Planting Yellow-Poplar—Where We Stand Today

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Summary

Yellow-poplar can be established on a wide variety of sites with bare-rooted seedlings and standard planting techniques. Many past plantings have performed poorly because substandard seedlings have been planted on unsuitable sites and competing vegetation has not been adequately controlled. Research over the past two decades, however, provides workable guides for site selection, planting practices, and competition control. Enough is now known that the forester can avoid or overcome the most common causes of failure.

This paper mentions the use of herbicides. If herbicides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

Some States have restrictions on the use of certain herbicides. Check your State and local regulations. Also, because registrations of herbicides are under constant review by the U.S. Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure intended use is still registered.

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Large volumes of yellow-poplar *(Liriodendron tulipifera* L.) are used for furniture, plywood, corestock, millwork, siding, and other light construction lumber. Though seldom managed exclusively for roundwood, yellow-poplar is used for pulping and for products manufactured from chips or flakes. Rapid growth and excellent form make this species an outstanding candidate for planting.

Yet despite its favorable potential for growth and the desirable properties of the wood, relatively few yellow-poplar plantations are being established. Most foresters and landowners are probably discouraged by the preponderance of failures in past efforts. For example, the North Carolina Division of Forestry sold 7 million yellow-poplar seedlings between 1947 and 1966, but by 1970, only 53 percent of the planting sites could be located and of these only 7 percent could be considered successful in terms of adequacy of stocking and growth (Boyette 1970). Comparable data are not available for other Southern States, but general observations indicate that the success rate in Tennessee and Alabama is about the same.

In view of this record of failures it is not surprising that so few foresters think of yellow-poplar as a plantable species. The problem may, however, reflect a lack of knowledge of recent developments in yellow-poplar research. The purpose of this paper is to review available information and to consider whether there is an adequate technical basis for planting yellow-poplar.

Technical Considerations

Yellow-poplar has been studied more than any other upland hardwood, and more is known about planting this species than is commonly realized. The key requirements for planting yellow-poplar are:

(1) Selection of suitable sites.
(2) Use of the best planting technology, including high-quality seedlings, careful stock handling, and choice of appropriate seasons and methods of planting.
(3) Adequate control of competing vegetation.

Site Selection

Improper site selection has probably caused more disappointing plantation performance than all other mistakes combined. The extremely high rate of failure in the North Carolina survey resulted mainly from planting on unsuitable sites (Boyette 1970).

Broad recommendations concerning planting sites can be made, but they should be modified to fit the local situation. Much information about soil and site requirements for yellow-poplar has been compiled in summary publications which are useful guides to selecting planting sites (Carmean 1970, Olson 1969). Although this information was derived largely from natural stands, many of the relations between topographic features or soil properties and site quality apply for plantations as well (Limstrom 1963, Smalley 1969, Tryon and others 1960).

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The definition of a suitable site for planting yellow-poplar depends largely on the rate of growth that the forester or land manager considers acceptable. We consider areas with a site index of 85 or more to be satisfactory; anything less is unsatisfactory. At site index 85, early growth of planted yellow-poplars will average about 2 feet per year. The best trees, those that will eventually dominate the stand, will average about 3 feet per year.

Where no yellow-poplar site-index trees are available, site index can be determined for other tree species and related to site for yellow-poplar by comparative site-index data (Doolittle 1958, Olson and Della-Bianca 1959). Where there are no site-index trees site evaluation involves more risk, but a judicious consideration of soil and topographic requirements should enable the planter to avoid doubtful situations and to put yellow-poplar on sites capable of yielding satisfactory growth.

Soils and topography. — Excessively drained soils and very wet soils are not good sites (Olson 1969). Some moderately to poorly drained soils in the Northeast are very productive, possibly because favorable amounts of moisture during much of the growing season compensate for poor aeration in the subsoil during part of the year.

Other important soil factors include depth of the A horizon (especially the Al), surface or subsoil texture, and total soil depth. Site quality generally increases with increasing soil depth and especially with increasing thickness of the A horizons (Carmean 1970). Ordinarily, yellow-poplar should not be planted on any soil with less than 24 inches of rooting depth over bedrock, fragipan, or other restrictive horizon.

Although few soil-site studies have found strong correlations between soil nutrients and site quality, yellow-poplar apparently grows poorly on nitrogen deficient soils and attains best growth only with an ample supply of nitrogen (Olson 1969). Some soils have low levels of calcium and high levels of soluble aluminum in the subsoil that may inhibit root development and thus lower site quality for yellow-poplar (Loftus 1971).

Topographic features that most consistently correlate with yellow-poplar site index in a number of studies are slope position and aspect, (Carmean 1970). In mountainous or hilly terrain, best sites are coves or deep hollows. North and east aspects are better sites than south and west aspects, lower slopes are usually better than upper slopes, and gently, concave land forms are more likely to be good sites than steep, convex slopes.

Yellow-poplar should not be planted on narrow, dry ridges. Broad ridges may be fair sites, provided that rooting depth and soil texture is favorable. For example, yellow-poplar planted on broad ridges of the Cumberland Plateau has grown well on soils with textures from fine sandy loams to clay loams, where rooting depth was adequate and the Al horizon was 2 or more inches thick. On steep slopes, subsurface flow may improve moisture conditions downslope enough to provide acceptable growth even where soils are less than 24 inches deep.

Planting on old fields. — Though some agricultural lands can grow hardwoods, abandoned fields or pastures are usually less favorable for yellow-poplar than recently forested areas occupying similar soils. Moreover, site quality on old fields in the uplands often varies greatly within short distances (Gilmore and others 1968), complicating the task of assessing site suitability for yellow-poplar. Adverse conditions commonly found on old fields include severe erosion, soil compaction, a depleted nutrient capital, and a heavy sod or weed growth. Loss of the A horizon, degradation of soil structure, and lack of appropriate soil micro-organisms are major reasons for poor performance of planted yellow-poplar on many old fields in the Central States (Clark 1964, Clark and Losche 1969). Where old fields have been invaded by a brushy cover of trees and shrubs, soil conditions may have improved enough to support yellow-poplar; an initial rotation of pines or nitrogen-fixing tree species can also improve soil conditions on old fields (Carmean and others 1976).

Planting Technology

Assuming that the site is capable of growing yellow-poplar at an acceptable rate, close attention to seedling quality, stock handling, and the actual planting operation is essential.

Seedling selection. — Seedling size indicates physiological vigor, and we have generally accepted that large hardwoods seedlings initially perform better than small seedlings (McElwee 1970, Rodenbach and Olson 1960). Moreover, the beneficial effects of planting high-quality seedlings may persist for many years (Funk and others 1974). Most yellow-poplar planting is done with 1-0, bare-rooted stock. Based on published guides for the Central States, seedlings with diameters of about 10/32 inch at the ground line are preferred (Limstrom 1963). The current trend in the South is to plant even larger hardwood seedlings; a root collar diameter of 12/32 inch is often considered the minimum acceptable size (McElwee 1970, Nugent 1971). Four-year-old yellow-poplar seedlings have been recommended for planting sites in West Virginia that are dominated by tall-growing herbaceous weeds

(Carvell 1966a). Seedlings within the 8/32 to 12/32 range have performed satisfactorily in many trials on a wide variety of sites in central Tennessee and northern Alabama (Russell and others 1970). Seedlings of this size not only provide satisfactory performance but also are not too unwieldy for bar-slit or machine planting.

Quality of planting stock depends on the genetic make-up of the seedlings as well as on their morphological grade. Current work on selection and breeding is in progress and offers the possibility of improved planting stock, but until improved stock becomes available, an important genetic consideration is seed origin.

In North Carolina, seedlings from local sources survived better than those from non-local sources although there were no significant differences in fifth-year heights (Sluder 1960). Moving yellow-poplars northward from their origin into areas of much longer day length may increase juvenile growth (Limstrom and Finn 1956) but increases risk of severe frost damage (Funk 1958). In a study of four mid-South seed sources, seed source had no important effects on sixth-year heights in outplantings at Vicksburg, Mississippi; Birmingham, Alabama; and at two locations near Sewanee, Tennessee. Trees of southern origins consistently leafed-out before those from northern sources in all four outplantings (Farmer and others 1967). Nor in 15 years have there been any serious climatic injuries to yellow-poplars from south Mississippi that were moved 4 degrees north and outplanted 1700 feet higher on Tennessee's Cumberland Plateau.

Yellow-poplars grown from seed collected in North Carolina's Appalachian Mountains have either survived poorly when planted in the Coastal Plain or have grown more slowly than seedlings from Coastal Plain sources (Kellison 1968, Lotti 1955). Apparently, there is a yellow-poplar ecotype adapted to the highly organic and poorly-drained soils of the Coastal Plain. In Tennessee, seedlings from high elevations have not grown as well as those from lower elevations even when planted at relatively high elevations (Thor 1976).

Wherever research or experience indicates the superiority of a specific non-local source that source should be used. When such information is lacking you should obtain seed from as near the planting site as possible. Local sources will not always grow best, but they will be well enough adapted to the environment to minimize risks of catastrophic losses from adverse weather.

Seedling handling and planting — Even when the nurseryman provides seedlings capable of surviving and growing well, proper stock handling and planting are necessary for success. Yellow-poplar seedlings apparently require more care than hardier species such as pines. Allowing yellow-poplar seedlings to dry out, heat, or freeze during shipment, storage, or planting may seriously reduce early survival.

Seedlings can be kept in bales for a few weeks in a cool, shaded place. They can be heeled-in safely for a longer time but should be planted before new leaves unfold. Refrigeration at about 36° F is best for long-term storage (Limstrom 1963). At Sewanee, Tennessee, cold storage has kept seedlings dormant and in good condition for almost six months. Cold storage, however, does not eliminate the need for reasonable care; bales should be turned about every 2 or 3 weeks to prevent heating and watered before the packing medium feels dry to the touch.

Optimum planting dates vary with local climate. In regions with severe winters, seedlings planted in the fall or winter may be injured by frost heaving, particularly on heavy soils or where intensive mechanical site preparation has removed all cover. Thus spring planting is usually preferable. In central Tennessee and northern Alabama, we usually plant between mid-February and April but have planted as early as January or as late as mid-May. Seasonal weather fluctuations have had no effect on planting success within this range of dates (Russell and others 1970).

The choice of planting methods depends mainly on the size of the planting area, its soils, topography, and the density of residual trees, brush, and logging debris. Although relatively little yellow-poplar has been planted with machines, machine planting has worked well on suitable terrain. Most yellow-poplar planting has been done by hand, using the bar-slit technique. The main requirement for hand planting is that the tool selected should be adapted to the soils of the planting site and make a hole large enough to accomodate the yellow-poplar root system.

Roots and shoots are often pruned in the nursery to reduce costs of packing and shipping. Root pruning tends to increase branching or root mass (Sluder 1964, Thor 1965) and may improve survival and early growth (Limstrom and others 1955, Sterling and Lane 1975). Roots should not be pruned without also clipping tops as this may reduce first-year growth. Seedlings that have not been pruned at the nursery can be pruned in the field for ease in handling and planting. Overlong roots should be cut back to about 10 inches; tops can be clipped to a length of 12 to 18 inches.

Choice of spacing depends on such factors as length of rotation, product size objective, anticipated survival, and whether or not plantations can be thinned profitably. There is little specific information about the effects of spacing on growth of planted yellow-poplar. Average heights of a 22-year-old plantation in Michigan were not affected by spacings ranging from 8 x 8 to 14 x 14 feet. Although mean diameters for the entire stand increased progressively with wider spacings, diameters of the largest 100 trees per acre were about the same at all spacings (Rudolph and others 1965). One general planting guide recommends giving yellow-poplar seedlings 60 to 90 square feet of growing space (McElwee 1970). Most of Sewanee's studies have been planted at spacings of 6 x 8 or 7 x 7 feet (about 900 trees per acre). In view of the excellent survival achieved, narrower spacing probably cannot be justified.

Control of Competing Vegetation

A crucial question facing the forest manager concerns the amount of competition control needed for satisfactory establishment and growth of yellow-poplar. Seedlings grow so fast that they can outstrip much low-growing vegetation on cutover sites, but they are also intolerant and will not persist for long in the understory or grow well on clearcut areas if overtopped by faster growing sprouts (Olson 1969). Lack of overstory removal and cleanings was a major reason for the poor performance of yellow-poplar in North Carolina even when planted on suitable sites (Boyette 1970).

Some general recommendations for planting hardwoods indicate that complete site clearing and one or more years of rigorous weed control are essential for successful hardwood establishment (Belanger and Saucier 1975, Kellison 1971, Nugent 1971, Smith 1973). But studies of yellow-poplar plantations indicate that satisfactory performance can be obtained on many sites without resorting to such intensive practices.

Chemical Control. — Research in central Tennessee and northern Alabama demonstrates that yellow-poplar can perform reasonably well on cutover sites of intermediate quality without complete elimination of competing vegetation (Russell and others 1970). Competition control methods commonly used when planting pines in these regions have also worked well with yellow-poplar. Where understories were sparse, with few trees under 2 inches dbh, deadening hardwoods by girdling, frilling, or injecting with a herbicide was all that was needed to insure satisfactory survival and growth of planted poplar. Similar techniques for underplanting and release have also worked in West Virginia (Carvell 1966b).

A recent study on the Cumberland Plateau illustrates how well yellow-poplar can grow on average sites with minimum site preparation and no follow-up cleaning (McGee 1977). Yellow-poplars were planted at a spacing of 7 x 7 feet. Before treatment the stand consisted of several species of oaks, hickories, red maple, sourwood and an occasional yellow-poplar. Basal area in trees over 4 inches dbh was 40 square feet per acre. The midstory had 650 hardwoods per acre smaller than 4 inches dbh but larger than 1 inch dbh. Understory stems smaller than 1 inch dbh varied from 5000 to 10,000 per acre over the study area. Where only the unwanted hardwoods over 2 inches dbh were injected, planted yellow-poplars averaged 25 feet in height and 2.3 inches in diameter after 10 years. Controlling all hardwoods boosted average height to 31 feet and average diameter to 3.2 inches. Survival after 10 years was 76 percent for both treatments. Even though complete control of competing hardwoods improved growth, the much cheaper treatment has provided 122 trees per acre 4 inches dbh and larger — an adequate number of crop trees for management.

On high-quality sites the minimum treatments described above will not provide sufficient release for adequate performance of yellow-poplar. Here a fairly complete control of small understory hardwoods will be needed. Foliar sprays before planting provide the only practical way to control dense thickets of small hardwoods and brush where mechanical clearing is not feasible.

Plantations should be checked annually for up to 5 years to determine whether additional release is necessary. On intermediate sites where stems 4.5 feet high and larger are killed before seedlings are planted, follow-up cleanings should seldom be needed. On high-quality sites, even preplanting foliar sprays seldom completely eliminate small hardwoods, and hand cleaning may often be needed. Cleaning can be done by cutting or basally spraying competing stems (Limstrom 1963). Area-wide foliar sprays cannot be used after planting because yellow-poplar is too sensitive to herbicides. In natural stands, total release of sapling yellow-poplars from competition significantly reduced height growth (Allen and Marquis 1970). Thus, cleaning should be limited to freeing only overtopped or severely crowded trees, and complete removal of all unwanted hardwoods should not be attempted.

Mechanical Control. — Intensive mechanical site preparation can be used in areas of gentle topography and nonerosive soils and essentially eliminates problems from unwanted hardwoods. However, on any site good enough to grow yellow-poplar, complete site clearing usually triggers a succession of dense herbaceous vegetation.

Although we have no direct comparisons, early growth on mechanically prepared Cumberland Plateau sites without weed control or fertilization has usually been somewhat poorer than growth on the same soils where unwanted hardwoods were deadened with chemicals. This suggests that drastic disturbance may lower the productivity of some upland sites for yellow-poplar, possibly because soil properties are altered or because complete clearing promotes a heavy invasion of herbaceous weeds and grasses.

Even though yellow-poplar can be planted on mechanically cleared sites without postplanting weed control, these treatments may greatly increase early growth. On well-drained alluvial sites in Georgia that were clearcut, sheared, and disked, control of invading herbaceous weeds markedly increased early growth of planted yellow-poplar (Fitzgerald and Selden 1975). Both survival and height growth in plantations in Iowa were improved by eliminating a dense grass sod (Erdman 1967).

Yellow-poplar seems to respond increasingly from moderate release up to complete elimination of herbaceous vegetation on sites where grasses and broadleaved weeds are a problem. Such intensive culture may not be practical now but may have a place in the future management of yellow-poplar wherever the objective is to achieve the full potential of the species.

Weed control on fertilized plantations. — Yellow-poplar reacts positively to nutrient additions, especially nitrogen (Broadfoot and Ike 1968, Ike 1972), and favorable responses have been obtained in several old-field plantations (Auchmoody and Wendel 1973, Blackmon and Broadfoot 1970, Farmer and others 1970, Finn and White 1966). Fertilizers increase growth and shorten the period to crown closure but also greatly stimulate weeds and increase the need for weeding.

Results from two recent unpublished studies at Sewanee show how postplanting weed control and fertilization can influence growth of yellow-poplar on Cumberland Plateau sites of average quality.[1] Both areas were prepared by shearing, windrowing, and disking. For both studies, fertilizers were applied at the start of the second growing season after planting at a rate of 150 pounds of nitrogen and 100 pounds of phosphorus per acre. Weed control treatments were started in the second growing season as soon as weeds began vigorous growth and were repeated whenever regrowth averaged about 18 inches in height. In the first trial, fifth-year heights averaged 11.1 feet where weeds were controlled for 2 years by mowing, 12.1 feet on broadcast fertilized plots, and 7.9 feet on plots that were neither mowed nor fertilized. Combining weed control with fertilization boosted fifth-year heights to 14.3 feet. In the second study, where fertilizers were applied to 4-foot-wide strips that were then cultivated yellow-poplars averaged 7.5 feet 2 years after planting (fig. 1). Heights were 5.9 feet on strips that were only cultivated and 5.5 feet on strips that were only fertilized. Second-year heights of seedlings that received no postplanting treatments averaged 3.2 feet.

[1]These continuing studies are recorded in the files of the Sewanee Silviculture Laboratory as studies 1105-1.22 and 1105-1.32.

Prospective Growth

Reluctance to accept planting as a viable way to regenerate yellow-poplar results partly from land managers' lack of confidence in being able to obtain adequate growth. Plantations growing on suitable sites are scarce, especially those that are old enough that we can forecast their ultimate growth. However, there is enough experience from a number of regions to show that satisfactory growth is possible and under appropriate conditions is not difficult to obtain.

Possibly the best recorded growth of planted yellow-poplar was on a bottomland old field in the Piedmont of Georgia where dominants attained an average height of 70 feet in 17 years (Nelson and Jackson 1956). In a

Figure 1 — A 2-year-old plantation on a sheared and disked site on the Cumberland Plateau. Trees were fertilized 1 year after planting and were cultivated during the second growing season.

Tennessee provenance trial with fertilization and weed control, the best seed source averaged 48 feet in height and 6 inches dbh fifteen years after planting on good agricultural soil (Thor 1976).

Two additional plantations in Tennessee illustrate the performance of planted yellow-poplar on cutover forested sites of widely differing quality.[2] One, located on a broad ridge on top of the Cumberland Plateau, has a 50-year yellow-poplar site index estimated to be 85. The second plantation is on a steep northwest facing slope of the Plateau escarpment and, with site index of about 110, typifies the best hardwood sites in the area. For both plantations site preparation consisted of applying a herbicide in frills to residual hardwoods over two inches in diameter and as a basal spray to smaller stems in the moderately dense understory. Seedlings were planted at a spacing of 5 x 5 feet, and both plantations were thinned after their eighth year to maintain diameter growth. After thinning, stands on the Plateau ridge and Plateau slope had 505 and 440 trees per acre, respectively.

Fifteen years after planting, yellow-poplars on the Plateau ridge averaged 34 feet in height and 3.7 inches dbh (fig. 2). The best 20 percent of the stand averaged 41 feet in height and 5.0 inches in diameter. On the Plateau slope, average height of the total stand was 51 feet and dbh was 5.4 inches (fig. 3). Trees in the top 20 percent averaged 59 feet and 6.8 inches.

Diameter distributions in these 15-year-old plantations provide additional insight into the prospective performance of yellow-poplar planted on cutover forested lands:

Planting Site	DBH — Inches								
	<4	4	5	6	7	8	9	>9	Total
	Number of stems per acre								
Plateau ridge	239	151	76	29	9	—	—	—	504
Plateau slope	67	91	109	84	49	27	7	6	440

Conclusions

Recent research and experience indicates that planting yellow-poplar is technically and biologically feasible. Expanded planting programs should be considered first on sites in the site-index range of 85 to 100. On these intermediate sites, yellow-poplar grows fairly well, and competition is less formidable than on higher quality sites. Planting should be particularly attractive where repeated high-grading, fires, or grazing have eliminated the yellow-poplar seed source. This situation occurs

[2] Eight-year results for these plantings were reported in Research Paper SO-63 as Plateau-ridge Plantation, No. 3 and Cove Plantation No. 12 (Russell and others 1970).

Figure 2.—A 15-year-old plantation on a Cumberland Plateau ridge with site index 85 for yellow-poplar.

Figure 3.—A 15-year-old plantation on a good Cumberland Plateau site.

throughout the range of yellow-poplar, but many suitable sites on the southern Appalachian plateaus that now support poorly stocked stands of low-grade oaks or oak-hickory are prime examples. Even where natural regeneration is feasible, planting may be desirable to promptly secure desired stand density and species composition. Also, planting is the only way to introduce genetically superior stock when it becomes available.

On hundreds of thousands of acres throughout the range of yellow-poplar unproductive hardwood stands have been or will be converted to pine. But on any tract of appreciable size there are almost always soils suitable for growing yellow-poplar. On these sites, planting yellow-poplar is an available alternative that deserves consideration.

Literature Cited

Allen, Rufus H., Jr. and David A. Marquis.
1970. Effect of thinning on height and diameter growth of oak and yellow-poplar saplings. U.S. Dep. Agric. For. Serv. Res. Pap. NE-173, 11 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Auchmoody, L. R. and G. W. Wendel.
1973. Effect of calcium cyanamide on growth and nutrition of planted yellow-poplar seedlings. U.S. Dep. Agric. For. Serv. Res. Pap. NE-265, 11 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Belanger, Robert P. and Joseph R. Saucier.
1975. Intensive culture of hardwoods in the South. Iowa State J. Res. 49: 339-344.

Blackmon, B. G. and W. M. Broadfoot.
1970. Fertilizer improves poplar growth. Miss. Farm Res. 33(11): 7.

Boyette, Warren G.
1970. Evaluation of yellow-poplar plantings in North Carolina 1947-1966. Unpublished Master's Thesis. Va. Polytechn. Inst., Blacksburg, 84 p.

Broadfoot, W. M. and A. F. Ike.
1968. Research progress in fertilizing southern hardwoods. *In* Forest Fertilization... Theory and Practice, p. 180-184, TVA Natl. Fert. Develop. Center, Muscle Shoals, Ala.

Carmean, Willard H.
1970. Site quality for eastern hardwoods. *In* The silviculture of oaks and associated species, U. S. Dep. Agric. For. Serv. Res. Pap. NE-144, p. 36-56. Northeast. For. Exp. Stn., Upper Darby, Pa.

Carmean, Willard H., F. Bryan Clark, Robert D. Williams, and Peter R. Hannah.
1976. Hardwoods planted in old fields favored by prior tree cover. U. S. Dep. Agric. For. Serv. Res. Pap. NC-134, 16 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Carvell, Kenneth L.
1966a. Combat herbaceous competition with the use of large yellow-poplar planting stock. W. Va. Agric. Exp. Stn. Bull. 520, p. 3-4, 16.

Carvell, Kenneth L.
1966b. Underplanting: A method of replacing unproductive hardwood stands with yellow-poplar. W. Va. Agric. Exp. Stn. Bull. 523, p. 3-5, 19.

Clark, F. Bryan.
1964. Micro-organisms and soil structure affect yellow-poplar growth. U. S. Dep. Agric. For. Serv. Res. Pap. CS-9, 12 p. Cent. States For. Exp. Stn., Columbus, Ohio.

Clark, F. Bryan and Craig K. Losche.
1969. Importance of the A horizon in hardwood seedling establishment. J. For. 67: 504-505.
Doolittle, Warren, T.
1958. Site index comparisons for several forest species in the Southern Appalachians. Soil Sci. Soc. Am. Proc. 22: 455-458.
Erdmann, Gayne G.
1967. Chemical weed control increases survival and growth in hardwood plantings. U.S. Dep. Agric. For. Serv. Res. Note NC-34, 4 p. North Cent. For. Exp Stn., St. Paul, Minn.
Farmer, R. E., Jr., T. E. Russell, and R. M. Krinard.
1967. Sixth-year results from a yellow-poplar provenance test. Proc. 9th South. Conf. For. Tree Improv., p. 65-68.
Farmer, R. E., Jr., E. A. Snow, and J. W. Curlin.
1970. Effects of nitrogen and phosphorus fertilization on juvenile growth of planted yellow poplar on an eroded old field. Soil Sci. Soc. Am. Proc. 34: 312-313.
Finn, Raymond F. and Donald P. White.
1966. Commercial fertilizers increase growth in a yellow-poplar plantation. J. For. 64: 809-810.
Fitzgerald, Charles H. and Charles W. Selden, III.
1975. Herbaceous weed control accelerates growth in a young yellow poplar plantation. J. For. 73: 21-22.
Funk, David T.
1958. Frost damage to yellow-poplar varies by seed source and site. U.S. Dep. Agric. For. Serv. Stn. Note CS-115, 2 p. Cent. States For. Exp. Stn., Columbus, Ohio.
Funk, David T., G. A. Limstrom, and Paul R. Laidly.
1974. Tall yellow-poplar seedlings still three years ahead of others. U.S. Dep. Agric. For. Serv. Tree Planters' Notes 25(1): 8-9.
Gilmore, A. R., W. A. Geyer, and W. R. Boggess.
1968. Microsite and height growth of yellow-poplar. For. Sci. 14: 420-426.
Ike, Albert F.
1972. Fertilization review — yellow-poplar. *In* Forest fertilization research in the South: a review and analysis, p. 53-59. South Coop. Series. Bull. 158, Texas Agric. Exp. Stn., College Station.
Kellison, R. C.
1968. Natural variation of yellow-poplar in North Carolina. 15th Northeast. For. Tree Improv. Conf. Proc., p. 7-14.
Kellison, R. C.
1971. Hardwood management philosophies and practices. *In* Proc. Symp. on Southeastern Hardwoods, p. 8-16. U.S. Dep. Agric. For. Serv. Southeast. Area, State and Private For., Atlanta, Ga.
Limstrom, G. A.
1963. Forest planting practice in the Central States. U.S. Dep. Agric. For. Serv., Agric. Handb. 247, 69 p.
Limstrom, G. A. and Raymond F. Finn.
1956. Seed source and nursery effects on yellow-poplar plantations. J. For. 54: 828-831.
Limstrom, G. A., R. F. Finn, and G. H. Deitschmann.
1955. Planting stock grades for yellow-poplar. J. For. 53: 28-32.
Loftus, Nelson S.
1971. Yellow-poplar root develoment on Hartsells subsoils. U.S. Dep. Agric. For. Serv. Res. Note SO-131, 5 p. South. For. Exp. Stn., New Orleans, La.
Lotti, Thomas.
1955. Yellow-poplar height growth affected by seed source. U.S. For. Serv. Tree Planters' Notes 22: 3.
McElwee, R. L.
1970. Artificial regeneration of hardwoods. *In* The silviculture of oaks and associated species. U.S. Dep. Agric. For. Serv. Res. Pap. NE-144, p. 17-25. Northeast. For. Exp. Stn., Upper Darby, Pa.
McGee, Charles E.
1977. Planted yellow-poplar grows well after essential site preparation. U.S. Dep. Agric. For. Serv. Tree Planters' Notes 28(1): 5-7.
Nelson, T. C. and L. W. R. Jackson.
1956. Yellow-poplar plantations. For. Farmer 15(10): 11.
Nugent, John.
1971. Artificial regeneration research. *In* Proc. Symp. on Southeast. Hardwoods, 1971, p. 50-55. U.S. Dep. Agric. For. Serv. Southeast. Area, State and Private For., Atlanta, Ga.
Olson, David F., Jr.
1969. Silvical characteristics of yellow-poplar *(Liriodendron tulipifera* L.). U.S. Dep. Agric. For. Serv. Res. Pap. SE-48, 16 p. Southeast. For. Exp. Stn., Asheville, N. C.
Olson, David F., Jr. and Lino Della-Bianca.
1959. Site index comparisons for several tree species in the Virginia-Carolina Piedmont. U.S. Dep. Agric. For. Serv. Stn. Pap. SE-104, 9 p. Southeast. For. Exp. Stn., Asheville, N. C.
Rodenbach, Richard C. and David F. Olson, Jr.
1960. Grading yellow-poplar planting stock is important. U.S. Dep. Agric. For. Serv. Res. Note SE-147, 2 p. Southeast. For. Exp. Stn., Asheville, N. C.
Rudolph, V. L., J. N. Bright, and T. D. Stevens.
1965. A spacing study of planted yellow-poplar in Michigan. Mich. Agric. Exp. Stn. Q. Bull. 47: 615-622.
Russell, T. E., N. S. Loftus, A. L. Mignery, and G. W. Smalley.
1970. Planting yellow-poplar in central Tennessee and northern Alabama. U.S. Dep. Agric. For. Serv. Res. Pap. SO-63, 17 p. South. For. Exp. Stn., New Orleans, La.
Sluder, E. R.
1960. Early results from a geographic seed source study of yellow-poplar. U.S. Dep. Agric. For. Serv. Res. Note SE-150, 2 p. Southeast. For. Exp. Stn., Asheville, N. C.
Sluder, E. R.
1964. Quality of yellow-poplar planting stock varies by mother tree and seedbed density. U.S. For. Serv. Tree Planters' Notes No. 65: 16-19.
Smalley, Glendon W.
1969. Ten-year growth of yellow-poplar planted in north Alabama. J. For. 67: 567-568.
Smith, H. Donnell.
1973. Decision-making under uncertainty: Should hardwood plantations be established? Sch. For. Resourc. N. C. State Univ. Tech. Rep. No. 49, 62 p. N. C. State Univ., Raleigh.
Sterling, Kenneth A. and Carl L. Lane.
1975. Growth and development of shoot and root pruned yellow-poplar seedlings on two sites. U.S. Dep. Agric. For. Serv. Tree Planters' Notes 26(3): 1-2, 25.
Thor, E.
1965. Effects of eight nursery treatments on yellow-poplar seedling characteristics and field performance. U.S. For. Serv. Tree Planters' Notes No. 72: 16-18.
Thor, Eyvind.
1976. Tree breeding at the University of Tennessee 1959-1975. Univ. Tenn. Agr. Exp. Stn. Bull. 554, 48 p.
Tryon, C. P., T. W. Beers, and C. Merritt.
1960. The measurement of site quality for yellow-poplar. J. For. 58: 968-969.

Russell, T. E.
1977. Planting yellow-poplar — where we stand today. U.S. Dep. Agric , For. Serv. Gen. Tech. Rep. SO-17, 8 p. South. For. Exp. Stn., New Orleans, La.

This review of published research on planting yellow-poplar indicates that workable guides are now available for site selection, planting practices, and competition control. With these guides, land managers can plant yellow-poplar successfully on a wide variety of sites.

Additional keywords: *Liriodendron tulipifera* L. planting, regeneration of hardwoods.