INFLUENCE OF STAND DENSITY ON STEM QUALITY IN POLE-SIZE NORTHERN HARDWOODS

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The objective in managing most northern hardwood stands is to produce high-value saw logs and veneer logs in the shortest possible time. Nearly two-thirds of the northern hardwood area in the Lake States is in young, second-growth stands approaching the need for their first commercial thinning (Cunningham and Survey Staff 1956). Most trees are still too small to have established their grade potential. Stem quality must be developed through a series of intermediate cuttings that also stimulate the growth of individual trees.

Generally, the improvement of stem quality results from a gradual process of natural pruning because live limbs and limb-related defects are the prime causes of degrade in potential crop trees. Many trees with other types of defects causing degrade and volume loss can be removed in intermediate cuttings to enhance the development of high quality stems (Jacobs 1966).

One of the primary means available to forest managers for improving bole quality is regulating residual stand density. Both stocking guides and criteria for tree selection have been prepared for Lake States stands (in which sugar maple is the principal species) to assure continuous growth and provide for desirable reproduction (Arbogast 1957, Eyre and Zillgitt 1953). Although these guides stress that moderate to high basal area is necessary to develop quality, particularly in older stands, their recommendations have not been evaluated for second-growth stands where trees are smaller and more uniform in diameter distribution. Nor do these guides indicate the range of residual stand density that may be acceptable for quality improvement.

To learn more about the effect of residual basal area on the total number and distribution of live limbs and limb-related defects, the first two logs (33 feet) of trees in pole-sized northern hardwood stands were studied 15 years after cutting. Only trees expected to be in the final crop were selected for study. Tree quality change will be further quantified by future measurements.

METHODS

Study Area

Three 40-acre tracts of second-growth northern hardwoods on the Argonne Experimental Forest in northeastern Wisconsin were selected for study. These stands, which consisted mainly of trees 5 to 8 inches in diameter, originated from a commercial cut in about 1905. Stocking of all trees 4.6 inches and larger averaged more than 90 square feet of basal area and about 240 trees per acre before cutting. A few holdover saw-log-sized trees ranging up to 25 inches in diameter were randomly distributed throughout the stand.

Sugar maple was the predominant species both in numbers and basal area. Basswood, white ash, yellow birch, and red maple were common associates, although none of these constituted more than 15 percent of the total basal area. Species distribution tended to be uniform, with basswood the most abundant of the associated species. All three stands are located on well drained, silt-loam soils with boulders in the surface layer.

Treatment

Six 2½-acre treatments, begun in 1951, left a uniformly distributed stand of the more desirable trees at specified residual basal areas:

Initial treatment	*Residual basal area per acre*	*Subsequent treatment*	*Basal area per acre after 15 years*
	Sq. Ft.		*Sq. Ft.*
Check	93	None	128
Improvement cutting	90	Recut after 10 years	101
Improvement cutting	75	Do	87
Improvement cutting	60	Do	76
Crop-tree release	60	None	105
8-inch stump diameter limit	20	None	69

The improvement-cutting stands were recut in the fall of 1961 on a planned 10-year cutting interval.

The crop-tree-release stands contained about 40 uniformly distributed trees per acre that were selected as potential crop trees. The stand residual basal area averaged 60 square feet per acre, although basal area around individual crop trees was slightly lower. Because the initial release of crop trees was considered fairly heavy, no additional treatments have been made.

The 8-inch stump diameter limit cutting did not result in uniform stocking throughout the compartment because of the arbitrary removal of all trees 8 inches d.b.h. and larger. However, stocking on and adjacent to the 1/10-acre sample plots was relatively uniform and the treatment is therefore included in this report.

Although the cutting methods varied widely, the primary difference in the residual stands was in basal area stocking. In all treatments the proportion of the stand made up by trees in the 5- to 8-inch diameter class increased after initial cutting to nearly 75 percent of the residual basal area. Trees of this initial size may eventually make up an even larger proportion of the stand, and thus are the most important trees to follow in determining the influence of residual basal area on the development of bole quality.

Sampling Procedures

Each treatment was replicated three times. Sample trees were located on five 1/10-acre plots established in each treatment area. Sample trees were selected from among the better trees on each plot that were between 4.5 and 8.6 inches d.b.h. when the study was established 15 years ago. Three trees of each of the major species — sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), yellow birch (*Betula alleghaniensis* Britton), basswood (*Tilia americana* L.), and white ash (*Fraxinus americana* L.) — were sampled on each plot, when they were available, for a maximum of 45 trees per treatment. Only sugar maple was present on all plots, so it was the only species consistently sampled.

Tree-Quality Measurements

Four classes of stem defects were recognized: live limbs, dead limbs, epicormic sprouts, and bumps. Live limbs included epicormic sprouts larger than ½ inch in diameter. Dead limbs included knots with the dead stub still visible. Bumps were swelling or protrusions rising more than ½ inch above the stem surface, and included open knots with no visible limb stub, overgrown knots, and other limb-related bumps.

The study zone extended from 1 foot above the ground to 33 feet in all sample trees. Defects were recorded by 4-foot height zones.

Crown diameter and growth rate of individual trees were measured, because these factors influence improvement in stem quality. The height of forks[1] on the main stem was recorded to the nearest foot.

RESULTS

Frequency of Bole Defects by Species

Sugar maple consistently had the greatest number of stem defects, while basswood and white ash had the fewest defects (table 1). Thus species composition alone can influence stand

[1] *A fork was recorded whenever the diameter of the stem above the juncture was at least 25 percent smaller than the diameter of the main stem below the juncture and/or when the smaller of the fork members was at least two-thirds the diameter of the larger.*

Table 1.—Defects in the first two logs of northern hardwood trees 15 years after initial cutting.

(In number of defects per tree)

Species	Treatment and residual basal area in sq. ft./acre						No. trees
	8 In. dia. limit	Improvement cuttings			Crop tree	Check	
	20	90	75	60	60	93	
Sugar maple	20	14	16	16	16	21	212
Yellow birch	--	8	8	12	14	12	54
Red maple	--	11	--	11	12	12	40
White ash	--	6	9	--	--	6	29
Basswood	--	8	9	6	5	4	70

quality and subsequent value. This partially explains the variation in quality within and between second-growth northern hardwood stands. Although several factors could account for the difference in number and retention of defects among species, shade tolerance appears to have the primary influence: the most tolerant species appear to have the greatest number of defects. The average number of defects per tree was not significantly different among residual basal area levels 15 years after initial cutting, although the sugar maple, yellow birch, and red maple in the check treatment usually had more defects than trees in the cut stands. Differences in the type and position of defects on the bole, however, were found to be associated with residual basal area density in all five hardwood species studied, although only those for sugar maple are reported here.

Effect of Basal Area on Defects on Sugar Maple

Frequency of the four types of defects influencing bole quality varied with residual basal area (fig. 1, table 2). Live limbs, which are the greatest deterrent to tree quality improvement, were much more abundant at the lower densities and in the second log (fig. 2). For example, the stands cut to residual densities of 60 square feet had nearly twice as many live limbs after 15 years as the untreated stand. Although most of the live limbs occurred on the second log, almost

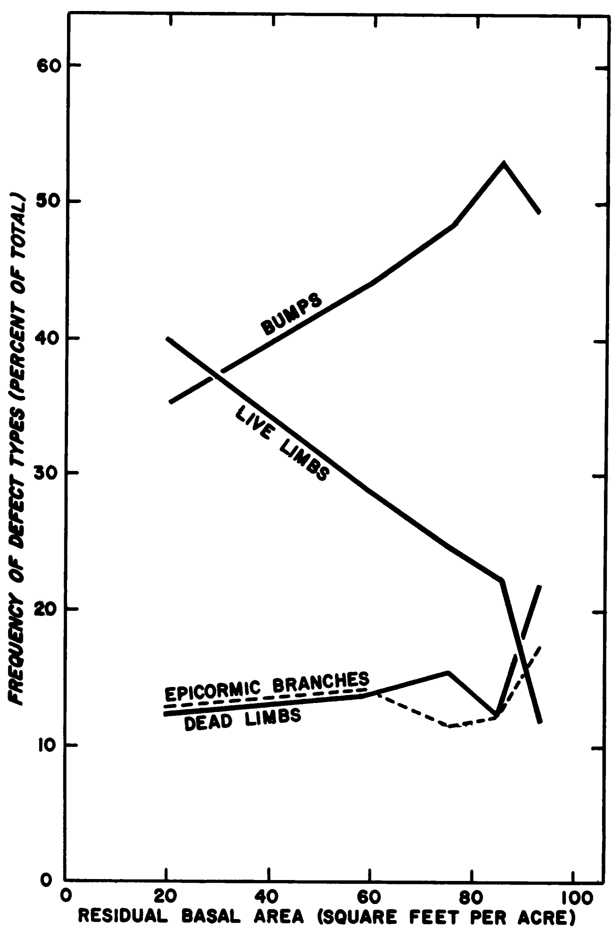

Figure 1.—Frequency of defect types in first 33 feet of stem 15 years after cutting to different residual basal area densities. Sugar maple trees originally 5 to 8 inches d.b.h.

Table 2.–Defects in sugar maple 15 years after cutting to different residual basal areas

(In number of defects per tree)

Defect type	16-Ft. Log Position	Treatment and residual basal area in sq. ft./acre					
		8-In. dia. limit	Improvement cuttings			Crop tree	Check
		20	90	75	60	60	93
Live limbs	First	0.9	0.3	0.4	0.4	0.3	0.2
	Second	7.0	3.0	3.6	4.2	4.5	2.2
	Total	7.9	3.3	4.0	4.6	4.8	2.4
Epicormic branches	First	.6	.6	.5	.7	.8	1.1
	Second	1.9	1.1	1.4	1.5	1.4	2.5
	Total	2.5	1.7	1.9	2.2	2.2	3.6
Dead limbs	First	.6	.1	.4	.3	.5	.6
	Second	1.8	1.7	2.1	1.9	2.2	3.9
	Total	2.4	1.8	2.5	2.2	2.7	4.5
Bumps	First	3.1	2.0	2.4	2.3	1.8	3.2
	Second	3.9	5.7	5.5	4.8	4.7	6.9
	Total	7.0	7.7	7.9	7.1	6.5	10.1
All defects	First	5.2	3.0	3.7	3.7	3.4	5.1
	Second	14.6	11.5	12.6	12.4	12.8	15.5
	Total	19.8	14.5	16.3	16.1	16.2	20.6

half the tree still had at least one live limb in the first log in the partially cut stands. Although the frequency of large limbs was not significantly greater in the heavier cuttings, most limbs in these cuttings can be expected to persist longer and become larger because of the lack of side competition. Under the improvement cutting to 60 square feet, approximately 30 percent of the limbs were considered large; however this percentage could be influenced by epicormic shoots that have since become small branches.

Epicormic sprouts were most abundant in the high density stands where the growing space between tree crowns was most restricted, particularly the check and 8-inch diameter limit cut. They were also more abundant in the second log than the first. While there were fewer epicormic sprouts in the intermediate density treatments, this was not necessarily because fewer epicormic sprouts developed. Possibly some sprouts grew into small live limbs, or partially developed and then died from suppression.

Dead limbs were most abundant on the trees in the untreated stand, probably due to the greater amount of competition for light, greater persistence due to the lack of disturbance in the stand, and a difference in moisture conditions at the branch that could influence the rate of decay (Heikinheimo 1953, Peace 1962). Trees in the crop-tree-release plots had a few more dead limbs 15 years after cutting than trees in the improvement cutting to the same stand basal area, perhaps because the crop-tree-release stand was not recut. In all treatments, most dead limbs were on the second log.

Bumps, which are the final stage in defect recovery, were the most abundant defect – more abundant than live and dead limbs combined in most treatments. The number of bumps per tree was greatest in the untreated stand, partly due to slower growth, and decreased gradually as residual stand density decreased. There were at least twice as many bumps in the second log as in the first log in all treatments except one.

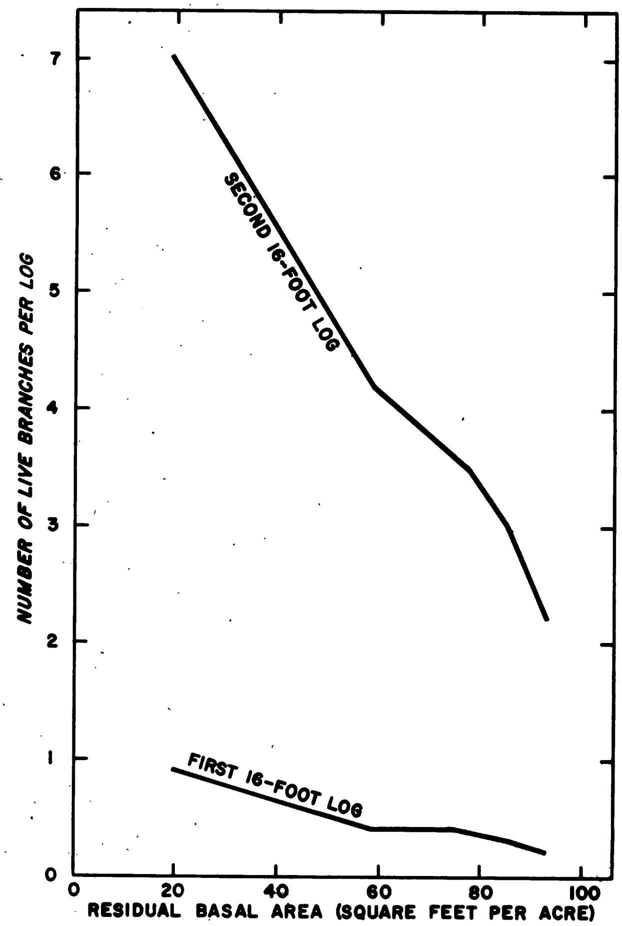

Figure 2.—Number of live limbs by log position 15 years after cutting to different residual basal area densities. Sugar maple trees originally 5 to 8 inches d.b.h.

While some differences in quality development may be due to the method of cutting (as indicated by the difference between the improvement cutting to 60 square feet and the crop tree release to the same density) this appears far less important than residual basal area density.

Other Characteristics Influencing Bole Quality

Forking, crown size, and diameter growth rate are also related to residual stand density and affect stem quality (table 3).

Forking is common in even-aged sugar maple stands and tends to increase after cutting (Conover and Ralston 1959, Godman 1968). In this study nearly three-fourths of the sample trees had forks.

In general, more trees in the thinned stands forked above 37 feet than trees in the check stands, probably due to the reduced crown competition. The crop-tree release, in which only about 40 carefully selected trees were released per acre, had the least forking (58 percent). But three-fourths of the forks in this treatment were above 37 feet. Forks in this position will probably prevent additional increase of merchantable bole length.

In addition to the reduction in merchantable length, these forks constitute a risk to tree survival and long-term growth rate. Numerous trees in the stand had split at the base of V-shaped forks and both members had broken out in some trees. Most of the breakage appeared to be old forks with large, heavy limbs that had long and apparently weak crotch seams (Eames and McDaniels 1925).

Height to the base of the live crown tends to vary because of differences in stocking within a stand. In all cuttings, both exceptionally poor and good trees were found. However, the proportion of trees with a height-to-live-crown of 25 feet or less is a good indication of the influence of basal area on natural pruning. Height-to-live-crown was greatest in the denser stands and decreased at lower basal areas. Although trees in the crop-tree release treatment had the greatest average height-to-live-crown, this advantage was offset by an increase in number of live branches in the second log (table 2).

Crown diameter in relation to stem diameter tends to increase in the less dense stands. However, sugar maples apparently develop into wolf-trees only in rather open stands.

Average diameter growth ranged from 1.8 inches per 15-year period in the untreated stand to 3.6 inches in the stand cut to 20 square feet of residual basal area. The maximum growth rate observed for any sugar maple tree was 6.0 inches in 15 years; this occurred in the crop-tree release treatment. The proportion of the desirable trees growing more than 2.0 inches per decade increased as the residual stand density decreased. This study indicates that with good tree selection and stand conditions favorable for improvement of bole quality following partial cuttings, sugar maple is capable of a rapid increase in diameter.

Table 3.—General form and growth characteristics of potential sugar maple crop trees 15 years after cutting to different residual basal area densities. Trees were originally 5 to 8 inches d.b.h.

Tree Characteristic	Treatment and residual basal area: 8-In. dia. limit	Improvement cuttings			Crop tree	Check
	20	90	75	60	60	93
Stem Form:						
Percent of trees with forks	77	64	78	72	58	73
Percent of forks at 37 ft. +	57	68	59	64	76	45
Crown Size:						
Percent of trees with height to live crown of 25 ft. or lower	57	14	21	26	10	15
Diameter Growth:						
Average 15-year increase in inches	3.6	2.1	2.7	2.9	3.0	1.8
Greatest 15-year increase in inches	5.4	4.9	4.0	4.5	6.0	2.9
Percent growing 2.0 in. + per decade	70	8	39	52	54	0

CONCLUSIONS

Stem qualilty improvement during the 15 years after initial cuttings in pole-size northern hardwoods was related to the residual stand density. While there was no significant reduction in the average number of defects per tree during this period, there was a difference in the type and position of the defects on the lower bole where the greatest volume and value of the stem occurs. This trend appears to be applicable to all northern hardwood species, but sugar maple generally has the greatest number of defects and retains them longest.

Because live limbs are the greatest deterrent to stem quality, they should be considered first in managing a stand for maximum quality development. The number of live limbs per tree decreases as residual stand density increases in pole-sized stands. Thus, the most rapid improvement in stem quality during the initial cuttings will occur at higher densities. Once the limbs have died, the rate of healing can be stimulated (hence the time required to produce clear wood shortened) by heavier cuttings.

Epicormic sprouting was variable within treatments, possibly because of differences in crown size and competition among trees. Forking is a common defect at all densities in even-sized stands of northern hardwood. At the lower stand densities there appears to be little chance of fork correction because of the lack of competition between crowns.

The relations between tree quality and stand density found in this study show that an acceptable compromise between quality improvement and growth rate can be obtained by thinning to 85 square feet of basal area per acre. This recommendation should be applicable for initial cuttings in pole-sized stands managed for production of high-quality saw logs. This guide could probably be modified to some degree, depending on management objectives or intensity. For instance, combining pruning with thinning, or thinning after an acceptable clear merchantable length has developed, would normally favor management at lower stand densities to further stimulate diameter growth and volume production.

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