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Survival, Growth, and Quality of Residual Trees

Following Clearcutting in Allegheny Hardwood Forests

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Abstract

A study of residual saplings and poles left after clearcutting indicates that sugar maple and beech are capable of surviving and growing well after this type of drastic release. Epicormic branches developed on many trees, but those that were free of epicormics before cutting tended to remain free of them after exposure. Residual trees did not interfere with the establishment of intolerant regeneration, but have begun to affect height growth of regeneration 6 years after cutting where the residual density exceeded 10 to 15 square feet (ft^2) of basal area per acre. Good results from residuals are likely only if trees with at least moderately vigorous crowns and clean boles are selected for retention prior to cutting; 30 to 80 such trees per acre should be retained.

Unmerchantable Residuals—Should they be removed?
Most silvicultural guides to clearcutting in eastern hardwoods recommend that all trees down to about 2 inches in diameter at breast height (dbh) be killed or cut following the removal of merchantable stems—no matter how good the unmerchantable trees may look at the time of cutting. If left uncut, it is generally believed that these residuals deteriorate in quality and develop into wolf trees that interfere with the development of desirable regeneration (Leak et al. 1969; Roach 1963; Roach and Gingrich 1968).

However, there is now evidence that this practice—originally prescribed for the oak type—is not always advantageous. In northern hardwood types that contain valuable tolerant species such as sugar maple, it appears that retaining carefully selected saplings and small poles at the time of final harvest can provide several distinct advantages. Particularly where tolerants occur in mixture with faster growing intolerant species, retaining residual trees can allow tolerants to reach mature size at the same time as intolerants. Thus, a new stand is produced that is more nearly even-sized than a truly even-aged one. And this facilitates management.

Some Background
The cherry-maple, or Allegheny hardwood, type of northern Pennsylvania provides a prime example. Allegheny hardwoods are predominantly second-growth stands that resulted from heavy turn-of-the-century logging in the original beech-birch-maple-hemlock forest. Because the final cuttings were very complete, we usually consider the trees in present stands to be all of one age. But this is an oversimplification that conceals some important facts.

The original forests of northwestern Pennsylvania received a series of partial cuttings during the 1800's that removed white pine, hemlock, and the better hardwood sawtimber. These partial cuts were usually followed by a clearcutting, which removed any remaining sawtimber plus poles and saplings of all species for chemical wood (for distillation into charcoal, wood alcohol, and other wood chemicals). Although these chemical wood cuttings were more nearly complete than most commercial clearcuts—trees down to 2 or 3 inches dbh were used—they almost always left a number of small sugar maple and beech, many of which had originated from the earlier partial cuts. These residuals, plus new regeneration that developed after cutting, make up the present stands.

Careful analyses of present stands reveal that the residuals, though few in number, have had an important effect on stand development and species composition. Fast-growing regeneration of intolerant species such as black cherry, white ash, yellow-poplar, and red maple has caught up with the slower growing tolerant residuals; together they form the main crown canopy. Beneath this main canopy is a second layer—almost an understory—of small sugar maple and beech that had been advance seedlings or originated as sprouts at the time of cutting. They were quickly overtopped by the faster growing intolerant regeneration. Almost invariably, sugar maple and beech found in the main crown canopy of cherry-maple stands had a significant head start on the intolerants. If the tolerants started at the same time, they are now relegated to the understory. A more detailed account of the effect of residual saplings left after chemical wood clearcutting is available.[1]

Truly even-aged stands of mixed black cherry and sugar maple are difficult to manage because the cherry matures at about 80 years of age while the maple requires 120 years or more. Clearcutting at age 80 produces a predominance of pulpwood and small logs from the maple; considerable future value that would accrue as the maple grew into large sawtimber size is lost. On the other hand, if the cherry is harvested and the maple retained for an additional 40 years or so, it will be very difficult to regenerate a new stand containing cherry, since the seed source would be gone.

An alternative for future stands is to retain some sapling or small pole-size sugar maple at the time of the regeneration cut; this would provide the maple with a head start over the new black cherry regeneration. This head start would ensure that the residual maples get into the main crown canopy of the next stand where they will grow more rapidly and mature at the same time as the cherry.

Retaining tolerant residuals at the time of the regeneration cut also helps perpetuate these species in the third-growth forest. Because sugar maple is largely confined to the understory in present second-growth Allegheny hardwood stands, seed production and advance regeneration of this species are limited. This, plus preferential deer browsing, tends to eliminate sugar maple and other tolerants from third-growth stands.

Will it work?
The old concerns about residual tree quality and interference with regeneration are still valid. Evidence from present stands suggests that the proportion of cherry is reduced where there were large numbers of residuals after turn-of-the-century chemical wood cuts,[1] but that stand development to commercial size has been more rapid. Most of the residuals left in those early cuttings were 20 to 40 years old, having originated from the prior partial cuts. Similar stems in current second-growth stands are older—usually the same age as the main stand. It is not clear that the older suppressed

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[1] Marquis, David A. Removal of unmerchantable saplings affects the development of regeneration following clearcutting in Allegheny hardwoods. Manuscript submitted to Journal of Forestry, Nov. 18, 1980.

stems in current stands will respond in the same way as the younger stems did.

Further, quality of the residuals left in those early cuttings varies widely. But those trees were not selected for retention; they were left unintentionally or were left because they were too poor to make it worth the effort to cut them. If only good-quality, high-vigor trees were retained, and if their numbers were carefully controlled, it may be possible to grow a good percentage of sawtimber maple and beech without seriously reducing the amount of cherry.

To test this idea, we initiated a study of the survival, growth, and quality of saplings and small pole-size trees retained after final harvest cutting in second-growth Allegheny hardwood stands.

Study Methods

In 1971, a 67-year-old, second-growth cherry-maple stand was clearcut on the Allegheny National Forest as part of its timber management program. The merchantable trees were removed, leaving a variety of unmerchantable residuals. None of these trees had been selected for retention—they were just those small trees that were not knocked down in logging, plus a few larger stems missed or not worth cutting for pulpwood. Because of the wide variety in size, species, and quality, these trees offered an excellent opportunity to study the responses of residuals.

In 1972, sixteen 1/2-acre plots were located within this clearcut. Various treatments representing different residual tree densities were applied to the plots; those that contained more residuals than prescribed were thinned to achieve the desired density and a uniform distribution. Residual stocking levels ranged from 0 to 150 trees per acre and from 0 to 19 square feet (ft^2) of basal area per acre in trees 1 to 9 inches dbh.

All measurements were confined to the central 1/4 acre, leaving the balance as an isolation strip. All residual trees were numbered, and periodic measurements of diameter growth, crown and bole quality, and survival were made over a 5-year period. Regeneration tallies were made on six 0.0026-acre subplots within each plot.

At the beginning of the study, all trees were separated into the following crown and bole condition classes:

Crown condition

A. Crown is average size or larger for tree of that diameter, and foliage is apparently healthy with reasonable density. Tree should survive and grow well.
B. Crown seems adequate for survival and moderate growth, but is small in size with good foliage density, or is average in size with sparse foliage.
C. Crown is definitely small for a tree of that diameter with foliage so thin and sparse, or so stunted or discolored as to create strong doubt about the tree's survival.

Bole condition

(Disregard minor sweep and small crooks that are not likely to affect log grade by the time tree is 16 inches dbh.)
A. Single straight stem for 25 feet or more.
B. Single straight stem for 17 to 24 feet. Strongly forked (two or more apparent leaders) or severe crook between 17 and 24 feet from ground.
C. Strong fork or severe crook in first 17 feet, or less than 1 log height.

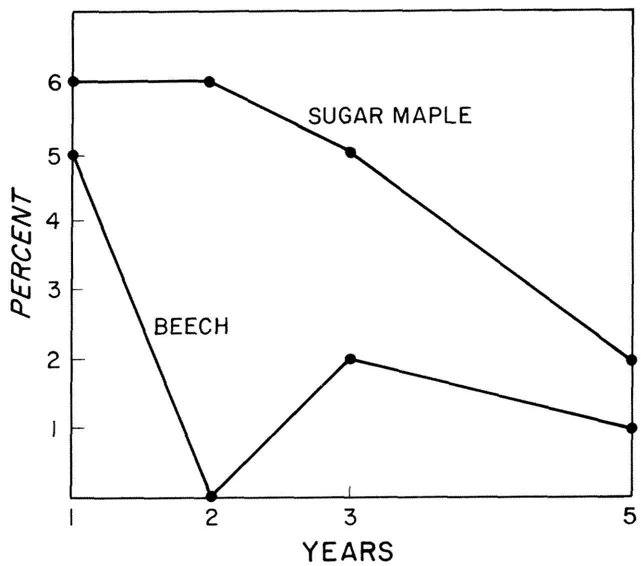
Results and Discussion

Mortality

Over the 5-year period, mortality has amounted to 19 percent for sugar maple and 8 percent for beech. Mortality was highest during the first few years after cutting, and has decreased steadily since then (Fig. 1).

Mortality varied significantly by original crown condition class for both species—the larger and more vigorous the crown, the lower the mortality. Mortality did not vary significantly by original dbh, though survival tended to be higher among the larger diameter trees (Table 1). Original diameter and original crown class were interrelated: most of the A crown trees were in the larger diameter classes, while most of the C crown trees were small (1 to 2 inches dbh).

Figure 1.—Mortality of residual trees, in percent.



So survival tended to be highest among the larger diameter, more vigorous crowned trees. But crown condition is a far more important criterion than dbh.

Of the sugar maples that died, 20 percent were windthrown, 40 percent never releafed after being completely defoliated by the saddled prominent *(Heterocampa quitivitta)* the year after cutting, and the balance died from a combination of exposure and defoliation. This maple defoliation was an unusual occurrence that apparently resulted in higher mortality than would otherwise be expected.

Of the beech that died, 55 percent were girdled by porcupine, 33 percent were windthrown, and the balance died from a combination of exposure and logging damage.

All of the mortality that occurred among A crown trees was due to windthrow, porcupine girdling, or insect defoliation—none to exposure. Most (86 percent) of the mortality attributed to exposure was in C crown trees.

Mortality also varied with residual tree density. Mortality was lower in plots with larger numbers of residuals. In plots with less than 5 ft^2 of basal area residual, there was a net loss in basal area and stocking over the 5-year period. In plots with more than 10 ft^2 of residual basal area, growth on surviving trees exceeded losses to mortality, resulting in a net increase in basal area and stocking (Table 2). Apparently, the mutual protection afforded by the larger number of residuals reduced the effects of drastic exposure observed in the completely isolated trees.

The overall average mortality reported here is probably higher than would be obtained in practice, not only because of the insect defoliation on sugar maple, but also because the trees retained in practice would not include those of poor crown vigor such as used in this experiment. I would expect mortality to total less than 10 percent over the first 5 years in actual practice, and decline to less than half that over the next 10 or 15 years, after which it should be nearly zero. Total mortality should average no more than 15 to 25 percent of the trees retained.

Table 1.—Mortality of sugar maple and beech residuals as affected by original diameter and crown vigor

Dbh class	Crown class			All crowns
(inches)	A	B	C	
	Percent			
Sugar maple				
1-3	12	15	29	20
4-6	11	20	44	21
7-9	3	40	33	10
All sizes	9	19	36	19
Beech				
1-3	12	11	17	12
4-6	4	6	0	4
7-9	6	—	—	6
All sizes	6	9	14	8

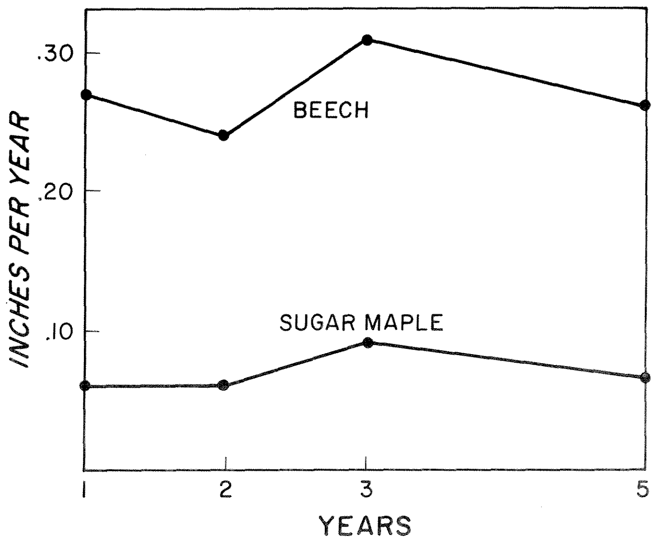
Table 2.—Mortality and stocking as affected by residual density

Original basal area	No. trees per acre		Percent mortality	Basal area			Percent stocking		
	1972	1977		1972	1977	change	1972	1977	change
ft^2/acre				*ft^2/acre*					
0-5	37	29	22	4.4	4.1	-0.3	4	4	-0.4
5-10	78	61	22	8.2	8.6	+0.4	8	8	0
10-15	104	92	12	12.2	14.7	+2.5	12	14	+1.8
15-20	126	113	10	18.1	21.6	+3.5	18	20	+2.6

Growth

Over the 5-year period, diameter growth has amounted to 0.35 inch (0.07 inch per year) for sugar maple and 1.35 inches (0.27 inch per year) for beech. Growth rates have shown no clear trends over time (Fig. 2).

Figure 2.—Diameter growth of survivors, in inches per year.



Growth rates of trees with more vigorous crowns were considerably better than for trees with poor crowns. As in the case of mortality, original crown size or vigor was considerably more important than original dbh, especially for sugar maple (Table 3).

Residual density did not have any consistent effect on the diameter growth of sugar maple, but beech grew somewhat more rapidly at the higher residual densities (Table 4, Fig. 3).

Some trees have grown very rapidly. The fastest growing sugar maple has grown 2.2 inches in 5 years (0.44 inch per year); the fastest growing beech has grown 2.8 inches in that time (0.56 inch per year). These are phenomenal growth rates for previously suppressed trees, most of which are approximately 67 years old—the same age as the previous main stand. Trees 5 inches dbh at the time of clearcutting had averaged only 0.07 inch per year over the previous 67 years; trees 3 inches dbh had averaged only 0.04 inch per year in that time.

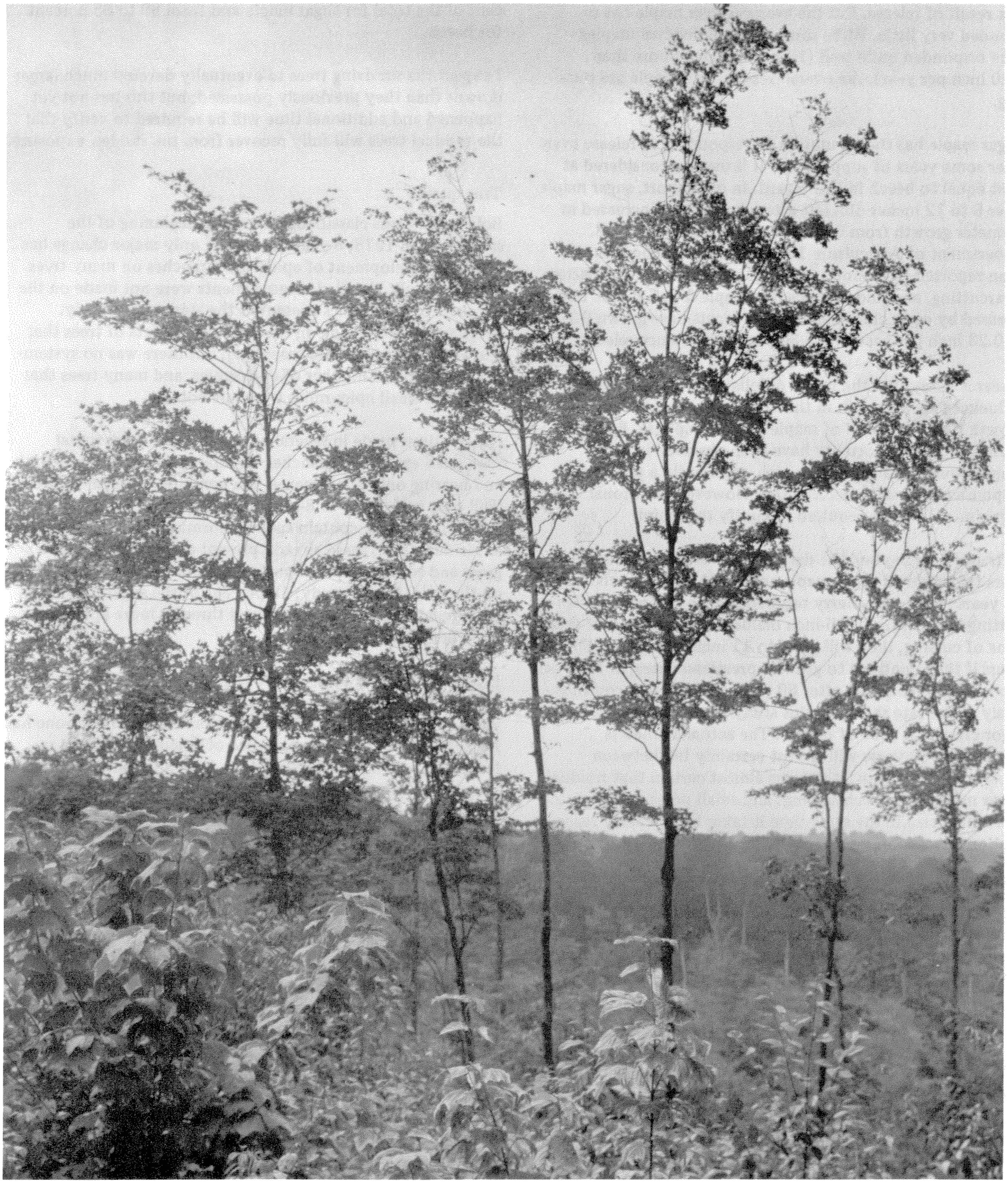
Table 3.—Diameter growth of sugar maple and beech residuals as affected by original diameter and crown vigor

Dbh class (inches)	Crown class A	Crown class B	Crown class C	All crowns
	Inches/5 years			
Sugar maple				
1-3	0.63	0.36	0.26	0.35
4-6	.51	.25	.26	.35
7-9	.39	.11	.10	.35
All sizes	.48	.28	.25	.35
Beech				
1-3	1.41	1.24	.91	1.23
4-6	1.50	1.23	.85	1.37
7-9	1.62	—	—	1.62
All sizes	1.50	1.24	.90	1.35

Table 4.—Diameter growth of residual sugar maple and beech as a function of residual density

Original basal area	Sugar maple	Beech
ft²/acre	*Inches/5 years*	
0-5	0.30	1.10
5-10	.40	1.10
10-15	.35	1.45
15-20	.30	1.50

Figure 3.—Stand of residual trees 5 years after clearcutting.



Based on the previous 67 years growth rate above, the growth rate of the average beech in this study has quadrupled as a result of release. But the average sugar maple has responded very little. While some of the individual maples have responded quite well (10 percent grew more than 0.20 inch per year), the overall results with maple are puzzling.

Sugar maple has the reputation of responding to release even after some years of suppression. It is usually considered at least equal to beech in this regard. In one report, sugar maple trees 5 to 12 inches dbh left after clearcutting increased in diameter growth from 0.08 to 0.21 inch per year (U.S. Department of Agriculture 1965). Good response has also been reported by Bennett[2] for sugar maple trees left after clearcutting, and understory sugar maple 3 to 6 inches dbh released by early chemical wood clearcuts have grown 0.17 to 0.23 inch per year over a 35-year period since release.[1]

It seems likely that the insect defoliations of maple have influenced their growth in this study, resulting in slow growth that is atypical of maple's usual response. Poor growth and high mortality have been observed in other maple stands throughout the area, apparently a prolonged response to the same defoliations. However, additional experiments will be required to clarify this point.

Extrapolating beyond the data, I have calculated the diameters that residual sugar maple and beech might reach after 80 years—when the cherry regeneration that develops after cutting has matured. If 5-inch diameter trees are left at the time of cutting, they will grow to 11 inches dbh after 80 years if they continue to grow at prerelease rates; or they will grow to 27 inches dbh after 80 years if they grow continuously at the rate shown in this study for beech with A or B vigor crowns at time of release. The actual diameters achieved in 80 years will almost certainly fall between these extremes. Thus, it appears almost certain that residual sugar maple and beech saplings and small poles will grow to sawtimber size in the same time it takes black cherry regeneration to mature.

Tree vigor

Shortly after cutting, many of the residual trees exhibited some dieback in the crowns; this was offset in some trees by the development of new crown and denser foliage. But after 5 years, 30 percent of the surviving residuals still exhibit some important amount of crown dieback. Trees classified in A or B crown classes have decreased from 80 to 58 percent of the total for sugar maple and from 89 to 83 percent for beech.

I expect the surviving trees to eventually develop much larger crowns than they previously possessed, but this has not yet happened and additional time will be required to verify that the residual trees will fully recover from the sudden exposure.

Tree quality

Bole quality was classified both at the beginning of the study, and in 1978, 6 years later. The only major change has been the development of epicormic branches on many trees. Unfortunately, detailed measurements were not made on the numbers of epicormics present at the start of the study. Some notes were made on the field tally sheets of trees that had abundant epicormic branching, but there was no systematic recording of number of epicormics, and many trees that contained small epicormics were not noted.

Observations made in several adjacent uncut areas reveal that small epicormic branches—several inches or less in length and bearing only a few leaves—are common on sugar maple. Well over half the 1- to 8-inch maples in stands such as this study stand often contain such epicormics. When exposed as residual trees, these already present epicormics begin to grow and soon become important sources of future degrade on the bole. In this study, 45 percent of the sugar maple and 27 percent of the beech contained three or more epicormic branches after 6 years.

However, many of these previously suppressed and then fully released trees have few or no epicormic branches after 6 years (Fig. 4, Table 5). Of these epicormic-free trees, none had field notes indicating the presence of epicormics before release. These data, and observations from adjacent thinning studies, suggest that most trees that develop an abundance of epicormics after exposure had small sprouts present before cutting; some—perhaps most—trees that lacked epicormics at the time of cutting remain free of them even after drastic exposure. Unfortunately, verification of this observation will have to await results of other studies now underway where detailed observations were made on epicormics prior to cutting.

Many suppressed beech trees carry small limbs and branches in addition to epicormics on the lower bole, even in tightly closed stands. When these trees are released, the branches survive and grow and the trees look positively hairy. But even in beech, there are exceptions—a few trees are straight and clean, and these seem to remain clean after release. However, our data suggest that the proportion of clean, limb- and epicormic-free beech stems is much lower than the proportion of clean maple stems (Table 5).

[2] Bennett, A.L. Insurance silviculture for perpetuation of the cherry-hardwood type in Northwestern Pennsylvania. Unpublished talk given at Allegheny Section, Society of American Foresters Winter Meeting, Pittsburgh, Pa., Feb. 7, 1980.

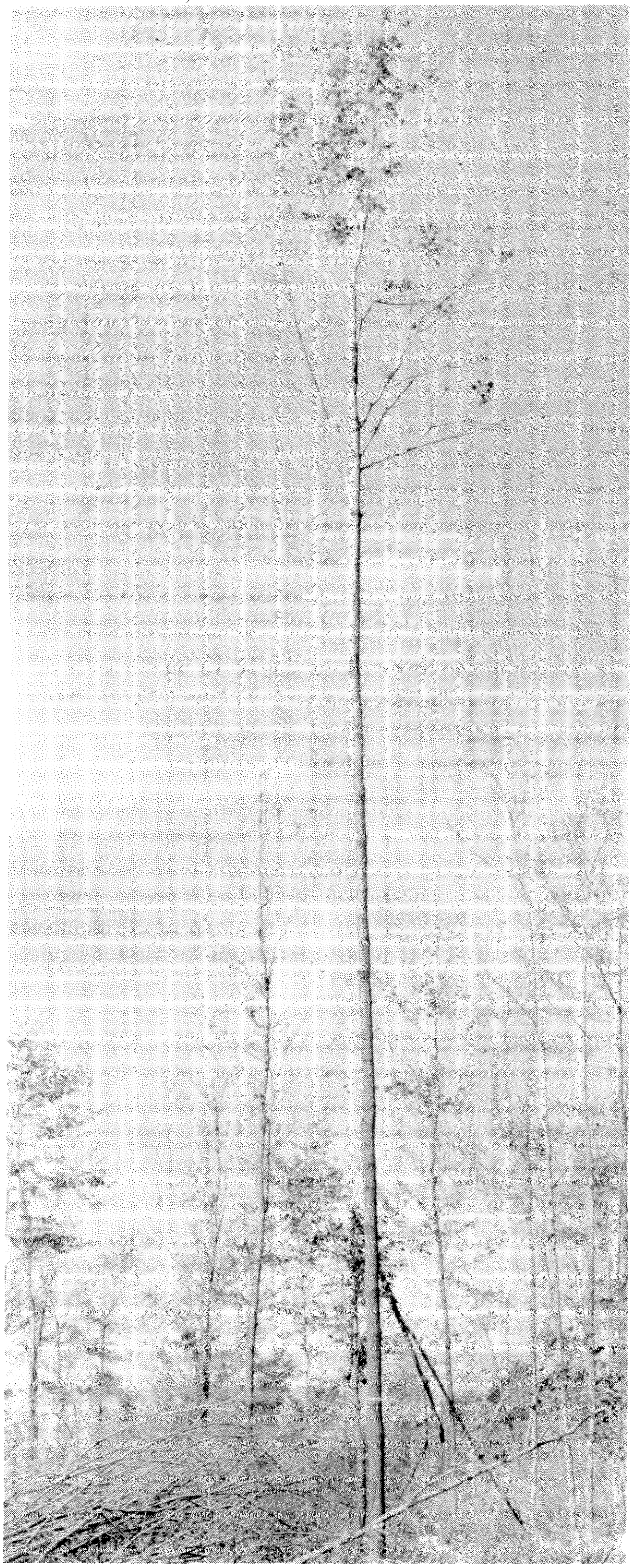


Figure 4.—Single residual sugar maple showing good bole form. This tree had no epicormic branches, and the first live branch was 34 feet above ground at the time of release. Crown size and vigor on this residual is marginal.

Table 5.—Proportion of trees with epicormic branches in first 17 feet and proportion of trees with 8 or 16 feet of clear bole 6 years after cutting

Trees with:	Sugar maple	Beech
	Percent	
0 epicormics	37	56
1-2 epicormics	18	17
3+ epicormics	45	27
8 feet clear bole	24	6
16 feet clear bole	4	1

Perhaps more important than epicormics in determining future quality is the length of bole free of live branches at the time of release. Although too early to tell from this study, it is quite likely that many of the existing live branches will persist after the trees are exposed, so that the length of bole suitable for sawlog material is essentially fixed by the limb-free length at time of release.

Regeneration

There were large initial differences in the amounts of advance regeneration of desirable intolerant species on the 16 study plots, and these initial differences have had a major influence on the amount of regeneration present 5 years later. Therefore, multiple regressions were computed, relating regeneration 6 years after cutting to both residual tree density and number of stems of desirable regeneration present at the start of the study. In this stand, 97 percent of the stems of desirable species were black cherry 6 years after cutting.

Two multiple regression models were run: The independent variable for the first was total number of desirable stems 6 years after cutting, and the independent variable for the second was the percentage of subplots stocked with at least 2 desirable stems over 5 feet tall. The latter criterion is used widely in Allegheny hardwoods as a measure of regeneration stocking—stands with 70 percent of the plots stocked with 2 stems over 5 feet tall after 10 years or so are considered to be satisfactorily established. The r^2 values for the two equations were 0.74 and 0.63, respectively. Both regressions were highly significant.

The resulting regression equations were solved for 0, 5, 10, 15, and 20 ft^2 of residual basal area at an initial regeneration level of 20,000 desirable stems per acre (the average of all plots). This procedure adjusts all plots to the same initial regeneration level, isolating the effect of residual tree density.

A third regression model was run of average regeneration height as a function of residual tree density. No adjustment for initial regeneration level was necessary in the case of height (because height growth was not affected by initial regeneration density). Because of wide variation from plot to plot, the contribution of residual tree density to the equations is often only barely significant, but the results are shown (Table 6) to indicate trends.

There was a tendency to have more stems of regeneration present 6 years after cutting in the plots with heavier residual tree density, but for height growth and stocking (the proportion of subplots with two stems over 5 feet tall) to be less there. Higher residual tree densities are apparently starting to reduce the height of the intolerant regeneration. But shade of these residuals, or perhaps reduced competition among the smaller regeneration, has allowed more stems of regeneration to survive. So it would seem that even the heaviest residual density is no handicap—and may be an advantage—in the initial establishment of intolerant species. But after 6 or more years, height growth and stocking of the intolerant regeneration may be affected at the heaviest densities.

Table 6.—Effect of residual tree density on regeneration 6 years after cutting

Basal area	Desirable stems[a]	Plots with two desirables > 5 feet[b]	Height of tallest desirable/plot[c]
ft^2/acre	*M/acre*	*Percent*	*Feet*
0	17	50	4.2
5	24	47	3.7
10	30	44	3.2
15	36	41	2.7
20	42	38	2.2

[a]Based on regression Y = 20.126 + 1.2362 BA + 1.8753 OR (r^2 = 0.74, BA term significant at 0.10 level)

[b]Based on regression Y = 18.525 — 0.5761 BA + 1.5856 OR (r^2 = 0.63, BA term not significant)

[c]Based on regression Y = 4.2098 — 0.09878 BA (r^2 = 57, significant at 0.10 level)

In all equations: BA = based area of residual trees in ft^2/acre
OR = original (1972) number desirable stems of regeneration
Y = dependent variable.

Conclusions

Additional time and further experimentation will be needed to provide definitive answers to the questions raised about survival, growth, and quality of residual trees and their effect on intolerant regeneration. But this study suggests, at least, that the idea may very well prove worthwhile in stands like those of the cherry-maple type.

One conclusion that stands out above all others is that the success of residual trees will depend heavily on the careful selection of trees of good vigor with at least moderately good crowns and with clean, straight boles free of even very small epicormic branches. Trees of this description in the current study have survived and grown very well, and appear to be maintaining bole quality that will allow their eventual use as sawtimber. It seems imperative that any trees to be retained after clearcutting be selected and clearly marked for retention so that they will not be cut or damaged during logging. The retention of any but the best trees seems clearly undesirable.

Two questions need further examination: a) the growth response of sugar maple that is of the same age and vigor as studied here, but not defoliated or otherwise damaged, and b) the development of epicormic branches on stems that do not have epicormics prior to cutting. Within the past year or two, the Allegheny National Forest began selecting sugar maple and beech for retention in its clearcuts. Detailed observations are now being made on a sample of these trees to provide further experience and data on these questions.

Until better information becomes available, I recommend that those wishing to retain sugar maple and beech residuals select only trees between 3 and 8 inches dbh that have at least a moderately vigorous crown, and a straight bole without low forks, branches, or epicormic branches (not even small ones). Selected trees should have at least 17 feet of limb-free bole, preferably more. Retaining 30 to 80 trees would seem to provide adequate stocking for mutual protection from extreme exposure without affecting early regeneration of intolerant species. Numbers of trees and basal area recommended for retention are shown in the tabulation below for various residual tree average diameters.

Average diameter Inches	*Number of trees No./acre*	*Basal area ft^2/acre*	*Stocking Percent*
3	80	4	5
4	80	7	7
5	65	9	9
6	50	10	9
7	40	11	9
8	30	10	9

In most stands, there will be areas where trees of the size and quality desired are absent. In such areas, it is better to clearcut completely rather than to leave less than desirable residuals. Residual trees should be considered an opportunity where they are present, but one should not become a slave to retention of residuals where stand conditions do not warrant this treatment.

Acknowledgment

Acknowledgment is made to Benjamin A. Roach, who helped set up this study before his death.

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Keywords: clearcutting, Allegheny hardwood type, regeneration, tree growth, tree quality, age class distribution

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