	10	6	2	—	—													
250	98	28	42	42	37	31	25	19	14	9	3	—	—	—													
300	106	44	59	53	44	35	27	19	13	6	—	—	—	—													
350	113	62	75	64	51	39	28	19	10	2	—	—	—	—													
Age *50*																											
50	55	—	—	1	1	2	3	4	5	5	6	6	6	5	4	2											
100	82	1	3	5	7	9	10	11	11	10	10	9	7	5	2	—											
150	98	4	10	14	16	17	17	16	14	13	11	9	6	3	—	—											
200	110	10	21	25	25	24	22	19	17	14	11	8	4	—	—	—											
250	117	21	34	36	34	30	26	22	18	14	10	5	—	—	—	—											
300	123	34	49	48	42	36	30	23	18	12	7	1	—	—	—	—											
Age *60*																											
50	68	—	—	—	1	2	2	3	3	4	4	5	5	5	5	5	4	2									
100	98	1	2	4	6	7	8	9	9	9	9	9	8	7	6	4	2	-									
150	116	3	8	12	14	14	14	14	14	13	12	10	9	7	5	1	—	—									
200	125	9	19	22	22	22	20	19	16	14	12	10	8	5	2	—	—	—									
250	130	19	31	33	31	28	25	22	18	15	12	9	6	1	—	—	—	—									
Age *70*																											
50	80	—	—	—	1	1	2	2	3	3	3	4	4	4	4	5	4	4	4	2							
100	114	1	2	4	5	6	7	7	7	8	8	8	7	7	7	6	5	4	1	—							
150	132	3	8	11	12	13	13	12	12	11	11	10	9	8	7	5	4	1	—	—							
200	141	9	18	20	20	19	18	17	15	14	12	11	9	8	6	4	—	—	—	—							
250	146	19	30	30	28	26	23	20	17	15	13	11	9	6	3	—	—	—	—	—							

'Source: McGee and Della-Bianca (1967).

Table 26.—*Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 100*[1]

Total trees (No.)	Basal area (ft²)	Number of trees per diameter class (inches): 5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Age 20																											
100	35	13	20	19	16	12	9	6	4	1																	
150	41	43	36	26	18	12	8	5	2	—																	
200	46	84	48	29	18	11	6	3	1	—																	
250	52	129	56	30	17	10	5	2	1	—																	
300	58	173	63	31	17	9	5	2	—	—																	
350	65	214	71	34	17	9	4	1	—	—																	
Age 30																											
100	56	2	7	11	13	14	14	12	11	8	6	2															
150	68	9	20	23	22	20	18	14	11	8	4	1															
200	77	23	35	34	30	25	20	15	10	6	2	—															
250	87	40	50	44	36	28	21	15	10	5	1	—															
300	94	60	66	54	42	31	22	15	8	2	—	—															
350	103	79	81	64	48	34	23	14	7	—	—	—															
Age 40																											
50	48	—	—	1	2	3	4	5	6	6	6	6	6	4	1												
100	74	1	4	6	9	10	11	11	11	11	9	8	6	3													
150	91	4	11	16	18	18	17	16	15	13	10	8	4	—	—												
200	104	11	22	26	27	25	22	20	16	13	10	6	2	—	—												
250	113	21	35	38	35	31	27	22	17	13	8	3	—	—	—												
300	122	32	49	49	43	37	30	24	18	12	6	—	—	—	—												
350	131	44	63	60	52	43	34	25	17	10	2	—	—	—	—												
Age 50																											
50	62	—	—	1	1	2	2	3	4	4	5	5	6	6	5	4	2										
100	95	1	2	4	6	7	8	9	10	10	10	9	8	7	6	3	—										
150	113	3	8	12	13	15	15	15	14	13	12	10	9	7	4	—	—										
200	127	8	17	21	22	22	21	19	17	15	13	11	8	5	1	—	—										
250	137	14	28	31	31	29	26	23	20	17	14	10	6	1	—	—	—										
300	147	23	39	42	39	36	31	27	22	18	13	8	2	—	—	—	—										
Age 60																											
50	76	—	—	—	1	1	2	2	3	3	4	4	4	5	5	5	4	4	3								
100	115	—	2	3	5	6	7	7	8	8	8	8	8	8	7	6	5	4	-								
150	137	2	6	10	11	12	13	13	13	12	11	11	10	9	7	6	4	—	—								
200	150	6	14	18	19	19	19	18	16	15	14	12	10	9	7	4	—	—	—								
250	159	13	24	27	27	26	24	22	20	17	15	13	10	8	4	—	—	—	—								
Age 70																											
50	92	—	—	—	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3	1					
100	136	—	2	3	4	5	5	6	6	7	7	7	7	7	7	6	6	6	5	4	—	—					
150	157	2	6	9	10	11	11	11	11	11	10	10	9	9	8	7	6	6	3	—	—	—					
200	169	7	14	16	17	17	17	16	15	14	13	12	10	9	8	7	6	2	—	—	—	—					
250	179	13	23	25	25	23	22	20	18	16	15	13	11	10	8	6	2	—	—	—	—	—					

Source: McGee and Della-Bianca (1967).

Table 27.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 110'

Total trees (No.)	Basal area (ft²)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Number of trees per diameter class (inches)																									
Age 20																											
100	37	11	18	18	16	13	10	7	5	2																	
150	44	38	35	26	19	13	9	6	3	1																	
200	50	74	48	30	20	13	8	5	2	—																	
250	56	113	58	34	20	12	7	4	2	—																	
300	63	150	68	37	21	13	7	3	1	—																	
350	72	184	78	41	23	13	7	3	1	—																	
Age 30																											
100	60	2	6	10	12	13	13	12	11	9	7	4	1														
150	74	8	17	20	21	20	18	15	12	10	6	3	—														
200	86	18	30	32	29	25	21	17	13	9	5	1	—														
250	97	31	44	42	36	30	24	18	13	8	4	—	—														
300	107	45	59	52	43	35	26	19	13	7	1	—	—														
350	117	59	72	63	51	39	29	20	12	5	—	—	—														
Ane 40																											
50	54	—	—	1	2	2	3	4	5	5	6	6	6	5	4	1											
100	83	1	3	5	7	9	10	10	11	10	10	9	7	5	3	—											
150	104	3	9	13	15	16	16	16	15	13	12	10	7	4	1	—											
200	117	8	18	23	24	24	22	20	18	15	12	9	6	1	—	—											
250	129	15	29	33	33	30	27	24	20	16	12	8	3	—	—	—											
300	142	23	40	43	41	37	32	27	22	17	12	6	—	—	_	_											
350	154	30	51	53	50	44	38	31	24	17	10	2	—	—	—	—											
Age 50																											
50	70	—	—	—	1	1	2	3	3	4	4	5	5	5	5	5	4	3									
100	109	—	2	3	5	6	7	8	8	9	9	9	8	8	7	6	4	1									
150	131	2	6	9	12	13	13	14	13	13	12	11	10	9	7	5	1	—									
200	148	5	13	17	19	20	20	19	17	16	14	13	11	8	6	2	—	—									
250	161	10	22	26	27	27	25	23	21	19	16	14	11	7	2	—	—	—									
300	175	16	30	35	35	34	31	28	24	21	18	14	10	4	—	—	—	—									
												3	4	4	4	4	5	4	4	4	2						
100	133	—	1	2	4	5	6	6	7	7	7	8	8	7	7	7	6	6	4	2	—						
150	161	2	5	8	9	10	11	11	11	11	11	11	10	9	9	8	7	5	2	—	—						
200	177	4	11	15	16	17	17	16	16	15	14	13	12	10	9	8	6	1	—	—	—						
250	190	9	19	22	24	23	22	21	20	18	16	15	13	11	9	7	1	—	—	—	—						
Age 70																											
50	109	—	—	—	—	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3				
100	159	—	1	2	3	4	5	5	6	6	6	6	6	6	7	6	6	6	6	5	5	3	—				
150	184	2	5	7	8	9	9	10	10	10	10	9	9	9	8	8	7	7	6	5	2	—	—				
200	209	4	10	13	14	15	15	14	14	13	13	12	11	10	10	9	8	7	6	2	—	—	—				
250	220	9	17	20	21	21	20	19	18	16	15	14	13	12	11	9	8	6	1	—	—	—	—				

Source: McGee and Della-Bianca (1967).

Table 28.—*Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 120*[1]

Total trees (No.)	Basal area (ft²)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Number of trees per diameter class (inches)																									
Age 20																											
100	39	10	17	17	16	13	10	8	5	3	1																
150	46	33	33	26	20	15	10	7	4	2	—																
200	54	64	47	32	22	15	10	6	3	1	—																
250	62	97	59	37	23	15	9	6	3	1	—																
300	70	128	70	42	26	16	10	6	2																		
350	80	154	82	48	29	18	11	6	2	—	—																
Age 30																											
100	67	1	5	8	10	12	12	12	11	10	8	6	4	1													
150	82	6	15	18	19	19	18	16	13	11	8	5	2	—													
200	95	14	26	29	28	25	22	18	15	11	8	4	—	—													
250	108	24	38	39	35	31	26	21	16	11	7	2	—	—													
300	121	34	50	49	43	36	30	23	17	11	6	1	—	—													
350	134	42	62	59	52	43	34	26	18	11	3	—	—	—													
Age 40																											
50	59	—	—	1	1	2	3	3	4	5	5	5	6	5	5	4	1										
100	93	1	2	4	6	8	9	9	10	10	9	9	8	7	5	3	—										
150	114	2	8	11	14	15	15	15	14	13	12	11	9	7	4	—	—										
200	133	6	15	19	21	22	21	20	18	16	14	12	9	6	1	—	—										
250	148	11	23	28	29	29	27	24	22	19	15	12	8	3	—	—	—										
300	163	16	32	37	38	36	32	29	25	21	16	12	6	—	—	—	—										
350	180	20	40	46	46	43	39	34	29	23	17	11	2	—	—	—	—										
Age 50																											
50	9	—	—	—	1	1	1	2	3	3	3	4	4	5	5	5	5	4	3	1							
100	122	—	1	3	4	5	6	7	8	8	8	8	8	8	7	7	6	5	1	—							
150	149	1	5	8	10	11	12	12	12	12	12	11	11	10	9	7	5	2	—	—							
200	172	4	10	14	16	17	18	17	17	16	15	14	12	11	9	7	3	—	—	—							
250	188	7	17	21	24	24	23	22	21	19	18	16	14	11	8	4	—	—	—	—							
300	206	10	23	29	31	31	29	28	26	23	20	18	15	11	6	—	—	—	—	—							
Age 60																											
50	98	—	—	—	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3					
100	154	—	1	2	3	4	4	5	6	6	6	7	7	7	7	7	7	6	6	5	4	—					
150	185	1	4	6	8	9	10	10	10	10	10	10	10	9	9	9	8	7	6	4	—	—					
200	208	3	8	12	14	14	15	15	15	14	14	13	12	11	11	10	8	7	4	—	—	—					
Age 70																											
50	121	—	—	—	—	—	1	1	1	1	2	2	2	3	3	3	3	4	4	4	4	4	4	4			
100	189	—	12		2	3	3	4	4	5	5	5	6	6	6	6	6	6	6	6	6	5	5	2			
150	223	1	3	5	7	7	8	8	9	9	9	9	9	8	8	8	8	8	7	7	6	5	1	—			

Source: McGee and Della-Bianca (1967).

Table 29.-*Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 130*[1]

Total trees (No.)	Basal area (ft²)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Number of trees per diameter class (inches)																									
Age 20																											
100	41	9	16	16	15	13	11	8	6	4	2																
150	50	29	31	26	20	15	11	8	6	3	1																
200	59	55	45	33	23	17	11	8	5	2	1																
250	67	82	58	39	27	18	12	8	4	2	—																
300	77	106	71	46	31	20	13	8	4	1	—																
350	89	125	83	54	36	23	15	9	4	1	—																
Age 30																											
100	73	1	4	7	9	11	11	11	11	10	9	7	6	3													
150	91	4	12	16	18	18	17	16	14	12	10	7	5	1													
200	105	11	22	26	26	25	22	19	16	13	10	7	3	—													
250	121	18	32	35	34	31	27	23	19	14	10	6	1	—													
300	137	24	42	45	42	37	32	26	21	16	10	5	—	—													
350	154	29	51	54	50	44	38	31	24	17	10	2	—	—													
Age 40																											
50	65	—	—	—	1	2	2	3	3	4	4	5	5	5	5	5	4	1									
100	104	—	2	4	5	6	8	8	9	9	9	9	8	8	7	5	3	—									
150	128	2	6	9	12	13	14	14	14	13	12	11	10	9	7	4	—	—									
200	150	4	12	16	19	20	20	19	18	17	15	13	11	9	6	1	—	—									
250	170	8	18	24	26	26	26	24	22	20	18	15	12	8	3	—	—	—									
300	190	11	25	31	33	33	32	29	27	24	20	16	12	7	—	—	—	—									
350	211	13	30	38	41	40	38	36	32	28	23	18	11	2	—	—	—	—									
Age 50																											
50	89	—	—	—	—	1	1	2	2	2	3	3	4	4	4	5	5	5	4	4	1						
100	138	—	1	2	3	4	5	6	7	7	7	8	8	8	7	7	7	6	5	2							
150	171	1	4	6	8	10	10	11	11	11	11	11	11	10	9	9	8	3	3	—	—						
200	195	3	8	12	14	15	16	16	16	15	15	14	13	12	11	9	7	4	—	—	—						
250	221	5	13	17	20	21	21	21	20	19	18	17	16	14	12	10	6	—	—	—	—						
Age 60																											
50	116	—	—	—	—	1	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	2			
100	176	—	1	2	2	3	4	4	5	5	6	6	6	6	6	7	6	6	6	6	6	5	2	—			
150	217	1	3	5	6	7	8	9	9	9	9	9	9	9	9	9	9	8	7	7	6	2	—	—			
Age 70																											
50	125	—	—	—	—	—	—	1	1	1	1	1	2	2	2	2	3	3	3	3	3	4	4	4	4	4	2
100	206	—	1	1	2	2	3	3	4	4	4	4	5	5	5	5	5	6	6	6	6	6	6	5	5	1	—

[1]Source: McGee and Della-Bianca (1967). table 6, rev.

Table 30.—*Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 90*[1]

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Age 20																										
100	47	48	48	49	49	49	50	50	50																	
150	49	49	49	49	50	50	50	50	50																	
200	50	50	50	50	50	50	50	50	—																	
250	50	50	50	50	50	50	50	50	—																	
300	50	50	50	50	50	50	50	50	—																	
350	50	50	50	50	50	50	50	—	—																	
Age 30																										
100	48	53	57	60	62	64	66	68	69	70	71															
150	50	55	58	61	64	65	67	68	70	71	—															
200	52	56	59	62	64	66	68	69	70	71	—															
250	53	57	60	63	65	67	68	70	71	—	—															
300	54	58	61	64	66	68	69	70	71	—	—															
350	55	59	62	65	67	68	70	71	—	—	—															
Age 40																										
50	44	51	57	62	66	70	73	75	77	79	81	83	84													
100	47	54	60	65	68	72	74	77	79	81	82	84	85													
150	49	56	62	66	70	73	76	78	80	82	83	85	—													
200	51	58	63	68	71	74	77	79	81	83	84	—	—													
250	53	59	65	69	73	76	78	80	82	84	—	—	—													
300	54	61	66	70	74	77	79	81	83	85	—	—	—													
350	55	62	67	72	75	78	81	83	84	—	—	—	—													
Age 50																										
50	43	51	58	64	69	73	76	79	82	85	87	89	90	92	93											
100	46	54	61	66	71	75	78	81	84	86	88	90	92	93	—											
150	48	56	63	68	73	77	80	83	86	88	90	92	93	95	—											
200	50	58	65	70	75	79	82	85	87	89	91	93	94	—	—											
250	52	60	66	72	76	80	83	86	89	91	93	94	—	—	—											
300	53	62	68	74	78	82	85	88	90	92	94	—	—	—	—											
Age 60																										
50	41	50	58	64	69	74	78	82	85	87	90	92	94	96	97	99	100									
100	45	54	61	67	72	77	81	84	87	89	92	94	96	97	99	100	—									
150	47	56	63	69	74	79	83	86	89	91	93	96	97	99	101	—	—									
200	49	58	65	71	76	81	84	88	90	93	95	97	99	101	—	—	—									
250	51	60	67	73	78	82	86	89	92	95	97	99	101	—	—	—	—									
Age 70																										
50	40	49	57	64	70	75	79	83	86	89	92	94	96	98	100	101	103	104	106							
100	44	53	60	67	73	77	82	85	88	91	94	96	98	100	102	103	105	106	—							
150	46	55	63	69	75	80	84	87	90	93	96	98	100	102	103	105	106	—	—							
200	48	57	65	71	77	82	86	89	92	95	98	100	102	103	105	107	—	—	—							
250	50	59	67	73	79	84	88	91	94	97	100	102	104	105	—	—	—	—	—							

[1] $\text{Log}(H) = \text{Log}(Hc) + 0.01857 - [2.28645 - 0.59146\,\text{Log}(T) - 0.64614\,(100/A) + 2.57302\,(S/100)]\,(1/D - 1/D_{max})$

Source: Beck and Della-Bianca (1970).

Table 31.—*Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 100*[1]

	Total height (feet) by diameter class (inches)																									
Trees per acre (number)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Age 20																										
100	49	50	52	53	53	54	54	55	55																	
150	50	52	53	53	54	54	55	55	55																	
200	51	53	53	54	54	55	55	55	55																	
250	52	53	54	54	55	55	55	55	—																	
300	53	54	54	55	55	55	55	55	—																	
350	54	54	55	55	55	55	55	55	—																	
Ane *30*																										
100	49	55	60	64	67	70	72	74	75	77	78	79														
150	51	57	61	65	68	71	73	75	76	78	79	—														
200	53	58	63	66	69	72	74	75	77	78	—	—														
250	54	59	64	67	70	72	74	76	78	79	—	—														
300	55	61	65	68	71	73	75	77	78	—	—	—														
350	56	62	66	69	72	74	76	78	79	—	—	—														
Age 40																										
50	44	53	60	65	70	74	78	81	84	86	88	90	92	93												
100	48	56	62	68	73	77	80	83	85	88	90	91	93	94												
150	50	58	64	70	74	78	81	84	87	89	91	93	94	—												
200	52	60	66	71	76	80	83	86	88	90	92	94	—	—												
250	53	61	68	73	77	81	84	87	89	91	93	—	—	—												
300	55	63	69	74	79	82	85	88	91	93	94	—	—	—												
350	56	64	71	76	80	84	87	90	92	94	—	—	—	—												
Age 50																										
50	43	52	60	67	72	77	81	85	88	91	94	%	98	100	102	104	105									
100	46	55	63	69	75	80	84	87	90	93	%	98	100	102	103	105	—									
150	48	58	65	72	77	82	86	89	92	95	97	99	101	103	105	—	—									
200	50	59	67	74	79	83	87	91	94	96	99	101	103	105	—	—	—									
250	52	61	69	75	81	85	89	93	95	98	100	103	104	—	—	—	—									
300	54	63	71	77	82	87	91	94	97	100	102	104	—	—	—	—	—									
Age 60																										
50	41	51	59	67	73	78	83	87	91	94	97	99	102	104	106	108	109	111	112							
100	45	54	63	70	76	81	86	90	93	96	99	101	104	106	108	109	111	112	—							
150	47	57	65	72	78	83	88	92	95	98	101	103	106	108	109	111	113	—	—							
200	49	59	67	74	80	85	90	94	97	100	103	105	107	109	111	113	—	—	—							
250	51	61	69	76	82	87	92	%	99	102	105	107	109	111	—	—	—	—	—							
Age *70*																										
50	40	50	59	66	73	79	83	88	92	95	98	101	104	106	108	110	112	113	115	116	118					
100	43	53	62	70	76	82	86	91	94	98	101	103	106	108	110	112	114	115	117	118	—					
150	46	56	65	72	78	84	89	93	97	100	103	105	108	110	112	114	115	117	118	—	—					
200	48	58	67	74	81	86	91	95	99	102	105	107	110	112	114	116	117	—	—	—	—					
250	49	60	69	76	83	88	93	97	101	104	107	110	112	114	116	118	—	—	—	—	—					

[1] Log (H) = Log (H,) + 0.01857
− [2.28645 −0.59146 Log (T)
− 0.64614 (100/A)
+ 2.57302 (S/100)]
(1/D − 1/Dmax)

Source: Beck and Della-Bianca (1970).

Table *32.-Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index* ***110***[1]

Trees per acre (number)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Total height (feet) by diameter class (inches)																									
Age 20																										
100	50	52	54	56	57	58	59	60	60	61																
150	51	54	55	57	58	59	60	60	61	61																
200	52	55	56	57	58	59	60	60	61	—																
250	53	55	57	58	59	60	60	61	61	—																
300	54	56	57	58	59	60	60	61	61	—																
350	55	57	58	59	59	60	61	61	—	—																
Age *30*																										
100	49	56	62	67	71	74	77	79	81	83	85	86														
150	51	58	64	68	72	75	78	80	82	84	86	87														
200	53	60	65	70	73	76	79	81	83	85	86	—														
250	54	61	66	71	74	77	80	82	84	86	87	—														
300	56	62	68	72	75	78	81	83	85	86	—	—														
350	57	63	69	73	76	79	82	84	86	87	—	—														
Age 40																										
50	44	53	61	68	73	78	83	86	89	92	95	97	99	101	103											
100	47	57	64	71	76	81	85	88	91	94	96	99	101	102	104											
150	50	59	66	73	78	83	86	90	93	%	98	100	102	104	—											
200	51	61	68	74	80	84	88	91	94	97	99	101	103	—	—											
250	53	62	70	76	81	86	89	93	%	98	101	103	—	—	—											
300	55	64	71	78	83	87	91	94	97	100	102	104	—	—	—											
350	56	65	73	79	84	89	92	96	99	101	103	—	—	—	—											
Age 50																										
50	42	52	61	69	75	81	86	90	94	97	100	103	106	108	110	112	114	115								
100	46	56	64	72	78	84	88	93	96	100	102	105	107	110	112	113	115	—								
150	48	58	67	74	80	86	90	95	98	101	104	107	109	111	113	115	—	—								
200	50	60	69	76	82	88	92	96	100	103	106	108	111	113	115	—	—	—								
250	51	62	71	78	84	89	94	98	102	105	108	110	112	114	—	—	—	—								
300	53	64	72	80	86	91	96	100	104	107	109	112	114	—	—	—	—	—								
Age *60*																										
50	41	51	61	69	76	82	87	92	%	100	103	106	109	111	114	116	118	120	121	123						
100	44	55	64	72	79	85	90	95	99	102	106	108	111	114	116	118	120	121	123	—						
150	46	57	66	74	81	87	92	97	101	104	108	110	113	115	118	120	121	123	—	—						
200	48	59	68	76	83	89	94	99	103	106	110	112	115	117	119	121	123	—	—	—						
250	50	61	70	78	85	91	%	101	105	108	112	114	117	119	121	123	—	—	—	—						
Age *70*																										
50	39	50	60	68	75	82	87	92	97	101	104	108	111	113	116	118	120	122	124	126	127	129	130			
100	43	54	63	71	79	85	91	95	100	104	107	110	113	116	118	120	122	124	126	127	129	—	—			
150	45	56	66	74	81	87	93	98	102	106	109	112	115	118	120	122	124	126	128	129	—	—	—			
200	47	58	68	76	83	90	95	100	104	108	111	114	117	120	122	124	126	128	130	—	—	—	—			
250	48	60	70	78	85	92	97	102	106	110	114	117	119	122	124	126	128	130	—	—	—	—	—			

[1] $\text{Log}(H) = \text{Log}(H_c) + 0.01857$
$- [2.28645 - 0.59146\ \text{Log}(T)$
$- 0.64614\ (100/A)$
$+ 2.57302\ (S/100)]$
$(1/D - 1/Dmax)$

Source: Beck and Della-Bianca (1970).

Table 33.-Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 120[1]

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Age 20																										
100	50	54	57	59	61	62	63	64	65	66																
150	52	55	58	60	61	63	64	65	66	66																
200	53	56	59	61	62	63	64	65	66	67																
250	54	57	59	61	63	64	65	66	66	—																
300	55	58	60	62	63	64	65	66	67	—																
350	56	58	61	62	63	65	65	66	67	—																
Aee 30																										
100	49	57	64	69	74	78	81	84	87	89	91	93	95													
150	51	59	66	71	76	79	83	86	88	90	92	94	—													
200	53	61	67	72	77	81	84	87	89	91	93	95	—													
250	54	62	68	74	78	82	85	88	90	92	94	—	—													
300	55	63	70	75	79	83	86	89	91	93	95	—	—													
350	57	65	71	76	80	84	87	90	92	94	—	—	—													
Age 40																										
50	43	54	62	70	76	82	87	91	95	98	101	104	106	108	110	112										
100	47	57	65	73	79	84	89	93	97	100	103	105	108	110	112	114										
150	49	59	68	75	81	86	91	95	98	102	104	107	109	111	113	—										
200	51	61	69	77	83	88	93	97	100	103	106	108	111	113	—	—										
250	52	63	71	78	84	90	94	98	102	105	107	110	112	—	—	—										
300	54	64	73	80	86	91	96	100	103	106	109	111	113	—	—	—										
350	55	66	74	82	88	93	97	101	105	108	110	113	—	—	—	—										
Age 50																										
50	41	52	62	70	78	84	90	94	99	103	106	109	112	115	117	120	122	124	125							
100	45	56	65	74	81	87	92	97	101	105	109	112	114	117	119	121	123	125	—							
150	47	58	68	76	83	89	95	99	103	107	111	114	116	119	121	123	125	—	—							
200	49	60	70	78	85	91	97	101	105	109	112	115	118	120	123	125	—	—	—							
250	50	62	72	80	87	93	98	103	107	111	114	117	120	122	124	—	—	—	—							
300	52	64	78	82	89	95	100	105	109	113	116	119	122	124	—	—	—	—	—							
Age 60																										
50	40	51	61	70	78	85	91	96	101	105	109	112	116	118	121	124	126	128	130	132	133	135				
100	43	54	65	73	81	88	94	99	104	108	111	115	118	121	123	126	128	130	132	133	135	—				
150	45	57	67	76	84	90	96	101	106	110	114	117	120	123	125	128	130	132	133	135	—	—				
200	47	59	69	78	86	92	98	103	108	112	116	119	122	125	127	129	132	134	—	—	—	—				
Age 70																										
50	38	50	60	69	77	84	91	96	101	106	110	114	117	120	123	126	128	130	132	134	136	138	139	141		
100	41	53	64	73	81	88	94	100	104	109	113	116	120	123	125	128	130	132	134	136	138	140	141	—		
150	44	56	66	75	83	90	97	102	107	111	115	119	122	125	128	130	132	134	136	138	140	141	—	—		

[1] $\text{Log (H)} = \text{Log (Hc)} + 0.01857 - [2.28645 - 0.59146 \text{ Log (T)} - 0.64614 (100/A) + 2.57302 (S/100)] (1/D - 1/Dmax)$

Source: Beck and Della-Bianca (1970).

Table 34.—*Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 130*[1]

Trees per acre (number)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Age 20																										
100	50	54	58	61	64	66	67	69	70	71	72															
150	51	56	60	62	65	66	68	69	71	72	72															
200	53	57	61	63	65	67	69	70	71	72	—															
250	54	58	61	64	66	68	49	70	71	72	—															
300	55	59	62	65	67	68	70	71	72	72	—															
350	56	60	63	65	67	69	70	71	72	—	—															
Age 30																										
100	48	57	65	71	77	81	85	89	92	95	97	99	101	103												
150	50	59	67	73	78	83	87	90	93	96	98	100	102	—												
200	52	61	68	75	80	84	88	91	94	97	99	101	103	—												
250	53	62	70	76	81	86	89	93	95	98	100	102	—	—												
300	55	64	71	77	82	87	91	94	97	99	101	103	—	—												
350	56	65	72	79	84	88	92	95	98	100	102	—	—	—												
Age 40																										
50	42	53	63	71	78	85	90	95	99	103	107	110	113	115	118	120	122									
100	46	57	66	74	81	87	93	97	102	105	109	112	114	117	119	121	—									
150	48	59	68	76	83	89	95	99	103	107	110	113	116	118	121	123	—									
200	50	61	70	78	85	91	97	101	105	109	112	115	117	120	122	—	—									
250	51	62	72	80	87	93	98	103	107	110	114	116	119	121	—	—	—									
300	53	64	74	82	89	95	100	104	108	112	115	118	121	123	—	—	—									
350	54	66	75	83	90	96	102	106	110	114	117	120	122	—	—	—	—									
Age 50																										
50	40	52	62	71	79	86	93	98	103	108	112	115	119	122	124	127	129	131	133	135						
100	43	55	66	75	83	90	96	101	106	110	114	118	121	124	126	129	131	133	135	—						
150	46	58	68	77	85	92	98	103	108	112	116	120	123	126	128	131	133	135	—	—						
200	47	60	70	79	87	94	100	105	110	114	118	122	125	128	130	133	135	—	—	—						
250	49	61	72	81	89	96	102	107	112	116	120	124	127	129	132	134	137	—	—	—						
Age 60																										
50	38	50	61	71	79	87	94	100	105	110	114	118	122	125	128	131	133	136	138	140	142	144	145			
100	42	54	65	74	83	90	97	103	108	113	117	121	124	127	130	133	135	138	140	142	144	145	—			
150	44	56	67	77	85	93	99	105	110	115	119	123	126	130	132	135	137	140	142	144	146	—	—			
Age 70																										
50	37	49	60	70	79	87	94	100	105	111	115	119	123	127	130	133	135	138	140	142	144	146	148	150	151	153
100	40	52	64	74	82	90	97	103	109	114	118	122	126	129	132	135	138	140	143	145	147	148	150	152	153	—

Total height (feet) by diameter class (inches)

[1]
$$\begin{aligned}\text{Log}(H) = {} & \text{Log}(H_c) + 0.01857 \\ & - [2.28645 - 0.59146\ \text{Log}(T) \\ & - 0.64614\ (100/A) \\ & + 2.57302\ (S/100)] \\ & (1/D - 1/D\text{max})\end{aligned}$$

Source: Beck and Della-Bianca (1970).

Table 35.-*Total cubic-foot yield of wood and bark for unthinned yellow-poplar stands of various stand densities, site indexes, and ages’*

Trees per acre (number)	20	30	40	50	60	70
	Cubic feet per acre					
Site Index 90						
50	—	—	1,560	2,170	2,850	3,590
100	730	1,510	2,330	3,180	4,080	5,020
150	860	1,810	2,760	3,710	4,660	5,580
200	980	2,020	3,050	4,030	4,950	5,780
250	1,110	2,210	3,280	4,260	5,130	5,870
300	1,250	2,400	3,490	4,450	—	—
350	1.410	2.600	3.710	—	—	—
Site Index 100						
50	—	—	1,920	2,730	3,640	4,670
100	840	1,810	2,870	4,020	5,270	6,610
150	990	2,180	3,430	4,730	6,080	7,450
200	1,120	2,450	3,820	5,180	6,540	7,840
250	1,270	2,700	4,140	5,540	6,870	8,090
300	1,430	2,950	4,460	5,870	—	—
350	1,620	3,220	4,770	—	—	—
Site Index 110						
50	—	—	2,340	3,380	4,600	5,990
100	960	2,150	3,500	5,020	6,720	8,600
150	1,130	2,600	4,210	5,960	7,840	9,830
200	1,280	2,940	4,740	6,610	8,550	10,540
250	1,450	3,270	5,200	7,160	9,130	11,060
300	1,650	3,610	5,650	7,670	—	—
350	1,870	3.980	6.120	—	—	—
Site Index 120						
50	—	—	2,810	4,150	5,730	7,600
100	1,090	2,530	4,230	6,200	8,470	11,070
150	1,290	3,080	5,130	7,440	10,020	12,870
200	1,470	3,520	5,830	8,360	11,100	—
250	1,670	3,960	6,480	9,170	—	—
300	1,910	4,410	7,120	9,960	—	—
350	2,180	4,910	7,790	—	—	—
Site Index 130						
50	—	—	3,360	5,040	7,080	9,530
100	1,240	2,970	5,080	7,600	10,590	14,130
150	1,460	3,630	6,210	9,220	12,700	—
200	1,680	4,190	7,140	10,490	—	—
250	1,920	4,760	8,020	11,660	—	—
300	2,220	5,370	8,920	12,830	—	—
350	2,560	6,030	9,850	—	—	—

Only trees 4.5 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Table 36.-*Cubic-foot yield of wood and bark to a Cinch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indexes and ages’*

Trees per acre (number)	20	30	40	50	60	70
	Cubic feet per acre					
Site Index 90						
50	—	—	1,470	2,050	2,700	3,410
100	640	1,380	2,170	2,990	3,860	4,750
150	730	1,640	2,560	3,470	4,380	5,260
200	810	1,810	2,800	3,740	4,620	5,420
250	900	1,960	2,990	3,930	4,760	5,470
300	1,010	2,110	3,160	4,080	—	—
350	1,130	2,270	3,330	—	—	—
Site Index 100						
50	—	—	1,810	2,590	3,460	4.450
100	740	1,670	2,690	3,800	4,990	6,280
150	860	1,990	3,190	4,440	5,740	7,050
200	950	2,220	3,540	4,850	6,150	7.400
250	1,060	2,430	3,820	5,160	6,430	7.610
300	1,180	2,640	4,090	5,440	—	—
350	1,330	2,860	4,360	—	—	—
Site Index 110						
50	—	—	2,210	3,220	4,380	5,720
100	860	2,000	3,300	4,760	6,380	8,190
150	990	2,400	3,950	5,620	7,430	9,340
200	1,100	2,700	4,420	6,220	8,080	9,990
250	1,240	2,980	4,830	6,710	8,600	10,460
300	1,390	3,280	5,240	7,180	—	—
350	1.570	3.600	5.650	—	—	—
Site Index 120						
50	—	—	2,670	3,950	5,470	7,260
100	980	2.370	4,000	5,890	8,070	10,570
150	1,140	2,860	4,830	7,050	9,520	12.260
200	1,280	3,250	5,470	7,900	10,530	—
250	1,440	3,640	6,060	8,640	—	—
300	1,640	4,040	6,650	9,370	—	—
350	1,870	4,490	7,250	—	—	—
Site Index 130						
50	—	—	3,190	4,810	6.770	9,110
100	1,120	2,780	4,810	7,240	10.110	13,500
150	1,310	3,390	5,870	8,760	12,100	—
200	1,480	3,900	6,730	9,950	—	—
250	1,690	4,410	7,540	11,040	—	—
300	1,940	4,960	8,380	—	—	—
350	2.230	5.560	9.240	—	—	—

Only trees 4.5 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Table *37.-Cubic-foot yield of wood only to a I-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indexes, and* ***ages***[1]

Trees per acre (number)	Age (years) 20	30	40	50	60	70
	Cubic feet per acre					
Site Index 90						
50	—	—	1,220	1,700	2,240	2,840
100	520	1,140	1,790	2,480	3,200	3,950
150	590	1,340	2,110	2,870	3,620	4,360
200	650	1,480	2,300	3,090	3,820	4,490
250	720	1,600	2,460	3,240	3,930	4,520
300	800	1,710	2,590	3,360	—	—
350	890	1,840	2,730	—	—	—
Site Index 100						
50	—	—	1,500	2,150	2,880	3,700
100	600	1,380	2,230	3,150	4,150	5,220
150	690	1,640	2,640	3,680	4,760	5,860
200	760	1,820	2,920	4,010	5,090	6,140
250	840	1,990	3,150	4,260	5,320	6,300
300	940	2,150	3,360	4,490	—	—
350	1,060	2,330	3,580	—	—	—
Site Index 110						
50	—	—	1,840	2,670	3,640	4,760
100	700	1,650	2,730	3,950	5,300	6,810
150	800	1,970	3,270	4,660	6,170	7,760
200	890	2,220	3,650	5,150	6,710	8,290
250	990	2,450	3,990	5,560	7,130	8,680
300	1,110	2,690	4,320	5,930	—	—
350	1,260	2,940	4,650	—	—	—
Site Index 120						
50	—	—	2,220	3,290	4,550	6,040
100	810	1,960	3,320	4,900	6,710	8,790
150	930	2,360	4,000	5,850	7,910	10,190
200	1,040	2,680	4,530	6,550	8,740	—
250	1,160	2,990	5,010	7,170	—	—
300	1,320	3,330	5,500	7,760	—	—
350	1,500	3,690	5,990	—	—	—
Site Index 130						
50	—	—	2,650	4,000	5,630	7,590
100	920	2,300	3,990	6,010	8,410	11,230
150	1,070	2,800	4,870	7,280	10,060	10,060
200	1,200	3,200	5,580	8,260	—	—
250	1,370	3,640	6,250	9,160	—	—
300	1,570	4,090	6,940	—	—	—
350	1,800	4,580	7,640	—	—	—

[1]Only trees 4.5 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Table 38.—*International* *IN-inch board-foot yield to an* ***8-inch*** *top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indexes, and ages'*

Trees per acre (number)	Age (years) 20	30	40	50	60	70
	Board feet per acre					
Site Index 90						
50	—	—	5,180	8,490	12,240	16,480
100	260	2,480	6,260	10,750	15,670	20,920
150	140	2,090	5,960	10,690	15,730	20,830
200	80	1,630	5,210	9,750	14,530	19,120
250	40	1,230	4,370	8,540	12,920	17,000
300	20	880	3,520	7,230	—	—
350	10	590	2,670	—	—	—
Site Index 100						
50	—	—	7,120	11,590	16,790	22,830
100	460	3,760	9,020	15,270	22,270	29,990
150	290	3,420	9,100	15,940	23,370	31,170
200	180	2,930	8,540	15,430	22,770	30,150
250	120	2,460	7,780	14,510	21,580	28,460
300	80	2,040	6,960	13,410	—	—
350	50	1,640	6,070	—	—	—
Site Index 110						
50	—	—	9,400	15.310	22,370	30,720
100	750	5,340	12,380	20,810	30,520	41,580
150	520	5,160	13,070	22,580	33,190	44,760
200	370	4,750	12,950	22,890	33,740	45,150
250	270	4,330	12,550	22,670	33,560	44,630
300	210	3,940	12,050	22,230	—	—
350	170	3.550	11.450	—	—	—
Site Index 120						
50	—	—	12,070	19,740	29,080	40,440
100	1,120	7,250	16,390	27,530	40,710	56,250
150	850	7,370	17,970	30,830	45,640	62,420
200	660	7,170	18,570	32,420	48,000	—
250	550	6,960	18,870	33,410	—	—
300	470	6,780	19,080	34,200	—	—
350	420	6,600	19,190	—	—	—
Site Index 130						
50	—	—	15,160	24,950	37,190	52,270
100	1,600	9,500	21,120	35,590	53,220	74,650
150	1,310	10,070	23,880	40,940	61,220	—
200	1,100	10,270	25,560	44,350	—	—
250	990	10,470	26,960	47,180	—	—
300	940	10,740	28,320	—	—	—
350	920	11.050	—	—	—	—

Only trees 11 inches d.b.h. and larger are included.
Source: Beck and Della-Bianca (1970).

Table 39.—*Total cubic-foot volume of wood and bark by age, site index, and basal area for unthinned yellow-poplar stands*

Site Index *80*

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	1,069	1,472	1,727	1,901	2,027	2,121
70	1,258	1,731	2,032	2,236	2,384	2,495
80		1,993	2,338	2,574	2,744	2,872
90		2,256	2,647	2,914	3,106	3,251
100		2,521	2,958	3,255	3,470	3,633
110			3,270	3,599	3,837	4,016
120			3,584	3,944	4,205	4,401
130				4.291	4,575	4,789
140					4,946	5,177

Site Index 90

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,212	1,668	1,958	2,155	2,297	2,404
70	1,425	1,962	2,303	2,534	2,702	2,828
80	1,640	2,259	2,650	2,917	3,110	3,255
90		2,557	3,000	3,302	3,520	3,685
100		2,857	3,352	3,690	3,933	4,117
110			3,706	4,079	4,348	4,552
120			4,062	4,470	4,766	4,988
130				4,864	5,185	5,427
140					5,606	5,868

Site Index 100

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,339	1,844	2,164	2,382	2,539	2,658
70	1,575	2,169	2,545	2,801	2,986	3,126
80	1,813	2,497	2,929	3,224	3,437	3,598
90		2,826	3,316	3,650	3,891	4,073
100		3,158	3,705	4,078	4,348	4,551
110		3,491	4,096	4,509	4,807	5,031
120			4,489	4,941	5,268	5,514
130			4,884	5,376	5,731	5,999
140				5,812	6,196	6,486
150				6,250	6,663	6,974
160					7,131	7,465
170						7,957
180						8.450

Site Index 110

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	1,454	2,002	2,349	2,585	2,756	2,884
70	1,710	2,354	2,762	3,041	3,241	3,393
80	1,968	2,710	3,179	3,500	3,731	3,905
90	2,228	3,067	3,599	3,962	4,223	4,421
100		3,427	4,022	4,426	4,719	4,939
110		3,789	4,446	4,894	5,217	5,461
120		4,153	4,873	5,363	5,717	5,985
130			5,301	5,835	6,220	6,511
140			5,731	6,308	6,725	7,039
150			6,163	6,784	7,232	7,570
160				7,261	7,740	8,102
170				7.740	8,251	8,636
180					8,762	9,172
190					9,276	9,709
200						10,248

Site Index 120

Basal area (ft²/acre)	20	30	40	50	60	70
60	1.556	2,143	2,514	2,768	2,950	3,088
70	1,831	2,521	2,958	3,255	3,470	3,633
80	2,107	2,901	3,404	3,747	3,994	4,181
90	2,385	3,284	3,854	4,242	4,522	4,733
100		3,670	4,306	4,739	5,052	5,288
110		4,057	4,760	5,240	5,586	5,847
120		4,446	5,217	5,742	6,122	6,408
130		4,837	5,676	6,247	6,660	6,971
140			6,136	6,754	7,200	7,537
150			6,599	7,263	7,743	8,105
160			7,063	7,774	8,287	8,675
170			7,528	8,286	8,834	9,247
180				8,800	9,382	9,820
190				9,316	9,931	10,395
200				9.833	10.482	10.972

Site Index 130

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,649	2,270	2,664	2,932	3,126	3,272
70	1,940	2,671	3,134	3,449	3,677	3,849
80	2,233	3,074	3,607	3,970	4,232	4,430
90	2,527	3,480	4,083	4,494	4,791	5,015
100	2,824	3,888	4,562	5,021	5,353	5,603
110		4,298	5,043	5,551	5,918	6,194
120		4,711	5,527	6,084	6,486	6,789
130		5,125	6,013	6,619	7,056	7,386
140		5,541	6,501	7,156	7,629	7,985
150		5.958	6,991	7,695	8,203	8,587
160			7,483	8,236	8,780	9,191
170			7,976	8,779	9,359	9,797
180			8,471	9,324	9,940	10,404
190			8,967	9,870	10,522	11,014
200			9,465	10.418	11.106	11.625

Table 40.—*Cubic-foot volume of wood and bark to 1-inch top d.o.b. for unthinned yellow-poplar stands*

Site Index 80

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	885	1,270	1,520	1,694	1,820	1,917
70	1,050	1,505	1,802	2,008	2,158	2,272
80		1,743	2.087	2,325	2,499	2,631
90		1,982	2,373	2,644	2,842	2,992
100		2,223	2,661	2,965	3,187	3,355
110			2,951	3,287	3,533	3,720
120			3,240	3,610	3,880	4,085
130				3,933	4,227	4,451
140					4.574	4.816

Site Index 90

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,012	1,451	1,738	1,936	2,081	2,191
70	1,200	1,720	2,060	2,295	2,467	2,597
80	1,389	1,992	2,385	2,658	2,856	3,007
90		2,266	2,713	3,023	3,249	3,420
100		2,541	3,042	3,390	3,643	3,835
110			3,373	3,758	4,039	4,252
120			3,704	4,127	4,435	4,670
130				4,496	4,832	5,087
140					5.229	5.505

Site Index 100

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,128	1,618	1,937	2,159	2,320	2,442
70	1,338	1,918	2,297	2,559	2,750	2,895
80	1,549	2,221	2,659	2,963	3,184	3,353
90		2,526	3,025	3,370	3,622	3,813
100		2,832	3,392	3,779	4,061	4,276
110		3,140	3,760	4,189	4,502	4,740
120			4,129	4,601	4,945	5,206
130			4,499	5,012	5,387	5,672
140				5,424	5,830	6,138
150				5,836	6,272	6,603
160					6,714	7,068
170						7,532
180						7,995

Site Index 110

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	1,235	1,771	2,121	2,363	2,540	2,674
70	1,464	2,100	2,514	2,801	3,011	3,170
80	1,696	2,431	2,911	3,244	3,486	3,670
90	1,928	2,765	3,311	3,689	3,965	4,174
100		3,101	3,713	4,137	4,446	4,681
110		3,437	4,116	4,586	4,929	5,189
120		3,775	4,520	5,036	5,413	5,699
130			4,925	5,487	5,897	6,209
140			5,329	5,938	6,382	6,719
150			5,734	6,388	6,866	7,229
160				6,838	7,349	7,738
170				7,287	7,832	8,246
180					8,313	8,753
190					8.793	9,258
200						9,762

Site Index 120

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,334	1,913	2,290	2,552	2,742	2,887
70	1,581	2,267	2,715	3,025	3,251	3,423
80	1,831	2,625	3,144	3,503	3,764	3,963
90	2,082	2,986	3,576	3,984	4,282	4,508
100		3,348	4,010	4,467	4,801	5,055
110		3,712	4,445	4,952	5,323	5,604
120		4,076	4,881	5,439	5,845	6,154
130		4,441	5,318	5,925	6,368	6,705
140			5,755	6,412	6,891	7,256
150			6,192	6,899	7,414	7,806
160			6,628	7,385	7,936	8,356
170			7,063	7,869	8,458	8,904
180				8,353	8,977	9,452
190				8,835	9,496	9,997
200				9,316	10,012	10,541

Site Index 130

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,425	2,044	2,447	2,727	2,941	3,085
70	1,690	2,423	2,901	3,232	3,474	3,658
80	1,957	2,805	3,359	3,743	4,023	4,235
90	2,225	3,191	3,821	4,257	4,575	4,817
100	2,495	3,578	4,285	4,774	5,130	5,402
110		3,967	4,750	5,292	5,688	5,988
120		4,356	5,216	5,812	6,246	6,576
130		4,746	5,683	6,332	6,085	7,165
140		5,136	6,150	6,852	7,364	7,753
150		5,525	6,616	7,372	7,923	8,341
160			7,082	7,891	8,481	8,929
170			7,547	8,409	9,038	9,515
180			8,011	8,926	9,593	10,100
190			8,474	9,441	10,147	10,683
200			8,935	9,955	10,699	11,264

Table 41.—*Cubic-foot volume of wood to 1-inch top d.o.b. for unthinned yellow-poplar stands*

Site Index 80

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	706	1,025	1,235	1,380	1,487	1,569
70	839	1,218	1,467	1,641	1,767	1,864
80		1,413	1,702	1,903	2,051	2,163
90		1,609	1,939	2,168	2,336	2,463
100		1,807	2,177	2,434	2,622	2,766
110			2,415	2,701	2,910	3,069
120			2,654	2,968	3,197	3,372
130				3,235	3,485	3,675
140					3.772	3.978

Site Index 90

Basal area (ft²/acre)	20	30	40	50	60	70
60	809	1,174	1,415	1,582	1,704	1,798
70	962	1,396	1,681	1,880	2,026	2,136
80	1,116	1,619	1,951	2,181	2,350	2,478
90		1,844	2,222	2,485	2,677	2,823
100		2,071	2,495	2,789	3,005	3,169
110			2,768	3,095	3,334	3,517
120			3,041	3,401	3,664	3,864
130				3,707	3,994	4,212
140					4.323	4,559

Site Index 100

Basal area (ft²/acre)	20	30	40	50	60	70
60	904	1,313	1,581	1,768	1,905	2,009
70	1,075	1,560	1,879	2,101	2,264	2,388
80	1,247	1,810	2,180	2,438	2,627	2,770
90		2,061	2,483	2,777	2,992	3,115
100		2,314	2,788	3,118	3,359	3,542
110		2,568	3,094	3,459	3,727	3,930
120			3,399	3,801	4,095	4,319
130			3,705	4,143	4,464	4,708
140				4,485	4,832	5,096
150				4,826	5,199	5,483
160					5,565	5,869
170						6,254
180						6,637

Site Index 110

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Cubic feet/acre					
60	993	1,441	1,736	1,941	2,091	2,205
70	1,180	1.712	2,063	2,306	2,485	2,620
80	1,369	1,986	2,393	2,676	2,883	3,040
90	1,559	2,263	2,726	3,048	3,284	3,463
100		2,540	3,060	3,422	3,686	3,888
110		2,818	3,395	3,797	4,090	4,314
120		3,097	3,731	4,172	4,495	4,740
130			4,067	4,547	4,899	5,167
140			4,402	4,922	5.303	5,593
150			4,736	5,296	5,706	6.018
160				5,669	6,108	6,442
170				6,041	6,508	6,864
180					6,907	7,284
190					7,304	7,703
200						8,119

Site Index 120

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,075	1,560	1,879	2,101	2,264	2,387
70	1,277	1,854	2,233	2,497	2,690	2,837
80	1,482	2,150	2,591	2,897	3,121	3,291
90	1,688	2,449	2,951	3,300	3,555	3,749
100		2,750	3,313	3,704	3,991	4,209
110		3,051	3,676	4,110	4,428	4,670
120		3,353	4.039	4,517	4,866	5,132
130		3,655	4,403	4,923	5,304	5,594
140			4,766	5,329	5,741	6,055
150			5,128	5,734	6,177	6,515
160			5,489	6,138	6,613	6,974
170			5,849	6,540	7,046	7,431
180				6,941	7,478	7,886
190				7,339	7,907	8,339
200				7,736	8,334	8.790

Site Index 130

Basal area (ft²/acre)	20	30	40	50	60	70
60	1,151	1,671	2,013	2,251	2,425	2,557
70	1,368	1,986	2,392	2,675	2,882	3,039
80	1,587	2,304	2,775	3,103	3,343	3,526
90	1,808	2,624	3,161	3,535	3,808	4,017
100	2,030	2,946	3,549	3,969	4,276	4,509
110		3,269	3,938	4,403	4,744	5,003
120		3,592	4,327	4,839	5.213	5,498
130		3,915	4.717	5,274	5,682	5,993
140		4,238	5,106	5,709	6.151	6,487
150		4,560	5,494	6,143	6,618	6,980
160			5,880	6,576	7,084	7,471
170			6,266	7,007	7,549	7,961
180			6,650	7,436	8,011	8,449
190			7,032	7,863	8,471	8,934
200			7,411	8,288	8.928	9.416

Table 42.—*International 1/4-inch board-foot volume to B-inch top d.o.b. for unthinned yellow-poplar stands*

Site Index 80

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Board feet/acre					
60	55	614	1,832	3,237	4,401	5,150
70	65	722	2,155	3,808	5,176	6,057
80		831	2,481	4,383	4,958	6,972
90		941	2,808	4,961	6,744	7,892
100		1,051	3,138	5,544	7,536	8,818
110			3,469	6,129	8,331	9,749
120			3,802	6,717	9,130	10,685
130				7,307	9,933	11,624
140					10.740	12.568

Site Index 90

Basal area (ft²/acre)	20	30	40	50	60	70
60	90	972	2,823	4.854	6,421	7,313
70	106	1,143	3,320	5,709	7,553	8,602
80	122	1,316	3,822	6,571	8,693	9,900
90		1,489	4,326	7,439	9,841	11,207
100		1,664	4,834	8,311	10,995	12,522
110			5,344	9,189	12,156	13,844
120			5,857	10,070	13,322	15,173
130				10,956	14,494	16,507
140					15,670	17.847

Site Index 100

Basal area (ft²/acre)	20	30	40	50	60	70
60	143	1,500	4,241	7,097	9.137	10,127
70	168	1,765	4,989	8,348	10,748	11,912
80	194	2,031	5,742	9,608	12,370	13,711
90		2,299	6,500	10,877	14,004	15,521
100		2,569	7,263	12,153	15,647	17,342
110		2,840	8,029	13,436	17,298	19,173
120			8,800	14,725	18,958	21,013
130			9,573	16,020	20,625	22,860
140				17,320	22,299	24,716
150				18,625	23,980	26,578
160					25,666	28,447
170						30,322
180						32.203

Site Index 110

Basal area (ft²/acre)	Age (years) 20	30	40	50	60	70
	Board feet/acre					
60	223	2,275	6,257	10,190	12,768	13,772
70	262	2,675	7,360	11,986	15,018	16,200
80	302	3,079	8,471	13,796	17,286	18,645
90	342	3,486	9,590	15,617	19,568	21,107
100		3,895	10,715	17,449	21,864	23,584
110		4,306	11,846	19,292	24,172	26,073
120		4,719	12,983	21,143	26,491	28,575
130			14,124	23,002	28,281	31,088
140			15,271	24,869	31,160	33,611
150			16,421	26,743	33,506	36,144
160				28,623	35,864	38,685
170				30,510	38,228	41,236
180					40,600	43,794
190					42.978	46,359
200						48,932

Site Index 120

Basal area (ft²/acre)	20	30	40	50	60	70
60	343	3,401	9,107	14,433	17,599	18,475
70	403	4,001	10,711	16,976	20,701	21,731
80	464	4,605	12,329	19,539	23,826	25,012
90	525	5,213	13,956	22,119	26,972	28,315
100		5,824	15,594	24,715	30,137	31,637
110		6,439	17,240	27,324	33,319	34,977
120		7,057	18,894	29,945	36,516	38,333
130		7,678	20,556	32,579	39,727	41,704
140			22,224	35,223	42,951	45,088
150			23,899	37,877	46,187	48,486
160			25,579	40,540	49,435	51,895
170			27,226	43,213	52,694	55,316
180				45,893	55,963	58,748
190				48,582	59,241	62,189
200				51,278	62,529	65,640

Site Index 130

Basal area (ft²/acre)	20	30	40	50	60	70
60	521	5,033	13,115	20,228	24,006	24,525
70	613	5,920	15,426	23,793	28,236	28,847
80	705	6,814	17,755	37,385	32,499	33,202
90	798	7,714	20,099	31,001	36,790	37,586
100	892	8,619	22,457	34,639	41,107	41,996
110		9,529	24,828	38,296	45,447	46,430
120		10,443	27,211	41,970	49,807	50,885
130		11,362	29,603	45,661	54,187	55,359
140		12,284	32,006	49,367	58,585	59,852
150		13,209	34,418	53,086	62,999	64,362
160			36,838	56,820	67,429	68,888
170			39,266	60,565	71,874	73,429
180			41,702	64,322	76,333	77,984
190			44,145	68,090	80,805	82,553
200			46.595	71.869	85.289	87.134

4. Growth and Yield of Thinned Yellow-Poplar Stands

Table 43 summarizes the system of equations needed for estimating growth and for projecting yields of basal area and cubic-foot and board-foot volumes for thinned stands of yellow-poplar. These data are based on remeasurement of the series of sample plots described in Appendix III. The methods used to derive the equations and tables were fully described by Beck and Della-Bianca (1972, 1975). Estimates of growth and yield require knowledge of stand age, dominant stand height, site index, basal area, and mean stand diameter. In application it should be remembered that the sample plots at establishment were free of insects and disease, showed no evidence of past disturbance, and were fully stocked with no “holes” in the canopy. Consequently, they represent maximum growth and yield potentials. If the stands to which the predictors are to be applied show any of these extraneous factors, which may detract from growth, allowances should be made for them.

Basal area.-Basal-area growth (from equation 1) by age, site index, and initial basal area is presented in table 44. Basal area at future ages may be obtained by summing annual increments, or it may be obtained directly by use of equation (2). From a given condition of age **(A_1),** site index (S), and initial basal area (B_1), future basal area **(B_2)** at future age **(A_2)** may be projected. Projections should be limited to **5** years or less. If longer projections are desired, they should be done in a series with new estimates of initial age and inital basal area inserted periodically. This is particularly important in young stands where rates of growth are changing rapidly with both age and density level.

Cubic-foot growth and yield.-Total cubic-foot volume growth from equation (4) is presented in table 45. Total cubic-foot yields at future ages may be obtained through use of equation 5. Projections of cubic-foot volume are similar to those for basal area, and the same techniques and conditions apply.

Boar&foot growth and yield.-The system for estimating board-foot growth and yield differs somewhat from that for cubic-foot volume. No direct estimators of growth are available. Instead, board-foot stand volume at a given point is expressed as a function of basal area, height, and mean stand diameter. Changes in these variables are estimated with equations (1), **(7),** and (8). Future volume is then estimated from future values of B, H, and D. Volume growth is computed as the difference between successive stand volume estimates.

The ratio of board-foot volume to stand basal area by height and mean stand diameter class (from equation (6)) is presented in table 46. Board-foot growth by age, site index, and initial basal area are shown in table 47. These estimates use an average value for mean stand diameter.

Table O.-*Equations for estimating growth and yield in thinned yellow-poplar stands*

Equation number	Equation[1]
1	$\Delta B = (B_1)(A_1^{-1})[3.82837 + 0.01667(S) - \ln B_1]$
2	$\ln B_2 = (\ln B_1)(A_1/A_2) + 3.82837\,(1 - A_1/A_2) + 0.01667(S)(1 - A_1/A_2)$
3	$\ln TCFV_1 = 5.36437 - 101.16296(S^{-1}) - 22.00048\,(A_1^{-1}) + 0.97116\,(\ln B_1)$
4	$\Delta TCFV = TCFV_1\,[3.71796(A_1^{-1}) + 0.01619(S)(A_1^{-1}) - 0.97116\,(A_1^{-1})(\ln B_1) + 22.00048\,(A_1^{-2})]$
5	$\ln TCFV_2 = 5.36437 - 101.16296(S^{-1}) - 22.00048\,(A_2^{-1}) + 0.97116\,(A_1/A_2)*(\ln B_1) + 3.71796\,(1 - A_1/A_2) + 0.01619(S)(1 - A_1/A_2)$
6	$BFV/B_1 = -545.33701 + 222.63551(D^{1/2}) - 18.18270(D) + 0.35306(H)(D^{1/2})$
7	$\ln H = \ln S + 21.08707\,(1/50 - 1/A_1)$
8	$\ln \Delta D = 0.89100 - 0.00852(B_1) - 195.13700(S^{-1}) - 0.05810(B_1 A_1^{-1})$

[1] A_1 = Initial age (years).
A_2 = Future age (years).
S = Site index in feet at age 50 years.
B_1 = Initial stand basal area in square feet per acre; all trees 4.6 inches d.b.h. and over are included.
B_2 = Future stand basal area in square feet per acre; all trees 4.6 inches d.b.h. and over are included.
ΔB = Stand basal area growth in square feet per acre per year.
$TCFV_1$ = Initial total bole volume (cubic-feet of wood and bark) of all trees 4.6 inches d.b.h. and over.
$TCFV_2$ = Future total bole volume (cubic-feet of wood and bark) of all trees 4.6 d.b.h. and over.
$\Delta TCFV$ = Stand growth in total bole volume in cubic feet per acre per year.
BFV = Board-foot stand volume per acre of trees 11 inches d.b.h. and over; International 1/4-inch rule to I-inch top (o.b.).
D = Quadratic mean stand diameter (inches), all trees 4.6 inches d.b.h. and over are included.
ΔD = Quadratic mean stand diamater growth (inches/year); all trees 4.6 inches d.b.h. and over included.
ln = Natural logarithm.
H = Dominant stand height (feet).

Table 44.—*Basal-area growth for thinned stands of yellow-poplar*'

Age (years)	Basal area (ft²/acre) 40	50	60	70	80	90	100	110	120	130	140	150	160
	ft²/acre/year												
Site Index 90													
20	3.3	3.5	**3.7**	3.8									
25			**2.5**	**3.0**	**3.0**								
30	2.2	2.4	**2.1**	**2.5**	**2.5**	2.5	2.4						
35	1.9	2.0	...	**2.2**	2.2	2.1	2.1	2.0					
40	1.6	1.8	**1.9**	1.9	1.9	1.9	1.8	1.7	1.6				
45	1.5	1.6	1.6	1.7	1.7	1.7	1.6	1.5	1.4				
50	1.3	1.4	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.2			
55	1.2	1.3	1.3	1.4	1.4	1.4	1.3	1.3	1.2	1.1			
60	1.1	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.1	1.0	0.9		
65	**1.0**												
70	**0.9**	**1.0**	1.1 1.1	1.2 1.1	1.2 1.1	1.1 1.1	1.1 1.0	1.1 1.0	0.9 1.0	0.9 0.9	0.8 0.8	0.7	
75	0.9	**0.9**	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.1	0.6	
80	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.6	0.5
Site Index 100													
20	**3.6**	4.0	4.2	4.4	4.5								
25	**2.9**	**3.2**	**3.4**	**3.5**	**3.6**	3.6							
30	**2.4**	**2.6**	**2.8**	**2.9**	**3.0**	3.0	3.0	2.9					
35	**2.1**	**2.3**	**2.4**	**2.5**	**2.5**	2.6	2.5	2.5	2.4				
40	**1.8**	**2.0**	**2.1**	**2.2**	**2.2**	2.2	2.2	2.2	2.1	2.0	1.9		
45	**1.6**	**1.8**	**1.9**	**1.9**	**2.0**	2.0	2.0	1.9	1.9	1.8	1.7		
50	**1.4**	**1.6**	1.7	1.7	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.3
55	**1.3**	**1.4**	**1.5**	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.4	1.3	1.2
60	1.2		**1.3**	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.2	1.1
65	1.1	1::	**1.2**	1.3	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.1	1.0
70	1.0	**1.1**		**1.2**	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.0	1.0
75	1.0	**1.1**	**1.1**	**1.2**	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.0	0.9
80	0.9	**1.0**	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	0.9	0.8
Site Index 110													
20	**3.9**	4.4	**3.8**	4.9	5.1								
25	3.2	3.5	**3.1**	4.0	4.1	4.2	4.2	4.2					
30	2.6	2.9	...	3.3	3.4	3.5	3.5	3.5	3.5	3.4			
35	2.3	2.5	**2.7**	2.8	2.9	3.0	3.0	3.0	3.0	3.0			
40	2.0	2.2	2.4	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.4	
45	1.8	1.9	2.1	2.2	2.3	2.3	2.3	2.4	2.3	2.3	2.2	2.2	2.1
50	1.6	1.8	1.9	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.0	2.0	1.9
55	1.4	1.6	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.7
60	1.3	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.7	1.7	1.7	1.6	1.6
65	1.2	1.3	1.4	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.4
70	1.1	1.3	1.3	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.3
75	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3
80	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2
Site Index 120													
20	4.3	4.8	5.2	5.5	5.8	6.0							
25	3.4	3.8	4.2	4.4	4.6	4.8	4.9	5.0	5.0				
30	2.9	3.2	3.5	3.7	3.9	4.0	4.1	4.1	4.2	4.2	4.1		
35	2.4	2.7	3.0	3.2	3.3	3.4	3.5	3.5	3.6	3.6	3.5	3.5	3.4
40	2.1	2.4	2.6	2.8	2.9	3.0	3.1	3.1	3.1	3.1	3.1	3.1	3.0
45	1.9	2.1	2.3	2.5	2.6	2.7	2.7	2.8	2.8	2.8	2.8	2.7	2.7
50	1.5	1.9	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.5	2.5	2.5	2.4
55	1.6	1.7	1.9	2.0	2.1	2.2	2.2	2.3	2.3	2.3	2.3	2.2	2.2
60	1.4	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.1	2.1	2.0	2.0
65	1.3	1.5	1.6	1.7	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
70	1.2	1.4	1.5	1.6	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.7
75	1.1	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.6
80	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.5

(continued)

Table 44.—*Basal-area growth for thinned stands of yellow-poplar (continued)*

Age (years)	Site Index 130 — Basal area (ft²/acre) 40	50	60	70	80	90	100	110	120	130	140	150	160
	ft²/acre/year												
20	4.6	5.2	5.7	6.1	6.5	6.7	7.0						
25	3.7	4.2	4.6	4.9	5.2	5.4	5.6	5.7	5.8	5.9			
30	3.1	3.5	3.8	4.1	4.3	4.5	4.6	4.7	4.8	4.9	4.9	4.9	4.9
35	2.6	3.0	3.3	3.5	3.7	3.8	4.0	4.1	4.1	4.2	4.2	4.2	4.2
40	2.3	2.6	2.9	3.1	3.2	3.4	3.5	3.6	3.6	3.7	3.7	3.7	3.7
45	2.1	2.3	2.5	2.7	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.3	3.3
50	1.8	2.1	2.3	2.4	2.6	2.7	2.8	2.8	2.9	2.9	3.0	3.0	2.9
55	1.7	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.6	2.7	2.7	2.7	2.7
60	1.5	1.7	1.9	2.0	2.2	2.2	2.3	2.4	2.4	2.4	2.5	2.5	2.5
65	1.4	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.3
70	1.3	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.1	2.1	2.1
75	1.2	1.4	1.5	1.6	1.7	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0
80	1.2	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8

[1] Only trees 4.6 inches d.b.h. and larger are included. Source: Beck and Della-Bianca (1972).

Table 45.—*Total cubic-foot growth for thinned stands of yellow-poplar*[1]

Age (years)	Basal area (ft²/acre) 40	50	60	70	80	90	100	110	120	130	140	150	160
	ft³/acre/year												
Site Index 90													
20	112	128	142	154									
25	102	116	128	138	146								
30	93	105	114	123	130	135	140						
35	84	95	103	110	116	120	123	126					
40	77	86	93	99	104	107	110	112	113				
45	71	79	85	90	94	97	99	100	100				
50	65	72	78	82	86	88	90	90	90	90			
55	61	67	72	76	79	81	82	82	82	81			
60	56	62	67	70	73	74	75	75	75	74	72		
65	53	58	62	65	68	69	69	69	69	68	66		
70	50	55	58	61	63	64	64	64	64	62	61	59	
75	47	52	55	57	59	60	60	60	59	58	56	54	
80	44	49	52	54	56	56	56	56	55	54	52	50	48
Site Index 100													
20	133	152	170	185	199								
25	122	139	154	167	178	188							
30	111	126	139	150	159	167	174	180					
35	102	115	126	135	143	149	155	159	163				
40	93	104	114	122	129	134	139	142	145	147	148		
45	85	%	104	112	117	122	126	128	130	131	132		
50	79	88	96	102	107	111	114	116	118	119	119	118	117
55	73	82	89	94	99	102	105	107	108	108	108	107	106
60	68	76	83	88	92	95	97	98	99	99	98	98	96
65	64	71	77	82	85	88	90	91	91	91	91	90	88
70	60	67	72	77	80	82	84	85	85	85	84	83	81
75	57	63	68	72	75	77	78	79	79	79	78	77	75
80	54	60	64	68	70	72	74	74	74	74	73	71	70

(continued)

Table 45.—*Total cubic-foot growth for thinned stands of yellow-poplar (continued)*

Age (years)	Basal area (ft²/acre) 40	50	60	70	80	90	100	110	120	130	140	150	160
	ft³/acre/year												
Site Index 110													
20	154	177	198	217	234								
25	142	163	181	197	212	224	236	246					
30	130	148	164	178	190	201	210	218	226	232			
35	119	135	149	161	171	180	188	195	200	205			
40	109	123	136	146	155	163	170	175	180	183	186	189	
45	100	114	124	134	142	148	154	159	162	165	168	169	170
50	93	105	115	123	130	136	141	145	148	150	152	153	153
55	86	97	106	114	120	125	130	133	136	137	139	139	139
60	81	91	99	106	112	116	120	123	125	126	127	128	127
65	76	85	93	99	104	108	112	114	116	117	118	118	117
70	71	80	87	93	98	101	104	106	108	109	109	109	109
75	67	75	82	87	92	95	98	100	101	102	102	102	101
80	64	71	78	82	87	90	92	94	95	%	%	95	94
Site Index 120													
20	174	202	227	250	270	289							
25	162	187	209	228	246	262	276	290	302				
30	149	171	190	207	222	236	248	259	268	277	285		
35	136	156	173	188	201	213	223	232	240	247	254	259	264
40	125	143	158	171	183	193	202	210	216	222	227	232	235
45	116	132	145	157	167	176	184	191	196	201	206	209	212
50	107	122	134	145	154	162	169	175	180	184	187	190	192
55	100	113	125	134	143	150	156	161	165	169	172	174	175
60	93	106	116	125	133	139	145	149	153	156	158	160	161
65	88	99	109	117	124	130	135	139	142	145	147	148	149
70	83	93	102	110	116	122	126	130	133	135	137	138	139
75	78	88	96	104	110	114	119	122	125	127	128	129	130
80	74	83	91	98	103	108	112	115	117	119	120	121	122
Site Index 130													
20	196	228	256	283	307	330	350						
25	183	211	237	260	281	300	318	334	349	363			
30	168	193	216	236	255	271	287	300	313	325	335	345	353
35	154	177	197	215	231	246	259	271	282	291	300	308	315
40	142	163	181	197	211	224	236	246	255	263	270	277	282
45	131	150	166	181	194	205	215	224	232	239	246	251	256
50	122	139	154	167	179	189	198	206	213	219	225	229	233
55	114	129	143	155	166	175	183	190	197	202	207	211	214
60	106	121	134	145	154	163	170	177	182	187	191	195	198
65	100	114	125	136	145	152	159	165	170	174	178	181	183
70	94	107	118	128	136	143	149	155	159	163	166	169	171
75	89	101	111	120	128	135	140	145	150	153	156	158	160
80	84	96	105	114	121	127	133	137	141	144	147	149	150

Only bole wood and bark of trees 4.6 inches d.b.h. and larger are included. Source: Beck and Della-Bianca (1972).

Table &-Ratio of board-foot stand volume per acre to stand basal area per acre for selected values of dominant stand height and mean stand diameter for thinned stands of yellow-poplar[1 2]

Residual quadratic mean stand diameter (inches)	Dominant stand height (feet)										
	50	60	70	80	90	100	110	120	130	140	150
7					0.49	9.83	19.17	28.52	37.86	47.20	56.54
8				18.80	28.78	38.77	48.76	58.74	68.73	78.11	88.70
9		22.48	33.07	43.66	54.25	64.84	75.44	86.03	96.62	107.21	117.80
10	32.69	43.86	55.02	66.19	77.35	88.52	99.68	110.85	122.01	133.18	144.34
11	51.60	63.31	75.02	86.73	98.44	110.15	121.86	133.57	145.28	156.99	168.70
12	68.85	81.08	93.31	105.55	117.78	130.01	142.24	154.47	166.70	178.93	191.16
13	84.66	91.39	110.12	122.85	135.58	148.31	161.04	173.77	186.50	199.23	211.96
14	99.18	112.39	125.60	138.81	152.02	165.23	178.44	191.65	204.86	218.08	231.29
15	112.56	126.23	139.90	153.58	167.25	180.93	194.60	208.27	221.95	235.62	249.30
16	124.89	139.02	153.14	167.26	181.38	195.51	209.63	223.75	231.87	252.00	266.12
17	136.29	150.85	165.41	179.96	194.52	209.08	223.63	238.19	252.75	267.31	281.86
18	146.83	161.81	176.79	191.77	206.75	221.73	236.71	251.69	266.66	281.64	296.62
19	156.59	171.97	187.36	202.75	218.14	233.53	248.92	264.31	279.70	295.09	310.48
20	165.61	181.40	197.19	212.98	228.77	244.56	260.35	216.14	291.93	307.72	323.51
21	173.97	190.15	206.33	222.50	238.68	254.86	271.04	287.22	303.40	319.58	335.76
22	181.70	198.26	214.82	231.38	247.94	264.50	281.06	297.62	314.18	330.74	347.30
23	188.84	205.78	222.71	239.64	256.57	273.50	290.44	301.37	324.30	341.23	358.17
24	195.45	212.74	230.04	247.34	264.63	281.93	299.22	316.52	333.82	351.11	368.41
25	201.54	219.19	236.84	254.50	272.15	289.80	307.46	325.11	342.76	360.42	378.07

[1]Board-foot stand volume per acre of trees 11 inches d.b.h. and over using International 1/4-inch rule. Source: Beck and Della-Bianca (1975).
*Residual stand basal area (square feet per acre) includes all trees 4.6 inches d.b.h. and over per acre.

Table 47.—*Annual board-foot volume growth per acre of ye&w-poplar trees 11 inches d. b. h. and over after thinning to specified residual basal area'*

Age (Years)	Residual basal area (ft²/acre)						
	40	60	80	100	120	140	160
	Board feet/acre/year						
Site Index 90							
30	336	390	420	—	—		
40	350	426	452	454	450		
50	364	412	438	444	434		
60	348	394	414	420	410		
70	328	372	394	400	390		
Site Index 100							
30	456	532	572	586	586	—	—
40	480	564	604	616	608	5%	—
50	464	544	586	598	584	570	542
60	414	512	550	562	550	532	502
70	406	480	518	528	520	504	476
Site Index 110							
30	582	684	744	764	766	—	—
40	602	716	776	800	800	784	—
50	576	686	744	772	766	754	726
60	536	642	698	724	722	706	674
70	498	5%	652	676	676	660	628

Age (Years)	Residual basal area (ft²/acre)						
	40	60	80	100	120	140	160
	Board feet/acre/year						
Site Index 120							
30	716	854	924	960	968	954	—
40	732	878	962	1,000	1,018	1,008	990
50	694	838	920	966	980	972	950
60	646	782	864	908	924	916	894
70	5%	722	798	840	854	848	824
Site Index 130							
30	862	1,028	1,126	1,170	1,190	1,192	—
40	866	1,050	1,162	1,228	1,258	1,258	1,244
50	816	1,000	1,114	1,182	1,214	1,222	1,212
60	758	928	1,038	1,102	1,138	1,144	1,134
70	698	858	962	1,026	1,056	1,064	1,054

[1]International 1/4-inch rule. Source: derived from Beck and Della-Bianca (1975).

5. Common and Scientific Names of Species

Common and Scientific Names of Trees, Shrubs, and Vines

Common Name	Scientific Name
Alder, tag	*Alnus serrulata*
Ash, white	*Fraxinus americana*
Baldcypress	*Taxodium distichum*
Basswood	*Tilia* sp.
Beech, American	*Fagus grandifolia*
Birch, sweet	*Betula lenta*
yellow	*Betula alleghaniensis*
Bittersweet, climbing	*Celastrus scandens*
Blackgum	*Nyssa sylvatica*
Buckeye, yellow	*Aesculus octandra*
Cherry, black	*Prunus serotina*
Cucumbertree	*Magnolia acuminata*
Dogwood, flowering	*Cornus florida*
Grapevine	*Vitis* sp.
Hemlock, eastern	*Tsuga canadensis*
Hickories	*Carya* sp.
Honeysuckle, Japanese	*Lonicera japonica*
Hornbeam, American	*Carpinus caroliniana*
Kudzu	*Pueraria lobata*
Locust, black	*Robinia pseudoacacia*
Magnolia, southern	*Magnolia grandiflora*
Maple, red	*Acer rubrum*
sugar	*Acer saccharum*
Oak, black	*Quercus velutina*
cherrybark	*Quercus faicata* var. *pagodaefolia*
chestnut	*Quercus prinus*
northern red	*Quercus rubra*
scarlet	*Quercus coccinea*
southern red	*Quercus falcata* var. *falcata*
swamp chestnut	*Quercus michauxii*
white	*Quercus alba*
Persimmon, common	*Diospyros virginiana*
Pine, eastern white	*Pinus strobus*
loblolly	*Pinus taeda*
pitch	*Pinus rigida*
shortleaf	*Pinus echinata*
Virginia	*Pinus virginiana*
Redcedar, eastern	*Juniperus virginiana*
sassafras	*Sassafras albidum*
Silverbell, Carolina	*Halesia Carolina*
Sourwood	*Oxydendrum arboreum*
Sweetgum	*Liquidambar styraciflua*
Tupelos	*Nyssa* sp.
Walnut, black	*Juglans nigra*
Yellow-poplar	*Liriodendron tulipifera*

Common and Scientific Names of Animals and Birds

Common Name	Scientific Name
Cardinal	*Cardinalis cardinal&*
Deer, white-tailed	*Odocoileus virginianus*
Finch, purple	*Carpodacus purpureus*
Mouse, white-footed	*Peromyscus* sp.
Quail, bobwhite	*Colinus virginiana*
Rabbit, cotton-tail	*Sylvilagus floridanus*
Sapsucker	*Sphyrapicus vaius*
Squirrel, gray	*Sciurus carolinensis*
Squirrel, red	*Sciurus hudsonicus*

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