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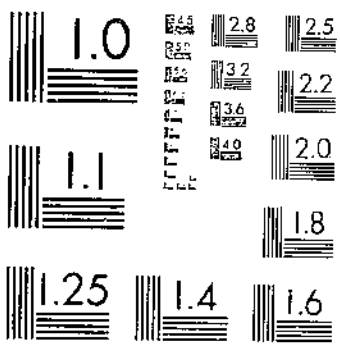
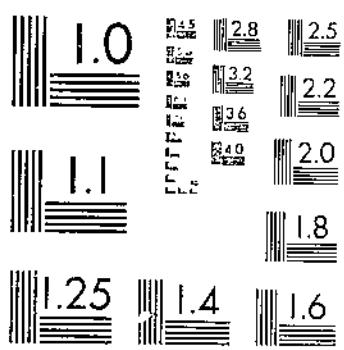


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



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NATIONAL BUREAU OF STANDARDS 1963 A

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YELLOW POPLAR CHARACTERISTICS, GROWTH, AND MANAGEMENT

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INTRODUCTION

Yellow poplar [3] (*Liriodendron tulipifera* L.) is a tree of paradoxes, even in name; throughout the South and wherever its wood products are used it is known as yellow poplar, but it is not in any sense a poplar; horticulturally it is perhaps best known as tuliptree, but it is not related to the tulips; its botanical name of "tulip-bearing lily tree" is in itself a paradox. Characteristics of the tree of a paradoxical nature have in the past proved baffling to foresters and disconcerting to timberland owners interested in the production of the species and its continued growth on their forest lands. Yellow poplar is one of the most adaptable of trees, having maintained its individuality intact all the thousands of years since Cretaceous times;

[1] The writer acknowledges his indebtedness especially to the late W. W. Ashe, of the Forest Service, for the use of his manuscript report on yellow poplar, including the records of 21 yield plots used in the construction of yield tables; to O. A. Alderman, Assistant Forester, Ohio Agricultural Experiment Station, and K. A. Sweenning, forester for the Mead Pulp & Paper Co., for assistance in the collection of yield data in Ohio; and to the division of forestry, Georgia College of Agriculture, for a similar service in Georgia. Thanks are also due the members of the staffs of both the Allegheny and Appalachian Forest Experiment Stations for their assistance in the preparation and review of this bulletin, as well as to members of the Central States Forest Experiment Station.

[2] Maintained in cooperation with the Ohio State University, Columbus, Ohio, and the Ohio Agricultural Experiment Station.

[3] Yellow poplar has been called tulip, poplar, tuliptree, tulip poplar, and whitewood. It should not be confused with the true poplars belonging to the genus Populus, and commonly known as poplar, cottonwood, aspen, etc.

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but it is at the same time one of the most capricious in its refusal to grow under a variety of circumstances which would be favorable to most other trees. In certain rather extensive areas within the range of its best growth, not a single specimen of this species can be found; on the other hand, at the very limits of its reported natural range yellow poplar trees are found in full development and better than average growth. Yellow poplar is a hardwood that floats almost as readily as a softwood. It is a valued special-use wood, and also an important wood of general utility. In the average timber stand yellow poplar either becomes one of the tallest species in the stand or will not grow at all. It is a prolific seeder, but also a very vigorous sprouter under certain circumstances. These and many other peculiarities of yellow poplar have led to misunderstanding of its

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FIGURE 1.—Leaf, fruit, and terminal buds of yellow poplar

requirements, a knowledge of which is of vital importance if the production of yellow poplar is to continue on a marketable basis.

Yellow poplar is very easily identified in the growing season because of the peculiar blunt or truncated appearance of the leaf, which terminates in a broad notch. (Fig. 1.) The leaf has four to six points and is 3 to 6 inches long and rounded at the base. It is a bright green in summer, turning to a strikingly clear yellow in the autumn; both surfaces are smooth. The flower is tuliplike in form and size, with six petals varying in color from a light yellowish green at the margin to deep orange at the center. It appears in May or early June and lasts but a week or two. The fruit is a conelike strobile composed of a central spike bearing winglike scales or carpels. In September or October, after the loosened carpels have been scattered by the wind, only the long, pointed central spikes and basal scales remain on the tree. The thumb-shaped terminal bud is inclosed in two scales which meet in a ridge.

Early settlers quickly recognized the value of yellow poplar because its comparatively soft but strong and straight-grained wood could be worked easily and proved very serviceable. Its admirable qualities brought it later into favor for such uses as interior finish for houses, carriage bodies, and saddle frames.

The popularity of yellow poplar is well deserved. As a tree, it is characteristically a hardwood of large size and excellent form, and its growth is vigorous. The wood, with which are often marketed small quantities of evergreen and cucumber magnolia (*Magnolia grandiflora* L. and *M. acuminata* L.), is strong, straight grained, and free from knots. It seasons very well, developing a minimum of defects under ordinary practice; it glues easily; and it is one of the most satisfactory woods for taking paint, enamel, or stain. It has a great variety of uses, and its lumber is in many respects a wholly adequate substitute for softwood lumber. Yellow poplar is used for cabinetwork, interior trim, and siding; in furniture manufacture it is used for drawer bottoms, backing, plywood, core stock, and for enameled furniture of all kinds. It is also used for pulpwood and excelsior, and for veneer baskets, containers, boxes, and crates.

A report (*6*)[1] on the wood-using industries in North Carolina made some years ago gives the following distribution of the annual consumption of yellow poplar lumber:

	Per cent
Furniture	53. 99
Planing-mill products	14. 18
Boxes and crates	12. 78
Miscellaneous products (caskets and coffins, sash, doors and blinds, fruit and vegetable packages, vehicles and vehicle parts, fixtures, elevator and machine construction, chairs, shuttles, spools, and bobbins)	15. 52
Unclassified	3. 53

While this list reflects mainly the well-developed furniture industry of North Carolina, it shows also a diversity of products made from yellow poplar that is indicative of the wide usefulness of the species throughout this State and elsewhere.

In addition to its usefulness, yellow poplar commends itself to the owner of forest land within its range by reason of its vigorous growth and early development into marketable sizes. Despite its reputation as a species difficult to establish, the indications are, as this study will attempt to make clear, that, once yellow poplar is established, satisfactory growth can be obtained on any moist, well-drained soil of good depth, including many desirable sites on abandoned fields, with comparatively little difficulty and at small expense.

In addition to its more obvious good qualities, yellow poplar has distinctive value as a honey tree. According to J. I. Hambleton, of the Bureau of Entomology, a yellow poplar of less than 20 years of age will yield during the season approximately 8 pounds of nectar, equal to 4 pounds of honey. At 10 cents a pound for honey, a tree of this size may produce upwards of 40 cents a year revenue for the beekeeper, an income that compares very favorably with the returns to be gained from other yellow poplar products.

The need for a better understanding of what constitutes desirable practice in the management of yellow poplar stands is evident in the fact that the drain on present stands, which threatens to have a

[1] Italic numbers in parentheses refer to Literature Cited, p. 51.

permanent effect upon its marketability, is almost entirely in the control of the timberland owner. Losses from disease and insects are negligible. Fire losses are at the present time moderate and can easily be reduced. The great need is for a cutting practice that will encourage and hasten new second-growth stands and, as far as possible, extend the area of these stands. Also, much can probably be done through artificial regeneration, if the requirements of the species are thoroughly understood. It is the purpose of this bulletin to assist the forest-land owner, particularly in the region of best growth of yellow poplar, to retain on a basis of permanent yield and to augment so far as possible his present stands of this species of considerable and increasing value.

DISTRIBUTION AND OCCURRENCE OF YELLOW POPLAR

RANGE

As is shown in Figure 2, yellow poplar is found extending throughout the eastern and central parts of the United States, north to Lake Ontario and Grand River, Mich.; south into northern Florida, but avoiding in general the uplands of the longleaf pine region; and west to include the Wabash and lower Mississippi Valleys. Within this range, the species is found at all altitudes up to about 1,000 feet in the northern part of the mountain and plateau regions and 4,500 feet in the southern. Above these altitudes the northern hardwoods predominate, and with these yellow poplar can seldom compete.

The designation on Figure 2 of a region of best growth is somewhat arbitrary. It is based rather upon the areas within which yellow poplar is found in sufficient quantity to render it potentially a profitable timber crop than upon the quality or size of timber grown within this region. Actually, the tree reaches approximately its best individual development in the lower Wabash Valley, and large, well-formed yellow poplar trees have been cut in the Finger Lakes district of central New York and in the Huron River Valley of Michigan. But individual scattered trees such as these can hardly be regarded as possible nuclei of cultivated, marketable stands. It is only within the so-called region of best growth that special effort and expense to cultivate and favor the extension of yellow poplar stands are justified at this time. Yellow poplar second growth is increasing, however, in northeastern Ohio on land formerly occupied by beech and sugar maple stands; and in northeastern Maryland, southeastern Ohio, western Kentucky, and northern Georgia good stands of second growth are to be found near the limits of best growth, giving every indication of a possible extension of the area of marketable production of yellow poplar in the future.

One very significant characteristic of the range of yellow poplar is that in many places where there is no apparent obstacle to its growth large areas are devoid of this species, as in Franklin and Pickaway Counties, Ohio, where soil and moisture conditions appear to be entirely favorable.

OCCURRENCE OF OLD-GROWTH STANDS

The remaining old-growth stands of yellow poplar are largely restricted to the more inaccessible parts of the mountain and plateau areas from southeastern Pennsylvania and West Virginia, south to northern Georgia and Alabama, although some scattered trees are

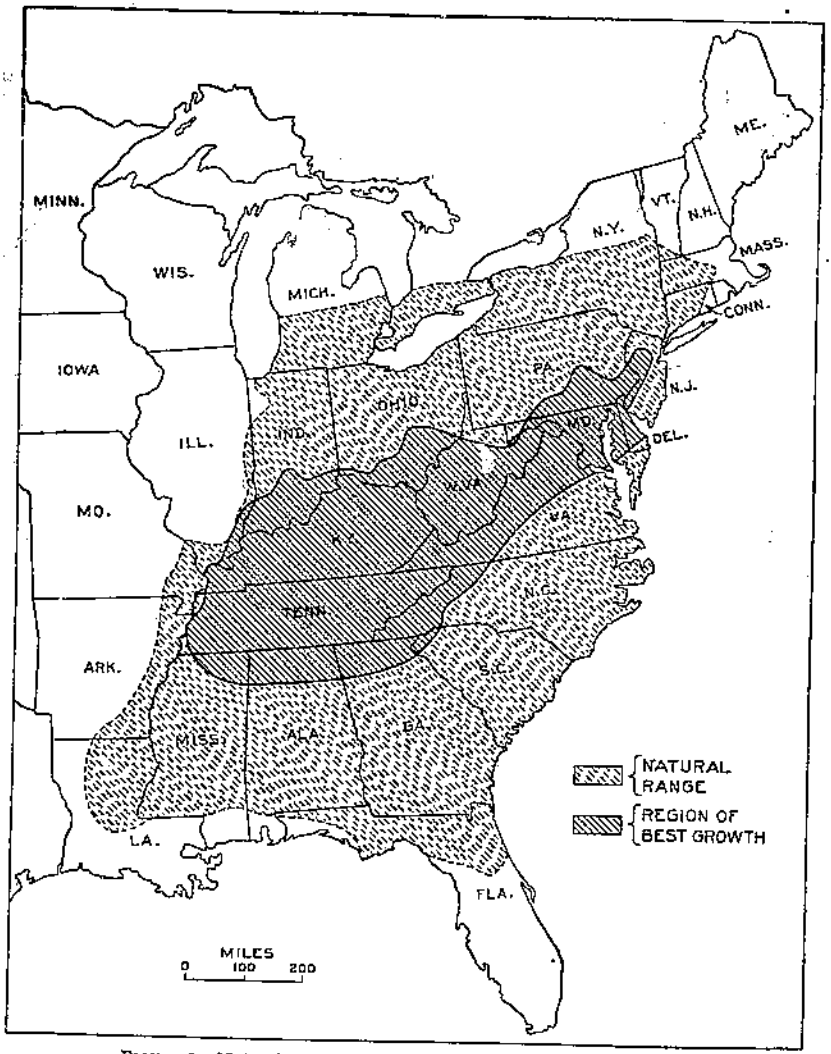

FIGURE 2.—Natural range of yellow poplar and region of best growth

still being logged from the swamps of the coastal plains, from the woodlands in the piedmont plateau, and in the Ohio drainage basin. (Figs. 3 and 4.) It is perhaps an exaggeration to refer to any of this old-growth yellow poplar as occurring in stands, since it appears universally as single trees or in small groups throughout this region and rarely forms pure stands even a few acres in size.

On stream-bottom lands and the better drained soils of the swamp and overflow lands of the coastal-plain region, old-growth yellow poplar occurs in mixture with tupelo gum, swamp black gum, southern cypress, red gum, several species of oak, red maple, water ash, swamp cottonwood, and sometimes loblolly pine. In the overflow lands along streams in the piedmont plateau, associated species include red gum, black gum, red maple, American elm, and several

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FIGURE 3.—Old-growth yellow poplar on highway between Burton Lake and Hiawassee, Ga. This group is a part of an excellent natural stand in a north-facing cove. Size shown by man in left foreground

species of hickory. In both regions, yellow poplar comprises numerically only a small percentage of the stand but grows to large size and is valuable for lumber.

At lower elevations in the Appalachian Mountains and through the more rugged parts of the Cumberland and Allegheny Plateaus, where yellow poplar was once common in the coves and on moist slopes in mixture with many other hardwoods and a few conifers, it is

still found singly or in groups in stands containing chestnut,[5] black locust, white oak, hemlock, northern white pine, and black walnut. Frequently the associated species include hickories, oaks, and yellow pines, as well as dogwood, sweet birch, black gum, silverbell, but-

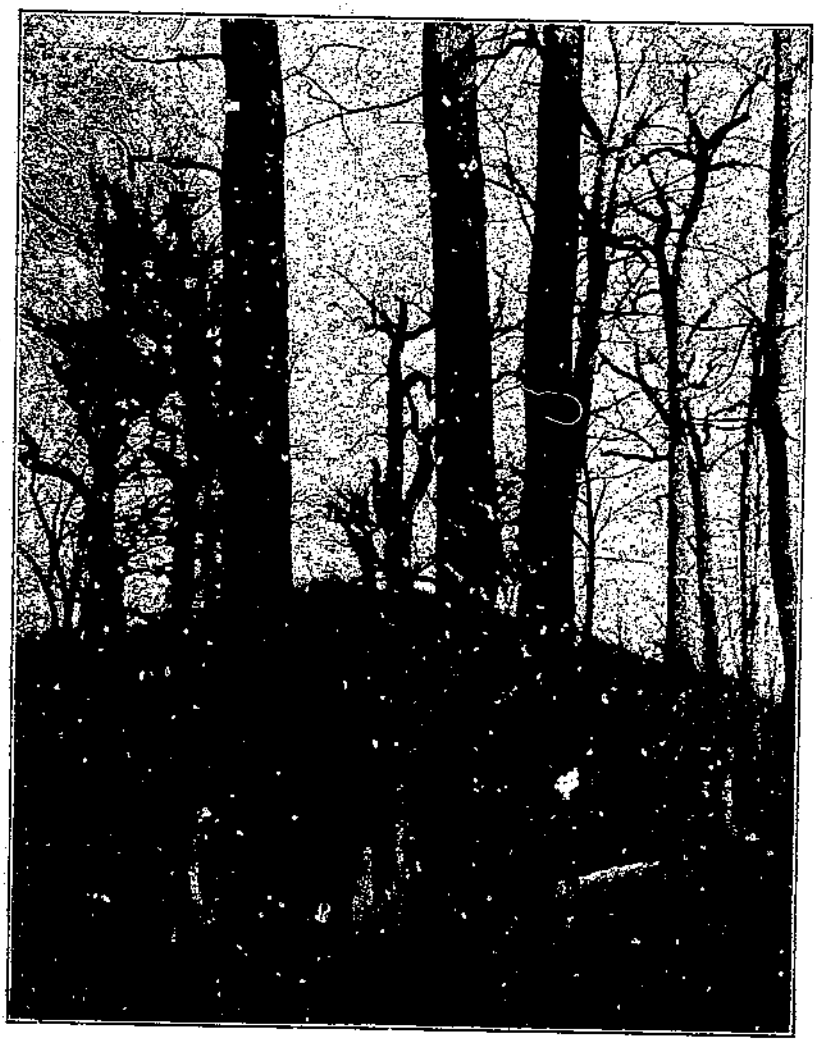

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FIGURE 4.—Old-growth yellow poplar located on a ridge top. In such locations poplar will not have as good form as when grown in the coves

ternut, basswood, and mountain magnolia. At higher elevations, especially in the higher part of the Allegheny Plateau, and also farther north, the associated species include red oak, white ash, black cherry, cucumber magnolia, slippery elm, buckeye (sp.), beech, sugar maple, and yellow birch.

[5] A list of the botanical names of species cited is given in the Appendix, p. 57.

SECOND GROWTH

Second growth of yellow poplar is of two very distinct types. One of these is found on cut-over forest lands where the species grew originally and is now returning in mixture with other hardwoods. Yellow poplar occurs only scatteringly on any forest area where the cutting was in any manner selective, but on those lands where logging was delayed until the advent of logging railroads and where increased demand for the poorer species resulted in heavier cutting of the old growth, the new seedlings have found little competition from sprouts of other hardwoods and have held their own without difficulty against other seedling growth. In the last 30 years the best yellow poplar second growth in heavily forested sections has become established as the direct result of the heavy cutting of the old growth. Lack of seed trees has, however, prevented yellow poplar from covering many such openings.

The other type is found on abandoned fields where the new forest must start entirely from seed and under very different conditions of light, soil, and moisture from those in the virgin forest. On these old fields yellow poplar comes up practically even-aged and in much less complex mixture with other species. Such even-aged stands of yellow poplar are only found, however, where there was little serious interference from other growth in the seedling stage and where fire has been eliminated and grazing has been strictly controlled.

The greater part of the second growth in the mountain region has come up on old fields, some of which were abandoned at the time of the Civil War. Such tracts, generally of small size, are found in the cove heads or on the better benches and slopes. Where the soils of these clearings have not been too badly impoverished by erosion, yellow poplar seeds blown in from the surrounding forests find a favorable place for germination and growth. Where the seed was produced near by in sufficient quantities, yellow poplar eventually took possession of the greater part of these abandoned fields, overcoming successfully the competition of black locust, sassafras, staghorn sumach, and in some cases chestnut, which also grew from seed or sprouted after the fields were abandoned. These species, with silverbell, often form a large part of the crown cover during the first 10 years in the establishment of second-growth poplar on abandoned fields. Sumach is the first of the competitors to be killed out, and sassafras rarely holds a place in the dominant stand after 20 years. The other species remain to grow up with the yellow poplar and the mixture frequently includes some black cherry, black walnut, and white ash, as well as several species of pine. Slippery elm, black cherry, sugar maple, and red oak are common in the second growth at higher elevations, whereas on the drier slopes at lower elevations pitch pine, Virginia pine, and shortleaf pine are found.

Throughout the Eastern States, where chestnut was formerly abundant, yellow poplar seedlings are now frequently found in the openings caused by the death of chestnut, especially on the better sites.

The contrast between even-aged stands of yellow poplar on old fields and on clear cuttings is given in Tables 1 and 2 which show, respectively, the composition of second-growth stands on old fields in Union and Towns Counties, Ga., and that resulting from clear

cutting for charcoal wood on lands of a coal and iron company near Cranberry, N. C.

TABLE 1.—*Composition of even-aged, second-growth yellow-poplar stands on old fields, north Georgia, on 10-acre basis* [1]

Diameter, breast high (inches)	Yellow poplar	Chestnut	Black locust	Pine [2]	Red oak	White oak	Black oak	White ash	Sassafras	Other species [3]	All species	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Per cent*
4	259.6	1.9	25.5	3.8	5.7	4.8	------	7.6	111.4	38.8	457.1	18
5	310.7	2.8	36.8	1.9	3.8	5.7	8.6	4.8	58.5	22.7	456.3	18
6	303.0	6.6	36.8	3.8	1.9	6.6	------	1.9	12.3	12.3	385.2	15
7	242.7	17.0	27.4	3.8	3.8	3.8	.9	4.8	7.6	5.7	317.5	12
8	190.7	11.3	25.5	.9	------	3.8	.9	.9	1.9	4.7	240.6	9
9	165.3	16.1	16.1	.9	1.9	.9	------	.9	.9	------	203.0	8
10	136.0	15.1	10.4	------	------	.9	------	.9	------	------	163.3	6
11	105.8	2.8	7.6	------	4.7	.9	.9	------	.9	.9	124.5	5
12	72.7	5.7	1.9	1.9	.9	------	------	------	------	------	83.1	3
13	42.5	3.8	1.9	------	.9	------	------	.9	------	------	50.0	2
14	36.9	6.7	2.8	.9	------	------	------	------	------	------	46.3	2
15	21.7	7.6	.9	------	------	------	------	------	------	------	30.2	1
16	13.2	9.4	------	.9	.9	------	------	------	------	------	24.4	1
17	8.5	.9	------	------	------	------	------	------	------	------	9.4	(4)
18	1.9	------	------	------	------	------	------	------	------	------	1.9	(4)
19	3.8	------	------	------	------	------	------	------	------	------	3.8	(4)
Total	1,915.0	105.7	193.6	18.8	24.5	27.4	11.3	22.7	193.5	83.1	2,596.6	------
Total per cent	74	4	8	1	1	1	(4)	1	7	3	------	100

[1] Computed from measurements on 26 sample plots totaling 10.59 acres. The stand averages 29 years old, ranging from 24 to 39 years.
[2] Virginia, shortleaf, and pitch pines.
[3] Includes hickory, red maple, silverbell, black gum, persimmon, sourwood, and post oak.
[4] Less than 0.5 per cent.

TABLE 2.—*Composition of even-aged, second-growth yellow-poplar resulting from clear cutting for charcoal wood, near Cranberry, N. C., on 10-acre basis* [1]

Diameter, breast high (inches)	Yellow poplar	Birch [2]	Beech	Black cherry	Chestnut	Ohio buckeye	Sugar maple	Black locust	Cucumber magnolia	Basswood	White oak	Hickory	Other species [3]	All species	
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*P.ct.*
2	9.8	174.0	396.0	7.8	3.8	90.0	111.0	------	3.0	2.2	6.8	4.5	42.0	850.6	17
3	42.8	174.8	210.0	4.5	5.2	67.5	59.2	0.8	5.2	4.5	7.5	1.5	35.2	618.7	13
4	89.3	201.0	147.8	10.5	13.5	99.0	57.8	.8	5.2	2.2	13.5	3.8	25.5	669.9	14
5	85.3	115.3	70.5	12.0	24.0	43.5	30.8	3.7	1.5	1.5	6.8	2.2	10.5	407.6	8
6	108.0	86.2	54.0	30.8	48.8	33.8	15.0	4.5	1.5	4.5	6.8	3.0	7.5	404.4	8
7	122.2	40.5	36.0	18.0	37.5	10.5	5.2	3.7	1.5	1.5	12.0	2.2	11.2	302.0	6
8	200.2	38.2	34.5	27.0	62.2	13.5	3.8	3.7	.8	2.2	10.5	4.5	15.0	416.1	8
9	156.0	9.0	5.2	14.2	30.0	9.8	2.2	3.0	2.2	3.0	2.2	2.2	3.8	242.8	5
10	178.5	0.8	13.5	18.8	69.0	6.8	.8	.8	3.8	1.5	2.2	1.5	4.5	311.5	6
11	111.8	.8	.8	6.0	18.8	------	------	3.0	------	.8	1.5	.8	1.5	145.8	3
12	214.5	3.0	7.5	22.8	53.3	------	3.8	15.0	.8	1.5	------	------	6.8	329.0	7
14	109.5	.8	1.5	9.8	34.5	.8	1.5	1.5	------	.8	------	------	3.0	163.7	3
16	30.0	------	.8	6.8	15.0	------	2.2	1.5	.8	------	.8	.8	------	58.7	1
18	5.2	.8	------	2.2	12.8	------	2.2	.8	------	------	------	------	------	24.0	1
20	.8	.8	.8	------	1.5	------	3.8	.8	------	------	.8	------	------	9.3	(4)
22	.8	.8	------	------	------	------	------	------	------	------	------	------	------	1.6	(4)
24	------	------	------	------	------	------	------	.8	------	------	------	------	------	.8	(4)
Total	1,464.7	855.8	978.9	190.9	429.9	375.2	299.3	44.4	26.3	26.2	71.4	27.0	166.5	4,956.5	100
Total per cent	30	17	20	4	9	8	6	1	(4)	(4)	1	1	3	------	100

[1] Computed from measurements on plots distributed over about 130 acres and totaling 13.3 acres in area. The trees are, roughly, 35 years old, and the stand is located about 3,500 feet above sea level.
[2] Largely yellow birch; a small quantity of sweet birch.
[3] Includes butternut, red oak, red maple, hophornbeam, black walnut, eastern hemlock, and pin cherry.
[4] Less than 1 per cent.

Table 1, based on observations antedating the ravages of the chestnut blight, indicates that chestnut and black locust were the only timber trees able to compete successfully with yellow poplar on old fields. With the elimination of chestnut, other percentages would rise accordingly. Clear-cut areas that have not been cultivated almost invariably contain a greater mixture of species competing with the yellow poplar. As previously stated, the yellow poplar in these old-growth stands is mainly seedling stock.

On the North Carolina tract one area of about 50 acres contained a much larger percentage of poplar than is shown in Table 2, but this was the result of thinning and therefore was omitted as being not entirely representative of the cove and lower-slope types. It could not be determined whether fire had followed the charcoal cutting on the tract as a whole. However, according to report, a considerable number of range stock had access to this area during the time it was regenerating. Obviously, grazing was not heavy enough to destroy all poplar reproduction, but it may have been heavy enough to reduce substantially the percentage of poplar on some parts of the tract. Several coves which contained a large percentage of Ohio buckeye, and which account for the large proportion of buckeye recorded, showed evidence of having been heavily grazed. Otherwise the mixture of species which this tract contains may be considered as representative of stands well up toward the higher altitudinal limit for yellow poplar. Although poplar shows up to much less advantage here than on the tract covered by Table 1, this stand illustrates the possibility, when other conditions are favorable, of obtaining a good regeneration of yellow poplar where old-growth forests are clear cut.

SUPPLY AND DEMAND

The present status of yellow poplar and the permanence of its position in the future as an important timber species have been largely influenced by the early agricultural and industrial development within the region of its range. Yellow poplar lends itself to pioneer uses. Since the green logs float as readily as those of northern white pine, individual yellow poplars were culled out of the woods along stream banks with the pine and floated down from as far up the waterways as the early logging operations could go. This resulted in the complete elimination of isolated trees and small groups of this species from much of the land where yellow poplar could grow to the best advantage. Later, when heavier cuttings would have permitted seedlings of yellow poplar to become established, few if any trees were available to furnish the necessary supplies of seed. Where yellow poplar was not eliminated through the cutting out of all seed trees, the stands were in many instances depleted through the clearing for crop production of the more moist and fertile lands on which it grows naturally. Even very steep coves and mountain slopes suitable to yellow poplar were cleared and farmed for a few years. This short period of tillage was sufficient to prevent yellow poplar from coming back again except as seed was blown in from adjacent forests.

As a result, many acres on which yellow poplar might have come in vigorously are barren of this valuable species, and the difficulty of supplying demands for this consistently popular wood is thereby greatly increased.

AVAILABLE SUPPLY

The wide and scattered distribution of yellow poplar makes it difficult to publish any very accurate estimate of the remaining stand. The estimate in 1920 (*13*) was 9,611,000,000 board feet. An estimate for 1931 gives 5,172,000,000 board feet lumber tally plus 19,146,000 cords (peeled).[6] It was estimated some years ago (*1, p. 176–177*) that three-quarters of the remaining stand of yellow poplar was in West Virginia, Virginia, Kentucky, Tennessee, and North Carolina. However, the report from which the 1931 figure was compiled indicates that over half of the timber stand is in the Gulf and Coastal States from Alabama to Virginia, with less than a third in the Middle Western States and the three States—West Virginia, Kentucky, and Tennessee—from which came the great bulk of the cut in earlier years. Of these remaining stands most of the virgin growth is in country which is inaccessible or very difficult to log. Much of the second growth, on the other hand, occurs in districts easily reached by rail and highway. This second growth, which is estimated to average barely 20 years of age, represents nearly two-thirds of the present total stand.

TIMBER CUT

The total annual production of yellow poplar lumber, together with the average value per thousand board feet from 1899 to 1930, is given in Table 3. A partial analysis of these annual totals is afforded by Figure 5 which compares graphically the trend of production for the three major States, Kentucky, Tennessee, and West Virginia, with the combined totals for North Carolina and Virginia, representing the two Atlantic States having a considerable share in the production of yellow poplar lumber in the past; Indiana and Ohio, the mid-Western States at one time considerable producers of yellow poplar; and Georgia, Alabama, and Mississippi, representing the southern group. The considerable falling off in the national total between 1909 and 1917 is reflected in the curves for these individual States and groups of States. Not all have recovered from this decline. While West Virginia and Tennessee have climbed back to something like an average production of 65,000,000 feet, Kentucky has reached the 20,000,000-foot level and shows no promising indication of remaining above it. Indiana and Ohio combined have sunk to even lower levels, but North Carolina and Virginia, taken as a group, compare very well with either West Virginia or Tennessee. One of the most interesting developments is shown in the curve for the combined output of Georgia, Alabama, and Mississippi. This group has increased fairly steadily in production since 1922 and shows no immediate sign of dropping off. It is considerably higher at the present time than are the two seaboard States, and the 1929 production is almost equal to that of Tennessee and West Virginia combined. This trend, due to the recent exploitation of the southern bottom-land hardwoods, has had a considerable influence on the national production figures, which show a fairly steady increase from 1921 to 1929.

[6] UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE. THE FOREST SITUATION IN THE UNITED STATES. A SPECIAL REPORT TO THE TIMBER CONSERVATION BOARD. 46 p., illus. January, 1932. [Multigraphed.]

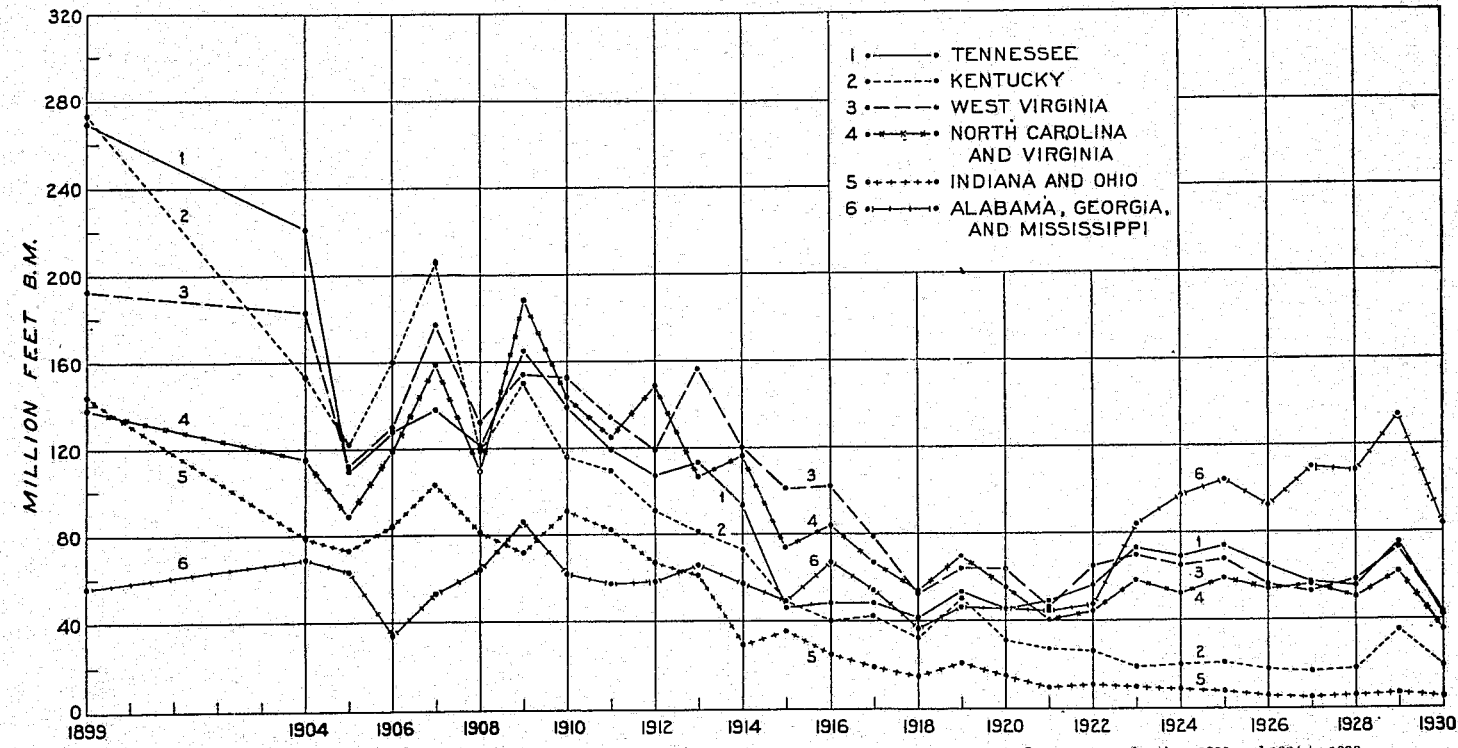

FIGURE 5.—Annual production of yellow poplar lumber, by States and groups of States of greatest past and present production, 1899 and 1904 to 1930.

TABLE 3.—*Annual production of yellow poplar lumber, with average value per thousand feet board measure at mill, 1899 and 1904–29* [1]

Year	Quantity	Value	Year	Quantity	Value
	M ft. b. m.	*Dollars*		*M ft. b. m.*	*Dollars*
1899	1,115,242	14.03	1917	325,968	27.17
1904	853,554	18.99	1918	241,693	35.06
1905	582,748		1919	328,538	41.65
1906	683,132	24.21	1920	270,407	58.87
1907	862,849	24.91	1921	235,418	37.31
1908	654,122	25.30	1922	273,971	39.18
1909	858,500	25.39	1923	333,150	51.29
1910	734,926	24.71	1924	350,727	44.38
1911	659,475	25.46	1925	375,662	43.44
1912	623,289	24.06	1926	321,579	38.63
1913	620,176		1927	334,604	38.58
1914	519,221		1928	327,883	40.90
1915	377,386	22.45	1929	435,953	41.66
1916	394,854	21.69	1930	257,803	35.19

[1] From (*14*) and later Forest Service compilations.

There is little likelihood that the upward trends for 1929, as shown in Figure 5, bear any promise for the future. With comparatively few old-growth stands remaining and these largely inaccessible, and with second-growth stands estimated as averaging barely 20 years, it is to be expected that production figures will fall off very materially in all States and that the total annual production of yellow poplar lumber will fall below 200,000,000 feet and average less than that.

In this connection it is of interest to note the considerable increase in the consumption of yellow poplar pulpwood since 1922, as shown in Table 4. This increase has a special significance in that a considerable portion of these totals is produced by clear cutting of poplar stands too young for timber and seed production and yet past the best sprouting age. The result is the practical denudation of such areas so far as future production of yellow poplar is concerned.

TABLE 4.—*Consumption of yellow poplar pulpwood in the production of paper, with price per cord, f. o. b. mill, 1916–30*

Year	Quantity	Price	Year	Quantity	Price	Year	Quantity	Price
	Cords	*Dollars*		*Cords*	*Dollars*		*Cords*	*Dollars*
1916	37,974	7.36	1921	43,220	16.85	1926	134,747	13.03
1917	41,155	8.97	1922	102,200	13.78	1927	131,168	13.54
1918	61,247	10.56	1923	102,781	13.94	1928	122,738	12.23
1919	72,665	15.02	1924	128,037	14.53	1929	129,697	11.41
1920	73,998	16.67	1925	145,871	13.83	1930	97,795	10.41

This drain on young stands of yellow poplar is a serious threat to the future supply. It is indeed possible that the future supplies of yellow poplar might be cut down to the point where the species would no longer be marketable except in relatively inconsiderable quantities for special uses. Such has been the fate of some other hardwoods, notably basswood. Although yellow poplar in 1929 stood fourth among hardwoods in volume of lumber cut, there is every evidence that it may fall considerably below this point before recuperative measures can be effective.

CHARACTERISTICS AND REQUIREMENTS OF THE SPECIES

Yellow poplar has maintained its place in the virgin forests through its large size, length of life, high resistance of the mature trees to injury, prolific reproduction, rapid growth in early life, and the fact that it develops a single leader and can, if this leader is destroyed,

immediately send up a substitute leader. These advantages are, however, insufficient in many instances to counterbalance its extreme intolerance of shade. Under dense stands of beech, yellow birch, and sugar maple in the northern forests yellow poplar has no chance of establishment, and even under the lighter-crowned oaks, hickories, and chestnut yellow poplar is usually eliminated. Yet among these lighter-crowned associates, wherever sufficiently large openings occur to allow a young poplar to thrust its leader up into the light, rapid growth brings the seedling quickly into sapling and pole size and enables the tree to find a place in the crown cover, whereupon it rarely fails to hold its own.

RESPONSE TO EXTREMES OF TEMPERATURE

It is very evident that the vagaries and inconsistencies in the occurrence of yellow poplar within its range, which have already been mentioned, are rarely to be explained by anything that affects the growth of the tree in later years. Evidence shows that, where seed was plentiful, the occurrence of the tree as single individuals or in small groups in the virgin forests was governed entirely by the degree of light and moisture that was available in early years. This, however, will not explain the absence of yellow poplar on large areas of suitable soil where there is little or no serious competition from other tree growth. Nor will it explain why, up to the very limits of its reported natural range, large trees in full vigor are quite commonly found. The implication in this vigorous growth at the limits of range is quite evidently that these individual trees have by some accident passed successfully crucial stages in early growth. There are many indications in the observed behavior of the younger trees that yellow poplar in early youth not only must have adequate light and moisture, but also must be favored by climate, both in protection from extremes of temperature and in the assurance of a reasonably long growing season. In Table 5 records are presented from stations that approximate the limits of range for yellow poplar. The approximations are manifestly crude and it is regretted that no better records are available. Very roughly, the indication is that yellow poplar, for growth in marketable quantities, requires a mean annual temperature of over 48° F. and a growing season of at least 180 days.

TABLE 5.—*Weather records for selected stations near limits of range for yellow poplar* [1]

Station	Precipitation		Temperature			Average growing season
	Growing season [2]	Dormant season	Mean annual	Mean maximum	Mean minimum	
	Inches	*Inches*	*°F.*	*°F.*	*°F.*	*Days*
Albany, N. Y.	18.84	19.55	48.2	57.0	40.0	176
Buffalo, N. Y.	15.69	21.59	46.8	54.0	40.0	173
Detroit, Mich.	15.94	17.12	48.2	58.0	41.0	184
Chicago, Ill.	16.85	18.09	48.7	74.0	59.0	181
St. Louis, Mo.	19.53	20.57	55.8	64.0	48.0	200
Pine Bluff, Ark.	19.13	31.52	62.9	74.2	51.3	221
Highlands, N. C.[3]	31.50	46.70	60.0	61.0	40.0	----------

[1] Summary of climatological data from Bulletins Q and W of the Weather Bureau, U. S. Department of Agriculture, for observation periods of 20 to 86 years (*7*, *16*).

[2] May, June, July, August, and September.

[3] Selected as being near the altitudinal limit of range of yellow poplar in North Carolina.

At its extreme southern range, yellow poplar grows only on moist sites where it is protected from extreme drying. To what degree temperature is a factor here it is impossible to judge. Other indications of the effect of climate are found in injury to the thin bark of young trees through sun scalds, which has been noted in southern Indiana, and the fact that frosts sometimes kill back the new growth. There is, however, no indication that any of the trees are killed in the dormant season by low temperatures.

SOIL-MOISTURE REQUIREMENTS

Yellow poplar has been generally characterized by observers as a tree very exacting in soil and soil-moisture requirements. The tree is nearly always found on moderately moist, well-drained soils of loose texture, but never in a thrifty condition on very dry or very wet soils. Good growth has been observed on alluvial soils bordering streams, on the dark-colored loam soils of mountain coves and ravines, on the talus slopes below cliffs and bluffs, and on well-watered gravelly soils. Sandy soils, as on the Cumberland Plateau of Tennessee, appear to be suitable only if free from excessive drying. The influence of chemical composition of soil on growth of poplar is apparently slight. In its range from the bottom lands of the coastal plains through the slopes of the Appalachian Mountains and Plateau, the tree obviously thrives on soils of many kinds of chemical composition and physical texture and grows well on both lime soils and those deficient in lime.

Favorable depth, aeration, and moisture of soils are commonly found in the heads of coves or on stream banks, which are characterized by loose, deep, dark loams well supplied with humus from the decay of abundant leaf litter. From such favorable situations, yellow poplar extends upward along the moist slopes where soils are good but less favorable. On south and west exposures, however, it is usually confined to the lower slopes. Dry site conditions are reflected in a marked reduction of growth rate and a lower density of stand. On steep hillsides yellow poplar will often exhibit a marked difference in height growth within a distance of 50 feet up or down the slope.

In the coastal-plain lowlands, as in the valley lands of Ohio, Indiana, and south through the river bottoms to Louisiana, yellow poplar occupies the better-drained alluvial or muck soils. A combination of thin soils, such as that formed by friable shales in southern Ohio, together with exposure to the south and west, causes it to give way to other species.

In the study of yellow poplar under natural conditions, it is not uncommon to find examples of a growth that is in one way or another exceptional. One such instance was found in Cecil County, Md., just northeast of Chesapeake Bay, on an old field with a northern exposure and medium slope in a Susquehanna gravel soil. An adjoining cultivated field might have been judged to be too dry for a good growth of yellow poplar, yet on the abandoned field a stand of second growth had come in, which in 31 years had attained a height of 90 feet. This stand was very dense and had the highest volume yield for its age of any second-growth stand of yellow poplar on record.

The reaction of yellow poplar to the effects of erosion is well illustrated in a badly washed field in a steep cove of Lawrence County,

Ohio, which was planted with poplar in 1918. Part of this field was a bench adjoining other woodland, and this portion had largely retained its soil. Here, 13 years after planting, the poplar had grown to a diameter of 8 inches and a height of 35 feet. In the center of the field, however, where the soil was noticeably eroded, were trees of the same age less than 10 feet high and less than 2 inches in diameter. This difference would seem to be solely attributable to soil conditions.

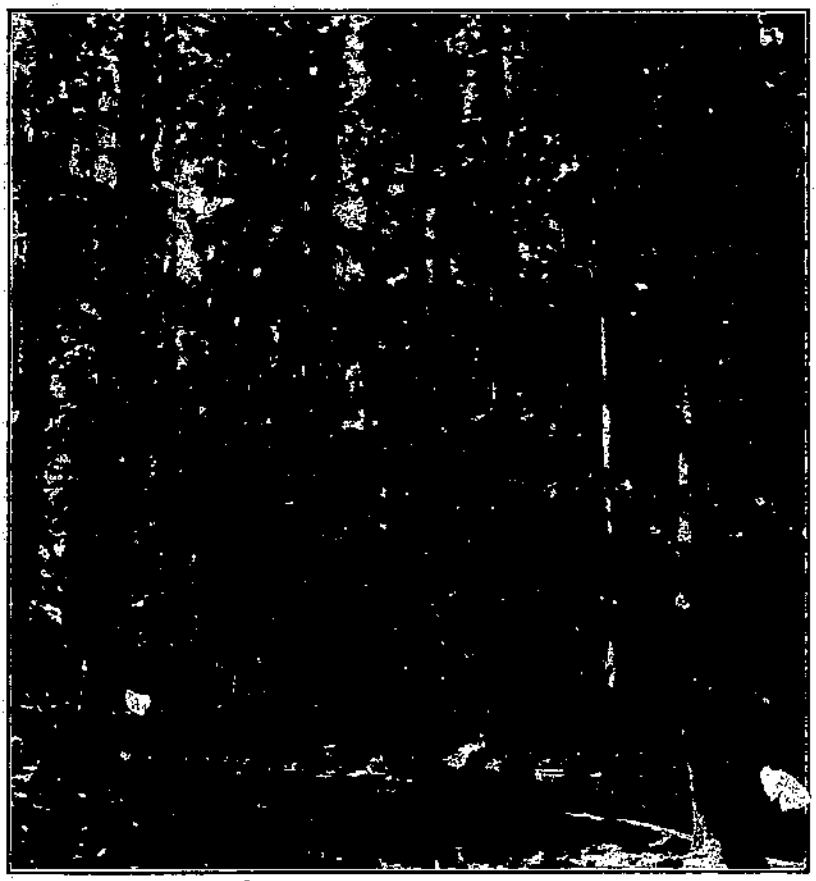

FIGURE 6.—Poplar second growth seeded naturally into an old field, Sosebee Cove, near Blairsville, Ga. This stand showed 6,961 cubic feet of wood per acre at 48 years of age. The average dominant tree was 110 feet high

The most spectacular stand of yellow poplar seen during the study of yield in second growth was in the Sosebee Cove about 10 miles south of Blairsville, Ga. (Fig. 6.) In this abandoned field yellow poplar had seeded in naturally and had grown up into a dense 48-year-old stand in which the dominant trees were 110 feet high and the largest tree measured 26 inches in diameter. This stand grew in a region of heavy rainfall which had probably washed away much of the better topsoil during the period of cultivation; but the stand had itself reestablished good soil conditions and achieved a phenomenal growth.

LIGHT REQUIREMENTS

Vigorous growth of yellow poplar has been found on land that would ordinarily be considered too dry, and even in places where the climate would appear to be too severe, but the one great obstacle to yellow poplar growth that is never surmounted is its intolerance of shade. Even under the oaks, hickories, and chestnut with which poplar is commonly associated, the seedlings of this species can rarely manage to persist for more than three years if the crown cover is of average density. Similarly, seedling yellow poplars which have started after a fire in a young stand are soon overtopped by the sprout growth of yellow poplar and other young hardwoods burned back by the fire. Even staghorn sumach, sassafras, and black locust may form stands too dense to allow poplar to grow up from beneath, although it is probable that the failure of yellow poplar in these instances is due partly to the competition of these light-crowned trees for water and nutrient elements, which so weakens the poplars as to make shading out an easy matter. The only shade under which yellow poplar appears to thrive is that of grass and low bushes, in old fields. Once well started in such situations, yellow poplar can survive the subsequent competition of any other seedlings of the same age.

This requirement of yellow poplar for an abundant supply of light chiefly explains many of the peculiarities of its occurrence which have already been described. Where only narrow openings were left in the crown cover of old stands by selective cutting, only occasional individual trees could push up into the light. On clear-cut areas the success of yellow poplar has depended almost entirely on the degree of sprout competition; hence abundant growth has come in only where the cutting has been made in mature timber which sprouted weakly if at all. Where younger stands are clear-cut, good yellow poplar seedling growth can follow only if the dominant sprout stand is cut back in the first or second year.

One feature of the tree's intolerance of shade which is often to the advantage of the stand is the complete and prompt dying out of all branches below the upper crown when the stand is at all dense. In dense pure stands of yellow poplar the crown may be reduced to as little as one-sixteenth of the total height of the tree. The branches not only die quickly when shaded but decay most rapidly at the point of union with the main stem, so that the limbs usually break off within the bark zone of the main stem leaving only a slight pit rather than a projecting stub. This results in the minimum blemish in the wood and consequently young poplars grown in dense stands can be cut for lumber in much smaller diameters than most species.

In even-aged stands of yellow poplar nearly all the living trees occupy a place in the upper crown level, the crown cover being of medium density. Trees which can not maintain their place in this crown cover quickly die out. When such stands are thinned, adventitious buds start out along the clean boles of the trees that are left, causing a considerable production of new branch growth commonly known as water sprouts. As the upper crown takes advantage of the increased light and spreads farther, these water sprouts die and fall off.

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NATURAL REGENERATION

Owing to the fact, already stated, that yellow poplar seedlings can not exist beyond the second or third year under the shade of the parent stand, no dependence can be placed upon advance growth to renew the stand.

In respect to sprout reproduction, yellow poplar is also somewhat at a disadvantage. Although in the case of a very young tree bending the stem or partial girdling is often sufficient to start sprout growth, stumps of trees that are not cut relatively young sprout with little vigor or not at all. Where sprouts do come in in any quantity they are subject to serious if not disastrous damage from wind and sleet, since the young stumps from which they spring decay very rapidly and afford them little support. (Fig. 7.) The sprouting ability of yellow poplar is mainly a safeguard in case a young seedling stand is destroyed by fire, or a last resort where young stands are clear-cut for pulpwood and seed is absent. If pulpwood cuttings become more intensive, as is threatened, the ability to sprout may become a much more important factor in the regeneration of yellow poplar than it is at present.

Successful reproduction of sprout yellow poplar has been observed in Pike County, Ohio, where a pure stand 28 years old was clear-cut for pulpwood in 1923. (Fig. 8.) Two years later the area was densely covered with blackberry bushes which partly overtopped the poplar sprouts. In 1929, however, a measurement on a representative ⅛-acre plot on this area recorded 269 sprouts 1 to 4 inches in diameter and about 20 feet in height. They had overtopped seedlings and sprouts of red and sugar maple, slippery elm, white ash, black locust, dogwood, and redbud. These sprouts came from stumps up to 16 inches in diameter, all of which had in the six years since cutting decayed to a mass of soft pulpy wood. Seed crops had been ample previous to cutting, but only seven yellow poplars on this area could be identified as seedlings. Seedling regeneration has little if any chance in competition with sprouts of yellow poplar and other species.

SEEDLING REPRODUCTION

Yellow poplar seed is borne annually in winged carpels about the central axis of an erect conelike fruit or strobile. The seed averages 12 to 15 per cent fertile, ranging from 5 to 30 per cent. Seeds borne at the base and apex of the fruit are usually sterile. Seed crops are heaviest on trees grown in the open and upon parts of the crown exposed to full light, such as the top of the tree and the ends of the limbs.

At maturity, the carpels become loosened in dry weather but are blown out of the cup-shaped ring of basal scales only by comparatively strong winds. The dissemination by wind is usually to a distance equal to four or five times the height at starting. Dissemination begins about the time of the leaf fall, and usually continues well into the winter.

Evidence gathered under various conditions and at different points indicates that yellow poplar seed which does not reach mineral soil may remain dormant for a year and possibly longer. Such seed has been known to germinate through the first part of the second growing

season after its fall, but the duration of its viability beyond that time is not definitely known.

On an area of moist bottom land in Cecil County, Md., which was lightly burned in the spring of 1922, examination in September of that

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FIGURE 7.—Yellow poplar sprouts readily and vigorously, but the old stumps rot quickly. In the six years since cutting this stump of a 28-year-old tree has decayed almost entirely, leaving poor support for the sprouts

year disclosed a very dense stand of yellow poplar seedlings that had followed the fire. Where the leaf litter had been removed by the light fire, seven or eight times as many seedlings had come in as on a

similar area on the opposite side of the small stream, where the leaf litter had not been removed. The fire was severe enough to have destroyed the seed of the fall crop of 1921 which was still mixed with the loose top layer of litter, and the assumption is therefore reasonable that practically all of this dense stand of seedlings came from an earlier crop of seed which was buried beneath the more inflammable top litter.

The disturbance of the forest litter caused by logging operations is generally sufficient to bring much of whatever dormant seed there

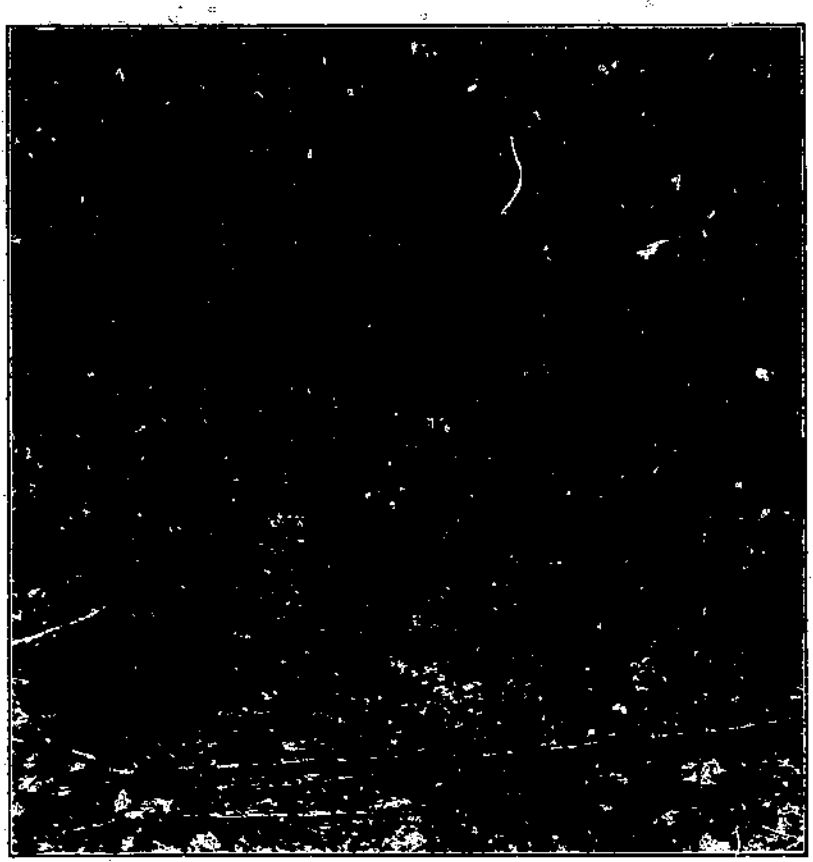

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FIGURE 8.—Poplar sprout growth which followed clean cutting in Hickson's Run, Pike County, Ohio, in 1923. This sprout yellow poplar, some of which is over 4 inches in diameter, was produced in seven growing seasons

may be into contact with the mineral soil. Also seed falling at the time of cutting can reach the soil and at the same time receive sufficient sun warmth to encourage germination. Once germination is accomplished, the seedlings must face a critical period of one to three years in which a number of different conditions must be favorable if they are to survive. The small seedlings must have protection from drying out in summer and from frost heaving in winter, but the grasses or weeds which provide this protection must cast little or no overhead shade. The seedlings must have moisture, with good drainage. They

must have no near-by rivals in sprout growth, and seedling competitors must be of about the same age or younger.

On an area in the Pisgah National Forest occupied by second-growth red maple with scattered yellow poplar trees of seed-bearing size dominating the stand, a fire of medium severity burned a part of the bottom land along Bent Creek. Periodic examination of 150 quadrats on this area, representing four different types of treatment, brought out the record of yellow poplar seedlings shown in Table 6.

TABLE 6.—*Seedlings per acre of yellow poplar on Bent Creek bottom land partly burned in April, 1925, at times of observation in subsequent years*

Quadrats (50 square feet each)		1925	1926	1927	1929	1931		
Number	Condition					Total	New [1]	Old
	Burned:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
40	Clear cut	35,741	9,234	900	1,118	283	44	239
60	Uncut	32,636	9,467	2,381	2,714	798	667	131
	Unburned:							
24	Clear cut	2,360	1,270	73	897	544	363	181
26	Uncut	1,321	1,463	355	4,976	1,575	871	704

[1] Identified by the presence of cotyledons.

Sims (*11*) sums up the evidence from these quadrats as favoring burning after clear cutting as a means of stimulating yellow poplar regeneration. He points out that the sudden loss suffered by the clear-cut quadrats was probably due to the fact that the lush growth of ferns that came in immediately received more benefit thereon than did the poplar. A dense mat of fern roots 2 or 3 inches thick covered the whole area. In 1931 only 87 seedlings per acre more than 6 inches high were found on the burned-cleared areas and only 36 per acre on the unburned cleared. No seedlings higher than 6 inches were found on the other two. Failure here was of course due to the severe light and moisture competition of the ferns.

The worst type of cut-over land for seedling reproduction is the young pulpwood cutting, where sprouts of all species invariably get the start on yellow poplar seedlings and greatly outgrow them. Some of the best sites are abandoned fields where seed is blown in from neighboring stands, and grass and low brush form ideal protection yet give little overhead shade. Many such abandoned fields through the mountains from north Georgia to southern Pennsylvania and west into Tennessee and Kentucky have seeded naturally to yellow poplar. Next best is the clear cutting in old-growth forest, where sprout growth is feeble or lacking and the only perils are drying out and frost heaving. If these can be survived during the first year, regeneration is fairly well assured. On cuttings of mature or nearly mature second-growth saw timber, it may be necessary, as will later be shown, to reduce disastrous competition from other species by relatively inexpensive thinnings. (Fig. 9.)

On suitable old fields where no seed trees are adjacent, any yellow poplar regeneration must be started by planting.

On any site favorable for yellow poplar growth, seedlings will attain a size by the end of the third year that leaves little doubt of the successful establishment of the new stand, provided it can be protected from adventitious injury.

SUSCEPTIBILITY TO INJURY

The agencies most likely to injure severely or to destroy a stand of yellow poplar are grazing and fire, both within the control of the owner. Until the period of settlement by the white man, yellow poplar had contended with all its natural enemies and maintained its place on the more moist, better-drained soils for hundreds of years. As the Eastern, Southern, and Middle Western States became settled, the clearing of land, the logging of merchantable trees, increase of fires, and grazing by domestic animals exerted new destructive influences upon yellow poplar.

GRAZING

Because of their succulence the twigs and smaller branches of yellow poplar are eagerly browsed by all classes of livestock in preference to

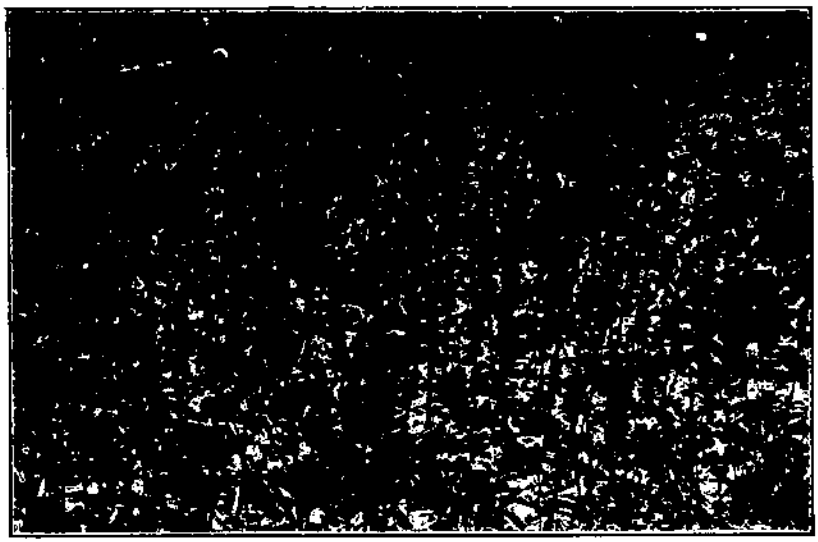

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FIGURE 9.—Three-year-old yellow poplar reproduction following the cutting of a large yellow poplar on the edge of a 40-year-old stand of *Pinus virginiana*. Seedlings have come in at the rate of 100,000 to the acre

other tree species. Even where cattle are not numerous, as in the mountain regions, individual trees are damaged here and there along trails and streams, and in other places where cattle congregate. Where the cattle are numerous, and particularly where they are confined, the damage is very severe. Seedlings are grazed to the ground, small saplings are trimmed back to stubs, and large trees up to 14 feet high may be ridden down and partly destroyed.

In the mountains of Pennsylvania where deer have become very numerous, yellow poplar seedlings are often extensively destroyed by their browsing.

Within the range of yellow poplar, grazing did not become a serious factor until the day of the fenced wood lot. In the early days cattle roamed over wide areas, but as settlement increased, fencing of stock became the rule. At first, cattle were put in inclosed pastures; now

the tendency, at least in the richer agricultural regions, is to use small inclosures not needed for cultivation as holding lots for the stock and to give the stock supplemental food. The result is that on areas where stock are so concentrated the young growth of yellow poplar is about wiped out.

FIRE DAMAGE

Yellow poplar seedlings and saplings are among the trees susceptible to fire killing because of their thin bark. (Fig. 10.) Stems up to 1 inch in diameter have little chance to escape any leaf fire hot enough to run over the dry forest floor. The damage in such cases is likely

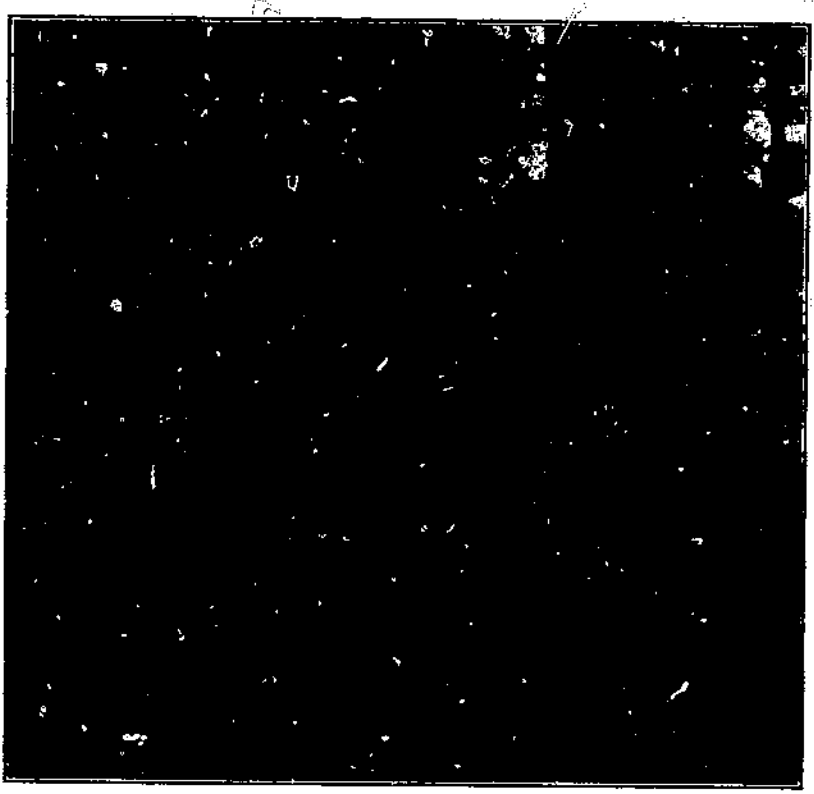

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FIGURE 10.—Yellow poplar trees 10 inches and less in diameter are very sensitive to fire injury. Fire damage is normally followed by decay

to be permanent in effect since the yellow poplar sprouts that follow the fire can not compete successfully with the sprouts of chestnut, oak, hickory, black gum, dogwood, and sourwood, as well as shrubby species that are already growing rapidly and are not seriously checked by light surface fires. Following even one such fire in a very young stand, only a few yellow poplar sprouts will be able to seize a place in the upper crown cover. A second light fire will practically eliminate young yellow poplar.

In any fire season, the nature and extent of possible damage to yellow poplars will also be determined somewhat by the maturity of

the tree. Recent experiments at the Appalachian Forest Experiment Station indicate that the yellow poplar bark will not burn readily and that when the bark of the larger saplings becomes thick enough (say, 0.5 inch or more) to insulate the cambium adequately, yellow poplar is one of the most fire-resistant of eastern trees.

The severity of damage by fire varies not only with the kind and quantity of fuel and its rate of burning, but also with the time of year in which the fire occurs. Fires in hardwood forests feed chiefly upon leaf litter and dead herbaceous vegetation. They burn most severely where there is an accumulation of deadwood, such as slash left from a logging operation, fallen trees, stumps, or deadwood left

F18308

FIGURE 11.—Fungus fruiting body indicating decay. This fungus entered the base of a yellow poplar through a fire scar

in the tree as a result of wounding by earlier fires. Fires are most common in the spring and fall, when the hardwood trees offer no shade and the forest floor dries out most severely.

Yellow poplars in sizes between the seedling stage and 18 inches in diameter are readily wounded in proportion to the severity of the fire; but the most serious feature of this wounding is that by means of it fungi are enabled to attack the heartwood. (Fig. 11.) Hollow-butted yellow poplar trees are common in the virgin forest as the result of such fire wounds.

An example of the degree of damage which a yellow poplar stand may suffer from the combination of decay and fire wounds is afforded by a detailed study made in 1924 on 144 trees. These represented

the complete cut on representative plots of two logging operations, one a plot of 79 trees along Cantrell Creek on the Pisgah National Forest, and the other of 65 trees about 10 miles west of Fontana, N. C. Of these trees, 94 (or 65 per cent) were diseased with wood-rotting fungi, 93 being rotted at the butt. The causal fungi were determined partly from cultures [7] but chiefly from the type of decay, as follows:

	Per cent
Armillaria mellea (Vahl.) Quel	62
Hypholoma sp	11
Polyporus sulphureus Fr	7
Polystictus hirsutus Fr	6
Polyporus fumosus Pers	4
Polyporus cerifluus Berk	3
Pleurotus ostreatus Jacq	1
Undetermined species	11

Some of these trees were attacked by more than one species of fungus, and in some cases wood partly rotted by one species was attacked and more completely destroyed by a second one. Of the 94 trees which were decayed, 59 had fire scars which had healed over, 34 had open fire scars, and 1 tree bore an open lightning scar. The ages at which different percentages of the trees in these two plots were infected were estimated as follows:

	Per cent
20 to 40 years	20
40 to 60 years	16
60 to 80 years	7
80 to 100 years	8
100 to 120 years	4
120 to 160 years	2
Undeterminable	43

The total scale of these 144 trees was 123,160 board feet (Scribner Decimal C log rule), of which 19,550 board feet, or 15.9 per cent, was deducted for decay due to fire. This deduction represented not only the actual amount figured as cull [8], but included the total volume of discarded logs which were left in the woods because of cull.

ICE DAMAGE

The greater part of the natural range of yellow poplar lies within the zone in which the formation of sleet ice is a relatively frequent occurrence. The possibility of damage by sleet is increased by the wide range of elevation characteristic of yellow poplar, which increases the chances of combination within poplar stands of the critical temperature, high humidity, and slow air movement necessary for sleet formation. The damage done by the sleet varies with the nature of the stand. Trees with a slender bole are easily broken when loaded with ice. Sprout growth inadequately supported at the base by rapidly rotting stumps is easily borne down by the weight of the sleet. Frequently trees which are not broken or prostrated by the

[7] Cultural and other determinations were made in 1923 and 1924 by E. E. Hubert and W. H. Long, of the Office of Forest Pathology, Bureau of Plant Industry.

[8] Cull was determined by the formula $\frac{\frac{1}{2}(a' \times b') + (a'' \times b'') \times L}{15}$ in which a' and b' represent the greatest and smallest diameters in inches of the decay at the smaller end of the log, and a'' and b'' represent the greatest and smallest diameters at the larger end of the log, while L represents the length of the decay in feet. This formula was adopted on the advice of Donald Bruce as giving a rough approximation of the number of board feet that would be lost in sawing the infected logs. The decay infections studied were in most cases approximately conical. For logs showing decay only in one end, a' and b' were considered as zero. The deduction for decay, like the total scale, was figured to the nearest 10 board feet, anything less than 5 board feet being ignored.

ice load are so bent out of position as to be quickly suppressed thereafter, or so broken in the top or stripped of branches as to lose out at once in the struggle for crown dominance. If the ice-injured tree, either broken or bent, is not immediately dominated by other trees in the vicinity, it is very likely to be infected with fungus at the point of injury. Instances of such forms of ice damage in yellow poplar stands 25 years old or older have been observed at Cranberry, N. C., on the slopes of Thunder Hill on the Natural Bridge National Forest in Virginia, in the Iron Mountains in Wythe County, Va., and near Berea, Ky.

Stands which have grown too densely are often subject to severe ice injury after thinning because of the lack of wanted support from adjoining trees.

LOSS FROM DISEASE[9]

The wood-rotting fungi that attack the heartwood usually enter through fire scars or other wounds at an early age of the tree, sometimes as early as the fifth year. The decay caused does not usually, however, extend more than 8 to 20 feet upward. The most common type of decay is a soft, spongy, white or gray pocket rot of both sapwood and heartwood, caused by the shoestring-forming fungus, *Armillaria mellea* (Vahl.) Quel. This fungus dissolves the wood in the region of the medullary rays, leaving irregular cavities or pockets, and occasionally attacks the roots. Less frequently present are a soft dark-brown or black heart rot caused by *Hypholoma* sp.; a honeycomb pocket rot of heartwood caused by *Polyporus cerifluus* Berk.; and a dark gray, brown, or almost black butt rot caused by *Trametes malicola* B. and C. Less frequent butt rots are caused by the following species: *Polyporus sulphureus* Fr., which causes a brown cuboidal rot; *P. fumosus* Pers., a white-mottled, yellow rot; *Fomes applanatus* (Pers.) Wallr., a white-mottled, cream-white rot; *Ganoderma curtisii* (Berk.) Murr., or a species similar in action, a white stringy pocket rot; and *Pleurotus ostreatus* Jacq., a white rot. The sapwood, when killed, is quickly attacked by a number of species, some of which extend their action to the heartwood. The most common are the following: *Irpex mollis* B and C., *Polystictus hirsutus* Fr., *P. versicolor* Fr., and *Pleurotus ostreatus*, all of which cause white rots; *Polyporus fumosus* Pers., a white-mottled yellow rot; and *Fomes applanatus*.

Several parasitic species of fungi attack the leaves, though without serious effect. The most common of these is *Gloeosporium liriodendri* E. and E. Others are species of Asterina, Cercospora, Cylindrosporium, Phyllosticta, Ramularia, and Sphaerella. Two species of mildew, *Erysiphe liriodendri* Schw. and *Phyllactinia suffulta* (Reb.) Sacc., occasionally attack the leaves of sprouts and young seedlings. If these attacks begin early in the growing season they can cause considerable injury. Fungi, mostly low in parasitism, that attack and kill the limbs and twigs of young crowded and suppressed trees, especially the lower limb and any others of low vitality, include *Creonectria coccinea* (Pers.) Seaver, *Diplodia liriodendri* (Peck), *Myxosporium coloratum* (Peck) Sacc., and *Leptosphaeria stictoides* (B. and C.) Sacc.

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[9] Prepared from information furnished by George G. Hedgcock, Senior Pathologist, Division of Forest Pathology, Bureau of Plant Industry.

Yellow poplar logs, especially when cut in the warmer seasons, are subject to rapid deterioration, because of the attack 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 commonest and most rapid staining species is *Ceratostomella pluriannulata* Hedgc. Other wood-staining species common in yellow poplar logs and boards are *C. capillifera* Hedgc., *Graphium rigidum* (Pers.) Sacc., and *Graphium* sp. The deterioration in grade resulting from staining is frequently great, owing to the large proportion of sapwood. Prompt utilization of logs will reduce stain losses.

DAMAGE BY INSECTS [10]

The yellow poplar has few insect enemies, and these seldom kill the tree. The most injurious is the Columbian timber beetle, *Corthylus columbianus* Hopk. (one of the ambrosia beetles). Holes bored by this insect in the sapwood of the trunks of living saplings and older trees become permanent defects. Staining fungi attack the wood about these holes and cause blue or greenish streaks that sometimes extend for several feet, producing an effect known as "calico poplar." In some localities timber is much reduced in value by this defect, which is apparently most common on wet soils in the coast region. Hopkins (*8*) finds the attacks of this insect on the decline. There is no known preventive or remedy.

The tuliptree soft scale, *Toumeyella liriodendri* Gmel., may sometimes be found in great clusters on the bark of branches. Although in heavy infestations branches sicken and die, the damage is not usually very serious. Undersides of leaves are often infested by an aphid, *Macrosiphum liriodendri* Mon., that feeds by sucking juices. These insects seldom appear in great numbers but when abundant cause paling and early falling of the foliage. The bark is sometimes inhabited by the boring caterpillar of a moth, *Euzophera ostricolorella* Hulst. Circular spots on the leaves about one-quarter inch in diameter and colored yellow or greenish and brown indicate the presence of the maggot of a small fly, *Cecidomyia liriodendri* O. S. The caterpillar of a moth, *Polychrosis liriodendrana* Kearfott, builds a small web on the underside of the leaf, usually near the midrib, and skeletonizes part of the leaf, folding the injured portion somewhat. Damage to forest stands is, however, negligible.

GROWTH AND YIELD

As previously intimated, the best growth rate of yellow poplar is ordinarily obtained on old fields which are characterized by a moist but well-drained soil, where the possibility of sprout growth has been removed by years of cultivation and grass and low brush species are growing not too densely. Few other hardwoods display a vigor equal to that of yellow poplar under such circumstances.

Characteristics of growth already mentioned have a definite effect on the yield of yellow poplar. Also more intensive management of yellow poplar stands could salvage many trees that are now killed by shading, and this would increase considerably the total volume harvested. Yellow poplar stands thin out severely as they increase in age.

[10] From information furnished by William Middleton, Entomologist, Division of Forest Insects, Bureau of Entomology.

HEIGHT GROWTH

Height growth of yellow poplar seedlings during the first year will range from a meager 2 or 3 inches to the 15-inch mark attained by seedlings on the best sites. The height reached depends upon the time of germination, the density of shade, and the moisture available in the surface soil. The smaller seedlings have a chance of final success only if there is sufficient light to encourage the single leader to

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FIGURE 12.—A 55-year stand of yellow poplar on a good site (elevation 2,700 feet) in northern Georgia in which heights range generally from 100 to 140 feet

shoot up and attain a position of dominance before light is shut off by the spreading crowns of larger individuals. Seedlings which grow only 2 or 3 inches during the first year are very likely to be heaved out by the frost, killed by short periods of drouth, or bent over and smothered by leaf litter.

Under full light the most rapid height growth of the seedlings begins in the second year. It is not uncommon for yellow poplar to reach 10 to 18 feet by the end of the fifth year. In one instance on a

cut-over old-growth area in the Smoky Mountain district, yellow poplar trees, apparently of seedling origin, made the unusual growth of 50 feet in 11 years.

Yellow poplar sprouts have an even more vigorous growth and in this respect exceed all other associated species except chestnut, black locust, silverbell, and sourwood. If not interfered with by grazing, yellow poplar sprouts will successfully take and hold their place in the dominant crown cover of any second-growth sprout stand. The only dangerous competitor is the chestnut. At present the chestnut blight tends to wipe out this competition.

In the early years yellow poplar sprouts definitely outdistance yellow poplar seedlings on equivalent sites. However, no differences in the later growth rates of sprout and seedling poplar trees have been found, except where two or more sprouts from the same stump have crowded each other and reduced the growth rate of all members of the group.

On good sites, mature yellow poplar attains a height of 140 to 160 feet. Recent measurements of a 55-year old stand in the Cherokee National Forest (Ga.), gave the average range of heights as 100 to 140 feet, with at least one tree well over 150 feet. (Fig. 12.) Heights of over 190 feet have been reported, but not thoroughly substantiated. One old-growth tree on Reems Creek, about 15 miles from Asheville, N. C., shown in Figure 13, measured 28.7 feet in circumference and 144 feet in height and may once have been of even greater height.

Taking 50 years as the standard age for the measurement of site quality by height growth (*5*), a height of 110 to 120 feet is considered characteristic of the best site quality, whereas 60 to 70 feet indicates the poorest. Some of the best stands measured averaged 110 feet in dominant-tree heights in 48 years, 92 feet in 26 years, and 50 feet in 11 years.

FIGURE 13.—An old-growth yellow poplar on Reems Creek, near Asheville, N. C. This tree was measured early in 1932 and was found to have a breast-high circumference of 28.7 feet, a height to base of main crown of 83 feet, and a total present height of 144 feet.

DIAMETER GROWTH

The rate of diameter growth of yellow poplar is determined by the size of the crown formed and retained by the tree. If a goodly portion of the total height of the tree is occupied by the crown, the tree will grow rapidly in diameter, but the bole will taper very sharply

within the crown. Trees of this species grown in the open stands on a good site often reach 15 inches in diameter at breast height in 30 years and make equivalent growth at other ages. If the same trees had been restricted by growth in dense stands, they would have made a much smaller diameter growth, but the boles of the trees would have been more cylindrical in form and freer from knots. The average diameters of all trees 5 inches and more d. b. h.[11] are shown in the Appendix (Table 17) for even-aged stands from 10 to 50 years of age and for the full range of site-index classes. The diameters shown in the table for ages up to 25 years are representative of average diameters attained by dominant trees, but those shown from 25 to 50 years are lower than may be expected in the dominant stand, since

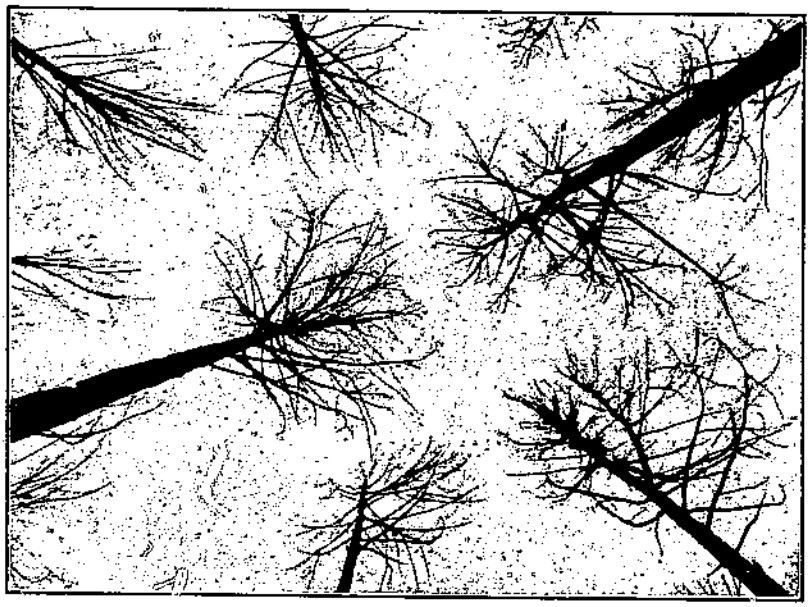

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FIGURE 14.—Crown development in a dense, 90-foot stand of yellow poplar near Cranberry, N. C. Natural pruning of limbs has materially reduced the crowns; swaying of the boles will now result in whipping off the leaves and in checking branch growth

trees from the codominant and intermediate classes are included in these age groups.

Where the crown cover of a stand has been completely closed for a decade or more the trees will be found so severely crowded that diameter growth has been checked, even though the stand is still young. In well-stocked cove stands this slowing down of diameter growth may be expected about the twentieth year and, if the stand is not thinned, the crowding will continue until the trees are seriously retarded and have lost the power to recover promptly the early growth rate. This is because in such dense stands the lower part of the crown is shaded out. Where this condition has existed until the crowns are reduced to one-sixth or less of the total height of the

[11] D. b. h. = diameter breast high.

tree, a further reduction will follow in area of crown because of the swaying of the slender boles in the wind, whereby leaves are whipped off and branch growth is checked. (Fig. 14.) Where this occurs, stand density is materially reduced and tree species more tolerant of shade are encouraged to grow up and crowd out the yellow poplar.

While there might be some question whether any of the stands examined so far could be called overstocked, certainly the majority of the dense yellow poplar stands examined show a marked retardation of diameter growth at about 25 years of age and have little possibility of resuming their normal rate of growth unless thinning operations make possible a prompt recovery of full crown development. An example of what might be termed overstocking is afforded by a natural stand of yellow poplar, 38 years old, located in a north-facing cove in southeastern Ross County, Ohio, which at the time of examination had a total basal area 25 per cent greater than the values shown in the yield table (Table 16) for the same site and age. During the drought of 1930, 33 per cent of the trees died. This loss, which was all from the subordinate stand, 8 inches or less in diameter, comprising 15 per cent of the total basal area, constituted a sufficient reduction to bring the stand down very close to yield-table values. This is reasonable evidence of overcrowding, and is a very good indication of the demand that this species makes for soil moisture.

From records of 413 trees grown in old-growth cove forests of North Carolina, Tennessee, and West Virginia, the following indication of average growth rate was determined:

Years	D. b. h. (inches)
50	9
100	17
150	23
200	27

A comparison of these diameters with similar measurements in pure second-growth stands makes it clear that these yellow poplars must have been greatly impeded in growth by adjacent trees, especially at the time when they should have been making their most rapid growth.

FORM

The straightness of bole in yellow poplar, the consistency with which it maintains a single stem, the clear length of bole, and the uniformity of taper in the well-grown tree are truly remarkable among the hardwoods of the region. Studies of forest-grown yellow poplar in several States [12] indicate that the clear length of such trees is about 50 per cent of the total height for sizes from 10 to 15 inches in diameter. Trees from different regions and sites have relatively little variation in the actual clear length for any one diameter class. For the larger trees, 24 inches d. b. h. and more, comparatively uniform average clear length was found for trees of a single diameter class, even though the records included older, slower growing trees from poorer sites, and young, vigorous trees of equal diameter from the best sites.

The bole is tapering in young trees, but as the crown is reduced by shading it becomes more cylindrical. In early life a certain

[12] The figures here quoted are from tables prepared by Walter Mulford, G. M. Homans, and F. E. Olmsted, of the Forest Service, about 1904.

degree of crowding is desirable to reduce the length of the crown; but if this crowding is not eliminated in time to preserve ample crown length, the return to satisfactory growth rate will be seriously retarded.

VOLUME AND YIELD TABLES

VOLUME

Tables 13–16 give the average volumes of second-growth yellow poplar trees of different sizes. The volumes are in terms of total cubic feet (Table 13), merchantable cubic feet (Table 14), board feet by the Scribner log rule (Table 15), and board feet by the International log rule (Table 16). These tables were computed from taper diagrams (*4*). The volumes were checked against values obtained by scaling the original taper diagrams for each height and diameter class. Tables 11 and 12 give the board foot (Scribner) volumes of yellow poplar trees over 100 years old. They are based on other measurements and other sets of taper curves than those used for Tables 13–16.

These volume tables are applicable to any average stand of second-growth yellow poplar of reasonable density, or in the measurement of volume of individual poplar trees grown in combination with other hardwood species of approximately the same size. Volume for open-grown yellow poplar trees will be lower than the average value shown in the table for any given height or diameter. The narrow range of form found in computation of the data used in the construction of these volume tables makes unnecessary the preparation of separate form-class tables for the species.

YIELDS

The yield-table values presented in Table 17 are normal values; they have been computed from 89 plots scattered well over the range of the species and representing the best stocked areas that could be found. Apparently they represent stands that have been well stocked throughout their life, and none of them was thinned or improved in any way prior to measurement. In obtaining plot measurements all acreage was horizontally measured; lines were run in such a way as to avoid selection so far as possible, except with regard to stocking of the area as a whole. No plot was discarded because it was overstocked. Diameters were taken largely with the diameter tape, heights with an Abney level and tape, and age by use of an increment borer or, wherever possible, by observation of cut timber.

Yield plots were computed by the use of the accompanying volume tables applied directly to the tally record. Basal area and numbers of trees were also obtained by direct computation from the tally sheets and were later converted to the acre basis. The curves of height on age used for the determination of site were made up from the dominant sample trees obtained upon the plots, further supported by other determinations of height-age on individual dominant trees. Plots were assigned to their respective sites as indicated by their height at a given age according to the height-age diagrams. Only plots located in a given site, according to site index, were used in computing yields for that site. Yields for several sites were then correlated.

The use of 50 years as a basis for site index was necessary since older stands were not available to raise the age basis to 100 years. Height-age curves are still rising sharply at 50 years, and a new site index based upon older stands should be computed when stands become available for this purpose.

COMPARISON WITH YIELDS OF OTHER SPECIES

Differences in standards of utilization and measurement render it impossible to make an exact comparison between yellow poplar yields and those of other species of equally rapid growth. Approximate comparisons, however, indicate that yellow poplar ranks well. Medium site quality for yellow poplar, indicated by a height of 90 feet at 50 years, produces a yield of 24,400 board feet per acre measured by the International (¼-inch) rule, or 4,480 cubic feet per acre of felled wood exclusive of stump and top. At the same age and on a similar site, Douglas fir (*10*) yields 31,400 board feet, or 5,690 cubic feet. Values for Douglas fir include only trees 7 inches in diameter and larger, whereas the yellow poplar tables include trees 5 inches, but this is of small importance since, at age 50, 5-inch yellow poplar trees would be eliminated and there would be few under 10 inches, whereas Douglas fir would retain all trees of the 7-inch class. The more rapid growth of the larger yellow poplar trees in early life is shown by yields at 30 years of 2,300 cubic feet, as against 1,500 for Douglas fir.

Yellow poplar compares equally well with the rapid-growing loblolly pine (*15*) which yields 5,300 cubic feet per acre of felled wood for all trees 4 inches and larger at 50 years, especially when this yield, which includes stump and top, is reduced by 2.5 per cent, to 5,168 cubic feet, to make it comparable with the yellow poplar yield.

Both Douglas fir and loblolly pine are recognized leaders in production in the regions in which they grow. Both are better able to grow under shade than yellow poplar and consequently can maintain a greater density of stand.

APPLICATION OF YIELD TABLE

The yield table given in the Appendix may be used not only to estimate the present volume of the yellow poplar stand at any given age but also to predict approximately the volume to be expected at any future time. It is necessary to know only the age, site class, and degree of stocking of any stand to which these tables are applied. Age may be determined by a ring count on cut trees or from cores bored in standing trees. Site class may be determined by comparing the average height of the dominant trees and the age of the stand with those given in the site-index table of heights at various ages. Height-age curves may also be constructed for this purpose.

Density of stocking is best expressed by the volume per acre of the stand, but this determination involves a rather laborious set of measurements and computations. On the other hand the attempt to judge density of stocking by eye will seldom result in a wholly dependable appraisal. A method that is both relatively simple and reasonably accurate is that of comparing the total basal area in square feet per acre on any stand, computed from diameters taken at breast height, with that given in the tables for stands of the same age and

site class (*15*). Tabulated yields may then be corrected proportionally to the percentage of deviation of the basal area for the stand from that shown in the table. Where yield predictions are made, especially for long periods in advance, allowance may possibly be made for a tendency of understocked stands to become more fully stocked as they grow older and therefore to approach the values given in the table.

MANAGEMENT

Several indications have already been given of the possibilities of increasing yellow poplar yields by thinning and by improved methods of cutting, and occasionally by the judicious planting of areas that would otherwise be greatly understocked or nonproductive. Of the desirability of extending the productive areas of yellow poplar there is obviously no question. Its rapidity of growth, and the adaptability of the wood to many uses—from substitution for softwood lumber, through a variety of secondary products for which it is perhaps better fitted than most other woods, down to its very profitable utilization for pulpwood, excelsior, and similar products—will keep it in demand so long as it is available in marketable quantities. If the point is reached, however, where yellow poplar can no longer be profitably marketed, the wood-using public will turn to substitutes, and yellow poplar, like other woods that have gone through this same cycle, may no longer be in demand even when the maturity of new growth renders it available. The yellow poplar saw timber still remaining, together with the new growth, is insufficient to maintain the present cut. At the same time, any serious and protracted reduction in the cut may fall so far below the demand for the wood as to result in a loss of market. It is desirable, therefore, that the remaining and future supplies of yellow poplar be so amplified that production in sufficient quantities may be stabilized.

The development of an adequate growing stock should be a primary principle in forest management. In the management of yellow poplar, the necessity of preserving seed trees, the ample supply of seed when these are available, the difficulty of sprout competition on young-growth cut-over areas, the utter failure of yellow poplar saplings unless they are able to establish themselves in a dominant position in the crown cover, and the tendency of young even-aged stands on good sites to become overcrowded, are some of the conditions that must be taken into account in determining not olny cutting practice but also the subsequent care of cut-over areas.

The growing interest in yellow poplar as a source of pulpwood has dictated a policy of cutting out young poplar from the woods and of clear-cutting young stands that is in effect very short-sighted, since it is a sure way to destroy all chance of future crops of this valuable species. Cutting young trees from mixed woods of course removes all possibility of yellow poplar seeding in the stand in the future. The clear cutting of very young stands involves at best a gradual shrinkage of the areas of poplar growth and in many instances brings about the elimination of yellow poplar, since the sprout growth that follows, as has been explained, is very liable to succumb before the new stand has become firmly established. The early harvest of yellow poplar results from the demand for an early cash return and a disregard of the rapid increase in value of these trees as they increase in size. Even

though yellow poplar pulpwood crops may prove profitable, the periodic cost of replanting which is necessitated thereby makes the holding of these stands to something nearer saw-timber size a much more profitable policy in the long run.

However, pulp mills offer a market for small-sized trees such as are removed in thinning, and such utilization is entirely compatible with good forest management. Since the demand for poplar pulpwood will undoubtedly continue in certain sections, this market indicates the desirability of increasing the acreage of yellow poplar and the possiblities of profitable intensive management.

CUTTING PRACTICE

OLD-GROWTH STANDS

As already explained, yellow poplar seedlings come in very readily and with good success following a heavy cutting of old-growth stands. Although there is considerable evidence to show that at least partial regeneration can come from the seed of the previous year or years that is lying dormant in the leaf litter on the forest floor, this dormant seed can never be depended upon to produce well stocked stands of seedlings. It is imperative that seed trees be left standing to supply seed for the whole area.

Seed trees should be selected for their location with respect to prevailing winds and slope; favorable sites are at the heads of coves or on slopes where their elevation will permit the most effective distribution of seed. Yellow poplar trees which are still in a stage of vigorous growth may be retained as seed trees without loss if the indications are that their stumpage value will increase rather than lessen in the course of time.

Since the rooting habit of yellow poplar on the moist soils where it most frequently occurs makes it very susceptible to windthrow, seed trees should be left in sheltered positions as far as possible.

The method of logging has no appreciable effect upon the regeneration of yellow poplar save in the matter of slash disposal. Logging in cove sites, as practiced at present, leaves the branches and tops, or "slash," collected in windrows or piles, with the spaces between very much torn up by travel of men and draft animals. This disturbance of the leaf litter is favorable to poplar regeneration, but the dense piles of brush tend to prevent the establishment of seedlings. Slash unburned should, therefore, be scattered widely so that it will offer as little interference as possible to the incoming seedlings.

Piling and burning slash furnishes some protection against subsequent severe fires, but the spots covered by the piles will remain barren and require reseeding after the slash burning. If protection of the area from later fires can be attained in any other way, piling and burning slash is probably not worth while. Complete protection must be secured, however, since even light fires are fatal to poplar reproduction. Fires which run over logged areas several years after the cutting are most destructive to poplar regeneration, and the subsequent sprouting of other species tends to eliminate yellow poplar from the stand.

SECOND GROWTH

Characteristics of growth already discussed force the conclusion—failing sufficient opportunity as yet to try out experimental methods of cutting—that second-growth stands of saw-timber size must have

the same method of treatment as virgin stands, namely, a heavy cutting with seed trees left in advantageous positions. In second growth, however, this treatment must be supplemented by measures effective in reducing competition from the sprouting of vigorous young hardwoods of other species, against which, as has been shown, seedlings can not hold their own. The greater the proportion of other hardwoods the greater the necessity for ridding the stand of this sprout growth of such species as black locust, chestnut, slippery elm, bitternut hickory, dogwood, sourwood, and silverbell, which is certain to come in so vigorously as to overtop and kill the yellow poplar seedlings. This competing growth can, of course, be cut back after the stand is cut, but this method must be well-timed to be effective. A more certain and probably less expensive method is to accomplish the elimination of competing sprout growth before the stand is cut, by combining this cleaning operation with the thinning practice described in the next section, which should be a definite part of the management of every second-growth poplar stand.

It does not seem advisable in second-growth poplar to clear-cut the stand and depend solely on poplar sprouts for reproduction. Sprouting of yellow poplar is sufficiently vigorous, when the stand is young, to overcome most other sprout growth, but dependence on sprout growth following cutting is undesirable for a number of reasons that have already been given, the most important of which is that this will involve a reduction or at best no extension of the growing stock on the area and no opportunity to seed in adjoining open areas.

THINNING

It has been shown that pure stands of yellow poplar slow down in diameter growth at a very early age. Fairly dense growth for the first few years is beneficial in that it assists the tree to develop a tall slender bole with the lower part of the trunk clear of branches. When this has been attained thinning is needful to avoid excessive restriction of crown and consequent loss in wood production. Thinning should begin as soon as a profitable return can be obtained from the thinning operation and its aim should be to retain in the reserved trees a crown length equal to at least one-third of the height of the tree. Dominant trees of good form with well-balanced crowns should be selected for the final saw-timber crop. Trees of subordinate crown classes should always be removed, since little can be expected from them in wood production and they will eventually be killed out. The operation should not leave the stand too open on the windward side, nor so open within the stand as to encourage excessive water sprouting on the part of the dominant trees. But no effort should be made otherwise to preserve those spindling, intermediate trees which are ordinarily the ones most damaged by sleet or ice. Where a pulpwood market is available, thinning can be made profitable as early as the twentieth year. For the best timber production thinnings should be repeated whenever there is evidence of overcrowding.

As pointed out in the previous section, thinning or cleaning in mixed stands is essential to remove or greatly reduce the sprout growth of inferior species that will otherwise choke seedling regeneration of yellow poplar following cutting.

ARTIFICIAL REPRODUCTION

The increasing acreage of abandoned crop land is adding annually to the large aggregate area suitable for the production of yellow poplar. This aggregate includes not only old fields but also much cut-over land that because of fire or grazing or lack of seed trees is likely to be seized by undesirable trees and shrubs. Almost any moist, well-drained site within its range is suitable for yellow poplar—even very steep slopes if the soils do not dry or wash excessively, or land which is infrequently flooded if the soil remains loose when it dries.

Whether sowing seed or planting with nursery-grown stock is the more successful method of reproducing yellow poplar on such lands can not be stated categorically. Experience with other species favors planting over sowing as a general rule. One recent experiment (*9*) with yellow poplar showed results definitely unfavorable to sowing.

SOWING

The labor cost of sowing yellow poplar seed in the field is high and will approximate that of planting for the same area. Furthermore, because of the uncertainty of weather conditions and the very serious results of unfavorable weather in seeding operations, the percentage of success is likely to be much lower than for planting. Unless some vegetation grows up around the seedlings, they may be frost-heaved during the first winter following germination. If the competing vegetation is too dense, seedlings may be smothered. For these and other reasons seeding is hardly feasible except in carefully selected places.

If the establishment of yellow poplar by sowing seed is attempted, small spots 15 to 18 inches across should be prepared, from which the sod or other vegetation has been removed. Considering the very low germination percentage of yellow poplar, even when the seed has been kept moist over winter by stratifications, 60 to 80 seeds per spot are no more than sufficient to insure establishment. The seed should be covered to a depth of about one-fourth inch.

PLANTING

Planting yellow poplar is not only practicable on the better soils but can be done quite cheaply if reasonable care is taken. It may be employed on very open burned areas or in favorable locations in cut-over old growth, as well as in suitable old fields, but it will not ordinarily succeed where a young hardwood forest has just been cut away or burned, for the vigorous sprout growth that follows immediately will suppress the planted poplar seedlings.

Where sizable openings occur between stumps or sprouts on woodlands recently cut or burned, it may be feasible to supplement the growing stock by planting yellow poplar seedlings. This may involve subsequent cleaning out of competing sprout growth in another three or five years; yet if the planting is carefully done and confined to the larger openings, the cost of such cleanings should not be excessive.

The results of the spread of the chestnut blight furnish an opportunity for yellow poplar planting. The lower chestnut slopes on northerly exposures will probably revert largely to oak after the death of the chestnut. These stands are likely, however, to be poorly

stocked for a number of years, and if yellow poplar trees can be established in small plantations to serve as centers of seed distribution, they will bear seed early enough to restock some of the land on which the chestnut has died out. Planting should not be undertaken on land naturally adapted to the growth of chestnut oak, black oak, scarlet oak, or pitch pine, because such land is usually too dry. Yellow poplar will not thrive as well as will shortleaf pine in the post-oak type on the piedmont plateau. It will do well, however, on land suited to white oak, in the beech, birch, and maple forests, on the heavier soils normally occupied by northern white pine in the lower edge of the beech, birch, and maple forests, and on such heavy soils as are occupied by red oak, white ash, Ohio buckeye, and basswood. It should not be planted on poorly drained soils or on land along streams subject to frequent or protracted overflows.

A word of caution should be added against the notion that promiscuous planting of yellow poplar or, for that matter, any other equally exacting species, will be successful on all abandoned fields. Investigations in forest soils undertaken recently by the Central States Forest Experiment Station are already producing evidence tending to invalidate the rather general belief that since soils were once capable of growing good species, as exemplified by remaining adjacent stands, they are still good enough for such species as walnut, poplar, etc. The present indication is that there has been a tremendous loss of fertility, porosity, and moisture capacity in abandoned fields. Apparently there are many such fields that are no longer capable of growing good hardwoods successfully, at least until they have been improved for a time by a cover of pine, locust, and similar species.

NURSERY PRACTICE

Some States have forest nurseries which are able to supply yellow poplar planting stock as demanded. Where such a source is not readily available and other conditions are favorable, it may be desirable to raise from seed the stock needed.

Yellow poplar seed can be collected most easily and at lowest cost following a logging operation that occurs in wet weather or immediately following wet weather in early fall. At such times the mature fruit closes tightly and will carry the seeds to the ground without scattering. Once the tops are down, the seeds are held in place even when dry by the ring of basal scales and the central stalk of the fruit and can be collected at a cost of 15 to 20 cents a pound. Seed can be purchased from seed dealers at prices varying from 40 cents to $1 a pound.

Seed collections should be made as soon as possible after the seeds are ripe in the autumn, since yellow poplar seeds quickly lose their germinating power if allowed to become dry. For the same reason it is necessary either to plant these seeds in the fall of the year or to stratify them in moist sand for cold storage through the winter. Seeds that are stored dry during the winter will not only have a low germination percentage, but will usually fail to germinate for a whole year after sowing. Nursery sowing can probably best be done in the fall, if the beds are mulched with dry leaves or rye straw to prevent drying out during the winter. This mulch should be removed before germination is expected. If sowing is delayed until

the spring, it will be necessary to stratify the seeds over winter in moist sand in such a way that they can be separated by screening when the nursery bed is prepared for planting. It is, of course, necessary to make sure that the sand is kept moist through the winter.

On moist, fertile land yellow poplar seedlings suitable for field planting can be grown easily and cheaply with no other care than weeding and cultivation.

Poplar seed ranges from 10,000 to 18,000 to the pound (*12*) and averages about 15,000 seeds, of which only 5 to 30 per cent will be fertile, the lower figure representing carelessly collected or dry-stored seed. Broadcast sowing in beds is advantageous when only a small number of trees are to be grown, but is not so desirable in larger projects, since the sensitiveness of the seedlings to shading and lack of moisture places them at a disadvantage in the crowded broadcast bed. Furthermore, seedlings grown in drills tend to produce sturdier planting stock with the same amount of shading and watering. Seed should be sown in drills at the rate of 50 to 75 to the linear foot, and the drills should be 8 to 12 inches apart (*9*). Mulching, as already stated, is essential.

Since planting the seedlings at the end of the first year saves nursery and planting costs, the stock should reach one-half to 1 foot in height in this first season. For this reason, it is desirable that the soil should be rich and otherwise similar to that found on the best natural poplar site. Stock should not be encouraged to grow higher than 1.5 feet before planting.

FIELD PLANTING

Experience has shown that in the Ohio Valley as well as in the southern Appalachians yellow poplar seedlings can be removed from the nursery and planted most successfully in March or early April just before the spring growth takes place. Spring planting has now largely superseded the earlier practice of fall planting. Trees which are planted in the fall are less able to withstand winter killing than if left rooted in the nursery. Planting too early in the spring must be avoided. Much of the failure in poplar planting is doubtless due to too long a period elapsing between the planting and the beginning of the new season's growth, permitting injuries to the fleshy root system to result in the decay of the roots and subsequent loss of the planting stock. If in spring planting it is found that the growth of the stock has started before the field work is accomplished, the top may be cut back to the last well-formed bud, and a new leader will develop. Yellow poplar has an advantage over conifer planting stock in that the terminal bud need not be preserved.

No special tool is needed for planting so long as the hole is made deep enough and broad enough for the root system. No preparation of the ground is needed except the clearing of vegetation immediately surrounding the place for the tree. Trees should be set erect and as deep in the ground as they were in the nursery. The roots should be straight and firmly packed with soil. Care should be exercised in handling the planting stock to prevent the drying out of the fine root hairs and small, fibrous roots, since these are easily injured by short periods of exposure to the sun and dry winds.

The correct spacing depends on the purposes of the planter. Close planting will cause side limbs to die and will result in trees free from knots; but unless an adequate system of subsequent thinnings is definitely planned, it will be safer to insure more rapid growth by giving plenty of room to each tree. As a general practice, it is not advisable to plant yellow poplar closer than 7 by 7 feet or wider than 10 by 10 feet. If the spacing is 7 by 7, it will take 890 trees to plant an acre; if 10 by 10, it will take 435 trees.

PURE VERSUS MIXED PLANTATIONS

Pure plantations of yellow poplar can very possibly be grown to maturity successfully. Observations this far made disclose an apparent tendency on the part of pure stands to stagnate after reaching pulpwood size, but this difficulty might well be obviated by making a pulpwood cutting by way of a first thinning operation. An auxiliary pulpwood crop may in many instances pay the cost of planting and management while the crop of saw timber is being grown. Ordinarily a mixed plantation is insurance against complete destruction by insects or other agencies which might kill or damage all trees of a single species; but, as has already been shown, yellow poplar seldom suffers serious damage from insects or disease, and there is no reason to anticipate serious trouble with a pure stand on this score. The dry leaves of yellow poplar deteriorate so rapidly that a pure stand of yellow poplar can rarely build up a heavy layer of leaf litter, but on the other hand this rapid deterioration of the leaves is largely responsible for one of the best porous, friable topsoils in the southern Appalachians.

Mixed plantations may, however, be deemed in general less risky at the present stage of observation of second-growth stands. If so, the question of a desirable mixture is not difficult to answer. The species which are commonly found with yellow poplar are species which do well in mixed plantations, and the choice will depend upon the purpose of the owner, and upon the soil and climatic qualities of the particular site. In the best southern mountain coves no species except chestnut has shown the ability to compete successfully with yellow poplar in natural seedling stands. On drier poplar sites, northern white pine, shortleaf pine, pitch pine, white oak, and black oak will succeed in maintaining a place in the upper crown cover.

Black locust is very commonly found with yellow poplar in second-growth stands. Because of its early rapid height growth, it competes very favorably up to 20 to 25 years, when the crown of the locust becomes thin and diameter growth falls off abruptly. At this stage in plantations of locust and poplar, the locust may be utilized for posts, poles, or whatever purpose it may serve, and the yellow poplar left to continue its growth. A suitable mixture in such a stand would consist of half to three-fourths locust, with the poplar spaced 14 feet apart.

While black walnut is also commonly found in mixture with yellow poplar in natural stands, these two species will probably not do well in mixed plantations for timber production only. The only purpose in mixing them would be to produce walnut saw timber with a subordinate crop of yellow poplar pulpwood. Both species require full

light and produce open stands, and the walnut must be given a start in growth for several years or the poplar will dominate it (*3*).

A striking example of an excellent mixed stand encouraged by wise management is found at the Cowan's Gap ranger station on the Buchanan State Forest, near McConnellsburg, Pa. In a Norway spruce and white pine plantation established in 1911–1914, various hardwood species including yellow poplar were seeded into the openings between the planted trees. In 1929 a cleaning of the competing hardwood growth left all good yellow poplar, with the result that there is now an excellent mixture of spruce, pine, and poplar. This mixed stand of conifers and hardwoods will undoubtedly become more valuable than the conifer stand alone, and growing conditions on the site will constantly improve.

If yellow poplar is grown in mixture with northern white pine, the slow early growth rate of the pine will give the poplar the advantage in height growth. On the best yellow poplar sites this advance growth will be too rapid and the pine will become permanently overtopped. The natural stand represented by Table 7 gives some indication of what might be expected from a plantation of this mixture, although this site was better suited to northern white pine than to poplar—a light sandy soil not well supplied with water.

TABLE 7.—*Number of northern white pine and yellow poplar trees per acre in a 19-year-old mixed seedling stand, Unicoi County, Tenn.*

Diameter breast high	White pine			Yellow poplar		
	Dominants	Intermediates	Suppressed trees	Dominants	Intermediates	Suppressed trees
1 inch			40			360
2 inches			910		270	570
3 inches		370	430	240	140	
4 inches	280	180	10	70		
5–7 inches	230			20		
Total	510	550	1,390	330	410	930

On the great majority of old fields, planting yellow poplar in mixture with shortleaf pine or pitch pine is of doubtful expediency. On the best soils the pine will be outshaded, and on the poorer soils the poplar will be overtopped by the pine.

Table 8 records the outcome of a natural mixture of yellow poplar with white ash, sugar maple, and black locust. Although of smaller diameter than the yellow poplar, the locust trees are the tallest in the stand, the larger ones being from 45 to 50 feet high. The poplar is 40 to 45 feet in height, the ash 30 to 45 feet, and the maple 25 to 40 feet. The ash, locust, and yellow poplar form the dominant crown class at the present time. The maple forms the lower story and will probably be joined later by ash. In this stand, the ash and maple show evidence of ability to endure shade and to continue to live as an understory to the stand. In a few years the locust can be removed, leaving a mixture of about one-third poplar and two-thirds ash as the dominant part of the stand.

TABLE 8.—*Number of yellow poplar and other species per acre in a 22-year-old mixed stand on an old field*

Diameter breast high	Yellow poplar	White ash	Locust	Sugar maple
2 inches	1	120	80	290
3 inches		40	50	40
4–5 inches		80	50	20
6–9 inches	40	60	40	10
Total	41	300	220	360

Spruce does not occur naturally as an understory to yellow poplar, but such mixtures might prove advantageous where most of the poplar is intended to be utilized as an early crop, since it would then be supplanted by the spruce underneath it. In this way successive pulpwood crops of poplar and spruce might be obtained while selected yellow poplars were permitted to grow to full development as a third crop of saw timber.

The fact that yellow poplar may be used for planting in many places, from the level of the coastal plains to an elevation of nearly 4,500 feet in the mountains, opens the way to the possibility of many more mixtures than those discussed. The determination of the proper mixtures is still a matter of experiment.

YIELDS FROM PLANTATIONS

Few yellow poplar plantations are old enough to give much indication of the yields which may be expected from planted stands, although the early growth rate seems to be comparable with that of natural stands on equivalent sites. Many studies are necessary before specific statements of growth rate can be safely made. On several plots measured for yield in a 19-year-old plantation near Pineville, Ky., the yield of trees 5 inches and more d.b.h. in the better parts equaled approximately a cord of felled wood per acre per year, or about 19 cords in 19 years. (Fig. 15.) The yields on all the plots measured were equal to or better than the yields from natural stands on equally good sites. More uniform spacing in plantations may well result in greater early yield in planted than in natural stands.

ROTATION AGE AS A FACTOR IN MANAGEMENT

The time for the final cutting of a stand of yellow poplar will be varied arbitrarily according to the utilization of the material grown or the financial demands made upon the property. Pulpwood may be cut from yellow poplar stands as young as 20 years on good sites, although to do so will be to lose advantage of the rapid growth that takes place on such sites for some time after this period. The greatest mean annual volume growth of pulpwood on average yellow poplar land will be obtained at about 50 years. If it is intended to produce saw timber, this point of maximum growth will probably be advanced to 70 years in stands which have not been thinned. Exact determination of this age must await extension of second-growth yield tables.

Another method of reckoning rotation age may be based upon the accumulation of carrying charges, which will represent the rotation of

greatest income and will generally be shorter than the rotation of greatest mean annual volume production. The rate of interest required by the owner, the amount of the initial investment, and the annual outlay for taxes and administration, are all factors which

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FIGURE 15.—A 10-year-old yellow poplar plantation near Pineville, Ky., yielding about 1 cord per acre per year

affect the financial return on any acre of forest land and, consequently, the policy of the owner.

With an interest rate of 5 per cent compounded annually, cordwood at $3 per cord, and annual expenses for taxes and administration at 25 cents per acre per year, the highest soil rental is obtained at about 25 years for unthinned stands on average poplar land, or possibly as

late as 30 years if it is considered that the increased size of the trees will somewhat reduce the cost of cutting per cord and yet increase the quality of the product. Reduction of the interest rate will extend the period further; and the removal of wood by early thinning, to save trees which would otherwise be lost, will increase the period of rotation to an age that will more nearly conform with that of the greatest mean annual growth in cubic feet.

For saw timber, with taxes and administration fixed at 25 cents per acre per year, interest at 5 per cent, and stumpage value at $8 per M feet b. m., the greatest soil rental will be obtained at 35 to 40 years. Rapid increase in quality and revenue obtained from thinnings may easily extend this period to 50 years. The most careful management of poplar stands will be required to extend the financial rotation, based upon the greatest soil rental, to the period of greatest mean annual board-foot increment, or 70 years. However, the earlier the cutting for saw timber the larger the percentage of sapwood in the lumber and the lower the price that it will bring. The increase in stumpage value due to increase in quality offers a considerable inducement to extend the saw-timber rotation to 70 years where possible.

RECOMMENDATIONS

Recommendations for the management of yellow poplar are concerned mainly with second-growth stands, since the area of old-growth forest containing yellow poplar is comparatively small. The retention of seed trees of this species, well placed, will materially increase the seedling regeneration of old-growth cuttings and should be practiced wherever such trees can be salvaged later, or where it does not represent too large an investment in the new crop. The only other feasible practice is heavy cutting of old-growth forest to give whatever yellow poplar seeds may be blown in or may be already present sufficient light and room for germination and vigorous seedling growth. This will result in scattered yellow poplar trees in the new stand.

Second-growth forests containing yellow poplar will prove most profitable if so managed as to increase the proportion of the species on sites with good, moist soil. Yellow poplar trees under 30 years of age in such stands may be expected to reproduce by sprouts with reasonable success, but this will not result in an increased representation of yellow poplar or in improvement in the growing stock.

A high percentage of yellow poplar in the stand can be obtained through natural seeding by several successive steps. Yellow poplar seed trees must be allowed to reach effective seed-bearing age (generally 35 to 40 years) before the stand is cut and enough of these should be retained (probably five per acre in most cuttings) to assure ample reproduction. Cutting must be heavy, permitting good germination and rapid early development of seedlings. If the less valuable species interfere with the growth of yellow poplar seedlings by overtopping and shading them, a release cutting will be necessary, and this should not be delayed until the poplar trees have lost their vigorous growth rate.

The time and character of each of these operations will be determined by the cost and by the willingness of the owner to make an investment in labor with the expectation of a future return.

Abandoned fields suited to yellow poplar, which for lack of seed trees are not being reseeded naturally, can often be profitably planted to this species, thus preventing occupation of these sites by inferior species and providing sources of yellow poplar seed for subsequent natural regeneration. Sites should be moist and well drained, with good depth of soil. Openings on cut-over forest land where no poplar seed trees are available should also be planted for similar reasons. Severely eroded and other drier areas in old fields, even though originally occupied by the species, should not be planted with poplar but with pines or other species suited to dry sites.

FINANCIAL RETURNS

The computation of financial returns from the production of yellow poplar involves many speculative elements. Profit or loss depends largely upon such conditions as accessibility to market, initial investment, interest rate, taxes, and lumber and pulpwood values. Anything resembling a close estimate is impossible.

STUMPAGE VALUES AND LUMBER AND PULPWOOD PRICES

During a period of approximately 30 years, production of yellow poplar lumber has decreased from what was perhaps its high point, in 1899, of 1,115,000,000 board feet annually to a trifle less than 436,000,000 board feet in 1929. It is evident, however, from Figure 16, which gives the trend of lumber production and lumber prices for this period, that 320,000,000 board feet would fairly represent the average for the past 15 years. To what degree the sharp decline for 1930 represents any permanent trend is of course problematical.

Each year during this period an increasing proportion of second-growth yellow poplar has come on the market, partly because of the dwindling supply of old growth. This means that during this time the percentage of lower grades of lumber, especially of the sap grade, has been increased, but, in spite of this (Table 3, p. 13), the average price of all grades of yellow poplar at the mill has increased from about $14 in 1899 to more than $41.50 in 1929. This figure of approximately $41.50 is virtually a return to the price of 1919 and appears from Figure 16 to represent a fairly average price for the last 10 or 11 years.

No general logging and milling costs can be applied throughout the field of production, since so many variable factors influence these costs. However, using the average 1929 mill-run price (approximately $41.50) as a basis and assuming logging and milling costs of $20 per thousand as well as a profit of 20 per cent on the sale price, the stumpage value per thousand board feet would work out at $13.20, which compares very well with the average stumpage price given in Table 9 for the year 1929. This price of $12.14 in Table 9 is of course weighted by the much lower prices paid for the smaller material cut for pulpwood. It is probable that costs of $20 per thousand represent a reasonable average. Most tracts include a mixture of species, a fact which obscures both the logging costs and stumpage price for yellow poplar. But if yellow poplar were cut alone, the cost of logging would be excessively high, since the trees are usually rather widely scattered.

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TABLE 9.—*Average stumpage and log prices and price range of yellow poplar, all States, 1928–1930*

Product and year	Average price	Price range	Product and year	Average price	Price range
Stumpage:			Logs:		
1928	$6.83	$2.00–$35.00	1928	$27.64	$11.00–$61.50
1929	12.14	2.00– 40.00	1929	35.09	13.75– 80.00
1930	8.79	1.00– 30.00	1930	28.70	6.00–[1] 278.08

[1] Influenced by the inclusion of a quantity of high-grade veneer logs. (Fig. 17.)

Second-growth yellow poplar will produce a high percentage of sap-grade lumber but will be very free from other defects. If well manufactured and protected from sap stain until seasoned, the clear sap lumber will command a price comparable with the mill run of the

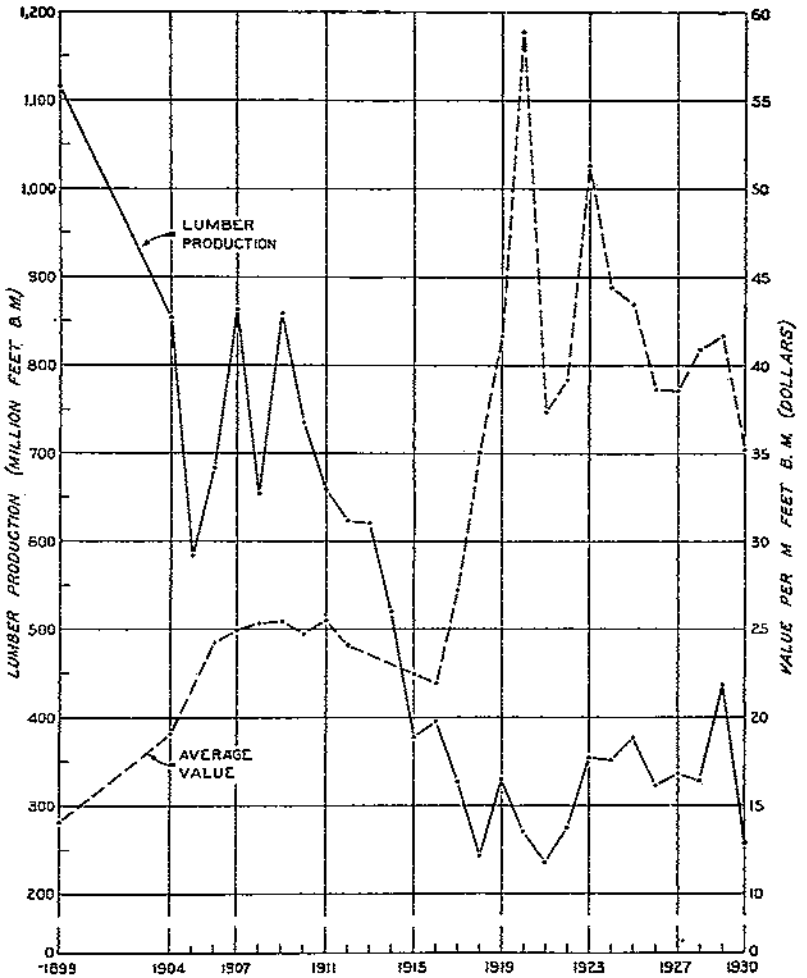

FIGURE 16.—Yellow poplar lumber production and average value per 1,000 feet board measure, f. o. b. mill, recorded years, 1899 and 1904–1930

present forest-grown poplar. New York quotations of wholesale prices for the sap grade of poplar have averaged for the past 25 years about double the average mill-run price for all grades of yellow poplar at the point of production. This should allow ample margin for freight, selling costs, and profit, and still leave a price comparable with the value of mill run for all grades. The logical assumption is that the usually accepted stumpage prices for poplar are much below its actual value and that stumpage values of $10 or $12 could now be justified for large-size second growth of average accessibility and distance from market.

An important consideration in any estimate of the profitable production of yellow poplar lumber is the possibility of loss in logging

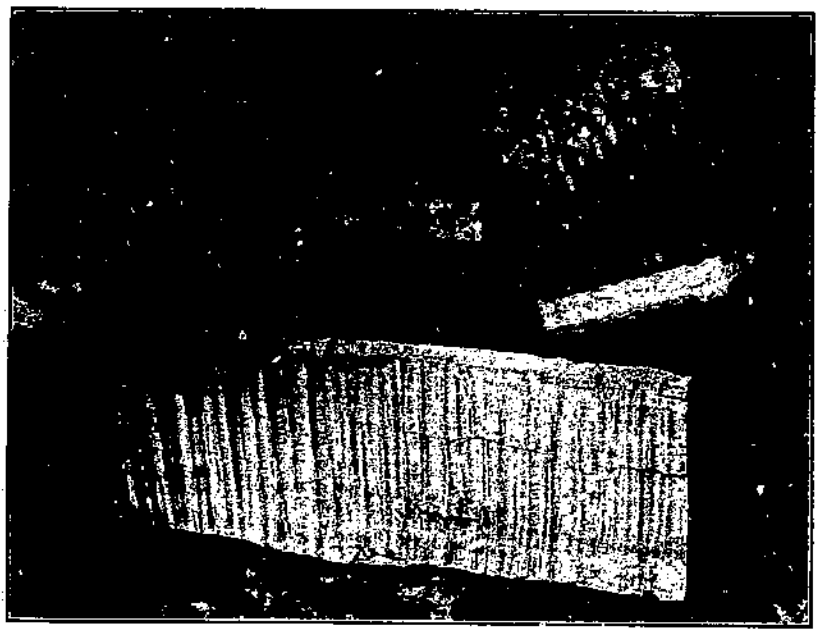

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FIGURE 17.—Samples from a curly yellow poplar veneer log; the wedge-shaped piece shows a tangential section; the others, radial sections. Grown in Union County, Ga.

small trees. The cost of logging and milling small logs may even exceed the value of the lumber produced from them. The diameter of a yellow poplar tree which can be logged and sawed at a profit will vary with changes in lumber prices, accessibility, and other factors of logging and milling costs. Ashe (*2*) has given examples illustrating the conditions which determine the size limit down to which yellow poplar and other trees can be cut profitably.

Cutting yellow poplar for pulpwood, which has in a number of cases been disastrous to the further production of yellow poplar on the areas so cut, has perhaps already reached its peak and is on the decline. Such would appear to be the evidence furnished by Figure 18. Although the production curve in Figure 18 is based on consumption figures in Table 4, for a species like yellow poplar that has

never been forced on the market these values are probably quite accurately representative of the actual cut of pulpwood.

The high prices paid in 1920 and 1921, which doubtless had a great deal to do with the considerable increase in the production of yellow poplar pulpwood from 1921 on, no longer rule, and the indication appears to be that the very considerable falling off in prices since 1927 has had its effect in bringing yellow poplar production back to the intermediate stage of 1922 and 1923. It may be expected that pulpwood prices will rise with the rise in other values, but it is doubtful that production will soon reach the height of 1924 to 1929. As has

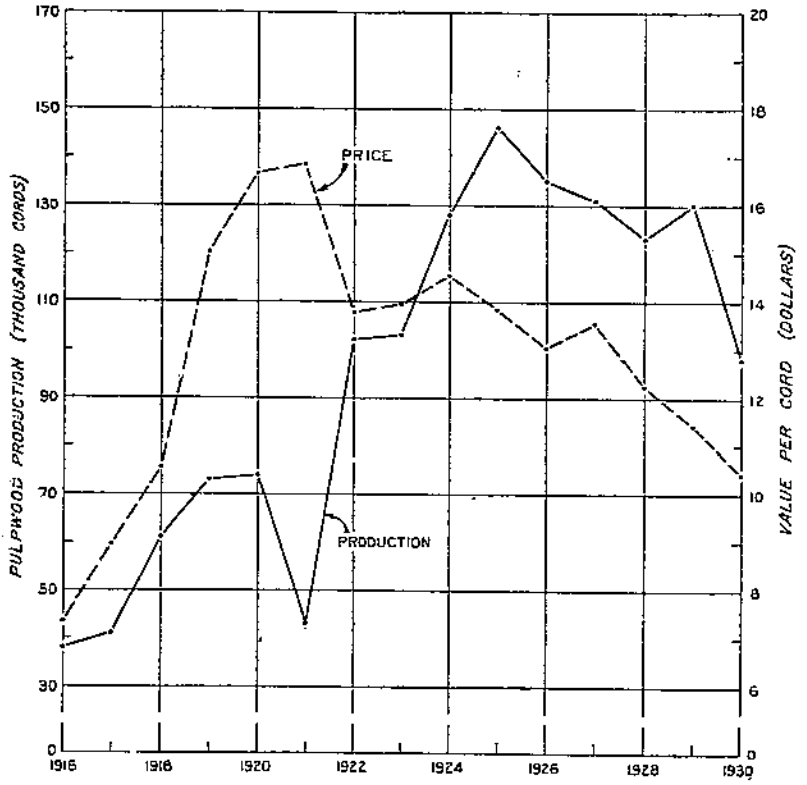

FIGURE 18.—Yellow poplar pulpwood production and average price f. o. b. mill, per cord, 1916–1930

been already intimated, it is to be hoped that the young stands of yellow poplar remaining and those that will later come to pulpwood size may be spared to realize the vigorous growth of which they are capable. The price of $10.40 a cord for poplar pulpwood corresponds to a lumber value of hardly more than $21 per thousand board feet, which, considering that logging costs are probably as high for pulpwood as for lumber logs, if not higher, constitutes a very much lower return per acre for pulpwood than for saw timber.

The method of computing actual returns from saw-log production of yellow poplar may be illustrated by the following example.

In this instance, the cost of production has been considered as the cost of the land with the annual charge for administration and taxes,

all computed with compound interest at 4 per cent to the end of the rotation. Natural reproduction is assumed, and no cost for planting is considered. If such a cost were involved, it would be treated as an initial investment and be carried with interest to the end of the rotation. A charge of 10 cents per acre per year is fixed for administration and protection without taking into account variations in quality of the land. Annual taxes are fixed at 1 per cent of the full value of the land, this amount to be paid on land alone. In addition, 10 per cent of the gross revenue is deducted as a yield or severance tax on the timber at the end of the rotation.

Stumpage is fixed at $8 per thousand board feet as a reasonable price for all grades without regard for the obvious fact that the larger timber at 50 years will cut a much higher grade of lumber than can be cut from the smaller trees. The land is valued at $12 per acre with interest for the full period but with the value of the land deducted at the end of the rotation. This is computed for 50 years as follows:

$$\$12\ (1.04^{50}-1)=\$73.28$$

Taxes and administration at 22 cents per acre per year amount to—

$$\$0.22\ \frac{(1.04^{50}-1)}{.04}=\$33.59$$

The yield of 40,200 board feet per acre (International rule) for site index 110 (Table 17), valued at $7.20 per thousand board feet after deduction of 10 per cent yield tax, gives a net yield of $289.44 or, after deducting the cost of production, a net profit of $182.57 per acre.

Table 10 shows the profit which may be expected on good, medium, and poor sites with land alone valued at $12, $8, and $4, according to its productivity, compared as in the preceding example.

TABLE 10.—*Net profit or loss per acre to be expected from crops of yellow poplar on three qualities of site at different ages*

Age	Good site [1]	Medium site [2]	Poor site [3]	Age	Good site [1]	Medium site [2]	Poor site [3]
10	−$6.90			35	$101.44	$52.81	$10.31
15	−2.50	−$5.33	−$3.13	40	130.40	69.85	20.32
20	10.46	−.49	−4.25	45	158.28	85.65	28.49
25	44.29	15.89	−2.41	50	182.57	99.35	36.28
30	73.06	34.67	2.26				

[1] Site index 110, valued at $12 an acre.
[2] Site index 90, valued at $8 an acre.
[3] Site index 70, valued at $4 an acre.

The negative values given for young stands indicate a loss at these ages. Assuming land values of $6, $4, and $2 per acre for good, medium, and poor qualities of land, with other conditions as stated in the example given, net profits of $228.37, $129.88, and $51.55, respectively, can be obtained in 50 years. Assuming land values of $18, $12, and $6 per acre, net profits of $136.77, $68.81, and $21.01 can be obtained in the same period. These estimates illustrate the effect of varying the initial investment.

The influence of high interest rate is shown by contrasting the effect of 4 per cent and 5 per cent compound interest on these profits. With interest computed at 4 per cent, compounded annually, the profit per acre on a good site has been shown to be $182.57; with the interest rate at 5 per cent compounded annually, this profit is reduced to $117.77.

SUMMARY

Yellow poplar has many good characteristics—the fine quality of its wood, good form, rapid growth, freedom from serious injury by disease and insects, and wide though scattered distribution—which combine to make it one of the most valuable of hardwood trees. Since this species is especially well adapted to the better forest soils in the region of its growth, it should be encouraged on such sites.

Natural regeneration by seed and sprouts will constitute the chief sources of new growth on areas now occupied by yellow poplar. Success in obtaining natural regeneration of yellow poplar can be better assured by giving attention to the following considerations based on natural characteristics of the species:

Seed trees must be of seed-bearing age and so located as to be effective.

Good seed crops may be expected annually and extra heavy crops at irregular intervals.

Seed will average 12 to 15 per cent viability.

Seed will blow to a distance of four to five times the height at the source.

Seed will germinate only if it has an ample and constant moisture supply and is free from the heavy cover of litter normally found in hardwood forests.

Early germination and vigorous growth in the first season are needed to assure a good percentage of survival of seedlings. Excessive competition of other vegetation or dryness of the site will prevent such growth.

Frost heaving, smothering by leaf litter, and shading are important causes of loss of natural seedlings in ungrazed areas; this loss is very heavy among underdeveloped seedlings less than a year old.

Yellow poplar seedlings that have competed successfully for leadership over other growth of equal age will, after the first four or five years, have entered upon a vigorous height growth which will enable them to retain their place in the upper crown level.

Yellow poplar will sprout vigorously only from young and vigorous root systems but sprout growth once started will maintain or recover leadership over all other tree and shrub growth of the same age.

The best natural seedling regeneration has occurred in abandoned fields where the competition of hardwood sprouts was negligible, the climate and soil-moisture conditions were favorable, and seed trees of yellow poplar were standing adjacent.

Plantations of yellow poplar on well-chosen sites have made a growth equal to that of stands seeded naturally on similar areas. Also, planting stock can be produced at a low cost, wide spacing in field planting is possible, and establishment is therefore cheap. Difficulties in the production of planting stock and failures in field planting largely disappear with a better understanding of the limitations of the species.

Clear cutting of old-growth stands containing some yellow poplar has resulted in certain instances in good second growth of this species. The lack of sprouting capacity of stumps of old trees and the suppressed condition of advance growth of other species in the old stand made this possible.

The heavy cutting practiced during the last two decades in the extensive ungrazed forests of the Appalachian Mountains and Plateau

has resulted in increased establishment of yellow poplar segs.edlin The survival of these seedlings depends chiefly on the age and sprouting vigor of the stand when cut. In more vigorous young stands many of the yellow poplar seedlings will be overtopped and distorted by sprouts of less valuable trees, and on good sites the release of the poplar by cutting or other measures is desirable.

Vigorous, well-stocked stands of other young hardwoods can not be economically replaced with yellow poplar, but stands which contain this species should be managed to promote its growth and later regeneration.

Clear cutting of young yellow poplar for pulpwood threatens the future production of this species through elimination of seed trees. This practice results in small profit to the owner and should be abandoned in favor of a practice which will produce some trees of sawtimber size that will be effective for seeding.

Success in the production of yellow poplar on land suited to its growth requires protection from fire and grazing. One fire may destroy all chance of profit from the fire-damaged stand; protection from grazing stock is imperative during the reproduction stage.

Methods of management of stands containing yellow poplar will vary because of differences in composition, accessibility, invested value, and requirements of the owner. Any of these factors may affect the length of periods between cuttings and the amount of care which can be given the stand throughout its life. The best results will be obtained where close supervision and intensive improvement of stands are possible.

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APPENDIX

VOLUME AND YIELD TABLES

TABLE 11.—*Yellow poplar volume table*[1] *for trees over 100 years old (Scribner Decimal C rule), southern Appalachians*

Diameter breast high (inches)	Volume in board feet, in tens, when height of tree is—								Diameter inside of bark of top	Basis
	70 feet	80 feet	90 feet	100 feet	110 feet	120 feet	130 feet	140 feet		
									Inches	*Trees*
10	6	7							6	1
11	7	9							7	1
12	9	11	14						7	4
13	11	14	17						8	3
14	13	17	20	22					8	3
15	16	20	23	26					8	4
16	19	23	27	30	31				8	8
17	22	27	31	34	37				9	16
18	25	31	36	39	43	47			9	16
19	29	35	41	45	50	54			9	18
20	33	39	46	52	58	63	68		10	20
21		44	52	59	66	72	77		10	20
22		49	58	67	74	81	86	91	10	27
23		54	64	75	83	91	96	101	11	27
24		60	71	84	91	101	106	112	11	22
25		66	78	93	102	111	117	123	12	32
26		73	86	102	112	122	129	136	12	29
27		80	94	111	123	133	141	148	12	21
28		87	103	121	134	145	154	162	13	21
29		95	113	132	145	158	168	176	13	19
30		104	124	144	158	171	181	190	14	22
31		113	135	155	171	185	195	205	14	14
32		123	146	168	184	199	210	220	14	13
33		133	158	181	198	214	225	235	15	14
34			171	194	213	228	239	250	15	10
35			183	207	226	243	254	265	16	5
36			196	220	240	257	269	281	16	3
37			209	233	254	272	285	297	16	
38			222	246	268	286	301	314	17	5
39			235	260	281	300	317	331	17	7
40			248	273	295	314	334	348	17	2
Total										407

[1] This table was made from taper curves by scaling the merchantable length in log lengths to the top diameters shown. Logs were 16.3 feet long whenever possible, with some 14.3 feet, 12.3 feet, and 10.3 feet logs to avoid waste. The assumed stump height was 2 feet. Top diameter inside bark. U. S. Forest-Service Region 7, 1915.

TABLE 12.—*Yellow poplar volume table* [1] *for trees more than 100 years old (Scribner Decimal C rule), southern Appalachians*

Diameter breast high (inches)	Volume in board feet, in tens, when the number of 16-foot logs in tree is—						Diameter inside of bark of top	Basis
	1	2	3	4	5	6		
							Inches	*Trees*
10	2	5	8				6	1
11	3	6	10				7	1
12	3	7	12	18			7	4
13	3	8	15	21			8	3
14	3	9	17	24			8	3
15	3	10	19	27			8	4
16	3	12	22	31			8	8
17	4	13	24	35	42		9	16
18	4	15	27	39	47		9	18
19	5	16	30	44	54		9	18
20	5	18	33	48	61	75	10	20
21		20	36	54	69	84	10	20
22		22	39	59	76	93	10	27
23		25	42	65	85	103	11	27
24		27	46	72	94	113	11	22
25		30	50	79	103	123	12	32
26		32	54	86	112	135	12	29
27		35	58	94	122	147	12	21
28		38	63	102	133	159	13	21
29		40	68	110	144	172	13	19
30		43	74	118	156	185	14	22
31			79	127	168	199	14	14
32			85	136	181	214	14	13
33			91	146	193	228	15	14
34			98	156	206	244	15	10
35			104	167	219	259	16	5
36			112	178	232	275	16	3
37			119	191	245	291	16	
38			126	204	258	307	17	5
39			133	216	271	322	17	7
40			140	230	284	338	17	2
Total								407

[1] This table is based on taper curves. Height of stump, 2 feet. Top diameters measured inside bark.

TABLE 13.—*Volume table* [1] *in cubic feet (total volume) for second-growth yellow poplar, Pike County, Ohio, and Fairfax County, Va.*

Diameter breast high outside bark (inches)	Volume in cubic feet when height of tree is—						Basis
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
							Trees
5	2.2	2.8					8
6	3.5	4.2					10
7	4.9	5.8	6.8				50
8	6.3	7.5	8.8	10.1			62
9	8.0	9.5	11.2	12.8			66
10	9.7	11.8	13.7	15.8	17.8		55
11	11.5	14.2	16.7	19.2	21.7		75
12	13.5	16.6	19.7	22.8	25.9	29.0	49
13		19.4	22.9	26.6	30.2	33.8	51
14		22.2	26.4	30.7	34.9	39.2	27
15		25.0	29.9	34.8	39.7	44.7	16
16			33.9	39.4	45.0	50.5	20
17			37.8	44.1	50.4	56.7	12
18			41.8	49.0	56.1	63.3	5
19				54.3	62.0	69.8	5
20				59.6	68.0	76.4	
21					74.5	83.9	
22					81.3	91.2	1
Total							512

[1] From taper tables computed by the form quotient method. Volume includes total stem without bark.

TABLE 14.—*Cubic-foot volume table*[1] *(merchantable volume) for second-growth yellow poplar Pike County, Ohio, and Fairfax County, Va.*

Diameter breast high outside bark (inches)	Volume in cubic feet when height of tree is—						Basis
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
							Trees
5	1.8	2.2					8
6	3.0	3.7					10
7	4.2	5.2	6.2				50
8	5.6	6.9	8.1	9.4			62
9	7.2	8.8	10.5	12.0			66
10	8.9	10.9	13.0	15.0	17.0		55
11	10.6	13.1	15.6	18.1	20.6		75
12	12.4	15.5	18.5	21.6	24.7	27.7	49
13		18.0	21.6	25.2	28.8	32.5	51
14		20.7	24.9	29.1	33.3	37.5	27
15		23.6	28.4	33.2	38.0	42.8	16
16			31.8	37.4	42.9	48.5	20
17			35.5	41.8	48.1	54.5	12
18			39.5	46.5	53.6	60.7	5
19				51.5	59.2	66.9	5
20				56.7	65.6	73.5	
21					71.6	80.2	
22					78.1	87.7	1
Total							512

[1] From taper tables computed by form quotient method. Stump height, 1 foot; diameter inside bark of top, 3 inches. Volume includes bark.

TABLE 15.—*Board-foot volume table*[1] *for second-growth yellow poplar (Scribner rule), Pike County, Ohio, and Fairfax County, Va.*

Diameter breast high outside bark (inches)	Volume in board feet when height of tree is—						Basis
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
							Trees
8	15	20	27				62
9	22	30	38	45			66
10	30	40	51	61	71		55
11	37	51	65	78	91		75
12	46	62	80	96	112	129	49
13	58	74	95	115	135	155	51
14		86	112	136	160	184	27
15		100	129	157	187	217	16
16			147	180	216	251	20
17			165	205	246	287	12
18			184	231	278	325	5
19				259	312	367	5
20				289	348	400	
21					386	453	
22					427	501	1
Total							444

[1] Volume scaled by Scribner rule from taper diagrams. Stump 1 foot high and top 6 inches in diameter inside bark.

TABLE 16.—*Board-foot volume table* [1] *for second-growth yellow poplar (International rule), Pike County, Ohio, and Fairfax County, Va.*

Diameter breast high outside bark (inches)	Volume in board feet when height of tree is—						Basis
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
							Trees
8	16	21	26				62
9	20	34	43	53			60
10	30	48	62	75	88		55
11	40	64	81	99	117		75
12	56	79	102	124	146	168	49
13		96	123	149	176	203	51
14		113	145	177	209	241	27
15		129	167	205	242	280	16
16			189	233	278	323	20
17			212	264	315	367	12
18			236	294	354	412	5
19				327	394	462	5
20				363	437	510	
21					481	563	
22					529	617	1
Total							444

[1] Volume scaled by International rule (¼-inch kerf) from taper diagrams. Stump 1 foot high and top 6 inches in diameter inside bark.

TABLE 17.—*Normal yield table for second-growth yellow poplar*

DOMINANT STAND

Age (years)	Total height in feet on site index [1]—						
	60	70	80	90	100	110	120
10		28	32	36	40	44	48
15		39	45	51	57	62	68
20		47	54	61	68	75	81
25		53	61	69	76	84	91
30		58	66	75	83	91	99
35		62	71	80	88	97	106
40		65	74	84	93	102	111
45		68	77	87	97	106	116
50		70	80	90	100	110	120

TOTAL STAND 5 INCHES D. B. H. AND MORE

Age (years)	Number of trees per acre						
10			18	66	92	116	135
15	58	130	173	200	228	238	246
20	150	206	235	252	264	266	264
25	206	246	264	268	269	264	256
30	218	264	268	260	252	244	234
35	258	268	260	246	236	224	212
40	265	264	246	230	218	204	190
45	266	253	230	212	198	184	168
50	264	240	214	194	176	164	148

Age (years)	Diameter breast high in inches						
10					5.1	5.2	5.3
15		5.3	5.5	5.8	6.0	6.2	6.4
20	5.4	5.9	6.3	6.6	6.9	7.2	7.5
25	5.9	6.4	6.9	7.4	7.8	8.2	8.6
30	6.3	7.0	7.6	8.3	8.8	9.3	9.8
35	6.7	7.6	8.4	9.2	9.9	10.5	11.1
40	7.2	8.2	9.3	10.1	10.9	11.8	12.4
45	7.7	8.9	10.1	11.1	12.0	12.9	13.6
50	8.2	9.7	11.0	12.2	13.2	14.1	14.9

[1] The 50-year values are site indices.

TABLE 17.—*Normal yield table for second-growth yellow poplar*—Continued

TOTAL STAND 5 INCHES D. B. H. AND MORE—Continued.

Age (years)	Basal area in square feet per acre [2]						
	60	70	80	90	100	110	120
10			2	8	13	17	21
15	8	20	30	38	45	50	56
20	24	39	50	60	68	75	81
25	38	56	69	80	89	97	103
30	51	70	85	97	107	116	123
35	64	84	100	113	125	134	142
40	75	97	114	128	140	150	159
45	86	109	128	143	156	167	176
50	97	122	141	157	172	183	193

Age (years)	Merchantable peeled volume in cubic feet per acre [3]						
10				50	135	250	360
15	80	250	415	600	800	1,000	1,180
20	320	600	880	1,180	1,475	1,765	2,040
25	570	955	1,340	1,745	2,145	2,550	2,900
30	825	1,305	1,800	2,300	2,800	3,320	3,770
35	1,080	1,660	2,250	2,845	3,450	4,070	4,600
40	1,335	2,010	2,690	3,380	4,085	4,800	5,410
45	1,590	2,360	3,130	3,935	4,710	5,510	6,200
50	1,840	2,705	3,570	4,480	5,330	6,220	6,970

TOTAL STAND 8 INCHES D. B. H. AND MORE

Age (years)	Yield in board feet per acre, Scribner rule [4]						
10				50	150	220	360
15	50	100	210	460	870	1,390	1,960
20	190	480	1,030	1,850	2,920	4,220	5,800
25	450	1,180	2,370	4,120	6,150	8,450	10,810
30	930	2,300	4,430	7,110	9,900	12,820	15,810
35	1,540	3,790	6,800	10,200	13,700	17,310	21,050
40	2,370	5,560	9,270	13,300	17,500	21,890	26,500
45	3,380	7,410	11,850	16,600	21,400	26,460	31,560
50	4,580	9,270	14,410	19,800	25,300	30,000	36,600

Age (years)	Yield in board feet per acre, International rule (¼-inch kerf) [4]						
10						200	400
15	200	400	530	650	1,050	1,000	2,400
20	350	650	1,200	2,000	3,400	5,180	7,000
25	600	1,400	2,700	5,100	7,600	10,200	13,100
30	1,000	2,650	5,500	8,710	12,150	15,600	19,250
35	1,700	4,500	8,300	12,450	16,800	21,250	25,900
40	2,950	6,780	11,230	16,300	21,700	27,300	33,150
45	4,000	9,000	14,380	20,300	26,880	33,750	40,700
50	5,600	11,400	17,620	24,400	32,150	40,200	48,450

[2] Basal area is the cross-sectional area inside bark measured at breast height.
[3] Peeled volume of the merchantable stem, excluding 1-foot stump and top less than 3 inches inside bark. All trees 5 inches and over in diameter outside bark breast high are included.
[4] Stump height, 1 foot; top diameter inside bark, 6 inches.

BOTANICAL NAMES OF TREES MENTIONED

Common name	Botanical name
Ash, white	*Fraxinus americana* Linn.
Basswood	*Tilia glabra* Vent.
Beech	*Fagus grandifolia* Ehrh.
Birch, sweet	*Betula lenta* Linn.
Birch, yellow	*Betula lutea* Michx.
Buckeye (sp.)	*Aesculus* spp., Linn.
Butternut	*Juglans cinerea* Linn.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, pin	*Prunus pennsylvanica* Linn. f.
Chestnut	*Castanea dentata* (Marsh.) Borkh.
Dogwood	*Cornus florida* Linn.
Elm, American	*Ulmus americana* Linn.
Elm, slippery	*Ulmus fulva*, Michx.
Gum, black	*Nyssa sylvatica* Marsh.
Gum, red	*Liquidambar styraciflua* Linn.
Hemlock, eastern	*Tsuga canadensis* (Linn.) Carr.
Hickory (sp.)	*Hicoria* spp., Raf.
Hophornbeam	*Ostrya virginiana* (Mill.) Koch.
Locust, black	*Robinia pseudoacacia* Linn.
Magnolia, cucumber	*Magnolia acuminata* Linn.
Magnolia, mountain	*Magnolia pyramidata* Pursh.
Maple, red	*Acer rubrum* Linn.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus montana* Willd.
Oak, post	*Quercus stellata* Wang.
Oak, red	*Quercus borealis maxima* (Marsh.) Ashe.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, white	*Quercus alba* Linn.
Persimmon	*Diospyros virginiana* Linn.
Pine, northern white	*Pinus strobus* Linn.
Pine, pitch	*Pinus rigida* Mill.
Pine, shortleaf	*Pinus echinata* Mill.
Pine, Virginia	*Pinus virginiana* Mill.
Redbud	*Cercis canadensis* Linn.
Sassafras	*Sassafras variifolium* (Salisb.) Ktze.
Silverbell	*Halesia carolina* Linn.
Sourwood	*Oxydendrum arboreum* (Linn.) DC.
Sumach, staghorn	*Rhus hirta* (Linn.) Sudw.
Walnut, black	*Juglans nigra* Linn.

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