



MINI- ROTATION FORESTRY

by Ernst J. Schreiner

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-174
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

THE AUTHOR

ERNST J. SCHREINER, principal forest geneticist, received his bachelor's degree from the New York State College of Forestry at Syracuse in 1926, and his Ph.D., with a major in genetics, from the Faculty of Pure Science of Columbia University in 1931. In April 1924, shortly before the end of his Senior year, he accepted employment as research forester to start the Cooperative Oxford Paper Company—New York Botanical Garden Poplar Hybridization Project under the supervision of Dr. A. B. Stout, plant geneticist at the Botanical Garden. In 1935 he accepted the post of associate tree-crop specialist with the Forestry Division of TVA to initiate breeding work with tree-crop species. He joined the USDA Forest Service's Northeastern Station in New Haven, Connecticut, in 1936 and began the Forest Service tree-breeding research in the Northeast. Within the past 7 years he has been appointed adjunct professor of forestry at the State Universities of New Hampshire and Pennsylvania. At present he is stationed at the Northeastern Station's Forestry Science Laboratory in Durham, New Hampshire.

Dr. Schreiner has had wide foreign experience, including advisory assignments on quinine breeding in Guatamala and on poplar breeding and forest genetics in Yugoslavia, a 1-year Fulbright Research Fellowship in Europe on poplar culture and forest genetics, and an FAO consultant assignment on plant gene resources. He has had an active part in eight international conferences on forestry and forest genetics. He is a Fellow of the Society of American Foresters.

MANUSCRIPT RECEIVED FOR PUBLICATION 17 JUNE 1970.

Mini- Rotation Forestry

*A paper presented at the spring meeting of the Northeastern
Technical Division of The American Pulpwood Association,
at Gorham, New Hampshire, 26 May 1970.*

IT HAS BEEN SAID that there is nothing new under the sun; and originality has been defined as the art of remembering what you hear and forgetting where you heard it. This paper is an attempt to utilize ideas, predictions, estimates, and facts from many sources to chart a possible avenue of approach for future production of fiber and timber in the Northeast.

I am not an economist and will not attempt to predict forestry's future economic environment. It has been said that, if all the economists in the world were laid end to end, they would still point in all different directions. I will quote briefly four economists who are pointing in the directions I like.

Pointing to the Future

Fedkiw (1970), writing about *Forestry's Changing Economic Environment*, noted that, "Forestry will have to go all out for genetically superior trees, fertilization, stocking and brush control, sycamore silage, highly intensified utilization, and other new technologies." And he added that, "There has never been a greater need for enlightened leadership and exploding innovations in forestry practice."

According to Wheeler (1960), the report of the Southern Resource Analysis Committee, titled *The South's Third Forest*,

includes an estimate that some 10 million acres of forest land in the South will be withdrawn for agriculture, urban expansion, rights-of-way, reservoirs, recreation, and other uses by the end of the century.

Drysdale (1969) hazards a guess that, by the year 2010, Canada will be retiring about one-third of its most expensive and least productive forest sites from the production of commercial wood products to concentrate major wood-production efforts on forest lands that have the best combination of productive capacity, accessibility, and proximity to markets.

How much forest land will be available for *profitable* timber production in the Northeast by the end of this century?

The key to continued and increased production of wood and fiber in the Northeast may well be the private landowners; their lands are usually the most accessible and most productive areas available for intensive forest culture.

Fields (1969) reported that a recent survey conducted by the Tennessee Valley Authority in the seven Tennessee Valley States indicated that approximately 139 thousand acres of private forests were already under long-term lease to a forest industry or some other party. More important, owners of almost 4 million acres said they might be interested in such an arrangement.

Swan (1969) has presented a dim picture of the availability of woods labor in the Northeast at present; and there is no reason to expect that it will improve in the future. He notes that young men can be recruited and trained to operate logging equipment—but by logging equipment I assume that he means only heavy equipment, not the chain saw. How much chain-saw labor will be available for the harvesting of fiber and timber in 1980? And how much will it cost?

Drysdale (1969) has suggested that in Canada during the next 40 years there will be a gradual switch from a single-tree harvesting system, in which the size of the individual tree is economically important, to a multi-tree system that depends more on the total volume per acre and provides an opportunity to take advantage of shorter rotation periods. We will not have as much as 40 years to effect such a change in our Northeast.

THE NEED FOR INTENSIVE SHORT-ROTATION FORESTRY

The probability of a shortage of softwoods in the Northeast for fiber and lumber is generally admitted. Although we are already aware of a serious shortage of quality logs for the hardwood lumber industry, it appears to be the general opinion that there will be no shortage of hardwood for conversion to fiber. Can we count on this? The hardwood will be here 10 or 20 years from now, but it is highly probable that a combination of the lack or high cost of chain-saw labor to harvest forest crops on the steep terrain in this region, and public pressure against clearcutting of the lowland forest areas visible from practically all of our highways, will result in a short and expensive supply of hardwood fiber.

We are now harvesting our Fourth—practically unmanaged—Forest. The First Forest was harvested with ax and oxen; the Second with the two-man saw, horses, and narrow-gage railroads; the Third with the buck saw, horses, and tractors; and the Fourth is now being managed and harvested with the chain-saw and tractors.

The Fifth Forest of the Northeast will have to be managed intensively. And it will have to be established, cultured, and harvested by machine.

The length of rotations in our Fourth Forest of the Northeast under *present* management recommendations for *present* utilization requirements are indicated in tables 1 and 2.

Table 1.—Years to reach a given mean diameter, by site index for managed (thinned) stands of mixed northern hardwoods ¹

Mean d.b.h. (inches)	Site index		
	70	60	50
	<i>Years</i>	<i>Years</i>	<i>Years</i>
5.0	33	38	44
9.0	62	77	93
15.0	118	—	—

¹ Excerpt from William B. Leak *et al.* (1969, p. 20).

Table 2.—Expected rotation ages and sizes for stands under management ¹

Species and objective	Paper birch site index (height at b.h. age 50)	Average diameter ²	Age
	<i>Feet</i>	<i>Inches</i>	<i>Years</i>
Paper birch boltwood	70	9	45
	50	8	65
Paper birch sawtimber	70	11	65
	50	9	75
Other hardwoods sawtimber	70	15	120
	50	11	135
Spruce-fir pulpwood	70	9	65
	50	8	75
Spruce only, sawtimber	70	14	120
	60	13	135

¹ Excerpt from David A. Marquis *et al.* (1969, p. 40).

² Average diameter of the species shown, not of the entire stand.

Table 1 gives estimates of the years to reach a given mean diameter, for managed (thinned) stands of mixed northern hardwoods. Estimates for a mean stand diameter of 5 inches are 33 years (site 70) to 44 years (site 50); for a 9-inch mean stand diameter, 62 years (site 70) to 93 years (site 50); and for a 15-inch mean stand diameter, 118 years on site 70.

Table 2 lists the expected rotation ages and sizes for two site qualities for paper birch for boltwood and sawtimber, for other hardwoods for sawtimber, for spruce-fir for pulpwood, and for spruce for sawtimber. The expected rotations for paper birch are: boltwood with an average stand diameter of 9 inches on site 70, 45 years; boltwood with an 8-inch average stand diameter on site 50, 65 years; sawtimber on site 70, 65 years; and sawtimber on site 50, 75 years. The rotation age in managed stands for hardwood sawtimber of other species has been estimated as 120 years for site 70, and 135 years for site 50. For spruce-fir pulpwood the estimated rotation for average 9-inch diameter wood is 65 years for site 70 and 75 years for 8-inch average stand diameter on site 50. For spruce sawtimber, the rotation ages are estimated at 120 years for site 70 and 135 years for site 60.

THE POSSIBILITIES FOR INTENSIVE SHORT-ROTATION FORESTRY

I predict that by 1980 our present long-rotation, chain-saw forestry will have begun to give way to intensive short-rotation forestry. And this could be started on our best sites with densely stocked young stands.

Although we do not have the large expanses of flat or rolling forest land most suitable for the use of heavy machinery, our climate and most of our soils are conducive to maximum wood production under intensive culture with the elimination of practically all hand labor. Heavy equipment is already available for intensive silviculture, including site preparation, planting, cultivation, thinning, and harvesting.

Hayes (1970) has reported the cost range for site preparation—including clearing, debris treatment, soil preparation, and planting—as from \$25 to \$45 per acre. He concludes that, “A new technological breakthrough is long overdue. We have tried to beat trees to death, poison them, chew them up, and drive them into the ground; but we usually revert to overpowering them.”

The economical establishment of densely stocked conifers and hardwoods that cannot now be propagated from cuttings will require direct-seeding. A furrow-seeder is available that can direct-seed an acre of white or red pine, in furrows spaced 12 feet apart, in approximately 15 minutes on an open field with a 0- to 8-percent slope; and in approximately 32 minutes on a brushy hillside with a 10- to 20-percent slope (*Graber and Thompson 1969*).

An efficient machine for planting dormant hardwood cuttings has been developed and used in the nursery at Indian Head, Saskatchewan. A four-row machine can plant 30,000 cuttings per hour with a crew of ten. This includes the labor for transporting the cuttings to the field and replenishing the cutting boxes on the planter (*Cram 1969*).

A mechanized harvesting-thinning machine has been designed to mechanically harvest undersized timber in overstocked natural stands and in plantations. The smaller timber could not be harvested manually because of excessive cost, but this new machine

is said to be turning this operation into a profit-maker (*Anon.* 1968).

Machine thinning will require mechanical (line or row) thinning rather than selective silvicultural thinning. Shortage of labor for forest management in Poland has led to research on machine thinnings. Bernadski (1969) has reported that line thinning, when compared with selection thinning, has resulted in reducing the number of the most valuable trees and has decreased the possibility for selection of plus trees. However, the negative impact of this thinning is more strongly marked in stands of poor quality than in stands of high quality growing at dense spacing.

MINI-ROTATION FORESTRY, THE FIFTH FOREST OF THE NORTHEAST

According to Wheeler (1960), "Even now the Third Forest of the South is beginning to materialize. Over 15 million acres—an area about the combined size of New Hampshire, Connecticut, Delaware, and Maryland—have been planted in pines."

How soon can we start to obtain the practical know-how needed to establish our Fifth Forest of the Northeast for mini-rotation forestry on the more productive and accessible lands, and in young, fully stocked natural stands that are available for fiber and timber production? We should have started at least 20 years ago. The eventually irresistible pressure of public opinion and limited land and woods labor will become effective much sooner than the selection and creation of genetically superior fast-growing trees and the development of establishment and cultural methods needed for maximum forest production on mini-rotations.

I am suggesting the term "mini-rotation forestry" to include the production of fiber, on rotations of 2 to 4 or 5 years (mini-rotation fiber production);¹ boltwood for fiber, particle board, or other uses on rotations of 6 to 15 years (mini-rotation boltwood production); and lumber and veneer logs on rotations of 15 to 30 years (mini-rotation timber production). Depending on the

¹ The utilization of juvenile growth of sycamore for fiber has been called "silage" sycamore by McAlpine *et al.* (1966).

species and the product, mini-rotations (like mini-skirts) may be of various lengths, but always short for the particular objective.

One or several species, varieties, or hybrids may be grown in mixture for one, two, or all three mini-rotations (fiber, boltwood, or timber).

Mini-rotation forestry will require: (1) machine site preparation, planting, cultivation, and harvesting; (2) intensive culture, including fertilization on good sites; (3) fast-growing superior varieties or hybrids; and (4) utilization of small stem-wood, and if possible, branch-wood.

The advantages of mini-rotation forestry will be: (1) early amortization of the cost of site preparation, planting, and early culture; (2) very much smaller land areas for the production of large quantities of fiber or timber; (3) profitable use of the most highly productive and economically manageable lands; and (4) smaller and cleaner clearcut area that are less likely to be objectionable to the general public.

Mini-rotation forestry must be based on even-aged culture.

I am fully aware of the possible public objection to clear-cutting, but there never has been any public outcry against the use of large open areas for extensive pasture or agricultural crop production. The main reason for public objection to clearcutting of forest stands may be the extent of such areas and the scraggly appearance of the nonmerchantable residual trees and the large amount of slash and debris left after logging, which aesthetically can be as objectionable as an automobile junk yard.

The utilization of the best productive timber sites for mini-rotation forestry will minimize the area of clearcutting; the less productive parts of forest properties should be left in long-rotation management. The need for intensive culture to maximize wood production on mini-rotations will profit most from complete disposal of slash by chipping all such material, either for commercial utilization or to provide a mulch that can be worked into the soil in fitting the land for the succeeding crop. With such utilization, site preparation at the end of the longest mini-rotation would leave the land with the same appearance as well-kept farm land.

Maximum production of usable material under mini-rotation management will require complete utilization of the site. This will necessitate close planting (the spacing depending on the species or variety and on the length of the longest and/or shortest rotation objective), with frequent thinnings to maintain the growth rate of the remaining stand. Each required thinning must provide a merchantable yield of fiber or boltwood.

Much of the land required for mini-rotation forestry would presently be classified as farmland, either actively farmed or abandoned. There is every indication that the availability of such land for forestry will increase in future years; extensive farming will be profitable on only a relatively small proportion of the land area in the Northeast. Considerable abandoned farmland in private ownership would probably be available for lease by wood-using industries interested in mini-rotation management. The owners themselves would not be in a position to manage for wood production, but either wood-using industries or forest-production companies with sufficient equipment could manage many of these smaller properties for mini-rotation production.

SPECIES AND HYBRIDS FOR MINI-ROTATION TRIALS

The following species and hybrids could be used immediately for small-scale trials of mini-rotation management in the Northeast:

Hardwoods:

- Poplar (*Populus*) hybrids
- Eastern cottonwood (*Populus deltoides* Bartr.)
- Silver maple (*Acer saccharinum* L.)
- Quaking aspen (*Populus tremuloides* Michx.)
- Bigtooth aspen (*Populus grandidentata* Michx.)
- American sycamore (*Platanus occidentalis* L.)
- White birch (*Betula papyrifera* Marsh.)
- Yellow birch (*Betula alleghaniensis* Britton)
- Northern red oak (*Quercus rubra* L.)
- Black cherry (*Prunus serotina* Ehrh.)
- Black willow (*Salix nigra* Marsh.)
- Red maple (*Acer rubrum* L.)
- European black alder [*Alnus glutinosa* (L.) Gaertn.]

Pin cherry (*Prunus pensylvanica* L.)
Gray birch (*Betula populifolia* Marsh.)
Tree of heaven [*Ailanthus altissima* (Mill.) Swingle]

Conifers:

Eastern white pine (*Pinus strobus* L.)
Hybrid larch (*Larix* $\times$ *eurolepis* Henry)
Japanese larch (*Larix leptolepis* Sieb. & Zucc.)
Norway spruce [*Picea abies* (L.) Karst.]
White spruce [*Picea glauca* (Moench) Voss]
Balsam fir [*Abies balsamea* (L.) Mill.]
Scotch pine (*Pinus sylvestris* L.)
Red pine (*Pinus resinosa* Ait.)
Jack pine (*Pinus banksiana* Lamb)
Japanese red pine (*Pinus densiflora* Sieb. and Zucc.)

Some of the species listed above will be suitable only for mini-rotation fiber production (gray birch, pin cherry), others may be used for all three mini-rotations (hybrid poplars, cottonwood, sycamore, white pine, larch). Nonsprouting species, such as the conifers, would require replanting after each harvest cutting. The possibilities of a few of these species will be indicated briefly. The hybrid poplars will be used to present a prototype for mini-rotation management.

Eastern cottonwood. — Superior genotypes of this species will grow as rapidly on the most fertile bottomland sites in the Northeast as cottonwoods do on the highly fertile soils of the batture lands of the Mississippi (figs. 1 and 2).

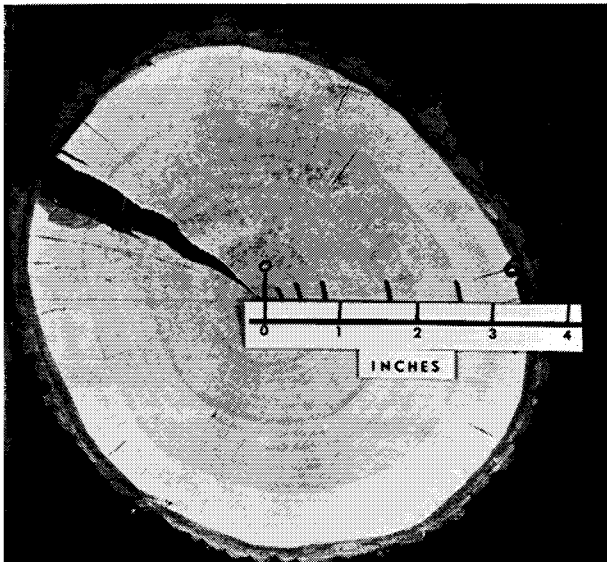


Figure 1.—A d.b.h. (diameter breast high) section from a native eastern cottonwood growing on a bottomland site near Albany, New York. This 6-year-old tree was 6.75 inches in d.b.h. inside bark (i.b.).

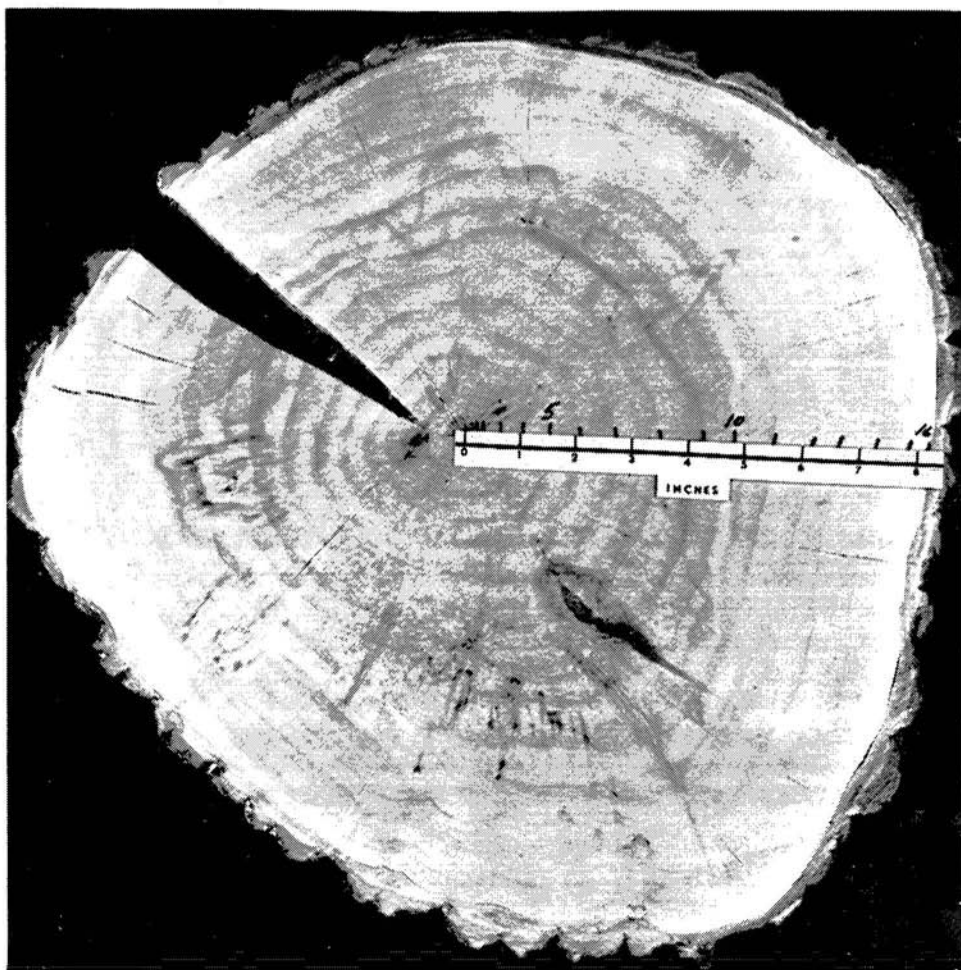
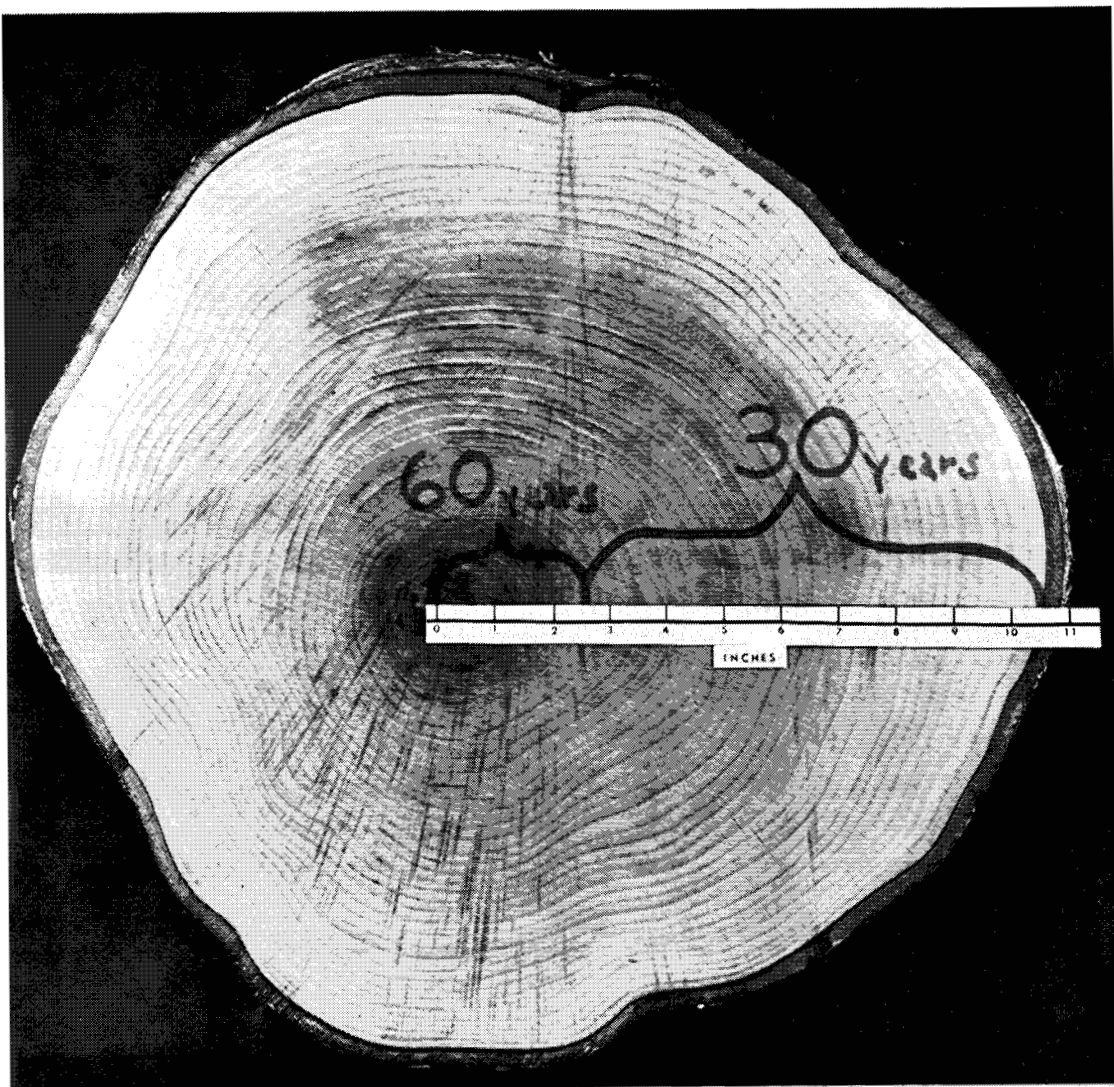


Figure 2.—A d.b.h. section from a 16-year-old eastern cottonwood from a bottomland site in the vicinity of Albany, New York; d.b.h. (i.b.) was 16.5 inches.

Yellow birch. — The growth possibilities of yellow birch are indicated in figure 3. During 60 years of suppression this tree grew approximately 5 inches in diameter at 18 inches above the ground. During the 30 years after release, it demonstrated a diameter growth potential of approximately 0.5 inch per year. This growth rate would be sufficient for mini-rotation timber production in 30 years.

Figure 3.—A yellow birch section taken 18 inches above the ground from a tree cut near Berlin, New Hampshire, 16 inches (i.b.). The total age is 90 years, but the tree was obviously suppressed during the first 60 years. In the last 30 years the tree has grown at a rate that indicates excellent possibilities for selection of genetically fast-growing trees for intensive mini-rotation timber culture.



Silver maple. — H. C. Larsson, of the Ontario Department of Lands and Forests, has been selecting plus trees of this species. Figures 4 and 5 show plus-tree selections in a stand that originated after clearcutting in 1926 (apparently largely from sprout reproduction). Note the gross volume available after approximately 36 years.



Figure 4.—Silver maple selection B-3-6; d.b.h. 12.2 inches; total height 90 feet; stand age approximately 36 years. (Ontario Dep. of Lands and Forests Photo.)



Figure 5.—Silver maple selection B-3-4; d.b.h. 11.0 inches; total height 75 feet; approximate stand age 36 years. (Ontario Dep. of Lands and Forests Photo.)

Hybrid larch. — The case for hybrid larch has been presented by Perry and Cook (1965), and by Cook (1969). The growth rates of five plus trees of the Dunkeld hybrid larch are listed in the following tabulation (*from Cook 1969*):

<i>Name or number</i>	<i>Years planted</i>	<i>D.b.h. (inches)</i>	<i>Height (feet)</i>
4752	3	—	10
4454	6	—	21
4131	11	5.6	32
Bedgebury Giant	12	6.4	40
Giant in No. 19	30	14.4	76
Giant in No. 7	30	16.0	75

Figures 6 and 7 illustrate the growth in Cooxrox Forest, Stephen-town, New York.

Figure 6.—The "Giant in number 19", probably an F_3 hybrid. This stand was planted with 2-0 seedlings in November 1935. The photograph was taken after 30 growing seasons when the Giant was 14.4 inches d.b.h. and 76 feet tall. (D. B. Cook Photo.)





Figure 7.—The "Giant in number 7" was planted as a 2-0 seedling in a single-tree failed spot in a red pine plantation that was established in 1931. After 30 growing seasons, this larch, although 5 years younger than the red pines, was 16.0 inches in diameter and 75 feet in total height—considerably taller than even the best of the red pines. (D. B. Cook Photo.)

Eastern white pine. — The excellent possibilities for mini-rotation management of eastern white pine are apparent in the reported yields of plantations in Pennsylvania (table 3). The first profitable cuttings on the basis of present pulpwood specifications would probably be at 20 years on site index 90 with a *merchantable volume* of 8.5 cords, and on site index 70 at 25 years with 10.4 cords.

With utilization of the *total volume* (small-diameter stemwood), site index 70 would yield 12 cords at 15 years, 23.4 cords at 20 years, and 35.9 cords at 25 years. Site index 90 would yield 14.8 cords at 15 years, 31 cords at 20 years, and 48 cords at 25 years. I believe that all these figures are minimums, that they could be increased by at least 50 percent, and that the earliest yields probably could be doubled by the use of inherently fast-

Table 3.—Eastern white pine. Empirical yield table for 4- x 4-foot plantations in Pennsylvania ¹

Stand age from planting (years)	50-year site index: 70					50-year site index: 90				
	Trees ²	Avg. d.b.h.	Volume			Trees ²	Avg. d.b.h.	Volume		
			Total	Merchant- able	Total			Total	Merchant- able	Total
	<i>No.</i>	<i>In.</i>	<i>Cu. ft.</i> ³	<i>Cords</i> ⁴	<i>Cords</i> ⁵	<i>No.</i>	<i>In.</i>	<i>Cu. ft.</i> ³	<i>Cords</i> ⁴	<i>Cords</i> ⁵
15	1,386	3.3	1,076	0.2	12.0	1,098	4.2	1,332	1.9	14.8
20	1,543	4.2	2,110	3.6	23.4	1,156	5.1	2,787	8.5	31.0
25	1,324	5.0	3,231	10.4	35.9	992	6.0	4,322	19.5	48.0
30	1,104	5.7	4,399	19.5	48.9	793	6.9	5,890	33.5	65.4
35	900	6.4	5,553	30.0	61.7	624	7.9	7,435	50.6	82.6
40	729	7.2	6,655	40.1	73.9	474	9.2	8,894	64.1	98.8
45	594	8.0	7,654	48.6	85.0	349	10.7	10,236	74.5	113.7
50	489	8.8	8,505	56.0	94.5	262	12.3	11,375	83.4	126.4
55	412	9.6	9,224	62.7	102.5	203	14.1	12,327	91.3	137.0

¹ Excerpt from Marty (1965, pp. 53,54). Source data: Delong, Thomas S. (1955).

² All trees 1.0 inch + d.b.h.

³ Total cubic-foot volume including stump, stem, and bark, but not limbwood.

⁴ Rough cords to a variable top of not less than 4.0 inches inside bark, and a 1-foot stump.

⁵ Total cubic-foot volume converted, for this paper, on the basis of 90 cubic feet per cord.

growing trees, closer spacing, adequate site preparation, fertilization, and early cultivation on the better sites available in the Northeast (fig. 8).

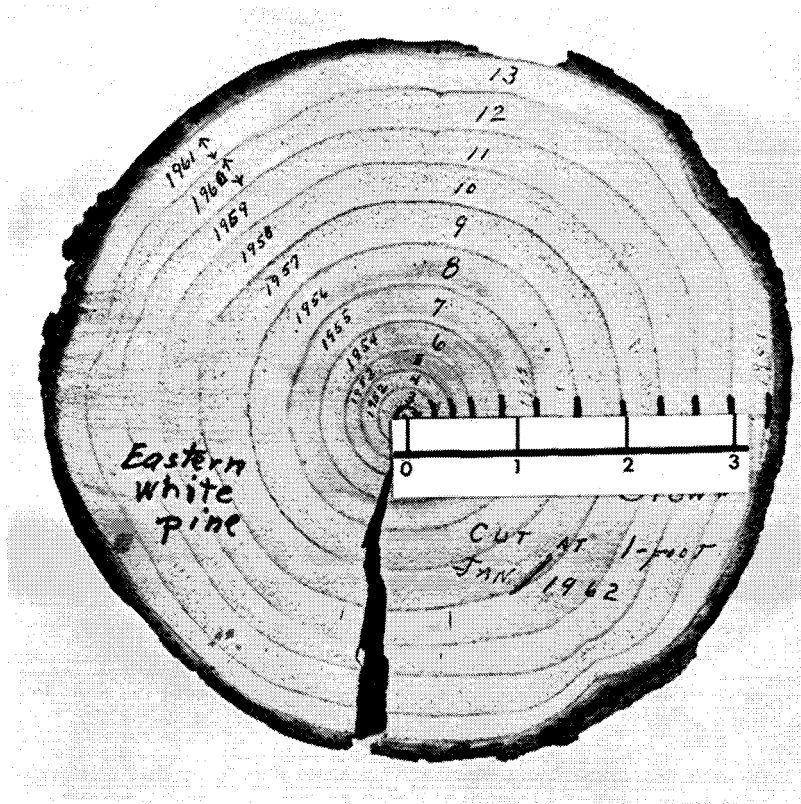


Figure 8.—A section of eastern white pine, cut 1 foot above the ground, to illustrate early growth without plantation culture. Age 13 years, diameter 6.5 inches (i.b.).

White spruce. — Fiber production in 6 to 8 years, boltwood production in 12 to 15 years, and timber production in 30 years will be possible with improved varieties of white spruce under intensive mini-rotation management. The growth possibilities of this species are shown in figures 9 and 10.



Figure 9.—A cross-section of white spruce 20 inches in diameter (i.b.) taken at 1-foot stump height. This tree, from Colebrook, New Hampshire, was 43 years old at the stump, 17 inches in d.b.h. (o.b.), and 58 feet in total height.

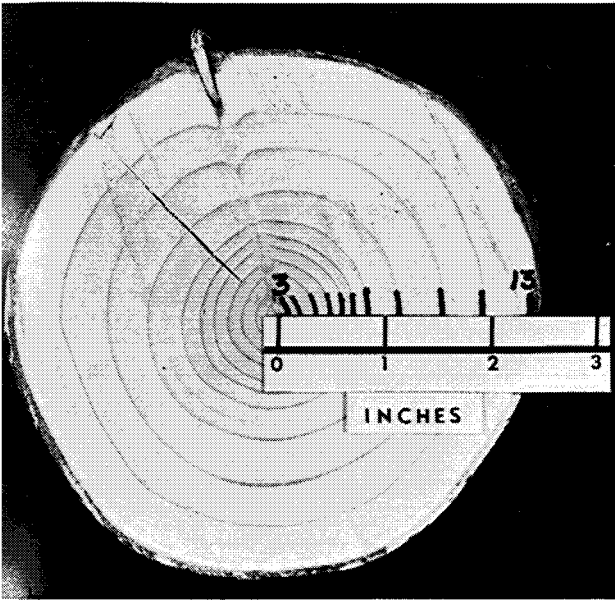


Figure 10.—A cross-section, 24 inches above the ground, of a pedigreed white spruce seedling planted in sod at Williamstown, Massachusetts. The tree was 13 years old from seed; diameter of this section 4.75 inches (i.b.). Note the rapid growth from the 9th to 13th year. Early cultivation and fertilization would have greatly increased the growth rate during the first 9 years.

Norway spruce. — This species has been planted in the Northeast since Colonial days. It usually outgrows white spruce in its early years. Hughes (1970) has reported that the mean annual net increment of a 51-year-old stand in Nova Scotia was 144 merchantable cubic feet per acre, and that this level of production (1.7 cords per acre per year) is almost twice the peak increment shown for site quality 1 in Nova Scotia. Figure 11 indicates the possibilities for rapid juvenile growth of this species.

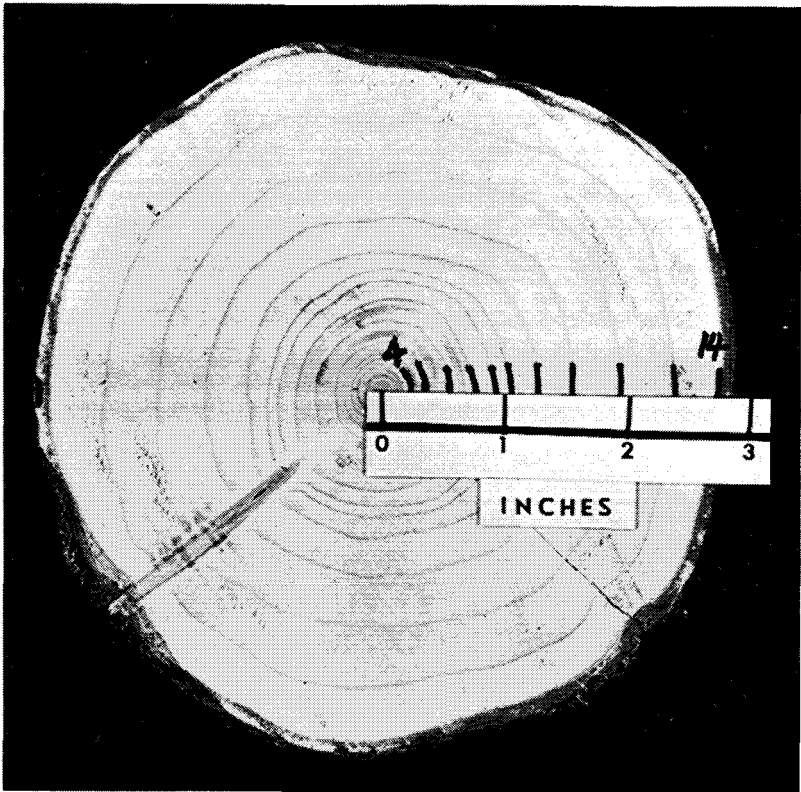


Figure 11.—Norway spruce. A cross-section taken 2 feet above the ground, 5.5 inches in diameter (i.b.). The tree, 14 years old from seed, was planted in sod without cultivation at Williamstown, Massachusetts. Note the improved growth from the 9th to 14th year. Selection for rapid inherent growth, site preparation, and cultivation undoubtedly would have doubled the earlier growth rate.

Scotch pine. — The total volume produced in 18 years by the two best seedlots in a provenance test planted at 8- x 8-foot spacing was 947 and 973 cubic feet per acre, approximately 10 cords (*Schreiner et al.* 1962). This volume could be more than doubled with site preparation, closer spacing, and cultivation. Pedigreed seedlings have grown 9 inches or more in d.b.h. (i.b.) in 15 years from seed without site preparation or cultivation at Williamstown, Massachusetts (fig. 12).

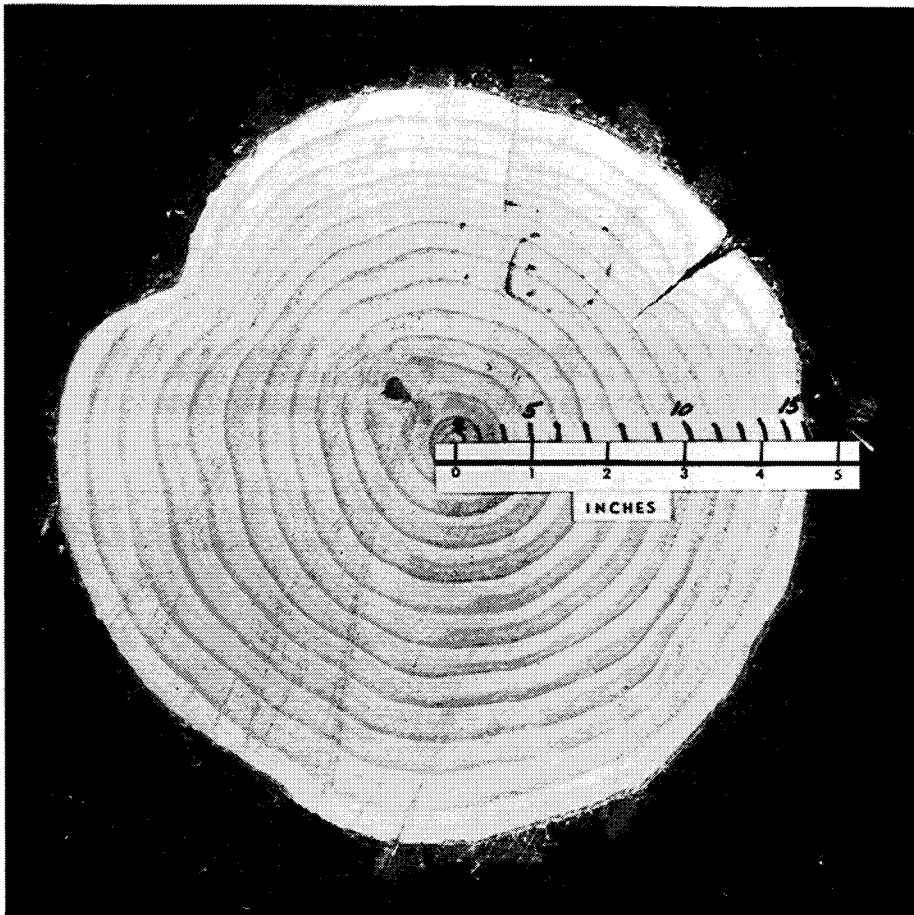


Figure 12.—Scotch pine. A section taken 2 feet above the ground of a Scotch pine 15 years from seed without site preparation or cultivation at Williamstown, Massachusetts, diameter (i.b.) 9.5 inches.

Red pine.— This species should be considered for mini-rotation fiber and boltwood management, particularly on marginal sites. The possibilities for rapid early growth are illustrated in figure 13. Intensive culture of this plantation in Alfred, Maine, would have increased early growth and maintained the growth rate through the last 5 years.

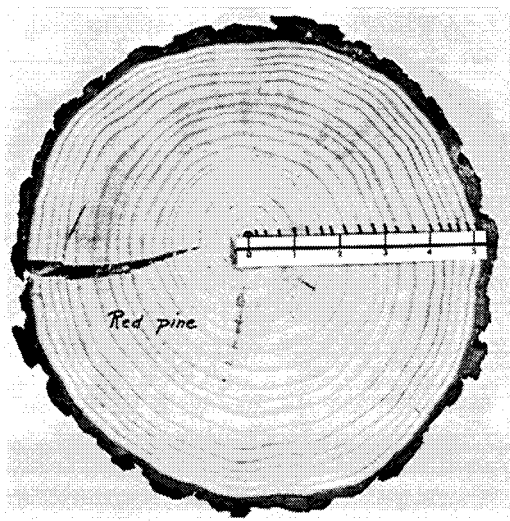


Figure 13.—A red pine plantation tree at Alfred, Maine. The section was cut 1 foot above the ground. Age 19 years, diameter 10.2 inches (i.b.).

Hybrid poplars.— Some 250 of the more than 13,000 hybrid poplars produced in 1925 and 1926 by the Cooperative Oxford Paper Company—New York Botanical Garden Hybridization Project (*Stout and Schreiner 1933; Schreiner 1937*) have been selected and tested by the Northeastern Forest Experiment Station for their performance on upland sites in the Northeast. The growth potential of some of the best hybrids is apparent in figures 14 to 19.

Figures 14 and 15 show one of the hybrids — NE-200 (*P. deltoides* $\times$ *P. trichocarpa*)—that were selected in the original Oxford Paper Company plantation at Frye, Maine, for clonal tests and were cut for pulping tests. These original hybrid seedlings were planted at 6- x 6-foot spacing and were never thinned. Figure 15 shows the merchantable pulpwood from this tree.



Figure 14.—Poplar hybrid NE-200 (*P. deltoides* × *P. trichocarpa*) selected for clonal and pulping tests. Age 18 years; d.b.h. 11.5 inches; total height 60 feet.

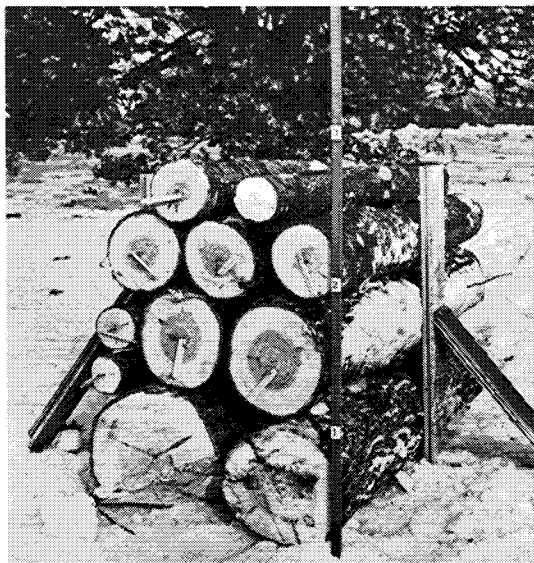


Figure 15.—This merchantable pulpwood was cut from the tree shown in figure 14.

The difference in growth of the same hybrid clone, the Andros-coggin poplar (*Schreiner and Stout 1934*), in the open and at 6- x 6-foot plantation spacing is shown in figures 16 and 17. The open-grown tree in Philadelphia (fig. 16) was 30 inches in d.b.h. and 80 feet tall at 16 years. The ramets of this clone in the 6 x 6 plantation near Frye, Maine (fig. 17) averaged 8 inches in d.b.h. and approximately 60 feet in total height at 15 years. But the total cubic volume per acre was practically the same for the 6- x 6-foot plantation as for the open-grown individual at an estimated spacing of 25 x 25 feet.

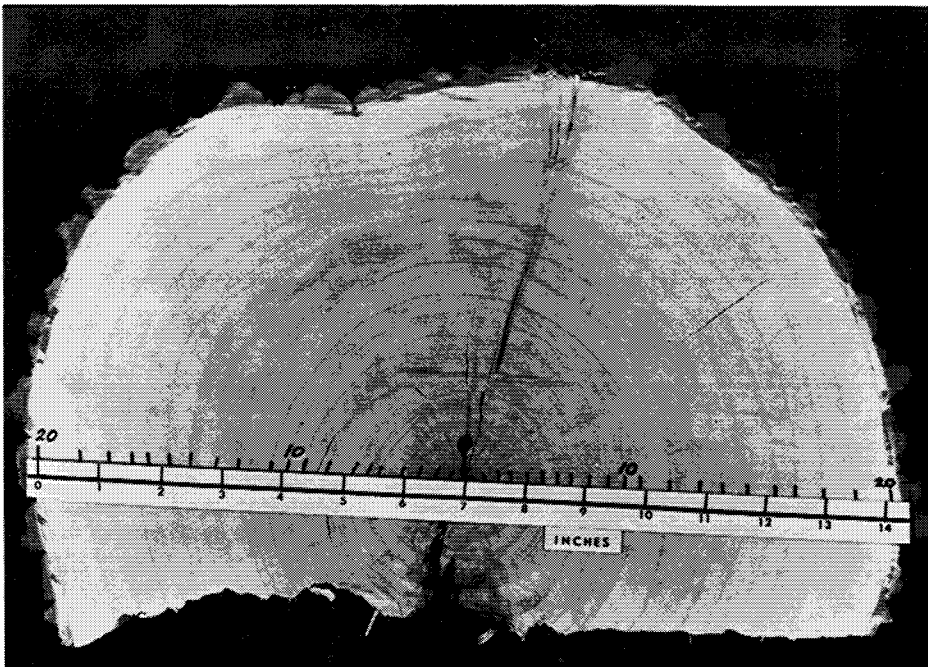


Figure 16.—Hybrid poplar. An open-grown specimen of the Andros-coggin poplar growing on fertile bottomland soil in Philadelphia. At 16 years this tree was 30 inches in d.b.h. (o.b.) and 80 feet tall. This same hybrid clone was planted at 6- x 6-foot spacing near Frye, Maine (fig. 17).



Figure 17.—Hybrid poplar. Ramets of the Androscoggin poplar planted in a 6- x 6-foot plantation on fertile bottom-land near Frye, Maine. The trees were 15 years old, their average d.b.h. was 8 inches, and their average total height was 60 feet (see also fig. 16).

Figure 18.—Hybrid poplar. This is a section (18 inches above the ground) from a 20-year-old tree in a test plantation established with dormant cuttings at 4- by 4-foot spacing, on a plowed and harrowed upland site at Williamstown, Massachusetts. The test plantation was cultivated during the first year only, and thinned lightly as needed.



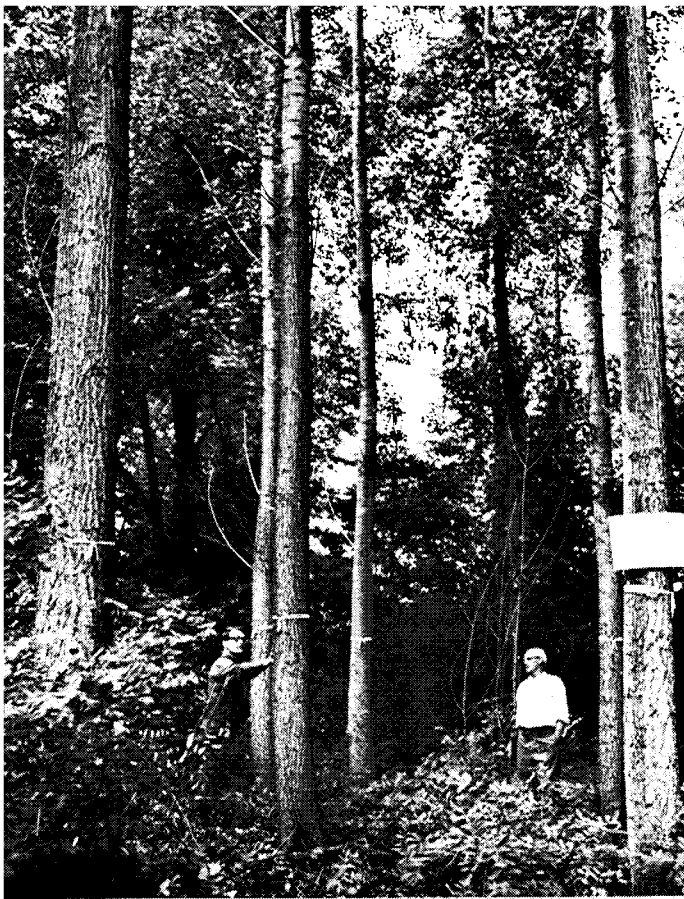


Figure 19.—Hybrid poplar clone NE-264 (*P. cv. Angulata* x *P. cv. Volga*) in a clonal test on an upland site in Williams-town, Massachusetts. This photo was taken when the trees were 20 years old. Fifteen-year average height was 61 feet; maximum height 76 feet. (Photo by John Ken-dig.)

MINI-ROTATION HYBRID POPLAR FIBER PRODUCTION

In the spring of 1935, 4-year-old nursery stock of 15 hybrid poplar clones in the Oxford Paper Company's nursery near Frye, Maine, were cut back to the ground to produce cutting stock for use in the spring of 1936. These hybrids had been grown from unrooted cuttings at 1-foot spacing in rows spaced 4 feet apart. Since this was an opportunity to determine the production of fiber on a short rotation, I stored the 4-year-old stems for dry-weight determination and possible pulping trials. The length of the row from which each lot of stems was taken and the percent survival in the row were recorded when the hybrids were cut.

Survival within the hybrid clones varied from 70 percent to more than 95 percent. Observations on the various hybrids indicated that the growth of trees spaced 1 foot apart (100-percent

survival) was fully as good as the growth in more sparsely populated portions of the same clones. Therefore, for comparison of the hybrids, the yield per acre of peeled stems was calculated on the basis of 95-percent survival.

The oven-dry weight of the branches with bark, and of the oven-dry weight of peeled stems exclusive of the leader (the fourth-year leader was not included) was determined in August 1935. The calculated yields per acre of side branches with bark, of peeled stem-wood and the equivalent in cords of peeled stem-wood, are given in table 4. The range in oven-dry weight of the peeled stem-wood of these 15 clones varied from 17,240 pounds (8.2 cords per acre) to 4,680 pounds (2.2 cords per acre). An examination of the growth rings indicated that the optimum rotation for

Table 4.—Yields of fifteen 4-year-old hybrid poplar clones at 1- x 4-foot spacing

[Oxford Paper Company Nursery, Frye, Maine, 1935]

Hybrid No.	Oven-dry yield estimated on basis of 95-percent survival		
	Branches with bark	Peeled stem-wood ¹	
	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Cords per acre²</i>
NE-44	5,920	17,240	8.2
-41	5,480	15,320	7.3
-49	2,440	14,300	6.8
-4	5,340	13,800	6.6
-50	4,460	13,560	6.5
-39	6,800	13,560	6.5
-46	6,320	13,480	6.4
-28	5,400	13,240	6.3
-29	4,560	11,680	5.6
-45	4,280	10,980	5.2
-32	3,600	10,900	5.2
-21	3,300	10,820	5.2
-54	5,200	8,100	3.9
-9	5,440	7,760	3.7
-26	1,760	4,680	2.2

¹ Oven-dry weight of peeled 3-year stems; the fourth-year leader was not included.

² Based on 2,100 pounds per cord, the reported oven-dry weight of aspen.

this spacing and this site in western Maine would be 3 rather than 4 years. Diameter growth was maintained during the third year, but it dropped considerably during the fourth year.

These early results in Maine indicated the possibilities of very short rotations for the production of poplar fiber, but unfortunately this 1935 research was at least 35 years ahead of its time. The pulp and paper management people agreed:

- That the production of fiber from fast-growing hybrid poplars on a 2- to 3-year rotation offered excellent possibilities in terms of the amount of fiber produced per acre.
- That a machine to economically harvest such small stems could be developed.
- That once the stand was planted, it would reproduce from sprouts after each fiber harvest.
- Cultivation to control weeds would be necessary only once or twice in the first year after each harvest.

But there was, at that time, one insurmountable obstacle to such short-rotation fiber production—the separation of the bark from the chips or pulp. And for the paper maker, this problem is still with us. Fortunately, there now is sufficient interest in separating bark from chips to predict that practical methods will be developed within the next decade.

Erickson (1970) has posed two questions that may bear on this problem within the next 10 years: "Will the technology in pulping change so that more bark will be allowed? Will it be feasible in the future to remove most of the bark during the pulping process?"

Present research on separation of bark after chipping has involved the bark of larger trees. I suggest that the young bark of 1-, 2-, or 3-year-old stems and branches may not be as troublesome as the mature bark of older trees; that it might be an allowable constituent of the pulp if we can persuade the pulp and paper researchers to seriously — *and strenuously* — attack this problem.

The utilization of such young wood may also involve shorter fiber. However, there is evidence that genetic selection for reason-

ably long-fibered young growth is possible. It is also reasonable to suggest that for many uses, even in paper stock, short fibers will prove suitable. This should apply, for example, to the use of short-fibered hardwoods for opacity and printability of high-grade papers.

Bowersox¹ and Ward (1968) are investigating the juvenile growth and yield in Pennsylvania of the Northeastern Station's hybrid poplar clone NE-388 (*P. maximowiczii* × *P. trichocarpa*). The yields per acre at three different spacings are reported in table 5 and illustrated in figures 20 and 21. The rate of increase (ta-

Table 5.—Yields of oven-dry peeled stem-wood; hybrid poplar clone NE-388

[State College, Pennsylvania]

Spacing (feet)	1-year-old ¹ trees		2-year-old ¹ trees		3-year-old ² trees	
	Pounds per acre	Cords per acre ³	Pounds per acre	Cords per acre ³	Pounds per acre	Cords per acre ³
1/2 x 2	1,024	0.5	3,816	1.8	11,940	5.7
1 x 2	658	.3	3,101	1.5	10,006	4.8
2 x 2	455	.2	1,923	.9	7,616	3.6

¹ Excerpt from Bowersox and Ward (1968).

² Todd W. Bowersox, personal communication.

³ Converted for this paper on the basis of 2,100 pounds per cord, the reported oven-dry weight of aspen.



Figure 20.—Hybrid poplar NE-388 (*P. maximowiczii* × *P. trichocarpa*). This is a 3-year-old stand from dormant cuttings. (Pa. State Univ. Agr. Exp. Sta. Photo.)



Figure 21.—Hybrid poplar NE-388 (*P. maximowiczii* × *P. trichocarpa*). Interior of the 2- x 2-foot, 3-year-old planting. (Pa. State Univ. Agr. Exp. Sta. Photo.)

ble 5) indicates that this hybrid will equal or surpass the 4-year yield of clone NE-44 in the 1935 tests in Maine.

A final word on the possibilities of mini-rotation of hybrid poplar for fiber production. The yields in Maine and those in Pennsylvania were based on 4- and 3-year-old trees from unrooted cuttings; the plants had not been cut back to the ground (stooled).

The 4-year-old clones in the Maine trials ranged from 8 to 18 feet in average height. If these hybrids had been stooled, they would have grown to the same heights in not more than 2 or 3 years. Stooled hybrids have grown to average heights of 10 to 14 feet in 1 year in nursery plantings in Philadelphia (fig. 22).

Figure 22.—Hybrid poplar nursery stools at 1- x 4-foot spacing, Philadelphia, Pa. This shows 1-year growth on 3-year-old stools that had been cut back annually for the production of cuttings.



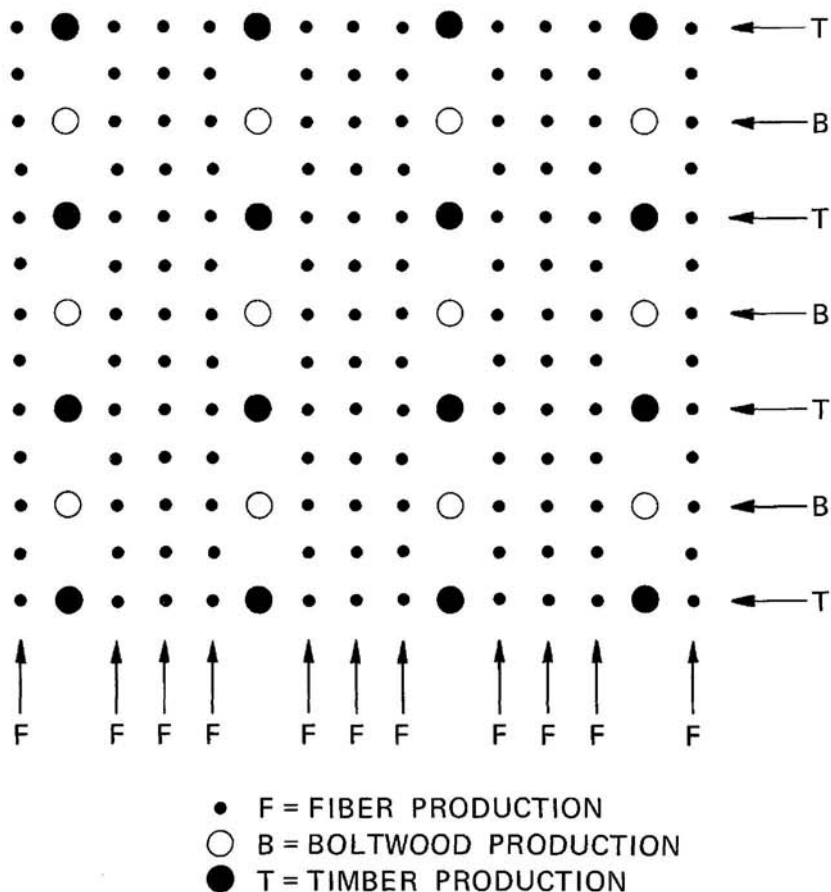
MINI-ROTATION HYBRID POPLAR BOLTWOOD AND TIMBER PRODUCTION

Hybrid poplars planted at 6- x 6-foot spacing on good upland sites would yield 10 cords per acre of boltwood from thinnings between the 8th and 10th years, and a final harvest of 30 cords per acre at 15 years (*Schreiner 1949*). With 4- x 4-foot spacing, two thinnings (one at 5 to 8 years and a second at 12 to 15 years) would produce considerable additional boltwood and would leave about 170 trees per acre spaced 16 x 16 feet for a final cordwood or timber and veneer-wood harvest between the 20th and the 25th years.

MINI-ROTATION FIBER, BOLTWOOD, AND TIMBER PRODUCTION WITH A SINGLE SPECIES OR WITH TWO OR THREE SPECIES

Figure 23 shows a generalized layout without designation of species or spacings. This could be for a single species. But for non-sprouting species, such as conifers, there would be only one fiber harvest; it would not pay to reseed the fiber (F) rows. For a sprouting species, the fiber harvests could be repeated at the most profitable intervals.

Figure 23.—A generalized layout for a mini-rotation plantation for producing fiber, boltwood, and timber.



A combination of species would be preferable: for example, hybrid poplar for fiber (F) with white pine for boltwood (B) and timber (T); or with larch for the boltwood (B) and white pine for the timber (T) mini-rotations.

Recommendations on choice of species, species mixtures, and spacing must await the results of small-scale applied research. I sincerely hope that such applied research will be started in the near future.

In closing, I will again quote Fedkiw: "There has never been a greater need for enlightened leadership and exploding innovations in forest practice."

Literature Cited

- Anonymous.
1968. IP DEVELOPS NEW TIMBER HARVESTING MACHINE. *The Unit* 113 (Dec.):7. So. Pulpwood Conserv. Assoc.
- Bernadski, Eugeniusz.
1969. ALTERATIONS IN THE SILVICULTURAL VALUE OF STAND DUE TO LINE THINNING. *Sylvan* 113(10):1-10. (In Polish; summary in English.)
- Bowersox, Todd W., and W. W. Ward.
1968. JUVENILE GROWTH AND YIELD OF HYBRID POPLAR CLONE NE-388. Pa. State Univ. Res. Briefs 3(1):2-6.
- Cook, Dave.
1969. PLANTED LARCH IN NEW YORK. 116 pp. Published by the author. 12 McPherson Terrace, Albany, N. Y.
- Cram, W. H.
1969. A NEW HARDWOOD CUTTINGS PLANTER. *Tree Planters' Notes* 19(4):24.
- DeLong, Thomas S.
1955. YIELD AND STAND TABLES FOR PLANTATION WHITE PINE IN PENNSYLVANIA. Pa. Dep. Forests and Waters Note 8-b.
- Drysdale, D. P.
1969. THE FORESTRY PICTURE TODAY AND FORTY YEARS HENCE. *Forestry Chron.* 45(4):284-288.
- Erickson, John R.
1970. BARK REMOVAL AFTER CHIPPING—A PROGRESS REPORT. *Pulp and Paper Mag. Canada* 71(5):78-79.
- Fedkiw, John.
1970. FORESTRY'S CHANGING ECONOMIC ENVIRONMENT. *J. Forestry* 68:137-138.
- Fields, Frederick B.
1969. PRIVATE FOREST MANAGEMENT IN THE TENNESSEE VALLEY. *Forest Farmer* 29(1):6-7.
- Graber, Raymond E., and Donald F. Thompson.
1969. A FURROW-SEEDER FOR THE NORTHEAST. USDA Forest Serv. Res. Paper NE-150. 14 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Hayes, Howard D.
1970. ECONOMIC COMPARISON OF SITE PREPARATION METHODS. *Forest Farmer* 29(4):8-10, 18.
- Hughes, E. L.
1970. RAPID GROWTH OF NORWAY AND RED SPRUCE NEAR THE BAY OF FUNDY. *Pulp and Paper Mag. Canada* 71(3):58-60.
- Leak, William B., Dale S. Solomon, and Stanley M. Filip.
1969. A SILVICULTURAL GUIDE FOR NORTHERN HARDWOODS IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-143. 34 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- McAlpine, Robert G., Claud L. Brown, A. M. Herrick, and H. E. Ruark.
1966. "SILAGE" SYCAMORE. *Forest Farmer* 26(1):6-7, 16.
- Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-130. 47 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marty, Robert.
1965. THE MENSURATIONAL CHARACTERISTICS OF EASTERN WHITE PINE.

- USDA Forest Serv. Res. Paper NE-40. 73 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Perry, Henry J., and David B. Cook.
1965. PULPWOOD FOR 1995. Pulp and Paper 39(15):33-34, 44.
- Schreiner, Ernst J.
1937. IMPROVEMENT OF FOREST TREES. USDA Yearbook 1937: 1242-1279.
- Schreiner, Ernst J.
1949. POPLARS CAN BE BRED TO ORDER. USDA Yearbook 1949: 153-157.
- Schreiner, E. J., E. W. Littlefield, and E. J. Eliason.
1962. RESULTS OF 1938 IUFRO SCOTCH PINE PROVENANCE TEST IN NEW YORK. USDA Forest Serv. NE. Forest Exp. Sta., Sta. Paper 166. 23 pp. Upper Darby, Pa.
- Schreiner, E. J., and A. B. Stout.
1934. DESCRIPTIONS OF TEN NEW HYBRID POPLARS. Torrey Bot. Club Bull. 61: 449-460.
- Stout, A. B., and E. J. Schreiner.
1933. RESULTS OF A PROJECT IN HYBRIDIZING POPLARS. J. Hered. 24: 216-229.
- Swan, D. A.
1969. ABSTRACT OF PAPER ON TRAINING WOODS LABOUR IN THE NORTH-EAST. Pulp and Paper Mag. Canada 70(22): 106-107.
- Wheeler, Philip R.
1970. THE SOUTH'S THIRD FOREST. J. Forestry 68: 142-147.





THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.