Growth of

Yellow-Poplar

and Associated Species in West Virginia

. . . as a Guide to Selective Cutting

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by

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INTRODUCTION

YELLOW-POPLAR (Liriodendron tulipifera L.) has long been recognized as a valuable species. Lumbermen prize the long, straight, clear boles. Foresters like its silvicultural attributes. They also regard well the other species that are associated with it: ash, basswood, birch, maple, and cherry.

Yellow-poplar occurs on some of the most accessible forest areas in West Virginia. Since the stands are usually located on the better sites, their growth rates are high.

These stands, because of their favorable location, rapid growth, and desirable species composition, will no doubt be among the first put under planned forest management in the State. Some of them are stocked well enough now that

improvement cuttings will pay for themselves. Already, particularly in the southern counties of the State, the initial steps in forest management and improved cutting practices are being taken by timberland owners.

The Stands

Yellow-poplar is the dominant species in two forest types: the cove hardwoods type and the second-growth yellow-poplar type. These two forest types occupy approximately one-fifth of the commercial forest area of West Virginia. They contain 20 percent of the saw-timber volume in the State; and one-third of this volume is yellow-poplar.

The cove hardwoods type is found on the well-drained, comparatively deep soils in the coves and on the moist north slopes of the Appalachian Mountains. The type is characterized by a mixture of many species: yellow-poplar, ash, basswood, birch, buckeye, cucumbertree, maple, red oak, and a host of other species in smaller numbers.

The present species distribution of this forest type is explained by the history of the sites. In past logging operations, the less valuable species were left behind. Fire usually followed the logging. In the mineral soil uncovered by logging or exposed by fire, the light-loving species came in. As a result yellow-poplar, which responds favorably to logged-over conditions, now dominates the sites.

The second-growth yellow-poplar type, on the other hand, is characterized by almost pure stands of even-aged yellow-poplar. The associated species are usually sassafras, black cherry, or black locust, with a scattering of trees of the original forest type. These yellow-poplar stands may be found on abandoned crop or pasture land or on almost any kind of forest land that favors the germination of yellow-poplar seed. While the majority of these stands are found on north and east slopes, they may also be found on sites that once supported oaks or northern hardwoods.

The largest area of cove hardwoods and second-growth yellow-poplar in the State is in the area generally south of the Kanawha River. In this Cumberland Plateau country about 30 percent of the land area and saw-timber volume is in

these forest types. Most of the other stands of cove hardwoods and second-growth yellow-poplar are in the Allegheny Plateau country.

The Forestry Problem

If his forest land is not too badly run down through past abuse, the forest-land owner who is interested in practicing better forestry may already have enough growing stock to begin his forestry work immediately with some form of partial cutting. Best results from partial cutting are obtained when each tree to be cut is selected on its own particular merits.

In deciding whether a tree should be cut now or left to grow some more, the forester usually considers three things: the tree's growth rate, its ability to respond to release, and the size and quality of its bole.

Size can be measured; and quality of the bole can be easily judged from its soundness, straightness, and freedom from limbs and large knots. Ability to respond to release can be judged from species, age, and degree of suppression. But determining growth rate is not so easy.

Past growth can be measured by using an increment borer and studying growth from the annual-ring pattern. But this is slow and cumbersome. A need was felt for some method by which growth rate can be judged easily from external evidence.

To fill this need, a method was developed. It is based on the hypothesis that, in yellow-poplar, vigor classes are a reliable guide to growth rate.

DEVELOPING THE METHOD

COLLECTION OF DATA

Stands of cove hardwoods and second-growth yellow-poplar were sampled by measuring more than 1,800 trees; about half of them were yellow-poplar. These trees were in

stands scattered throughout the State. The 121 areas sampled were located by means of the forest-survey type map for West Virginia.

Since the primary interest was in individual trees, information was needed on species, diameter breast high (d.b.h.), vigor class, and radial growth. To translate radial growth to volume growth, data were also needed on merchantable height, Girard form class, and quality class. Type, site, topographic position, and aspect of each sample area were also recorded.

Diameter, radial growth, merchantable height, and form class were measured. The other data were estimated.

Vigor Class

Since vigor class is the basis of the method developed for estimating growth rate, proper identification of vigor class is essential. In developing definitions of vigor classes for yellow-poplar, first consideration was given to crown size in relation to the diameter and height of the tree. Almost as important was crown position in relation to its neighbors: dominant, co-dominant, intermediate, or overtopped. Other factors considered were crown density, color of foliage, appearance of twigs, and occurrence of dead, broken, and dying limbs. The four vigor classes used were defined as follows:

Vigor 1 A tree in this vigor class has a large crown in a dominant or co-dominant position. At least half the crown is exposed to direct sunlight. The crown is typically dense, with no evidence of disease or mechanical injury. The bark and twigs have good color.

Vigor 2 A tree in this vigor class has a fair-sized crown in a co-dominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and not quite so perfect as that of a Vigor 1 tree. This class may also include a large-crowned or dominant tree that otherwise fails to meet the requirements for Vigor 1.

Vigor 3 A tree in this vigor class has a medium to small crown of intermediate position. Only the tip is exposed to direct sunlight. The crown may be open, with some dead or broken limbs. This class also includes trees of

fair to large crowns or in a co-dominant position, but that cannot meet requirements for Vigor 1 and Vigor 2. It may also include overtopped trees of a tolerant species that have dense crowns of good color.

Vigor 4 A tree in this class usually has a small crown in an overtopped position. This class includes all living trees that fail to meet the requirements of the higher vigor classes.

In the study, the vigor class of each sample tree was estimated and recorded before the increment boring was made.

Radial Growth

Radial growth was the chief dependent variable. It was converted to diameter growth (by doubling), which in turn was translated into estimated volume growth.

The trend of growth from one period to another was also considered important; so each tree was bored deep enough to sample the last 20 years' growth--if present. Radial growth for each of the last two decades was measured to the nearest 0.05 inch. This was doubled to get diameter growth, which was recorded to the nearest 0.1 inch.

Other Data

Merchantable height was measured with an Abney level in accordance with the Mesavage-Girard definitions of merchantable height.

Girard form class is 100 times the ratio of diameter inside bark at top of the first 16-foot log to diameter breast high. Diameter outside bark was measured at the 17.3-foot height, double bark thickness was deducted, and form class was computed for each tree.

Quality classes used in the study were derived from the U. S. Forest Products Laboratory hardwood log grades.

ANALYSIS OF DATA

In analyzing these data, diameter growth inside bark during the last 10 years was used as the dependent variable. This could be correlated directly with present d.b.h. or with growth during the previous decade. These data were then converted in turn to d.b.h. growth, volume growth, and increment in value.

Each step introduces new sources of error; so in using the derived averages, the forest owner should appreciate that they are subject to greater error.

Diameter Growth: Inside Bark

In this study, the growth measured from increment cores included only the growth of the wood. These growth data were used to identify the important influencing factors.

Average growth in diameter inside bark for the last 10 years was calculated by species and vigor class (Appendix I). Excepting yellow-poplar, no single species was represented well enough to permit detailed analysis. To overcome this, all other species were grouped. Thus two groups were considered: (1) yellow-poplar and (2) associated species.

With the data so grouped, all mean differences between vigor classes were much too large to be random. Mean differences between yellow-poplar and the associated-species group were also significant for vigor classes 1, 2, and 3, but not for vigor class 4. Analysis of growth data within vigor classes revealed no important differences due to aspect, slope, stand-size class, or topographic position.

The possibility was explored that diameter growth of yellow-poplar (within a vigor class) was correlated with d.b.h. Analysis revealed a significant regression coefficient for trees of vigor class 1, but not for the other vigor classes (Appendix II). No equations were fitted to data for the associated-species group because the samples for individual species were too small and the pooled data were too heterogeneous.

Regression equations were obtained for diameter growth (inside bark) during the last decade over growth of

the previous decade. Separate equations were obtained for yellow-poplar and the associated-species group, and for each of the four vigor classes (Appendix II). All the coefficients were significantly greater than zero, but no tests were made to determine whether they were really different from each other.

It was notable that all these coefficients are positive and less than 1. This indicates a tendency: the greater the growth in the previous decade, the greater the growth in the present decade. Another tendency shown is that growth tends to average 35 to 60 percent of growth during the previous decade.

Assuming that the growth trend indicated during the last 20 years is constant, these equations may be used to estimate growth during the next decade. This is done by substituting average or measured diameter (inside bark) growth in the appropriate equation for growth in the previous decade, and solving for growth in the following decade. This assumption should be valid if there is no marked change in climate and if the stand is not disturbed by cutting, fire, wind, or the like. Use of a formula like this to estimate growth of a tree that has been released by cutting will give a result that is generally too small.

Diameter Growth: Outside Bark

The data described above were for wood alone. But the forest manager, to estimate volume growth or value increment, must have data on growth in wood and bark at breast height. So measured growth of wood was adjusted to growth of wood and bark.

This was done by fitting a regression equation of diameter outside bark over diameter inside bark to measurements of these diameters taken in this study (Appendix III). It was then assumed that this average would be independent of time, and growth rates (table 1) were calculated by species group and vigor class.

Since growth of Vigor 1 yellow-poplar is significantly affected by d.b.h., the growth rates for yellow-poplar were refined further (table 2).

Table 1.--Average d.b.h. growth in last 10 years, by species group and vigor class

Species group	Vigor class 1	Vigor class 2	Vigor class 3	Vigor class 4
	Inches	Inches	Inches	Inches
Yellow-poplar	3.29	2.56	1.76	1.07
Associated species	2.22	1.76	1.32	.97

In choosing trees to leave for future growth, behavior in the next decade is more important than past growth. So from the data on past growth (tables 1 and 2), d.b.h. growth during the next 10 years was estimated by species group and vigor class (table 3) and, for yellow-poplar, by d.b.h. (table 4).

These estimates of future growth are averages rather than estimates of any individual tree's behavior. A particular tree may vary much one way or the other as a result of factors not measured and the usual variations in behavior from one tree to another.

Table 2.--Average d.b.h. growth of Vigor 1 yellow-poplar in last 10 years

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

Table 3.--Estimated d.b.h. growth in next 10 years, by species group and vigor class

Species group	Vigor class 1	Vigor class 2	Vigor class 3	Vigor class 4
	Inches	Inches	Inches	Inches
Yellow-poplar	2.89	2.08	1.35	0.66
Associated species	1.92	1.42	1.04	.61

Another aspect of d.b.h. growth is how long a tree of a certain size must grow to reach a specified larger size. Table 5 was prepared to answer this question for Vigor 1 yellow-poplar. For associated species and other vigor classes, the time intervals should be longer.

Table 4.--Estimated d.b.h. growth of vigor 1 yellow-poplar in next 10 years

Present d.b.h.	D.b.h. growth	Present d.b.h.	D.b.h. growth
	Inches		Inches
6	3.21	16	2.63
8	3.10	18	2.51
10	2.98	20	2.40
12	2.86	22	2.28
14	2.75	24	2.16

Volume Growth

These diameter-growth data are useful, but the forest manager is more often concerned with volume growth. Volume growth is affected by height growth as well as diameter

growth and initial volume. So a local volume table (Appendix V) is needed for estimating volume growth from these diameter-growth data.

Table 5.--Estimated number of years needed for vigor 1 yellow-poplar to attain certain larger sizes

Present d.b.h.	Future d.b.h. to be attained		
	8 inches	10 inches	12 inches
	Years	Years	Years
0*	23	29	35
2	18	24	30
4	12	19	25
6	6	13	19
8	--	7	13
10	--	--	7

*Seedlings 1 foot high and less than 1 inch d.b.h.

The local volume table was built up from data taken in this study: merchantable height over diameter curve and average Girard form class. It is assumed that increment in merchantable height associated with present diameter provides an adequate adjustment for height growth.

Estimates of volume growth (table 6) were made from this local volume table and the data on diameter growth. In these estimates, no change in vigor class during the next 10-year period is allowed for. This phase of the study was carried out only for yellow-poplar, because of the heterogeneity of the associated species in form and merchantable height.

Table 6.--Average growth of yellow-poplar in West Virginia, by vigor classes

(In board feet, International ¼-inch rule)

Present d.b.h. class	Vigor class 1	Vigor class 2	Vigor class 3	Vigor class 4
AVERAGE 10-YEAR GROWTH, LAST 10 YEARS				
14	91	83	59	38
16	113	104	75	47
18	129	125	90	--
20	141	--	--	--
22	150	--	--	--
24	155	--	--	--
26	156	--	--	--
ESTIMATED 10-YEAR GROWTH, NEXT 10 YEARS				
12	100	68	43	21
14	119	86	55	27
16	129	103	67	32
18	145	121	79	--
20	160	139	90	--
22	172	156	--	--
24	181	--	--	--
26	192	--	--	--

Value Increment

In some situations a forest manager may want to select which tree to leave on the basis of what it is earning in dollars or in terms of interest. As a guide for doing this, the current growth earnings of yellow-poplar trees have been calculated in compound interest rates for various vigor and diameter classes (table 7).

The interest rates were calculated from data on quality of butt logs and expected yields by lumber grades. They were prepared to show how quality increases value and earnings, beyond the simple influence of volume.

As expected, the earnings of yellow-poplar trees decline as the trees grow larger, and decline from higher to lower vigor classes. For example, suppose you considered 3 percent the smallest worth-while return from your investment in forest management. By referring to table 7 you can see what sizes and vigor classes of yellow-poplar fail to earn this minimum return.

Table 7.--Earnings of yellow-poplar trees during next 10 years, expressed in compound interest rate

(Based on expected average growth)

Present d.b.h.	Vigor class 1	Vigor class 2	Vigor class 3	Vigor class 4
	Percent	Percent	Percent	Percent
12	7.6	5.5	3.7	2.0
14	5.9	4.5	3.0	1.5
16	4.7	3.8	2.8	1.2
18	4.0	3.3	2.5	--
20	3.4	3.0	1.9	--
22	3.0	2.8	--	--
24	2.7	--	--	--
26	2.2	--	--	--

Applying these rates to selective cutting would mean that the trees that do not earn at least 3 percent should be removed to make room for trees that can earn that much. According to this table, the following tree classes should be removed: all Vigor 4 trees; Vigor 3 trees 16 inches d.b.h. and larger; Vigor 2 trees 22 inches and larger; and Vigor 1 trees 24 inches and larger.

A word of caution is needed here. This was primarily a growth study, and data on quality were taken only to show

that volume alone is not enough to indicate the true advantage in growing trees to a large size before cutting them.

As clear lumber becomes even more scarce than it is now, price differentials in favor of large, clear trees may increase even further. Special uses and exceptional quality may often be more important than average earnings. For thrifty yellow-poplar that is suitable for veneer, there may be no diameter limit above which trees should be cut solely on the basis of their earning capacity. The factor of interest rate should seldom be decisive.

PRACTICAL APPLICATION

The forest manager can use these data in selecting those trees to leave when marking for a partial cutting. Vigor class can be used as a guide to diameter and volume growth of individual yellow-poplar trees; and this growth can be translated into increment in value. The vigor classes can also be used to identify diameter growth of associated species, which can likewise be translated into volume growth and increment in value.

In choosing trees to leave when making a partial cut, spacing and soundness may be more important than relative growth in the first cut or two. As successive cuts remove the poorest trees, however, relative growth will become more important in selecting future crop trees.

If a choice must be made between two sound trees, equally well spaced, the tree to leave is the one that has the greater potential growth. A Vigor 1 tree should be preferred to a Vigor 2 tree. A yellow-poplar should be preferred to most associated species. A tall tree to a short tree, and so on.

It may be possible to make the choice on the basis of species and vigor class alone. For example, a Vigor 1 white ash is probably preferable to a Vigor 3 yellow-poplar, to leave for future growth. Sometimes d.b.h. may be important in the choice: for example, between two Vigor 1 yellow-poplars. The more alike the two trees, the less the difference which one is left. In case of doubt, the trees may be bored and radial growth compared.

Besides guiding the forest manager in selecting trees to be left in a partial cutting, these data provide guides to the desirable composition of growing stock. It is evident that Vigor 4 trees should generally be cut if there are better trees to take their place. The data show that yellow-poplar is generally preferable to its associates. Value of the wood should be considered as well as growth and other factors.

To build up the desired growing stock, a series of partial cuttings may be necessary. The objective to strive for is to maintain a nearly complete canopy of full-crowned, high-vigor trees. At first the damaged, defective, and deformed trees should be removed, if merchantable. If not merchantable, they should be poisoned or girdled.

Next, trees in the poorer vigor classes should be removed, especially those of intolerant species that may respond to release poorly or not at all. In planning these cuttings, the canopy should be opened only enough so that it is reclosed--through normal crown expansion--before the next cutting. A series of partial cuttings such as these will result in a growing stock made up of Vigor 1 and Vigor 2 trees of desirable species.

This building up of a desired growing stock will reverse the deterioration that results from the usual cutting practices of the past. Each cutting removes the poorest trees, leaving the better trees for future crop trees. Under this method, successive cuttings will become more and more profitable as these better trees reach economic maturity.

BIBLIOGRAPHY

1. Besley, Lowell.
   1941. Practical forest management for cut-over hardwood lands in southern West Virginia. W. Va. Agr. Expt. Sta. Bul. 300. 15 pp.

2. Briegleb, P. A.
   1945. Calculating the growth of ponderosa pine forests. Pacific Northwest Forest Expt. Sta. 60 pp., illus.

3. Frothingham, E. F.
   1931. Timber growing and logging practice in the southern Appalachian region. U. S. Dept. Agr. Tech. Bul. 250. 93 pp., illus.

4. Holsoe, Torkel.
   1950. Profitable tree forms of yellow poplar. W. Va. Agr. Expt. Sta. Bul. 341. 23 pp., illus.

5. Hough, A. F., and Taylor, R. F.
   1946. Response of Allegheny northern hardwoods to partial cutting. Jour. Forestry 44: 30-38.

6. Jemison, George M.
   1949. Timber stand improvement in the southern Appalachian region. U. S. Dept. Agr. Misc. Pub. 693. 80 pp., illus.

7. McCarthy, E. F.
   1933. Yellow poplar characteristics. Growth and management. U. S. Dept. Agr. Tech. Bul. 356. 57 pp., illus.

8. Society of American Foresters.
   1932. Forest cover types of the eastern United States. Soc. Amer. Foresters. 48 pp. Washington, D. C.

9. Tillotson, C. R.
   1927. Timber growing and logging practice in the central hardwood region. U. S. Dept. Agr. Bul. 1491. 39 pp., illus.

10. United States Forest Products Laboratory.
1949. Hardwood log grades for standard lumber. Proposals and results. U. S. Forest Prod. Lab. Rpt. D1737. 60 pp., illus. Madison, Wis.

APPENDIX

Table 8.--Average diameter growth inside bark during last 10 years, by species and vigor class

Species	Vigor class 1	Vigor class 2	Vigor class 3	Vigor class 4
	Inches	Inches	Inches	Inches
Yellow-poplar	3.07	2.38	1.64	0.99
Associated species:				
Basswood	2.02	1.86	1.55	1.22
Sugar maple	2.26	1.59	1.07	.78
Cucumber tree	1.83	1.84	1.21	.70
Sweet birch	2.02	1.29	1.05	.62
Red maple	1.13	1.55	1.07	1.10
Beech	1.65	1.26	1.25	.82
Walnut	1.50	1.01	.77	--
White ash	2.43	1.78	1.14	.62
Northern red oak	2.30	2.04	1.67	.57
Butternut	2.00	2.15	1.33	1.00
Hickory, shagbark	1.93	1.01	.99	.70
Hickory, pignut	3.80	1.51	1.30	.97
Chestnut oak	--	1.81	.77	.80
Sassafras	--	1.43	.99	.48
Black gum	--	.98	.60	.50
Black cherry	3.63	1.53	1.30	.97
Buckeye	2.55	.60	1.22	.70
Average, all associated species*	2.05	1.63	1.21	0.91

*Includes, in addition to species listed, hemlock, cottonwood, yellow birch, white oak, pin oak, black oak, elm, mulberry, magnolia, sycamore, choke cherry, black locust, and sourwood.

Regression of diameter growth (i.b.) over d.b.h. for Vigor 1 yellow-poplar:

$$\triangle d_1 = 4.096 - (0.091)\ D$$

in which $\triangle d_1$ is growth in d.i.b. during last decade and D is diameter breast high.

Growth-trend equations for yellow-poplar:

Vigor class	Equation
1	$\triangle d_1 = 0.8604 + 0.596\ \triangle d_2$
2	$\triangle d_1 = 0.6145 + 0.554\ \triangle d_2$
3	$\triangle d_1 = 0.6704 + 0.357\ \triangle d_2$
4	$\triangle d_1 = 0.2436 + 0.375\ \triangle d_2$

in which $\triangle d_1$ is as defined above and $\triangle d_2$ is growth in d.i.b. during previous decade.

Growth-trend equations for associated species:

Vigor class	Equation
1	$\triangle d_1 = 0.6143 + 0.578\ \triangle d_2$
2	$\triangle d_1 = 0.4292 + 0.567\ \triangle d_2$
3	$\triangle d_1 = 0.3740 + 0.502\ \triangle d_2$
4	$\triangle d_1 = 0.1910 + 0.400\ \triangle d_2$

Application of these formulas is rather simple: Future diameter is estimated diameter growth added to present diameter. Estimated diameter growth is obtained by substituting past growth, in the appropriate formula, for $\triangle d_2$ and solving for $\triangle d_1$.

For example, if it is known that 14-inch yellow-poplar of vigor class 1 have an average d.b.h. of 14.3 and an average $\triangle d$ of 3.0 for the last 10 years,

$$\triangle d_1 = 0.8604 + 0.596(3.0) = 2.6484$$

and estimated d.b.h. 10 years from now is 14.3 + 2.6 = 16.9. The formulas may be used for single trees, but this should be done only with the realization that such use is subject to greater error than when the formulas are used to estimate the average of a class.

III

To estimate growth in d.b.h. from growth in d.i.b., the following argument is used:

$$D = A + Bd$$

in which D is d.b.h. in inches, d is d.i.b. in inches, and A and B are parameters. Then--

$$D + \triangle D = A + B\,(d + \triangle d)$$

in which $\triangle D$ is d.b.h. growth in inches and $\triangle d$ is growth in d.i.b. From this--

$$\begin{aligned} \triangle D &= A + B\,(d + \triangle d) - D \\ &= A + B\,(d + \triangle d) - A - Bd \\ &= B\triangle d \end{aligned}$$

For yellow-poplar, fitting a regression equation by least squares gave:

$$D = 0.4346\ldots + (1.0794\ldots)\,d$$

Whence $\triangle D = (1.0794)\,\triangle d$

This equation was also used to estimate $\triangle D$ for associated species, as shown below:

Average 10-year growth by species group and vigor class in inches

Species group		Vigor 1	Vigor 2	Vigor 3	Vigor 4
Yellow-poplar	$\triangle d$	3.05	2.37	1.63	0.99
	$\triangle D$	3.29	2.56	1.76	1.07
Associated species	$\triangle d$	2.06	1.63	1.22	.90
	$\triangle D$	2.22	1.76	1.32	.97

Estimates of future d.b.h. growth of yellow-poplar, based on $\triangle D = (1.0794)\ \triangle d$ and assuming no change in vigor class. $\triangle d_k = 4.096 - (0.091)\ D$

Vigor Class 1

$$\triangle d_{k-1} = 0.8604 + 0.596\ \triangle d_k$$
$$= 0.8604 + 0.596\ (4.096 - (0.091)\ D)$$
$$= 3.302 - (0.054)\ D$$

$$\triangle D_{k-1} = (1.0794)\ \triangle d_{k-1}$$
$$= 3.5642 - (0.0583)\ D$$
$$= 2.8908$$

Vigor Class 2

$$\triangle d_{k-1} = 0.6145 + 0.554\ \triangle d_k$$
$$= 0.6145 + (0.554)\ (2.37)$$
$$= 1.92748$$

$$\triangle D_{k-1} = 2.0805$$

Vigor Class 3

$$\triangle d_{k-1} = 0.6704 + 0.357\ \triangle d_k$$
$$= 0.6704 + (0.357)\ (1.63)$$
$$= 1.25231$$

$$\triangle D_{k-1} = 1.3517$$

Vigor Class 4

$$\Delta d_{k-1} = 0.2436 + 0.375\ \Delta d_k$$

$$= 0.2436 + (0.375)\ (0.99)$$

$$= 0.61485$$

$$\Delta D_{k-1} = 0.6637$$

Table 9.--Local volume table for West Virginia yellow-poplar, in board feet, International ¼-inch rule

(Girard Form Class 78)

D.b.h. in inches	Tenths of inches									
	0	1	2	3	4	5	6	7	8	9
11	75	77	79	81	83	86	89	92	95	98
12	101	104	107	110	113	116	119	122	123	128
13	132	135	138	141	144	147	150	154	158	162
14	166	169	173	177	181	185	189	193	197	201
15	205	209	213	217	221	225	229	233	238	243
16	248	252	256	260	265	270	275	280	285	290
17	295	300	305	310	315	320	325	330	335	340
18	346	351	356	361	366	371	377	383	389	395
19	401	407	413	419	425	431	437	443	449	455
20	461	467	473	479	485	491	497	504	511	518
21	525	531	537	544	551	558	565	572	579	586
22	593	600	607	614	621	628	635	642	649	657
23	665	672	679	686	693	701	709	717	725	733
24	741	749	757	765	773	781	789	797	805	813
25	821	829	837	845	853	861	869	878	887	896
26	905	913	922	931	940	949	958	967	976	985
27	994	1,003	1,012	1,021	1,030	1,039	1,048	1,058	1,068	1,078
28	1,088	1,097	1,107	1,117	1,127	1,137	1,147	1,157	1,167	1,177
29	1,187	1,197	1,207	1,217	1,227	1,237	1,247	1,257	1,268	1,279
30	1,290	1,300	1,310	1,321	1,332	1,343	1,354	1,365	1,376	1,387
31	1,398	1,409	1,420	1,431	1,442	1,453	1,464	1,475	1,486	1,498

Table 10.--Average d.b.h. growth of yellow-poplar, by vigor class, in inches

Present d.b.h. (inches)	Average growth in last 10 years, vigor class--				Estimated average growth in next 10 years, vigor class--			
	1	2	3	4	1	2	3	4
6	3.8	2.6	1.8	1.1	3.2	2.1	1.4	0.7
8	3.6	2.6	1.8	1.1	3.1	2.1	1.4	0.7
10	3.4	2.6	1.8	1.1	3.0	2.1	1.4	0.7
12	3.2	2.6	1.8	1.1	2.9	2.1	1.4	0.7
14	3.0	2.6	1.8	1.1	2.8	2.1	1.4	--
16	2.9	2.6	--	--	2.6	2.1	--	--
18	2.7	--	--	--	2.5	--	--	--
20	2.5	--	--	--	2.4	--	--	--
22	2.3	--	--	--	2.3	--	--	--
24	2.1	--	--	--	--	--	--	--
26	1.9	--	--	--	--	--	--	--

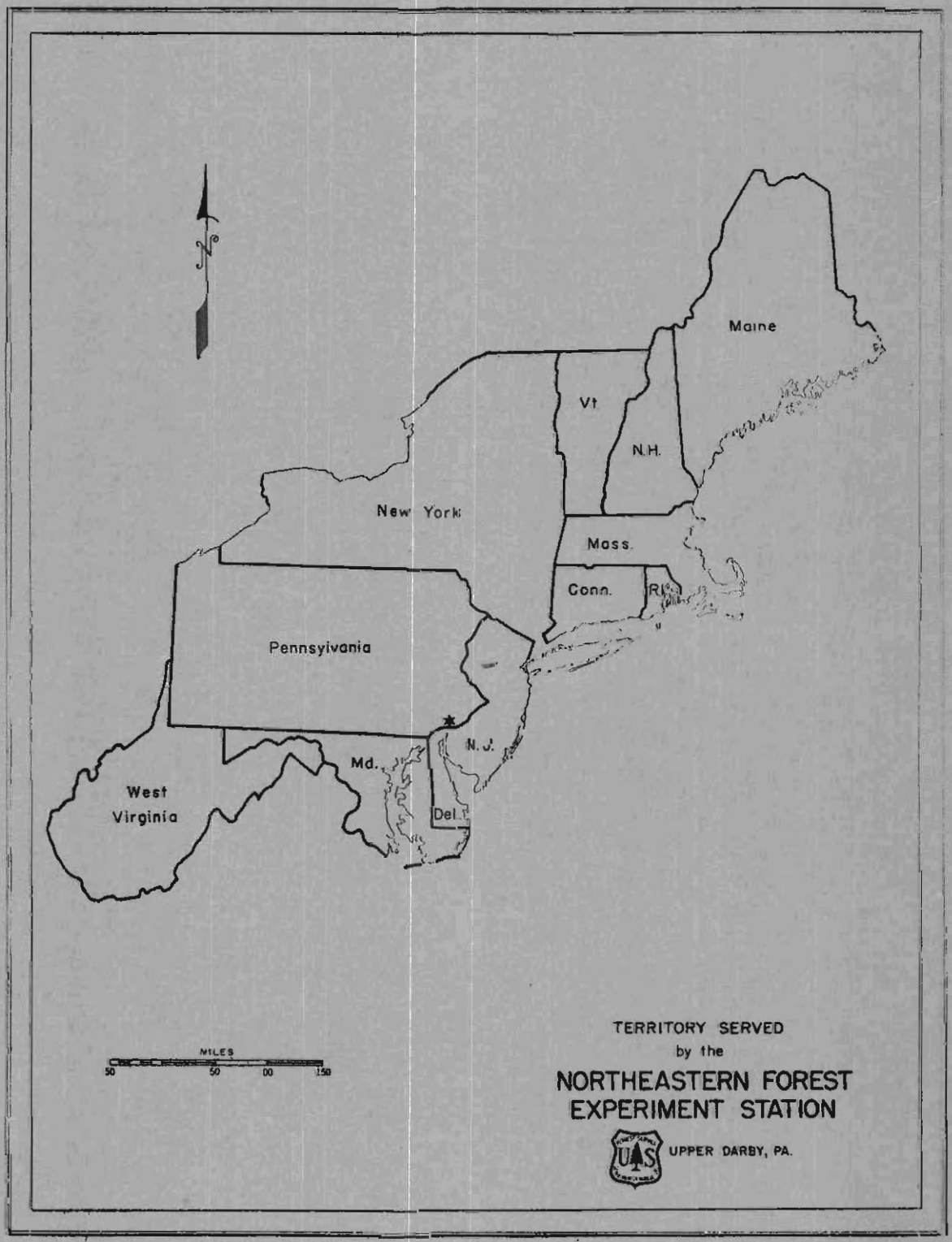
Table 11.--Estimated average volume growth and value increment of yellow-poplar, by vigor class

D.b.h. (inches)	Volume per tree	Value--		Average volume growth[1] in 10 years				Increase in value[2]			
		Per M board feet	Per tree	Vigor 1	Vigor 2	Vigor 3	Vigor 4	Vigor 1	Vigor 2	Vigor 3	Vigor 4
	Board feet			Board feet	Board feet	Board feet	Board feet				
12	101	$22.66	$ 2.29	100	68	43	21	$2.45	$1.63	$1.01	$0.49
14	166	23.96	3.98	119	86	55	27	3.11	2.19	1.37	.65
16	248	25.84	6.41	129	103	67	32	3.74	2.90	1.81	.84
18	346	28.32	9.80	145	121	79	--	4.64	3.79	2.39	--
20	461	31.22	14.39	160	139	90	--	5.65	4.86	3.04	--
22	593	34.54	20.48	172	156	--	--	6.71	6.02	--	--
24	741	38.16	28.28	181	--	--	--	7.69	--	--	--
26	905	42.26	38.25	192	--	--	--	8.78	--	--	--

[1]International ¼-inch rule. [2]Adjusted for quality increment as well as volume increment.

Table 12.--Interest earned by yellow-poplar, by vigor class, in percent

D.b.h. (inches)	Based on volume alone								Annually compounded interest based on value adjusted for quality			
	Average annual simple interest				Annually compounded interest							
	Vigor 1	Vigor 2	Vigor 3	Vigor 4	Vigor 1	Vigor 2	Vigor 3	Vigor 4	Vigor 1	Vigor 2	Vigor 3	Vigor 4
12	9.9	6.7	4.3	2.1	7.1	5.3	3.6	1.9	7.6	5.5	3.7	2.0
14	7.2	5.2	3.3	1.6	5.4	4.3	2.9	1.5	5.9	4.5	3.0	1.5
16	5.2	4.2	2.7	1.3	4.3	3.5	2.5	1.2	4.7	3.8	2.8	1.2
18	4.2	3.5	2.3	--	3.5	3.0	2.1	--	4.0	3.3	2.5	--
20	3.5	3.0	2.0	--	3.0	2.7	1.8	--	3.4	3.0	1.9	--
22	2.9	2.6	--	--	2.6	2.3	--	--	3.0	2.8	--	--
24	2.4	--	--	--	2.2	--	--	--	2.7	--	--	--
26	2.1	--	--	--	1.9	--	--	--	2.2	--	--	--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