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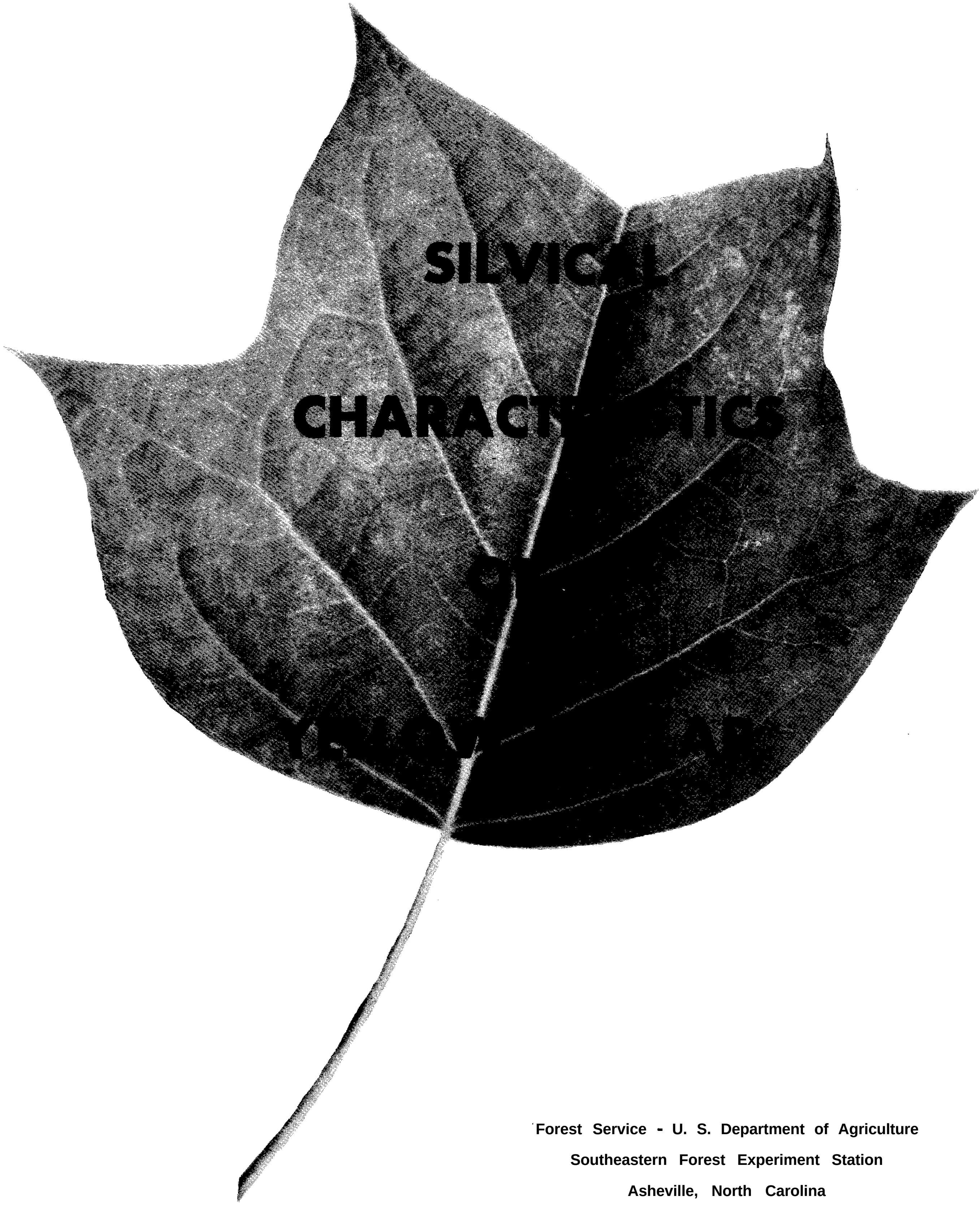

**Forest Service - U. S. Department of Agriculture**

**Southeastern Forest Experiment Station**

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# SILVICAL CHARACTERISTICS OF YELLOW-POPLAR[1]
## (*Liriodendron tulipifera* L.)

*by*

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Yellow-poplar (*Liriodendron tulipifera* L.) is also commonly known as tulip poplar, tulip-tree, white-poplar, whitewood, and "poplar" (60). It gets its name from the tulip-like flowers which it bears in the late spring. Because of the excellent form and rapid growth of the tree, plus the fine working qualities of the wood, yellow-poplar is one of the most important hardwood species in the United States.

Yellow-poplar grows throughout the eastern United States from southern New England west to Michigan and south to central Florida and Louisiana. The species is also found in southern Ontario. It is most abundant and reaches its largest size in the valley of the Lower Ohio River Basin and on the mountain slopes of North Carolina, Tennessee, Georgia, Kentucky, Virginia, and West Virginia.

## HABITAT CONDITIONS

### Climate

Yellow-poplar is widely distributed and grows under a variety of climatic conditions. Temperature extremes vary from severe winters in southern New England to almost frost-free winters in central Florida. Within the range of the species, the average annual maximum and minimum temperatures vary between 100" and -20" F. Rainfall in the territory varies from 30 inches to more than 80 inches in restricted areas of the Southern Appalachians. Yellow-poplar's optimum development occurs where rainfall is well distributed over a long growing season. In a study in West Virginia, adequate rainfall early in the growing season had more effect on diameter growth than did total rainfall during the entire season (107). Temperature during the present and past growing season and precipitation during the past growing season showed no relationship to current annual radial growth or height increment (105).

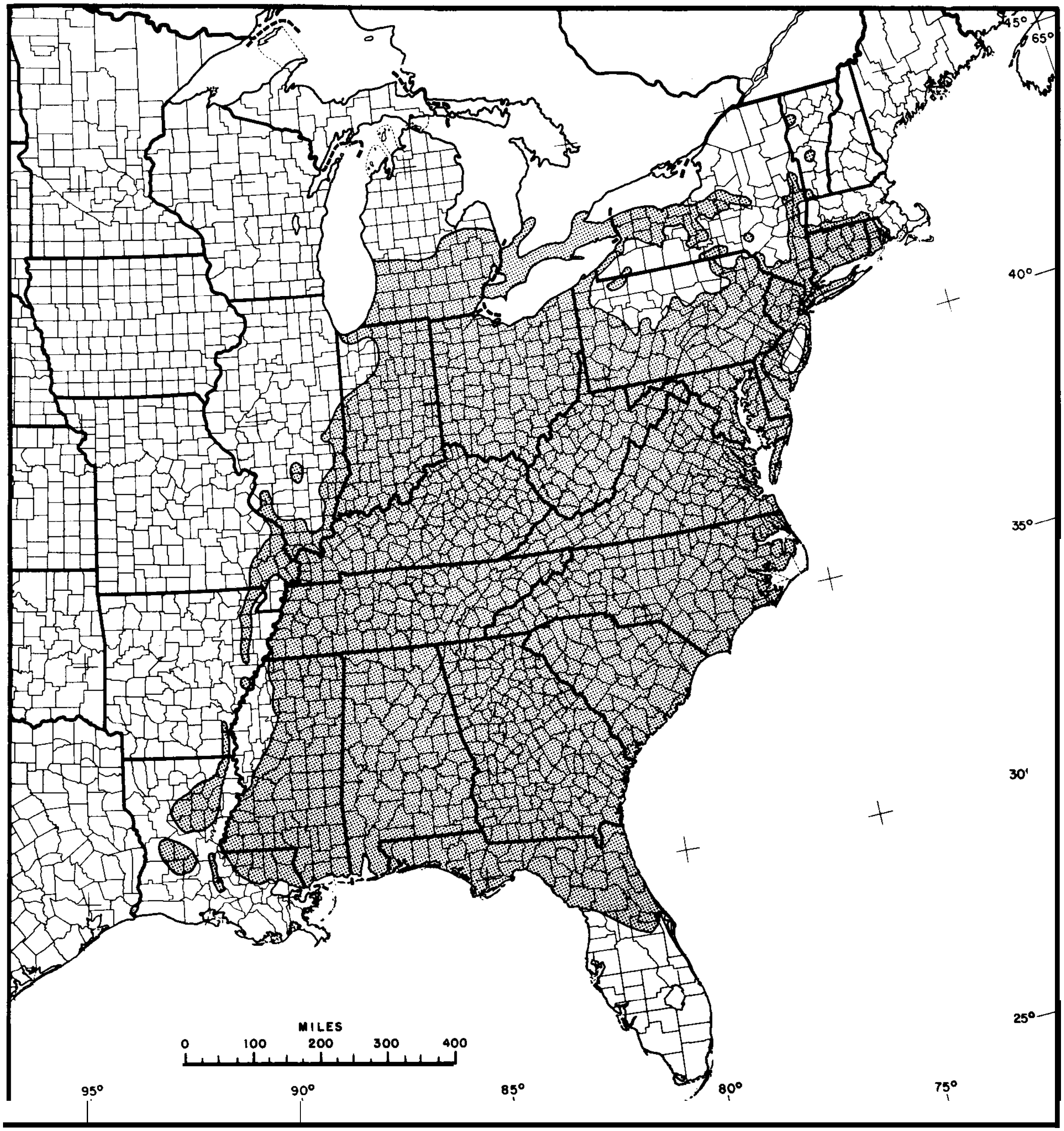
[1]Original authors were James F. Renshaw, deceased, and Warren T. Doolittle, Assistant Director, Watershed, Recreation, Wildlife, and Engineering Research, Northeastern Forest Experiment Station, U.S.D.A. Forest Service, Upper Darby, Pa. At time of authorship, both were employed by the Southeastern Forest Experiment Station.

### Soils and Topography

For good growth and form, yellow-poplar is exacting in soil and moisture requirements. Where it occurs naturally, the sites are usually moderately moist, well-drained, loose-textured soils; it rarely grows well on very dry or very wet sites (66). However, in the coastal plain of the Northeast, yellow-poplar also occurs on moderately to very poorly drained soils, where the site index sometimes reaches 110 (81) .

In the Central States, studies showed that the depth of the A, horizon and depth to a tight subsoil are directly correlated with site index; in general, a tight subsoil less than 24 inches below the surface indicates a below-average site (2, 3) . The studies showed no correlation of site quality with soil nutrient levels or pH.

A soil-site study showed that in the New Jersey coastal plain yellow-poplar grows best in soils with deep, well-drained surface layers overlying loamy or moderately fine-textured subsoils with a good supply of available moisture (81). Subsoil mottling had a positive correlation with yellow-poplar site index. Apparently, poor aeration in the subsoil-for some periods of the year at least-is less harmful than is lack of moisture.




**The range of yellow-poplar.**

In another New Jersey study, both physical and chemical soil properties were significantly correlated with yellow-poplar height growth when considered separately; but when the physical and chemical factors were combined in analysis, only the physical soil properties were correlated with tree height growth (20) .

In one study in the Piedmont of North Carolina, the site indices of yellow-poplar and loblolly pine were found to be similar on good sites. Because of this similarity, the site index of yellow-poplar on lower slopes and alluvial soils can be predicted from an equation for loblolly pine on lower slopes (18). Depth of the A horizon and plasticity of the B horizon are the important soil factors in this relationship.[2] Site index increases with increasing depth of the A horizon and greater friability of the B horizon.

[2]Metz, Louis J. Site indices of yellow-poplar and red gum on alluvial soils in the vicinity of Durham, N. C. 31 pp. 1947. (Unpublished M.F. thesis, School of Forestry, Duke Univ., Durham, N. C.)

Another study of yellow-poplar and loblolly pine in the North Carolina Piedmont showed that there is no difference between the site indices of the two species on good sites.[3] On sites where yellow-poplar is found, depth of the A horizon alone gives an approximate estimate of site quality. In this study, too, site index increased with increasing depth of the A horizon.

In a comprehensive study of the productivity of soils in near-climax Piedmont forests of South Carolina, North Carolina, and southern Virginia, several factors of the soil and topography were found to be correlated with the total height of yellow-poplar (21) . The factors were topographic position on slope, percentage of organic matter in the A, horizon, horizon thickness of the A, horizon, thickness of the total A horizon, percent of sand in the A, horizon, and geographic latitude. Site index was highest on lower slopes and more northerly latitudes, and was positively correlated with the depth, texture, and organic matter of the soil. While these correlations did not result in strong predicting equations, they do provide important facts about soil and topographic factors that affect the growth of the species.

In a north Georgia study, it was found that site index of yellow-poplar is related primarily to topographic position and to soil series (43) . Sheltered coves proved to be the best yellow-poplar sites for a given soil series; open coves and the lower portion of sheltered side slopes were next best; ridge sites were poorest. Soils classified as Burton or Tusquitee were unquestionably the best for yellow-poplar.

In a study in Ohio of the effect of nitrogen fertilizer on potted yellow-poplar seedlings, the height growth of the seedlings increased as the amount of nitrogen was increased from 0 up to 100 pounds per acre (12). This growth response is in agreement with findings on the Black Rock Forest in New York where yellow-poplar made poor radial growth on nitrogen-deficient soils and approached maximum growth on soils that had a high nitrogen content (75) .

In central Georgia, yellow-poplar seedlings fertilized with diammonium phosphate had significantly more height growth after 1 year than did unfertilized seedlings (63) . Three years later the fertilized seedlings were still increasing their height advantage each year over unfertilized seedlings (42).

[3] Hocker, Harold W., Jr. Relative growth and development of loblolly pine and yellow-poplar on a series of soil sites in the lower Piedmont of North Carolina. 40 pp. 1953. (Unpublished M.F. thesis, School of Forestry, N. C. State Univ., Raleigh, N. C.)

Black locust increased soil nitrogen and improved the growth of yellow-poplar in 24-year-old forest plantations in Ohio and Indiana (23). Height and diameter growth of yellow-poplar decreased as distance from the black locust increased. Nitrogen in the soil under the yellow-poplar also decreased with increased distance from the black locust.

Pot-culture studies in Illinois showed that growth of yellow-poplar seedlings was favored by the natural soil structure in forest and plantation soils as compared to old field soil and sieved and packed soil (15, 16) . The presence of endotrophic mycorrhizae also resulted in increased growth.

Aspect, position on slope (2, 70) , and elevation are important factors that can influence yellow-poplar site quality because they indirectly influence the moisture and nutrient-supply of the soil as well as the microclimate. At the northern end of its range, where low temperatures are limiting, yellow-poplar is usually found in valleys and streambottoms and at elevations below 1,000 feet. In the Appalachian Mountains, and up to a maximum elevation of 4,500 feet in the Southern Appalachians, it grows on a wide variety of sites including streambottoms, coves, and moist slopes. Toward the southern limit of the range, where high temperatures and soil moisture probably become limiting, the species is usually confined to well-drained streambottoms.

## Associated Trees

Yellow-poplar is a component of 16 forest cover types (92), being a major species in 4 of these types and a minor species in the other 12:

Major **Component**

| Type No. | Type |
|---|---|
| 57 | Yellow-poplar |
| 58 | Yellow-poplar-Hemlock |
| 59 | Yellow-poplar-White oak-Northern red oak |
| 87 | Sweetgum—Yellow-poplar |

**Minor Component**

| Type No. | Type |
|---|---|
| 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 the better drained soils of the Coastal Plains, yellow-poplar occurs in mixture with the tupelos, baldcypress, the oaks, red maple, sweetgum, and loblolly pine. In the Piedmont, associated species include the oaks, sweetgum, blackgum, red maple, loblolly pine, shortleaf pine, Virginia pine, the hickories, flowering dogwood, sourwood, and redcedar.

At the lower elevations in the Appalachian Mountains, yellow-poplar is found with black locust, white pine, eastern hemlock, the hickories, white oak, other oaks, black walnut, yellow pines, flowering dogwood, sourwood, sweet birch, blackgum, basswood, and Carolina silverbell. At the higher elevations, associated species include northern red oak, white ash, black cherry, cucumbertree, 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, ash, beech, sugar maple, blackgum, dogwood, and the hickories.

Pure stands of yellow-poplar occupy only a small percentage of the total land within the range of the species, but pure stands are usually on productive sites which include some of the most valuable timber-producing forests in eastern North America.

# LIFE HISTORY

## Reproduction and Early Growth

Flowering and fruiting.-Yellow-poplar flowers from April to June, depending on location and weather. The solitary, perfect flower occurs at the tips of slender lateral branches; it is tulip-like in form and size and is one of the favorite sources of nectar for honeybees. In fact, the number of sound seeds produced is apparently related to the number of bees visiting the flowers (97) . -The fruit is a cone-like aggregate of many winged carpels or samaras borne on a central spike. About 80 samaras are produced in each fruit and each one bears two seeds, one usually aborted. The development of the seed is slow; it reaches morphological maturity between mid-August and mid-September (*34*).

A study of the embryology of yellow-poplar was made from trees growing in southern Illinois (48). The account presents findings from two successive seasons of normal flower development. The observations indicate that few stigmas receive compatible pollen during their short receptive period; cross-pollination by insects appears inefficient; compatible trees are rarely adjacent; and it is doubtful that wind is effective in transporting the sticky pollen to flowers of other trees.

Seed production and dissemination.—Although yellow-poplar is a prolific seed bearer, few seeds per strobile are fertile-most are empty seedcoats. Whether a samara contains filled seeds or not can be determined by low dosages of soft X-rays (49, 97). Such X-rays have no effect on subsequent seed germination.

Seed of yellow-poplar normally require 2 years or more for complete germination. For germination tests. direct seeding, and nursery seeding, it is desirable to have all viable seed germinate within a few weeks after the samaras are planted. It has been found that storage of seed for 24 weeks at specified alternating temperatures results in germination of all viable seed (5) . Temperature cycles of 36” and 54° F. and 36” and 70” F. were both successful.

In an Indiana study, controlled cross-pollination of yellow-poplar resulted in up to 90 percent filled seed per cone, while the highest percentage of filled seed for an open-pollinated tree was 34.8 (9) . Four months after germination, seedlings from the cross-pollinated seed parent were taller than seedlings from the open-pollinated parent. It was suggested that, by putting seedlings from widely separated seed parents in the same plantations, seed might be produced that would give both improved germination and more vigorous seedlings. Essentially similar results were obtained in Slovakia in central Europe (95) .

In an anatomical and cytological study of seed development, lack of fertilization because of ineffective pollination was found to be the principal cause for nonviable seeds (6) . Self- and cross-incompatibilities were judged to be more important factors in the development of poor seed than were tree size or location, position of the cone on the tree, or position of the seed in the cone.

As they dry in the cone, the individual winged samaras are scattered by the wind to distances equal to four or five times the height of the trees (66) . In the Piedmont of North Carolina, seedfall begins in early October and reaches a peak in early November (*10*). Sound seed is disseminated from mid-October to mid-March; and the percentage of soundness is about equal throughout the seedfall period. Dissemination is generally high during warm, dry weather and low during cool, wet weather.

In southern Indiana the seedfall pattern around yellow-poplar seed trees is oval shaped with the center north of the seed tree (26). The prevailing south and southwest winds occasionally carry seed over 600 feet.

The minimum seed-bearing age of yellow-poplar trees is about 15 years, and the maximum age is known to be more than 200 years. Bumper seed crops occur at frequent intervals. A study in North Carolina showed that a fall of 300,000 seeds or more per acre is not uncommon (*10*). Cutting tests in this study gave an average of 11.1 percent of sound seeds for a 3-year period; however, cutting tests usually show a much higher seed viability than do germination tests. To cite some examples of production by tree size, a IO-inch tree in the study produced about 750 cones with 7,500 sound seeds, and a 20-inch tree produced 3,250 cones with 29,000 sound seeds. In West Virginia more than 500,000 seeds were produced per acre per year during a 4-year period from 1953 to 1956, and a cutting test on the 1955 crop indicated that 12.4 percent of the seed was sound (106). As part of a research program now underway at the Southeastern Forest Experiment Station, measurements of the 1966 seed crop in 16 stands in the Southern Appalachians showed an average fall of 1.5 million seeds per acre.

In a study in Indiana, it was determined that the percentage of filled seed for trees 15 inches or less in diameter was as high as or higher than that for larger trees (35). Seed from the upper two-thirds of the crown were better filled than were 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. Another study demonstrated that individual trees in Indiana vary widely in their production of viable seed, and that a given tree consistently produces seed of a given viability (114). A low producer will be consistently low, and a high producer will be consistently high over the years. In a study in Ohio, it was found that the percentage survival of year-old yellow-poplar seedlings varied among seed trees within a stand as much as among different stands (57).

Seedling development.-The successful establishment of yellow-poplar stands calls for adequate seed, a seedbed of exposed mineral soil (7), adequate soil moisture, and direct sunlight (74). As a consequence, many of the finest second-growth yellow-poplar stands have become established on old fields in the southern Appalachian Mountains (*19*).

Clearcutting, seed-tree cutting, and group selection have been successfully used to regenerate yellow-poplar. In most cases the extra cost involved in leaving a seed source is unnecessary if seed-producing yellow-poplar were present in the harvested stand.

It is important that the cutover area be large enough for the new crop to grow rapidly. In southeastern Ohio, it was found that yellow-poplar grew faster than oaks after the stand was clearcut (68). Combining clearcutting and selection cutting to obtain openings ½- to l-acre in size also gave good regeneration when a seed source was available. Similar results were obtained in West Virginia where heavier cuttings (including group selection and clearcutting) favored yellow-poplar and other intolerant species on the better sites when a seed source was available (101).

While an area is being cut and logged, proper seedbed and light conditions can usually be provided. It is important that the forest floor be scarified (27). In the Central States, it was found that yellow-poplar seed in the forest floor retains viability up to 4 years (17). When heavy seed crops of viable seed have been frequent for several years, regeneration can usually be obtained with ease following any moderately heavy cut.

Burning following clearcutting has been suggested as a means for preparing a seedbed (87). Although this may be a good idea on areas with a heavy accumulation of raw humus, regeneration can usually be obtained without burning.

In a recent study conducted in the coastal plain and Piedmont sections of New Jersey and Maryland, various methods of favoring the establishment and growth of yellow-poplar reproduction were tested (*61*). Most of the regeneration originated from seed stored in the forest floor rather than from current seed crops. Results corroborate the importance of fairly large overstory openings (1 acre or more) and show the need for reduction of understories by burning, disking, or the mistblowing of herbicides. However, such seedbed preparation should be necessary only where deep litter or dense herbaceous growth predominate or where the seed supply is scant.

After germination, several critical years follow. During this period sufficient soil moisture must be available; good drainage and protection against drying and frost heaving are necessary, and there must be no severe competition from nearby sprout growth. In a study in which various mulches were used to induce soil temperature variation, seedlings grew faster in warm soil than in cool soil (96) . Soil temperatures up to 97" F. had a beneficial effect on seedling growth. Yellow-poplar seedlings will survive dormant-season flooding, but intensive studies in Georgia showed that l-year-old seedlings were usually killed by 4 days or more of flooding during the growing season (64) . This vulnerability during the growing season explains why yellow-poplar is not found on flood plains of rivers that flood periodically for several days at a time.

On favorable sites the success of regeneration can usually be determined by the size and vigor of the seedlings at the end of the third year. Height growth during the first year ranges from a few inches to more than a foot on the best sites. With full light, rapid height growth begins the second year, and at the end of 5 years heights may be 10 to 18 feet. During its seedling and sapling stages, yellow-poplar is capable of making extremely rapid growth. An 11-year-old natural seedling 50 feet tall has been recorded (66) ·

Yellow-poplar has a rapidly growing and deeply penetrating juvenile taproot, as well as many strongly developed and wide-spreading lateral roots (*100*) . It is considered to have a "flexible" rooting habit, even in the juvenile stage.

The behavior and duration of height growth of yellow-poplar varies by latitude. In a Pennsylvania study, seedlings had a 95-day height-growth period beginning late in April and ending about August 1 (44). A sharp peak in height growth was reached about June 1. In a northwestern Connecticut study, yellow-poplar had a 1 IO-day height-growth period beginning in late April and ending in mid-August (52). Ninety percent of this growth took place in a 60-day period from May 20 to July 20, and a sharp peak in height growth was noted in the middle of June. In a study conducted in the lower Piedmont of North Carolina, yellow-poplar had a 160-day height-growth period beginning in early April and ending about the middle of September (56) . Growth was fairly constant, and there was no peak in growth rate during the growing season.

Winter dormancy in yellow-poplar seedlings can be broken by exposure to low temperatures or by treatment with ethylene chlorohydrin (55). A combination of the two treatments is even more effective in shortening the period before dormancy is broken.

Artificial regeneration.-Experiments in the planting and direct seeding of yellow-poplar have provided important information concerning growth requirements and silvical characteristics of the species.

Artificial regeneration should not be attempted on dry, exposed, old field sites because the few seedlings that survive make poor growth (66, 71).

In the Appalachian Valley of Tennessee, north and east exposures should be favored for planting yellow-poplar and steep south slopes should be avoided (70, 72, 73). The planting site should not be eroded, the soil should be moist but well-drained, preferably with a light-to-moderate cover of vegetation. Other factors affecting plantation success are soil type, first-year precipitation, permeability and porosity of the soil, and rodent activity.

A study of the effect of various preplanting ground treatments on survival and growth of yellow-poplar in the Central States revealed that planting in the lay of double furrows was superior to scalping, single furrow plowing, and no preparation (69) . This same study showed that 5-year height growth increased with increases in soil depth and that machine-planted seedlings survived and grew better than bar- or mattock-planted seedlings.

Planting and nursery research on yellow-poplar shows the importance of grading seedlings and improving nursery techniques (31, 58, 59, 82, 89) . A study in southeastern Ohio revealed that the heights of 5-year-old seedlings originally graded to a 6/20-inch stem diameter (1 inch above ground line) were 1 foot taller than seedlings of the same age that had been graded to 3/20 inch (58). Seedlings 15 inches high at time of planting were 1 foot taller than seedlings that had been 5 inches high at time of planting. In a North Carolina study, it was found that 3-year survival was significantly greater for seedlings with a root-collar diameter of 0.25 inch or more than for smaller seedlings (82). A combination of root pruning and grading of seedlings can improve survival even more (59). A study of the quality of planting stock revealed that seedbed density exerts some influence on seedling grade, independent of the mother tree (89) .

As early as 1931, a study in the Southern Appalachians demonstrated that planting yellow-poplar is more reliable than direct seeding in spots (54). More recently an experiment in direct seeding in the North Carolina Piedmont revealed that yellow-poplar seeds planted in the ground produced more seedlings than did those sown on the surface (90) . Screen protection of seeded spots increased establishment of the seedlings, and spring seeding gave better results than did fall seeding. In southern Indiana, a direct seeding in forest openings at the rate of 120,000 seeds per acre resulted in 800 seedlings per acre attributable to direct seeding (14). An additional 1,000 seedlings per acre were attributable to natural seedfall. Establishment was better on scarified ground than on unscarified ground.

A study in Indiana demonstrated that many soil-site relationships previously established for natural stands also hold true for plantations (104). Fifteen-year height growth increased as depth of the A, horizon and depth to tight subsoil increased. Survival and growth were satisfactory only where water table depths were greater than 24 inches.

Large differences in height and diameter growth occurred in two portions of a yellow-poplar plantation in southwestern Michigan (86). Foliar analysis revealed that the soil-nutrient regimes in the two growth areas were significantly different, especially in nitrogen and phosphorus. Both elements were severely limiting in the poor growth area.

A mixed plantation of 85 percent white pine and 15 percent yellow-poplar was established in 1912 near Baltimore, Maryland (29) . This is one of the few examples of a successful mixed plantation which includes yellow-poplar as one of the species.

Vegetative reproduction.-A number of investigators have attempted to root yellow-poplar cuttings, but most early attempts were not successful (4, 41) . In a more recent study, cuttings were rooted successfully after they were dipped in indolebutyric acid and a mist of water was sprayed over the propagation bed (28). However, it is not known whether or not these rooted cuttings would have successfully survived outplanting. Yellow-poplar has been successfully

**Typical second-growth yellow-poplar stand 45 years of age. This stand occupier a bottom-land site which at one time was a cultivated field.**

rooted from stump sprouts of 7-year-old trees (65, 93, 94); soft-tissue cuttings placed in a mist bed began rooting in 4 weeks and successfully survived transplanting. Cuttings from a fast-growing clone grew faster, both above and below ground, than did cuttings from a slow-growing clone (93). A system of splitting seedlings longitudinally and then propagating the halves was also highly successful (77) . However, splitting seedlings only provides one additional new plant from the ortet, while the rooting of stump sprouts provides several.

A technique for propagating yellow-poplar by making use of its epicormic branching ability has recently been described (53) . Partial girdles into the outer one or two annual rings result in a profusion of epicormic sprouts which can then be rooted in the same manner as stump sprouts. This method has the advantage of preserving the selected ortet for repeated use. Experience with this method, however, reveals that not every girdled tree will sprout well. Young trees and trees with low vigor are better sprouters than old trees and rapidly growing trees.

Yellow-poplar sprouts readily and vigorously from stumps and frequently develops satisfactorily in clumps, but sprout stands are not as desirable as stands from seed. Trees of sprout origin are more apt to develop heart and butt rot than are seedlings (33, 102) . When, as is often done, large, well-formed trees of sprout origin are joined to a suppressed, ancillary stem in a V-type union, several decay fungi usually infect the large tree through the dead stub (32) . Small stumps provide little support for sprouts against ice and, wind damage because the stumps rot quickly, but sprouts from small stumps and seedling sprouts do have high vigor and can usually outgrow the sprouts and seedlings of competing species. It is important to recognize that many existing young stands of sprout origin may need extra cultural attention during the early years.

## Sapling Stage to Maturity

Yield and quality.-Mature yellow-poplar trees have reached 190-foot heights and lo-foot diameters, but trees approaching this size are now rare. Good second-growth trees may attain heights of over 120 feet and diameters of 18 to 27 inches in 50 to 60 years (67) . Probable normal yields for various ages and sites are shown in table 1 (66). Table 2 contains selected empirical yields for natural, unthinned yellow-poplar in the Southern Appalachians.[4]

In a study in West Virginia, the average 10-year diameter growth of yellow-poplar by diameter classes was as follows (38) :

| Present d.b.h. | D.b.h. growth in last 10 years |
|---|---|
| Inches | *Inches* |
| 6 | 3.55 |
| 8 | 3.37 |
| 10 | 3.19 |
| 12 | 3.00 |
| 14 | 2.82 |
| 16 | 2.64 |
| 18 | 2.46 |
| 20 | 2.28 |
| 22 | 2.09 |
| 24 | 1.91 |

The quality of yellow-poplar trees is also important in determining their value as commercial timber. Quality index is a relative measure of tree value. High quality-index values of yellow-poplar were associated with high site-index values in second-growth Southern Appalachian stands (8) .

Reaction to competition.-Although it is an intolerant species, yellow-poplar can overcome some competition simply because it grows so fast. In the Piedmont and the mountains of the Southeast, it is extremely sensitive to site change. Several studies in this area have demonstrated

[4]Unpublished data. Southeastern Forest Exp. Sta., Asheville, N. C.

Table I.-Normal yield per acre for second-growth yellow-poplar[1]
(Table adapted from McCarthy 1933 (66))

| Age (years) | Basal area by site indices of— | | | Volume[2] by site indices of— | | | Volume[3] by site indices of— | | |
|---|---|---|---|---|---|---|---|---|---|
| | 70 | 90 | 110 | 70 | 90 | 110 | 70 | 90 | 110 |
| | - - . *Square feet* - - - 17 | | | - - - - *Cubic jeet* - - - | | | - - - Board *feet* - - - | | |
| 10 | 39 — | 8 | 75 | 600 | 1,180 50 | 1,765 250 | 650 — | 2,000 — | 5,180 200 |
| 20 | | 60 | | | | | | | |
| 30 | 70 97 | 128 97 | 116 150 | 2,010 1,305 | 2,300 3,390 | 4,800 3,320 | 2,650 6,780 | 16,300 8,710 | 27,350 15,600 |
| 40 | | | | | | | | | |
| 50 | 122 | 157 | 183 | 2,705 | 4,480 | 6,220 | 11,400 | 24,400 | 40,200 |

[1]All trees 5 inches or more d.b.h.
[2]Peeled volume of merchantable stem to a 3-inch top diameter inside bark.
[3]International 1/8-inch rule. Stump height 1 foot; diameter inside bark 6 inches.

**Table P.-Empirical yield per acre for second-growth yellow-poplar in the Southern Appalachians[1]**

**SITE INDEX 90**

| Basal area (sq.ft./acre) | Age (years) | | | | Age (years) | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| | *Cubic feet per acre[2]* | | | | *Board feet per acre[3]* | | | |
| 60 | | | | | | | | |
| 100 | 2,075 1,212 | 2,857 1,668 | 3,352 1,958 | 2,155 3,690 | 154 90 | 1,664 972 | 4,834 2,823 | 8,311 4,854 |
| 140 | 2,957 | 4,071 | 4,777 | 5,258 | 220 | 2,372 | 6,889 | 11,845 |
| **SITE INDEX 110** | | | | | | | | |
| 60 | 1,454 | 2,002 | 2,349 | 2,585 | 223 | 2,275 | 6,257 | 10,190 |
| 100 | 2,489 | 3,427 | 4,022 | 4,426 | 382 | 3,895 | 10,915 | 17,449 |
| 140 | 3,548 | 4,885 | 5,731 | 6,308 | 544 | 5,551 | 15,271 | 24,869 |

1All trees 5 inches or more d.b.h.
2Inside bark volume of the entire bole.
3International ¼-inch rule. Stump height 1 foot; 11-inch d.b.h. class and larger to top diameter of 8 inches outside bark.

that on the best sites it has the highest site index of all hardwoods and conifers studied, and that on the poorest sites it has the lowest site index (24, 78, 79)

Successionally, pure yellow-poplar is temporary. It is often a pioneer on abandoned or clearcut land that has adequate seed and favorable soil-moisture conditions. But it in turn is invaded by more tolerant species, such as oaks, hickories, or northern hardwoods. More often it regenerates as a mixed type with other species, and it commonly persists in climax stands as scattered individuals. In these mixed stands, site quality exerts a strong influence on stand composition. On fertile sites yellow-poplar outstrips most competitors and forms a high percentage of the overstory. On poorer sites other species assume greater importance.

Because this species is intolerant, the cleaning of seedling or sapling stands is an important part of its management (I, 25, 109, 116). Dominant and codominant yellow-poplar seedlings or saplings respond little to cleaning, but overtopped or intermediate trees with good vigor respond quite readily in greater height and diameter growth (25) . A study of yellow-poplar in the Southern Appalachians showed that the greatest benefits of cleaning were more desirable stems and better species composition (I, 109). The cleaning also increased yield by 6 cords at 25 years. A New Jersey study showed that competition from understory vegetation under partially cut stands was detrimental to seedling survival (80) . Shrubs were more detrimental than herbs.

Four years after a clearcut in southeastern Ohio, the best indicators of the growth potential of yellow-poplar seedlings were their immediate past growth and present crown position (112). Overtopped trees responded to release, but did not grow as rapidly as did trees that were free to grow from the outset.

In well-stocked stands on good sites, individual tree growth may slow down about the 20th year. Unless the stands are thinned, crowding may continue until growth is seriously retarded. Thinnings made at about 20 years will produce some material large enough for pulpwood, but in most cases stands must be about 30 years old to provide an operable cut. A study in West Virginia showed that moderate thinnings may be desirable at short intervals (111). Such thinnings keep a stand sufficiently closed so that epiconnic branches do not grow (*110*) , nor will the danger from ice or glaze be as great as with heavier thinning (II).

Desirable crown length of yellow-poplar can be maintained by repeated thinnings; 60-foot crown lengths are possible when trees reach 100 feet in height (39). Moderate to heavy thinnings in which 30 to 40 percent of the volume is removed have been recommended at 8- to IO-year intervals (40) . Through such intensive management, it may be possible to obtain an annual growth of nearly 1,000 board feet per acre during the last half of the rotation. In the process, basal area growth will be increased, the rotation shortened, and the specific gravity and strength of the wood increased.

## Pruning and Epicormic Branching

Yellow-poplar prunes itself well except in very sparsely stocked stands. Consequently, artificial pruning is probably not necessary in natural stands.

Some epicormic branching occurs on yellow-poplar trees, and thinning of young yellow-poplar has often been delayed for fear of causing an increase in sprouting. A recent study in the Southern Appalachians showed that the initiation of epicormic branching on butt logs of second-growth yellow-poplar trees was not related to intensity of thinning.[5] Epicormic branches large enough to cause degrade were concentrated on the upper portion of the butt log. For old-growth yellow-poplar in the Southern Appalachians, epicormic branching increased on residual trees following logging but the increase was concentrated on the upper logs and reduction in value yield was small (46). In West Virginia, a comparison of epicormic branching in northern red oak, black cherry, and yellow-poplar border trees showed that yellow-poplar produced the fewest sprouts (91).

## PRINCIPAL ENEMIES

Yellow-poplar is considered to be unusually free from damage by pests. Though subject to various canker, stain, and decay fungi and to a variety of insect attackers, it is seldom extensively damaged in forest stands. However, with the mounting interest in scenic and recreational areas of high value, damage or loss of even a few individual trees concerns many land managers. With these facts in mind, we have listed and discussed some of the important organisms and agents known to damage the species.

Young yellow-poplar is susceptible to cankers caused by *Nectria magnoliae,* but these cankers soon heal on dominant or codominant trees (45, 76).

A canker disease caused by *Fusarium solani* was found on yellow-poplar in Ohio (22). The study revealed that the organism is not a virulent pathogen and damages only weakened host trees.

A disease referred to as yellow-poplar dieback was first described in Mississippi in 1954 (99). A species of *Myxosporium* was isolated as the probable causal organism. Further work on this disease in the Piedmont of North Carolina cast doubt on this early conclusion and identified an undetermined species of *Xanthomonas* as being consistently associated with the cankered trees (47). In North Carolina the disease is more severe in upland sites than in bottomland stands; site, therefore, may be a determining factor in severity of the disease.

Decay often follows top breakage (83) or butt wounds from fire (37), but these infections may or may not become extensive, depending upon the size of the wound and the specific fungus. Most decay is caused by *Collybia velutipes, Pleurotus ostreatus, Hydnum erinaceus,* and *Polyporus versicolor.* In one study, *Armillaria mellea* was the most common rot affecting fire-damaged trees (66). Yellow-poplar is also subject to heart rot in the main stem by way of dead branches. In another study, 20 percent of the dead branches of trees examined were entry points for heart rot into the main stem; the larger the branch, the greater the chances for heart rot (98).

The common leaf spots caused by species of *Cercospora, Cylindrosporium, Gloeosporium, Phyllosticta,* and *Mycosphaerella* do not result in excessive damage.

In the Northeast, inoculations showed that infection by *Verticillium albo-atrum* may cause wilting and death of young twigs of yellow-poplar (113). Similar wilt symptoms caused by *Verticillium dahliae* were reported in West Virginia (51).

Sapstreak, a disease caused by the fungus *Endoconidiophora virescens,* has killed occasional trees. At present, this disease is rare and known to occur only in western North Carolina (85).

A nursery root rot disease caused by *Cylindrocladium scoparium* causes root and stem lesions (50). It is frequently lethal in nursery beds and causes low survival and poor growth when infected seedlings are outplanted.

Yellow-poplar foliage is occasionally fed upon by larvae of miscellaneous butterflies and moths and by chewing and sucking insects; it is frequently attacked by the tulip gall fly (*Thecodiplosis liriodendri*), which causes purplish blister-galls on the leaves. The branches and twigs may be attacked by several species of scale insects; the most common is the tulip tree scale (*Toumeyella liriodendri*) (23). These attacks seldom affect the tree seriously.

borers occasionally degrade lumber by tunneling in the sapwood or heartwood. Most important is the Columbian timber beetle (*Corthylus columbianus*), a very aggressive ambrosia beetle that enters the sapwood of living trees. The defect, known as "calico poplar," consists of black-stained burrows and discolored wood a

[5] Della-Bianca, Lino. (Unpublished manuscript, Southeastern Forest Exp. Sta., Asheville, N. C.)

foot or more both above and below the point of attack. Dying trees and logs may be injured by the sapwood timberworm (*Hylecoetus lugubris*), and the heartwood beneath the blazes and wounds is often riddled by the flatheaded sycamore borer (*Chalcophora campestris*). Yellow-poplar trees were observed dead or dying along the Cumberland River in Kentucky because of attacks by a root collar borer (*Euzophora ostricolorella*) (36). Degrade was not a serious problem in the lumber obtained from a salvage cutting. No new attacks were observed after spraying the basal 6 feet of residual trees with insecticides.

Considerable lumber degrade from "bird peck" is periodically caused by the common sapsucker.

Wood discolorations are common following any type of wounding, but these discolorations, except when associated with decay, do not affect wood strength (84). Such nondecay discolorations are attributed to oxidation rather than to infection by organisms.

Yellow-poplar seed form part of the diet of wildlife. Quail, purple finch, cardinal, cottontail rabbit, red squirrel, gray squirrel, and the white-footed mouse are some of the animals that eat yellow-poplar seed.

The-twigs and branches of yellow-poplar are tender and tasty to livestock and white-tailed deer, and young trees are often heavily browsed. Seedlings are grazed to the ground, small saplings are trimmed back, and even large saplings may be ridden down and severely damaged. On areas where animals are concentrated, young yellow-poplar is frequently wiped out. Rabbits also eat the bark and buds of seedlings and saplings and can be quite destructive at times.

Because of extremely thin bark, yellow-poplar seedlings and saplings are extremely susceptible to fire damage, and even a light ground fire is usually fatal to stems up to an inch in diameter (66). On large trees, which have bark a half inch thick or more, good insulation is provided against all but the hottest fires.

Sleet and glaze storms, which occur periodically within the range of yellow-poplar, may cause considerable damage (II, 66). Stump sprouts are particularly susceptible to injury, and slender trees may be broken off. The tops of dominant and codominant trees are often broken, and if breakage is severe the growth rate will be reduced. Top damage is often the point of entry for fungi. Although yellow-poplar usually makes remarkable recovery after such storms, repeated damage can result in a serious growth reduction and loss of quality.

When the sap is running in the spring, yellow-poplar is very susceptible to logging damage. If a falling tree strikes a standing poplar, there is often considerable bark loss up and down the bole of the standing tree. Even if the bark only appears lightly bruised, it may subsequently dry up and fall off in long strips.

Other enemies of this species include grapevines that can reduce growth and sometimes even kill the trees. Japanese honeysuckle can be particularly serious because it thrives on the best sites, smothers small saplings, and precludes regeneration.

Frost, especially in frost pockets, can affect the early growth and development of yellow-poplar. Following a late spring frost in a 20-year-old plantation, it was found that leaf mortality varied from 5 to 100 percent of the leaves on the individual trees (115). Leaf mortality was lowest on trees with a high foliar content of potassium. 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, was described in 30-year-old yellow-poplar trees in West Virginia (103).

## RACES AND HYBRIDS

There are no known natural hybrids of yellow-poplar, but the possible existence of races and geographic strains is being studied (30, 58, 62, 88).

A study conducted in the Coastal Plain of South Carolina revealed that yellow-poplar seedlings originating in the North Carolina Coastal Plain were almost twice as high after the third growing season as were seedlings that originated in the mountains of North Carolina (62).

Seed from southern latitudes may have a lower germinative capacity and may produce plants that are less frost-hardy than those produced by seed from northern latitudes.

A growth-chamber study revealed that yellow-poplar seedlings of northern and of. southern origin responded very differently to day-length treatments. A day-length of 18 hours inhibited the northern but not the southern seedlings (108).

# LITERATURE CITED


(1) Abell, Charles A.
1935. Results of 1924 cleanings of cove hardwoods, Pisgah National Forest. J. Forest. 33: 626-627.

(2) Auten, John T.
1935. Successful forest planting requires better site appraisals. J. Forest. 33: 861-864.

(3) ———
1945. Prediction of site index for yellow-poplar from soil and topography. J. Forest. 43: 662-668.

(4) Bailey, L. F.
1948. Figured wood: a study of methods of production. J. Forest. 46: 119-125.

(5) Boyce, S. G., and Hosner, J. F.
1963. Alternating storage temperatures increase the germination of yellow-poplar seed. J. Forest. 61: 731-733.

(6) Boyce, Stephen G., and Kaeiser, Margaret
1961. Why yellow-poplar seeds have low viability. U. S. Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 168, 16 pp.

(7) ——— and Parry, Robert E.
1958. Effect of seedbed conditions on yellow-poplar regeneration. J. Forest. 56: 751-753.

(8) Campbell, Robert A.
1959. Tree grades give accurate estimate of second-growth yellow-poplar values. U. S. Forest Serv. Southeast. Forest Exp. Sta. Pap. 108, 14 pp.

(9) Carpenter, I. W., and Guard, A. T.
1950. Some effects of cross-pollination on seed production and hybrid vigor of tulip tree. J. Forest. 48: 852-855.

(10) Carvell, Kenneth L., and Korstian, C. F.
1955. Production and dissemination of yellow-poplar seed. J. Forest. 53: 169-170.

(11) ———Tryon, E. H., and True, R. P.
1957. Effects of glaze on the development of Appalachian hardwoods. J. Forest. 55: 130-132.

(12) Chapman, A. C.
1933. Some effects of varying amounts of nitrogen on the growth of tulip poplar seedlings. Ohio J. Sci. 33: 164-181.

(13) ———
1935. The effects of black locust on associated species with special reference to forest trees. Ecol. Monogr. 5: 37-60.

(14) Clark, F. Bryan
1958. Direct seeding yellow-poplar. J. Forest. 56: 351.

(15) ———
1963. Endotrophic mycorrhizae influence yellow-poplar seedling growth. Science 140: 1220-1221.

(16) ———
1964. Micro-organisms and soil structure affect yellow-poplar growth. Cent. States Forest Exp. Sta., U. S. Forest Serv. Res. Pap. cs-9, 12 pp.

(17) ——— and Boyce, Stephen G.
1964. Yellow-poplar seed remains viable in the forest litter. J. Forest. 62: 564-567.

(18) Coile, Theodore S.
1948. Relation of soil characteristics to site index of loblolly and shortleaf pines in the lower Piedmont region of North Carolina. Duke Univ. Forest. Bull. 13, 78 pp.

(19) Creasy, W. D.
1954. Secondary succession and growth of yellow-poplar on the "Green Mountain," Nicholas County, West Virginia. Castanea 19: 81-87.

(20) Czapowskyj, M. M.
1962. Site quality of yellow-poplar in relation to soil factors in the coastal plain of New Jersey. (Abstr.) Diss. Abstr. 23: 1849-1850.

(21) Della-Bianca, Lino, and Olson, David F., Jr.
1961. Soil-site studies in Piedmont hardwood and pine-hardwood upland forests. Forest Sci. 7: 320-329.

(22) Dochinger, L. S., and Seliskar, C. E.
1962. Fusarium canker found on yellow-poplar. J. Forest. 60: 331-333.

(23) Donley, D. E., and Burns, D. P.
1965. The tuliptree scale. U. S. Forest Serv. Forest Pest Leafl. 92.

(24) Doolittle, Warren T.
1958. Site index comparisons for several forest species in the Southern Appalachians. Soil Sci. Soc. Amer. Proc. 22: 455-458.

(25) Downs, A, A,
1946. Response to release of sugar maple, white oak, and yellow-poplar. J. Forest. 44: 22-27.

(26) Engle, LaMont G.
1960. Yellow-poplar seedfall pattern. U. S. Forest Serv. Cent. States Forest Exp. Sta. Note 143, 1 pp.

(27) ——— and Williams, Robert D.
1957. Scarifying seedbed boosts yellow-poplar germination. U. S. Forest Serv. Cent. States Forest Exp. Sta. Note 110.

(28) Enright, L. J.
1957. Vegetative propagation of *Liriodendron tulipifera.* J. Forest. 55: 892-893.

(29) Fenton, Richard H., and Pfeiffer, Karl E.
1965. Successful Maryland white pine-yellow-poplar plantation. J. Forest. 63: 765-768.

(30) Funk, David T.
1958. Frost damage to yellow-poplar varies by seed source and site. U. S. Forest Serv. Cent. States Forest Exp. Sta. Note 115.

(31) ———
1964. Premium yellow-poplar seedlings, eight years after planting. Cent. States Forest Exp. Sta., U. S. Forest Serv. Res. Note cs-20.

(32) Ginns, J. H.
1962. Yellow-poplar butt rot infection from dead ancillary stems. (Abstr.) Phytopathology 52: 1218.

(93) ——— and True, R. P.
1967. Butt rot in yellow-poplar seedling sprout stands. Forest Sci. 13: 440-447.

(34) Guard, A. T.
1943. The development of the seed of *Liriodendron tulipifera* L. Indiana Acad. Sci. Proc. 53: 75-77.

(35) ——— and Wean, Robert E.
1941. Seed production in the tulip poplar. J. Forest. 39: 1032-1033.

(36) Hay, C. J.
1958. Life history and control of a root collar borer (*Euzophora ostricolorella* Hulst.) in yellow-poplar. J. Econ. Entomol. 51: 251-252.

(37) Hepting, George H., and Hedgcock, George G.
1937. Decay in merchantable oak, yellow-poplar, and basswood in the Appalachian region. U.S. Dep. Agr. Tech. Bull. 570, 30 pp.

(38) Holcomb, Carl J., and Bickford, C. Allen
1952. Growth of yellow-poplar and associated species in West Virginia. . a guide to selective cutting. U. S. Forest Serv. Northeast. Forest Exp. Sta. Pap. 52, 28 pp.

(39) Holsoe, Torkel
1950. Profitable tree forms of yellow-poplar. W. Va. Agr. Exp. Sta. Bull. 341, 23 pp.

(40) ———
1951. Yellow-poplar: reaction to crown release and other factors influencing growth. W. Va. Agr. Exp. Sta. Bull. 344 T, 83 pp.

(41) Huckenpahler, B. J.
1955. Auxins fail to stimulate rooting of yellow-poplar cuttings. Bot. Gaz. 117: 73-75.

(42) Ike, Albert F., Jr.
1962. Fertilized yellow-poplar seedlings maintain growth advantage after four years. U. S. Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 175, 2 pp.

(43) ——— and Huppuch, C. D.
1968. Predicting tree height growth from soil and topographic site factors in the Georgia Blue Ridge mountains. Ga. Forest Res. Counc. Res. Pap. 54, 11 pp.

(44) Illick, J. S.
1919 When trees grow. Amer. Forest. 25: 1386-1390.

(45) Jemison, George M., and Hepting, George H.
1949. Timber stand improvement in the Southern Appalachian region. U. S. Dep. Agr. Misc. Pub. 693, 80 pp.

(46) ——— and Schumacher, F. X.
1948. Epicormic branching in old-growth Appalachian hardwoods. J. Forest. 46: 252-255.

(47) Johnson, T. W., Jr., Goforth, M. H., Powell, R. W., Jr., and Haar, N. D.
1957. Observations on yellow-poplar dieback. Forest Sci. 3: 84-89.

(48) Kaeiser, M., and Boyce, S. G.
1962. Embryology of *Liriodendron tulipifera* L. Phytomorphology 12: 103-109.

(49) ——— and Boyce, Stephen G.
1962. X-ray negatives for sorting yellow-poplar samaras with filled and empty seeds. J. Forest. 60: 410-411.

(50) Kelman, A., Gooding, G. V., and Slocum, G. K.
1959. Cylindrocladium root rot of yellow-poplar. Elisha Mitchell Sci. Soc. J. 75: 66-67.

(51) Kessler, K. J., and True, R. P.
1960. Symptoms of *Verticillium* wilt in yellow-poplar (*Liriodendron tulipifera* L.). (Abstr.) Phytopathology 50: 572.

(52) Kienholz, Raymond
1941. Seasonal course of height growth in some hardwoods in Connecticut. Ecology 22: 249-258.

(53) Kormanik, Paul P., and Porterfield, E. J.
1966. Rooting yellow-poplar cuttings. Forest Farmer 26: 24, 41-42.

(54) Korstian, C. F., and MacKinney, A. L.
1931. Planting versus direct seeding of yellow-poplar in the Southern Appalachian region. J. Forest. 29: 1178-1181.

(55) Kramer, Paul J.
1934. Methods of breaking dormancy in certain forest trees. J. Forest. 32: 734-741.

(56) ———
1943. Amount and duration of growth of various species of tree seedlings. Plant Physiol. 18: 239-251.

(57) Limstrom, Gustaf A.
1959. Yellow-poplar seed quality varies by seed trees, stands, and years. U. S. Forest Serv. Cent. States Forest Exp. Sta. Note 134.

(58) ——— and Finn, Raymond F.
1956. Seed source and nursery effects on yellow-poplar plantations. J. Forest. 54: 828-831.

(59) ———Finn. R. F.. and Deitschman. G. H.
1955. Planting stock grades for yellow-poplar. J. Forest. 53: 28-32.

(60) Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). U. S. Dep. Agr. Handbook 41, 472 pp.

(61) Little, Silas
1967. Treatments needed to regenerate yellow-poplar in New Jersey and Maryland. Northeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note NE-58.

(62) Lotti, Thomas
1955. Yellow-poplar height growth affected by seed source. U. S. Forest Serv. Tree Planters' Notes 22: 3.

(63) McAlpine, Robert G.
1959. Response of planted yellow-poplar to diammonium phosphate fertilizer. U. S. Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 132, 2 pp.

(64) ———
1961. Yellow-poplar seedlings intolerant to flooding. J. Forest. 59: 566-568.

(65) ———
1964. A method for producing clones of yellow-poplar. J. Forest. 62:115-116.

(66) McCarthy, E. F.
1933. Yellow-poplar characteristics, growth, and management. U. S. Dep. Agr. Tech. Bull. 356, 58 pp.

(67) McGee, Charles E., and Della-Bianca, Lino
1967. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp.

(68) Merz, Robert W., and Boyce, Stephen G.
1958. Reproduction of upland hardwoods in southeastern Ohio. U. S. Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 155, 24 pp.

(69) ——— and Finn, Raymond F.
1955. Yellow-poplar responds to preplanting ground treatment. U. S. Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 150, 18 pp.

(70) Minckler, Leon S.
1941. Forest plantation success and soil-site characteristics on old fields in the great Appalachian valley. Soil Sci. Soc. Amer. Proc. 6: 396-398.

(71) ———
1941. The right tree in the right place. J. Forest. 39: 685-688.

(72) ———
1946. Old field reforestation in the great Appalachian valley as related to some ecological factors. Ecol. Monogr. 16: 88-108.

(73) ———
1948. Tree planting in the central, Piedmont, and Southern Appalachian regions. U. S. Dep. Agr. Farmers' Bull. 1994, 39 pp.

(74) ——— and Jensen, Chester E.
1959. Reproduction of upland central hardwoods as affected by cutting, topography, and litter depth. J. Forest. 57: 424-428.

(75) Mitchell, Harold J., and Chandler, Robert F.
1939. The nitrogen nutrition and growth of certain deciduous trees of Northeastern United States. Black Rock Forest Bull. 11, 94 pp.

(76) Nelson, R. M.
1940. Vigorous yellow-poplar trees can recover from injury by nectria cankers. J. Forest. 38: 587-588.

(77) Nelson, Thomas C.
1957. A method for vegetatively propagating yellow-poplar. J. Forest. 55: 589.

(78) ——— and Beaufait, William R.
1957. Studies in site evaluation for southern hardwoods. Soc. Amer. Forest. Proc. 1956: 67-70.

(79) Olson, David F., Jr., and Della-Bianca, Lino
1959. Site index comparisons for several tree species in the Virginia-Carolina Piedmont. U. S. Forest Serv. Southeast. Forest Exp. Sta. Pap. 104, 9 pp.

(80) Phillips, J. J.
1962. Some effects of competition on the survival of yellow-poplar seedlings. U. S. Forest Serv. Northeast. Forest Exp. Sta. Forest Res. Note 134.

(81) ———
1966. Site index of yellow-poplar related to soil and topography in southern New Jersey. Northeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. NE-52, 10 pp.

(82) Rodenbach, R. C., and Olson, D. F., Jr.
1960. Grading yellow-poplar planting stock is important. U. S. Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 147, 2 pp.

(83) Roth, Elmer R.
1941. Top rot in snow-damaged yellow-poplar and basswood. J. Forest. 39: 60-62.

(84) ———
1950. Discolorations in living yellow-poplar trees. J. Forest. 48: 184-185.

(85) ———, Hepting, G. H., and Toole, E. R.
1959. Sapstreak disease of sugar maple and yellow-poplar in North Carolina. U. S. Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 134, 2 pp.

(86) Schomaker, C. E., and Rudolph, V. S.
1964. Nutritional relationships affecting height growth of planted yellow-poplar in southwestern Michigan. Forest Sci. 10: 66-76.

(87) Sims, I. H.
1932. Establishment and survival of yellow-poplar following a clear cutting in the Southern Appalachians. J. Forest. 30: 409-414.

(88) Sluder, Earl R.
1960. Early results from a geographic seed source study of yellow-poplar. U. S. Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 150, 2 pp.

(89) ———
1964. Quality of yellow-poplar planting stock varies by mother tree and seedbed density. U. S. Forest Serv. Tree Planters' Notes 65: 16-19.

(90) ——— and Rodenbach, R. C.
1964. Yellow-poplar direct seeding in the North Carolina Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-25, 2 pp.

(91) **Smith,** H. Clay
1965. Effect of clearcut openings on quality of hardwood border trees. J. Forest. 63: 933-937.

(92) Society of American Foresters
1954. Forest cover types of North America (exclusive of Mexico) . Soc. Amer. Forest., 67 pp., illus. Washington, D. C.

(93) Steinbeck, K., and Kormanik, P. P.
1968. First-year root system development of two clones of yellow-poplar. Ga. Forest Res. Counc. Res. Pap. 55, 4 pp.

(94) ―――――――― and Porterfield, E. J.
1967. Short-term storage of yellow-poplar softwood cuttings. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-71, 4 pp.

(95) Steinhubel, G.
1959. Increasing yellow-poplar seed production by artificial cross pollination. Biologia 14 (12) : 888-895. (In Czech, German summary) .

(96) Stephens, G. R.
1965. Yellow-poplar seedlings respond to soil temperature. J. Forest. 63: 701-703.

(97) Taft, Kingsley A., Jr.
1962. The effect of controlled pollination and honeybees on seed quality of yellow-poplar (*Liriodendron tulipifera* L.) as assessed by X-ray photography. N. C. State Univ., Sch. Forest. Tech. Rep. 13, 21 pp.

(98) Toole, E. Richard
1961. Rot entrance through dead branches of southern hardwoods. Forest Sci. 7: 218-226.

(99) ――――――――and Huckenpahler, B. J.
1954. Yellow-poplar dieback. U. S. Dep. Agr. Plant Dis. Reptr. 38 (11) : 786-788.

(100) Tourney, J. W.
1929. Initial root habits in American trees and its bearing on regeneration. Int. Congr. Plant Sci. Proc. 1: 713-728.

(101) Trimble, George R., Jr., and Hart, George
1961. An appraisal of early reproduction after cutting in Northern Appalachian hardwood stands. U. S. Forest Serv. Northeast. Forest Exp. Sta. Pap. 162, 22 pp.

(102) True, R. P.
1962. Decay in thinned sprout clumps of yellow-poplar. (Abstr.) Phytopathology 52 (5) : 486.

(103) ―――――――― and **Tryon,** E. H.
1952. Blister-shake, a weather-induced defect in yellow-poplar. W. Va. Agr. Exp. Sta. Bull. 350T, 15 pp.

(104) **Tryon,** C. P., Beers, T. W., and Merritt, C.
1960. The measurement of site quality of yellow-poplar. J. Forest. 58: 968-969.

(105) **Tryon,** E. H., Cantrell, J. O., and Carvell, K. L.
1957. Effect of precipitation and temperature on increment of yellow-poplar. Forest Sci. 3: 32-44.

(106) ――――――――and Carvell, K. L.
1960. Environmental factors affecting yellow-poplar survival under a young stand. Castanea 25 (2) : 69-73.

(107) ―――――――― and Meyers, C. A.
1952. Periodic precipitation affects growth of yellow-poplar on a West Virginia hillside. Castanea 17: 97-102.

(108) Vaartaja, 0.
1961. Demonstration of photoperiodic ecotypes in *Liriodendron* and *Quercus.* Can. J. Bot. 39: 649-654.

(109) Wahlenberg, W. G.
1950. A long-term test; a quarter century of forest regrowth in a cut-over and cleaned Appalachian cove. South. Lumberman 18 (2273) : 183-187.

(110) ――――――――
1950. Epicormic branching of young yellow-poplar. J. Forest. 48: 417-419.

(111) ――――――――
1952. Thinning yellow-poplar in second-growth upland hardwood stands. J. Forest. 50: 671-676.

('12) Walters, R. S.
1963. Past growth of yellow-poplar and oak reproduction key to future. Cent. States Forest Exp. Sta., U. S. Forest Serv. Res. Pap. CS-4.

(113) Waterman, A. M.
1956. *Verticillium* wilt of yellow-poplar. U. S. Dep. Agr. Plant Dis. Reptr. 40 (4) : 349-350.

(114) Wean, R. E., and Guard, A. T.
1940. The viability and collection of seed of *Liriodendron tulipifera* L. J. Forest. 38: 815-816.

(115) White, D. P., and Finn, R. F.
1964. Frost damage in a tulip poplar plantation as related to foliar potassium content. Mich. &cad. Sci., Arts and Letters Pap. 49: 75-80.

(116) Williams, R. D.
1964. Release accelerates height growth of yellow-poplar seedlings. J. Forest. 62: 95-97.

# APPENDIX

## list of Common and Scientific Names of Trees, Shrubs, and Vines

| Common Name | Scientific Name |
|---|---|
| Ash, white | *Fraxinus americana* |
| Baldcypress | *Taxodium distichum* |
| Basswood | *Tilia* sp. |
| Beech, Anierican | *Fagus grandifolia* |
| Birch, sweet | Betula *lenta* |
| yellow | *Betula alleghaniensis* |
| Blackgum | *Nyssa* sylvatica |
| Buckeye | *Aesculus* sp. |
| Cherry, black | *Prunus serotina* |
| Cucumbertree | *Magnolia acuminata* |
| Dogwood, flowering | *Cornus florida* |
| Grapevine | *Vitus* sp. |
| Hemlock, eastern | *Tsuga canadensis* |
| Hickories | *Carya* sp. |
| Honeysuckle, Japanese | Lonicera *japonica* |
| Locust, black | *Robinia pseudoacacia* |
| Magnolia, southern | Magnolia *grandiflora* |
| Maple, red | *Acer rubrum* |
| sugar | *Acer saccharum* |
| Oaks | *Quercus* sp. |
| Oak, black | Quercus *velutina* |
| cherrybark | *Quercus falcata* 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* |

## list of Common and Scientific Names of Animals and Birds

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

Olson, David F., Jr.
1969. Silvical Characteristics of Yellow-Poplar (Liriodendron tulipifera L.). Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-48, 16 pp.

Because of research completed in the past decade, much new knowledge concerning the silvical characteristics of yellow-poplar is now available. This paper is a revised and up-dated version of Station Paper No. 89, issued in January 1958.

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