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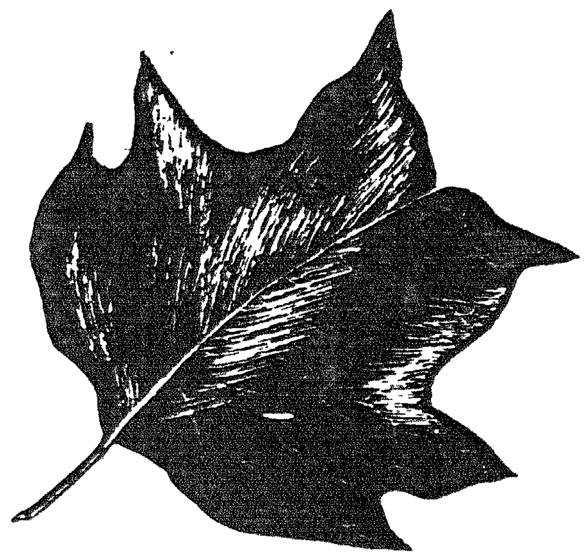

by John J. Phillips

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Site Index of YELLOW-POPLAR Related to Soil and Topography in Southern New Jersey

The Author

JOHN J. PHILLIPS, soils scientist, was graduated from the University of Wisconsin with a major in soils in 1956. He was employed by the Northeastern Forest Experiment Station from 1956 to 1964, where he conducted research on timber and watershed management, mostly in connection with soils. Work reported in this paper was performed while he was assigned to the Experiment Station's timber-management research unit at New Lisbon, New Jersey.

YELLOW-POPLAR (*Liriodendron tulipifera* L.) is one of the most desirable tree species in the Middle Atlantic States, but little has been known about the effects of various soil and topographic conditions on its growth in this region. In 1963 a study was begun to determine these relationships in New Jersey, Maryland, Delaware, and eastern Pennsylvania. This paper presents the findings in one small portion of this area, the Coastal Plain of New Jersey.

Yellow-poplar is limited mostly to the inner portion of the New Jersey Coastal Plain, a strip of land 15 to 20 miles wide and about 100 miles long extending along the Delaware River from Bridgeton to Trenton and then northeastward south of the fall line, which crosses New Jersey roughly from Trenton to Perth Amboy. Much of this portion of the Coastal Plain is a low-relief plain, the result of erosion and deposition. The uplands are seldom more than 60 feet higher than the stream valleys and flood plains. The slopes in between vary up to 30 percent, but the steeper slopes are short—often 200 feet or less. The relatively flat uplands often have fine-textured soils, with poorer drainage than that found in sections with coarse soils or greater relief.

Well-drained soils in this portion of the New Jersey Coastal Plain are Gray-Brown and Red-Yellow Podzolic intergrades, derived either from old upraised ocean-bottom sediments or from younger surficial deposits of Pleistocene age. The ocean-bottom sediments consist primarily of sands, silts, and clays in varying mixtures, in most places carrying glauconite as a clay mineral. Although the younger surficial deposits include all four separates —gravel, sand, silt, and clay—they have frequently been sorted so that the coarse materials predominate in one place, silts and clays in another. The soils are usually low in fertility, high in iron, and strongly acid, generally with a pH of 4.4 to 4.8.

In this part of New Jersey, yellow-poplar occurs most commonly on the stream-cut slopes, frequently on bottomland sites, and occasionally on low-relief upland sites.

STUDY PROCEDURE

In the inner Coastal Plain, 44 plots were established in even-aged stands. Each plot included 4 to 6 dominant yellow-poplars that were 30 to 70 years old and growing on a uniform soil. Total height and age at breast height were determined for each sample tree, and the average values were computed for each plot. Total age from seed was estimated by adding 3 years to the number of rings at breast height. The site index—height at 50 years of age—was then determined from Beck's curves for the Piedmont.[1]

Data on soil and topographic factors that might affect site index were taken and handled as described below. Soils were examined to a depth of 5 feet by the use of a bucket-type auger (3 inches in diameter); 2 to 5 borings were obtained in each plot.

Soil type.—Classified for each plot according to the National Cooperative Soil Survey standards by M. L. Markley or Van R. Powley, soil scientists of the U. S. Soil Conservation Service.

[1] Beck, Donald E. YELLOW-POPLAR SITE INDEX CURVES. U. S. Forest Serv. SE. Forest Exp. Sta. Res. Note 180. 2 pp., illus., 1962.

Topographic position.—Grouped into three classes to indicate landscape position and surface drainage. Though slope, aspect, and position on slope were determined for each plot, only the following classes seemed desirable in the analysis:

(1) Poor bottomland sites: flat, poorly drained bottomlands having less than 2-percent slope and located more than 100 feet from deep-cut streams (streams where normal summer flow is 3 feet or more below the banks). Bottomland, as used here, is a topographic position in that it includes alluvial and residual soils. Some stream valleys that are seldom subject to overflow are included. All areas where stream surfaces approach the level of soil surfaces fall in this class.

(2) Good bottomland sites and the lower 25 percent of stream-cut slopes: bottomland sites with 2-percent or more slope or less than 100 feet from a deep-cut stream, and the lower 25 percent of stream-cut slopes.

(3) Mid and upper portions of stream-cut slopes and occasional upland sites: The upper 75 percent of stream-cut slopes and occasional upland sites where yellow-poplar occurs.

Depth to tight subsoil.—Measured in inches in each hole and averaged for the plot. A tight subsoil was any strongly developed moderately fine layer resulting from a relatively high clay content (usually 18 percent or more). These layers often occurred in the B_2 horizon. None of the tight subsoils encountered were considered to be fragipans. In the analysis, soils with depths to tight subsoil of 36 inches or slightly more did not differ in site index from those with no tight subsoil within 5 feet, so all such values were grouped into one class and given the value of 36 in developing the regression equation. Depth to tight subsoil did not fall between 32 and 36 inches on any of the soils sampled, so the effect of such depth on site index cannot be confidently predicted from the results of the study.

Depth to mottling and depth to each soil horizon.—Measured in inches in each hole and averaged for the plot. While depth to mottling was easily measured in most plots, it was obscured in some poorly drained soils and in all very poorly drained ones by a thick black A_1 layer. Where this occurred, mottling was considered to extend to the soil surface. Justification for such a procedure is found in poorly drained soils with gray A_1 layers where mottling often occurs at 2 or 3 inches from the surface.

Soil texture.—Determined for each plot from samples collected of the A horizon and of the finest-textured layer within 36 inches of the soil surface. The latter layer was usually the B_2 horizon. In soils having no noticeable change in texture within 36 inches, the depth between 24 and 36 inches was used as the subsoil in texture analyses. These analyses were made by the Bouyoucos hydrometer method as modified by Wilde and Voigt,[5] except that samples were allowed to rehydrate overnight in the dispersing solution.

pH of A horizon and pH of subsoil.—Determined by using a simple colorimetric pH kit.

RESULTS

Regression Analysis

By regression analysis, an equation was derived that expressed site index in relation to several soil and topographic factors. This equation is:

$$\text{Site index} = 88.1 + 0.739X_1 - 0.686X_2 + 0.555X_3 - 0.140X_4 + 3.558X_5 - 1.288X_6 - 18.374X_7$$

X_1 = depth to mottling, in inches.
X_2 = $(X_1)^3 \div 1{,}000$.
X_3 = percent clay in subsoil.
X_4 = $(X_3)^3 \div 1{,}000$.
X_5 = 1 (for poor bottomland sites).
= 2 (for mid and upper portions of stream-cut slopes and occasional upland sites).
= 3 (for good bottomland sites and the lower 25 percent of stream-cut slopes).
X_6 = 36 inches minus depth to tight subsoil, in inches.
X_7 = 0 (if tight subsoil is less than 36 inches from the soil surface).
= 1 (if tight subsoil is 36 inches or more from the surface).

[5] Wilde, S. A., and G. K. Voigt. ANALYSIS OF SOILS AND PLANTS FOR FORESTERS AND HORTICULTURISTS. 117 p., illus. J. W. Edwards, Inc., Ann Arbor, Mich., 1955.

This equation explains 67 percent of the variation in site index (R=0.82) and has a standard error of estimate of ± 5.5 feet. The equation predicted site index within ± 5 feet for 70 percent of the plots in this study. However, 14 percent of the plots differed from the predicted site index by 8 feet or more; maximum difference observed was 13 feet.

Table 1 gives site-index values derived from the equation. With this table, and appropriate knowledge of the soil and topographic factors of a given area, the site index can be estimated.

Table 1.—Site index for yellow-poplar on soils of the inner Coastal Plain of New Jersey[1]

A

Depth to mottling (inches)	Percent of clay content of B_2 horizon (or 24- to 36-inch depth) 5	10	15	20	25	30	35	40	45	50
0	91	94	96	98	100	101	102	101	100	98
5	94	97	100	102	103	105	105	105	104	102
10	98	100	103	105	106	108	108	108	107	105
15	100	102	105	107	109	110	110	110	109	107
20	100	103	105	107	109	110	111	111	110	108
25	99	101	104	106	108	109	109	109	108	106
30	95	97	100	102	103	105	105	105	104	102
35	87	90	92	95	96	97	98	98	97	95
40	77	79	82	84	85	87	87	87	86	84

B

Depth to tight subsoil (inches)	Topographic position and surface drainage: Good bottomland sites and lower slopes	Mid and upper slopes and upland sites	Poor bottomland sites
10	−23	−26	−30
15	−16	−20	−23
20	−10	−13	−17
25	− 3	− 7	−11
30	+ 3	− 1	− 4
36-60[2]	− 8	−11	−15

[1] First obtain base value in A; then correct as indicated in B. Estimated site index is the result of adding these two values.

[2] Includes plots with no tight subsoil within the 5-foot zone sampled

Discussion of Individual Variables

Soil Factors

Depth to mottling (X_1 and X_2).—This variable has a curvilinear relationship with site index. Site index increases 9 feet with increasing depth to mottling from zero (soil surface) to 20 inches. With greater depths to mottling, site index declines so that, according to the equation, its effect reaches zero at a depth of about 33 inches and becomes negative for greater depths.

In general, this variable has less effect on site index than the author expected. Auten[3] found a much larger difference due to poor drainage, possibly because he was dealing with soils of finer texture than those of our study.

Percent clay in subsoil (X_3 and X_4).—Site index increases sharply with clay content of the subsoil from 3 to 30 percent, then levels off with a peak at 36 percent, and apparently declines at clay contents above 40 percent. The maximum clay content found was 46 percent. Maximum change in site index due to this variable is about 12 feet.

Depth to (and presence of) tight subsoil (X_6 and X_7).—Soils with a tight subsoil at depths of 22 inches or less form relatively poor sites. Site index increases as depth to tight subsoil increases up to 32 inches at least.[4] Soils with a tight subsoil slightly deeper than 36 inches seem similar to those with no tight layer within the 5-foot depth sampled (preceding statement based on 2 and 12 plots, respectively). Both form poorer sites than those that have tight subsoils between 23 and 32 inches of the surface. These results agree fairly well with Auten's conclusion that soils must have a depth to tight subsoil of 24 inches or more to be classified as good sites for yellow-poplar.

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[3] Auten, John T. PREDICTION OF SITE INDEX FOR YELLOW-POPLAR FROM SOIL AND TOPOGRAPHY. J. Forestry 43: 662-668, illus., 1945.

[4] Equation shows values increasing to 35 inches and then dropping sharply; but depths between 32 and 35 inches were not sampled.

Topography

As already mentioned, topographic differences in the Coastal Plain are relatively minor. They result either from stream dissection of the Plain or from differences in erodibility of the various types of sediments. In much of the New Jersey area the topographic change induced by these factors is less than the 25-percent slope or 50-foot difference in elevation Auten found to be necessary before topography has an important effect on site index in the Central States.

However, two topographic factors—landscape position and surface drainage—have significant effects on the site index of yellow-poplar in the New Jersey Coastal Plain. Together, these account for a variation of about 7 feet in site index.

Other factors being equal, the best sites were those on the lower portions of stream-cut slopes and in bottomlands where deep-cut streams within 100 feet or slopes of 2 percent or more provided good surface drainage. Site index there was about 7 feet more than on relatively flat bottomlands where the lack of slope and absence of nearby deep-cut streams provided poor surface drainage. The latter sites were also about 3.5 feet poorer than those sampled on mid or upper slopes and on uplands.

Soil Series

The site-index values for various soil series are shown in table 2. In general, not enough data are available to properly assess the value of soil series in estimating yellow-poplar site index.

Even with drainage classes there is no clearcut relationship. Site indexes on soils classified as well drained varied from 78 to 108, while in the combined groups of moderately well to somewhat poorly drained soils the variation is almost the same: 79 to 110 (table 2). Apparently on the poorer drainages site index does decrease, especially on the finer-textured soils. However, on some poorly and very poorly drained soils with sandy or loamy textures site indexes between 90 and 100 were measured (table 2).

Table 2.—Site index by soil series[1]

Drainage class and soil series	New classification	Plots	Range (and average) in site index
		No.	*Feet*
	WELL DRAINED SOILS		
Collington	Alfic Normudults; fine loamy, mixed, mesic.	1	94
Downer	Alfic Normudults; coarse loamy, siliceous, mesic.	1	90
Freehold	Alfic Normudults; fine loamy, mixed, mesic.	5	78-108 (96)
Matapeake	Alfic Normudults; fine silty, mixed, mesic.	1	78
Sassafras	Alfic Normudults; fine loamy, siliceous, mesic.	3	78-100 (89)
Westphalia	Typic Normudults; coarse loamy, siliceous, mesic.	1	92
Westphalia-Freehold[3]	(See above series descriptions)	1	96
Westphalia-Lakeland[4]	(Lakeland: Typic Quartzipsamments; sandy, siliceous, acid, mesic[5] for Westphalia see above.)	2	88-88 (88)
Mixed Sandy Colluvium		1	86
	WELL TO MODERATELY WELL DRAINED SOILS		
Adelphia-Marlton	Adelphia: Aqualfic Normudults; fine loamy, mixed, mesic; for Marlton, see below.	1	98
Howell	Typic Normudults; clayey, mixed, mesic.	3	89-103 (95)
Marlton	Typic Normudults; fine, mixed, mesic.[2]	1	88
Matawan	Aqualfic Normudults; fine loamy, mixed, mesic.	1	91
	MODERATELY WELL DRAINED SOILS		
Keyport	Paraquic Normudults; clayey, mixed, mesic.[2]	1	98
Klej-Nixonton[4]	(Klej: Aquic Normi psamments; sandy, siliceous, mesic; Nixonton—see below.)	2	88-90 (89)
Mattapex	Aqualfic Normudults; fine silty, mixed, mesic.	1	79

CONTINUED

TABLE 2, CONTINUED

Drainage class and soil series	New classification	Plots	Range (and average) in site index
		No.	*Feet*
Nixonton	Aquic Dystrochrepts; coarse silty, mixed, mesic.[5]	1	87
Woodstown	Paraquic Normudults; fine loamy, siliceous, mesic.	1	82
MODERATELY WELL TO SOMEWHAT POORLY DRAINED SOILS			
Holmdel	Paraqualfic Normudults; fine loamy, mixed, mesic.[2]	5	81-102 (91)
SOMEWHAT POORLY DRAINED SOILS			
Barclay	Aquic Dystrochrepts; coarse silty, mixed, mesic.	2	86-105 (96)
Bertie	Aqualfic Normudults; fine loamy, mixed, mesic.[2], [3]	1	110
Lenoir	Aquic Normudults; fine, mixed, mesic. [2], [5]	1	98
POORLY DRAINED SOILS			
Pasquotank	Typic Normaquepts; coarse silty, mixed, acid, mesic.[5]	1	82
Loamy alluvial lands		2	91-100 (96)
VERY POORLY DRAINED SOILS			
Sandy alluvial lands		3	72-85 (80)
Muck, sand surface		1	97

[1] Soils classified by M. L. Markley and V. R. Powley, U. S. Soil Conservation Service.

[2] Classification tentative, not correlated.

[3] Slightly glauconitic surface overlying loamy fine sands.

[4] Uniform fine sands to fine sandy loams with discontinuous B horizons. When present, these B horizons are only slightly finer-textured than overlying horizons.

[5] Type location is in thermic, not mesic, zone.

DISCUSSION AND CONCLUSIONS

This study indicates that yellow-poplar grows best on soils with deep, well-drained surface layers overlying loamy or moderately fine-textured subsoils with a good supply of available moisture. The last is indicated by the importance of mottling and of favorable topographic positions (lower slopes and bottomlands with good surface drainage). Conversely, the poorest growth, although no yellow-poplars were found there, would be on flat-lying, poorly drained soils with shallow depths to tight subsoil. Except for the desirability of a mottled subsoil, the findings are in accord with the commonly accepted generalizations of the site requirements for the species. Apparently poor aeration in the subsoil—for some periods of the year at least—is less harmful than is lack of moisture.

Although yellow-poplar roots were found throughout the 5-foot soil depth studied, neither mottling in the 3-to-5-foot zone nor presence of a tight layer there affected site index. However, it is possible that conditions in this zone were reflected in other factors.

Yellow-poplar is commonly found on fine-sand soils, but seldom found on the coarser sand soils. Size of particles in the sand fraction did not appear as a significant variable in this study because no measurable stands could be located on well-drained coarse sand soils. Hence, this equation should not be applied to such soils.

SUMMARY

Yellow-poplar grows rapidly on the deep, moist soils of New Jersey's inner Coastal Plain, attaining heights of 70 to 110 feet at 50 years of age. Factors related to height growth are depth to mottling, depth to tight subsoil, clay content of the subsoil, topographic position, and surface soil drainage. The resulting equation explains about 67 percent of the observed variation in site index.