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Effect of Thinning on Growth and Potential Quality of Young White Oak Crop Trees

Martin E. Dale
David L. Sonderman

The Authors

Martin E. Dale, research forester, joined the USDA Forest Service in 1957, specializing in forest management and silviculture research at Berea, Kentucky. In 1973, he received a Ph.D degree in forest biometry from Iowa State University, and was assigned to the Northeastern Forest Experiment Station's research unit at Delaware, Ohio. Currently he is specializing in studies of growth and yield of managed upland oaks.

David L. Sonderman, research forest product technologist, received a B.S. degree in forestry from West Virginia University in 1962. He joined the Northeastern Forest Experiment Station in June 1962, and was a member of the staff of the Eastern Softwood Timber Quality Project until June 1972. He is currently with the Northeastern Station's project on Management and Utilization Alternatives for Nonindustrial Private Forests at Delaware, Ohio.

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Abstract

Relative change in several types of stem defects were studied over a 16-year period to determine the effect of thinning intensity on the development of tree quality. We studied quality changes on sample white oak crop trees that were selected from five density levels created in a 1961 thinning. Branch-related and other stem defects on the butt 16-foot section were studied from stereo pairs of photographs taken in 1961 and 1977. The number of live and dead branches greater than 0.3 inch in basal diameter increased on all density plots. Except for extremely heavy thinnings, those below C-level stocking, tree quality was not markedly affected by residual stand density.

Introduction

The goal of hardwood managers often is to produce high-quality trees for lumber or veneer in the shortest possible time. A primary means of achieving this is regulating residual stand density through a series of intermediate cuttings. These treatments affect the growth rate of individual trees as well as the development of bole quality. Gingrich (1970) suggested that thinnings in hardwoods should depend more on species composition, tree vigor, and potential stem quality than merely on growth response due to reduced stand density. The effects of residual stand density on growth rates are better understood and documented than its effects on the development of stem quality. This report summarizes research findings on the development of limb-related defects and other quality characteristics associated with a range of residual stocking levels created by an earlier thinning.

Cull, defective, and lower quality stems are removed during intermediate cutting; and this process of eliminating undesirable trees theoretically enhances the development of high-quality stems. However, detrimental effects on stem quality can result, especially from extremely heavy cutting. The rate of natural pruning of live limbs also can be reduced and, in some instances, heavy cutting promotes increased branching and degrade through epicormic sprouting. Generally, changes in tree quality occur very slowly, so it is difficult to detect and quantify this rate of change on an objective basis. And little response data are available from long-term studies of changes in tree quality.

Research on bole-quality development following thinning has been neglected but not ignored completely. Stem-quality development in hardwoods is recognized to be at least as important as growth in defining optimum stocking regimes (Tubbs 1977). Since branch-related defects are the most common cause of degrade in hardwoods (Bryan 1958; Godman and Books 1971), the effect of stand stocking on branch occurrence, development, and retention is especially important. In the oak type, Brinkman (1955) reported that the tendency for individual trees to develop epicormic branches might be inherited, though the amount of branching was influenced by degree of partial cutting and the relative crown class. More epicormic branches were found in understocked stands and on trees in the subdominant crown position. Krajieck (1959) reported similar results for a 95-year-old stand of white oak where dominant stems had fewer than 3 epicormic branches on the lower 17 feet, while stems in other crown classes had 6 to 10 branches. Oaks are more prone to develop epicormic branches than species such as yellow-poplar or white ash (Smith 1966). White oak apparently produces and retains more branches or epicormics than most other species, even other oaks (Della-Bianca 1983). Research has shown that in hardwood forests the occurrence and persistence of branches—both living and dead—varies with species, tree age, crown class, site quality, and stand density.

This study examined changes in various types of limb-related defects and other tree-quality factors for white oak crop trees over a 16-year period. We were especially interested in the relative rate of change in defect indicators over the extremely broad range in stand densities created by an initial thinning in 1961. The rate of change and the trends in potential tree defects coupled with information on growth and cost of treatment will help evaluate tree and stand values and serve as a basis for selecting silvicultural treatment regimes.

Methods

Data on tree quality were collected on sample crop trees from a thinning on the Daniel Boone National Forest, Jackson County, Kentucky. The design consisted of fifteen 1/2-acre plots, plus an isolation zone of about 1/2 acre surrounding each plot. At the time of the initial thinning in 1961, this fully stocked natural white oak stand was 33 years old and showed no evidence of fire, cutting, or other disturbance. All plots were remarkably uniform in basal area, age, distribution of size class, species composition, and site quality. Before thinning, the plots averaged 687 trees per acre that were 2.6 inches or larger in d.b.h. and 75 ft^2 of basal area.

The average mean stand diameter was 4.5 inches and the average site index was 70. White oak was the principal species accounting for more than two-thirds of all trees over 2.6 inches in d.b.h. Other oaks, mainly black and scarlet, accounted for 19 percent of the trees, while hickory, black gum, and red maple accounted for most of the remaining 14 percent.

Three plots each were thinned to residual basal areas of 15, 30, 45, and 60 ft^2 per acre, leaving the three control plots with approximately 75 ft^2 per acre. The objective was to leave a suitable number of the best stems as evenly spaced as possible over the plot. In general, we cut the larger cull and defective trees first, then the competing trees of poor form and quality, then the intermediate and suppressed trees of lower quality and value. Finally, if necessary, we cut the lower value species of the main crown class. High-quality desirable species were cut also if necessary to achieve a uniform spatial distribution. Table 1 shows that much of the thinning was from below.

Dominant and codominant white oak trees that were well dispersed over the plot were selected as sample trees.

Table 1.—Relative frequency of trees larger than 2.6 inches in dbh after 1961 thinning, by crown class

Crown class	Residual basal area after 1961 thinning (ft²/acre)									
	15		30		45		60		75	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Dominant	22(5.4)[a]	18	30(5.9)	12	33(6.4)	8	54(6.1)	8	46(6.7)	7
Codominant	64(4.9)	53	127(4.9)	49	181(5.0)	45	217(4.7)	34	233(4.7)	33
Intermediate	34(3.9)	28	88(4.0)	34	119(3.8)	29	198(3.7)	31	176(3.6)	25
Suppressed	1(3.8)	1	13(3.4)	5	72(3.1)	18	168(3.0)	27	247(3.2)	35

[a]Quadratic mean diameter in parenthesis.

They were selected because of their high potential as crop trees based on tree vigor, crown position, dbh, and the apparent quality judged by form, straightness, freedom from branches, and other defect indicators. Five of these sample trees were selected randomly to determine changes in tree quality by the stereo-photo technique described by Worley and Dale (1960). This technique entailed taking stereo pairs of photographs from the four cardinal directions in 1961 and again in 1977 after 16 growing seasons. Because of the poor quality of some of the 1961 photographs, the sample consisted of only 66 trees.

Various types of stem characteristics and limb-related defects were identified and classified on each sample tree from 1961 and 1977 photographs. Prints of each negative were enlarged to 8 × 10 inches and examined with 4-power stereoscopic binoculars. Other tree characteristics such as dbh, crown class, crown length, and total tree height were observed or measured in the field on both occasions. In 1961, total height and crown length were measured with a Haga altimeter.[1] Targets and a range finder were used to establish a horizontal distance 1 chain from the measured tree. In 1977, these measurements were taken with a relaskop at a taped distance of 75 feet from the tree. Crown length was measured starting with the first major branch in the main crown.

To verify the reliability of classifying branch defects from the photographs, we conducted an independent field test using the 1977 data. The number of branches, alive or dead, and branch size were classified independently in the field in 1977 and compared with data as observed and classified from the 1977 photographs. We were able to identify the total number of branches on the 16-foot butt section very well, obtaining a correlation between photo and ground observations of 0.98. This technique was not as accurate in determining whether the branches were alive or dead, but we were able to correctly classify the status, obtaining a correlation of 0.8.

Results and Discussion

As was expected, it was easier to document the effects of thinning on growth than on quality characteristics. The main focus of this paper is on quality, but growth is discussed briefly because of its importance in evaluating thinning practices.

Diameter Growth

The effect of stocking on growth was quite evident over the 16-year period for tree characteristics such as dbh and cubic volume (Table 2). Mean diameter growth of sample trees on the lowest density plots was twice as great as on the control plots. Differences in mean diameter growth due to thinning treatments were highly significant ($P < 0.01$). From the lowest to highest stocking, annual diameter growth was respectively: 0.28, 0.23, 0.18, 0.16, and 0.14 inch, or an increase over control of 100, 64, 28, and 14 percent. Hilt (1979) reported similar growth trends in relation to stocking based on a much larger base.

Height Growth

The effect of stocking on height growth appeared to follow a different pattern than for diameter or cubic-volume growth (Table 2). Mean height growth from lowest to highest stocking was, respectively: 15.4, 17.3, 17.4, 16.6, and 13.3 feet. Covariance analysis, adjusting for initial tree height, indicated no significant difference in mean height growth due to treatment.

Cubic-Volume Growth

Stocking level influenced cubic-volume growth even more than diameter growth but followed the same pattern (Table 2). Cubic-volume growth

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Table 2.—Summary of average sample tree characteristics in 1961 and 1977 for each thinning treatment

		Residual basal area after 1961 thinning (ft^2/acre)				
Characteristic	Year	15	30	45	60	75
Dbh (inches)	1961	5.7	5.7	6.1	5.3	5.5
	1977	10.2	9.4	8.9	7.8	7.7
Crown class (% of trees)						
Dominant	1961	30.8	23.1	69.2	23.1	21.4
Codominant	1961	69.2	76.9	30.8	76.9	78.6
Dominant	1977	46.2	38.5	38.4	23.1	7.1
Codominant	1977	53.8	61.5	53.9	69.2	71.4
Intermediate-suppressed	1977			7.7	7.7	21.5
Crown ratio (% live crown)	1961	42.4	43.2	41.5	44.2	40.8
	1977	50.4	33.1	27.7	26.2	25.0
Total height (ft)	1961	51.8	52.2	53.5	51.2	51.3
	1977	67.2	69.5	70.9	67.8	64.6
Sweep and crook (departure in inches, 16-foot butt log)	1961	1.23	0.85	1.31	0.92	1.57
	1977	0.91	1.77	1.23	1.15	1.50
Cubic volume (ft^3)	1961	4.8	4.8	5.6	4.2	4.5
	1977	18.0	15.9	14.6	10.9	10.1
Stem surface area on butt 16-foot (ft^2)	1961	4.8	4.8	5.6	4.2	4.5
	1977	36.4	33.6	31.9	27.9	27.6

was 2⅓ times greater per tree at the lowest stocking compared with the control. This was expected since diameter in the volume equation is squared while height enters as a linear term. From lowest to highest stocking, growth in volume for 16 years was, respectively: 13.2, 11.1, 9.0, 6.7, and 5.7 cubic feet per tree, or an increase over the control of 132, 95, 58, and 18 percent. Differences in mean cubic-volume growth between density levels after adjusting for initial volume were highly significant ($P < 0.01$). Although growth per tree is greatest at the lowest stocking, there are too few trees (121 per acre, Table 1) to fully occupy the site; hence, on a per-acre basis, growth is less at the lowest stocking level (Dale 1972).

Tree Crown

Stand density influenced both the crown position and crown ratio of sample trees. As was expected, the proportion of trees in the dominant crown class increased with lower stocking. Likewise, crown ratio increased. The crown class and crown ratios shown in Table 2 for 1961 were observed before thinning. In 1977, more of the sample trees at the lower stocking levels had a dominant crown position and greater crown length. These characteristics probably are responsible for the increased diameter and cubic-volume growth.

In 1961 there was little difference in crown length between density levels; the average was about 22 feet overall. By 1977, the average crown length was about 34 feet at the lowest stocking but had decreased to about 16 feet on the control plots. After adjusting for initial crown length, the difference in crown length in 1977 between treatments was highly significant ($P < 0.01$).

Statistical tests on total height, crown length, and diameter growth were recomputed, omitting trees that were intermediate or suppressed in 1977. Earlier results were not changed appreciably, though the mean diameter and mean total height increased slightly over the values given in Table 2 for density levels 60 and 75.

Quality Characteristics

Tree quality is not one single measureable characteristic but consists of many factors, some of which may depend on the intended product. Certain tree characteristics or factors, however, are generally regarded as desirable for most products. Such quality indicators might be stem straightness, freedom from branches and overgrown knots, absence of forks and crooks, few insect holes or wounds, no seams, and no evidence of internal or external decay.

In this study we identified and classified several types of defects or quality indicators such as crook and sweep; various classes of live and dead branches; forks; and overgrowths. Since limb-related defects are the greatest deterrent to potential tree quality (Godman and Books 1971; Bryan 1958), most of the analysis deals with various types and sizes of branches. It is difficult to interpret the effect of stocking on branch development unless all branch-related defects are considered simultaneously. For example, over the 16-year period it is possible for some small epicormic branches to develop into large, live limbs, later die, and finally drop from the stem and become overgrowths. Specific defects must be identified and their development traced over time to develop this information. We are doing this in a separate study. In this analysis we classified the various types of defects from the 1961 and 1977 photographs independently.

Branch Characteristics

The several categories of branches we recognized depended on size and whether the twig was alive or dead. Twigs that were alive and smaller than 0.3 inch in diameter at the base were classified as epicormic. Limbs 0.3 inch or larger in diameter were called branches and further classified as alive or dead (Table 3). The number of branches on the butt 16-foot section was recorded on each of the 8-foot stem sections. When the entire 16-foot log was considered (Table 3), it is obvious that the number of trees with live branches increased at all density levels between 1961 and 1977. The greatest increase in the number of live branches was at the lowest stocking level; here, the number of trees with branches increased from about 8 percent in 1961 to 92 percent in 1977. Although there were significantly more trees with branches in 1977 than in 1961, the increase did not appear entirely related to stocking level. Many twigs were less than 0.3 inch in diameter in 1961, but in 1977, they had grown larger and were classified as branches. We believe that most branches developed from the numerous epicormics present on most trees before the initial thinning in 1961 (Fig. 1).

Not only did more trees have branches in 1977, regardless of the density level, but there were more branches per tree. Table 3 shows that about 46 percent of the sample trees on the lowest density plots had at least five or more branches per tree. The following shows the average number of live and dead branches per tree for the 16-foot section at each density level:

Branch	*Residual basal area in 1961*				
	15	30	45	60	75
Live	5.0	2.46	1.92		1.79
Dead	3.62	1.15	0.85	<0.85	<0.50

Except for the control plots, the number of live branches decreased as stand density increased.

Covariance analysis that adjusts for the initial number of live branches in 1961 indicated that the effect of density on number of live branches was significant ($P < 0.08$). Comparison of density levels revealed significantly more live branches only at the lowest density level.

The effect of density on the number of dead branches was more evident. In 1961 there was no difference between density levels in the number of trees with dead branches on the butt 16-foot log (Table 3). The lowest density level had the most trees with dead branches, 40 percent in 1961, and all of the trees in 1977. Only the highest stocked plots showed a decrease in number of trees with dead branches between 1961 and 1977. The difference between density levels in the number of dead branches in 1977 was highly significant ($P < 0.01$). The lowest density had the most dead branches in 1977 but the lower two stocking levels were significantly different than the higher stocked plots ($P < 0.01$). The tabulation also shows that there were still more living than dead branches at all density levels in 1977.

There were significantly more living and dead branches in the upper 8-foot section of the butt 16-foot log. A comparison of the living branches for the lower and upper sections is shown in Table 4. Analyses indicated that the effect of stand density on both living and dead branches was the same for the upper section as for the 16-foot log. No analyses were performed on the lower stem section because less than 23 percent of sample trees had either living or dead branches on the lower 8 feet.

Table 3.—Percentage of sample trees in 1961 and 1977 by number of living and dead branches (butt 16-foot log)

Number of branches	Residual basal area in 1961 (ft^2/acre)									
	15		30		45		60		75	
	1961	1977	1961	1977	1961	1977	1961	1977	1961	1977
					LIVING					
0	92.3	7.6	76.9	30.7	92.3	30.7	100.0	46.1	85.7	35.7
1-2	7.7	23.1	15.4	23.1	7.7	30.8	—	53.9	14.3	28.5
3-4	—	23.1	7.7	23.1	—	30.8	—	—	—	21.5
5-8	—	38.7	—	23.1	—	7.7	—	—	—	14.3
9-16	—	7.5	—	—	—	—	—	—	—	—
					DEAD					
0	61.5	—	100.0	46.1	69.2	61.5	69.2	61.5	64.2	85.7
1-2	38.5	15.3	—	46.2	30.8	23.1	30.8	38.5	28.6	14.3
3-4	—	61.6	—	7.7	—	15.4	—	—	7.2	—
5-8	—	23.1	—	—	—	—	—	—	—	—

Figure 1.—Typical 50-year-old white oak trees in fully stocked stands have many epicormics.

Table 4.—Percentage of sample trees in 1961 and 1977 by number of living branches in butt and second sections of 16-foot log

Number of branches	Residual basal area in 1961 (ft^2/acre)									
	15		30		45		60		75	
	1961	1977	1961	1977	1961	1977	1961	1977	1961	1977
	BUTT SECTION									
0	100.0	84.6	92.3	76.9	100.0	84.6	100.0	100.0	100.0	78.5
1-2	—	15.4	7.7	23.1	—	15.4	—	—	—	22.5
	SECOND SECTION									
0	92.3	7.6	76.9	30.7	92.3	30.7	100.0	46.1	85.7	35.7
1-2	7.7	23.1	23.1	38.5	7.7	30.8	—	53.9	14.3	35.7
3-4	—	23.1	—	7.7	—	31.8	—	—	—	23.8
5-8	—	38.5	—	23.1	—	7.2	—	—	—	—
9-16	—	7.7	—	—	—	—	—	—	—	—

Epicormic Branches

Small epicormic branches were difficult to identify and count accurately from the photos so we only recognized three broad categories of trees with epicormic branches: none, one to six, or seven or more epicormics for each 8-foot section (Table 5). In both sections there were few trees with no epicormics in 1961. The percentage of trees free of epicormics on the butt 8-foot section in 1977 ranged from 23 percent at 15 ft² of basal area to 53 percent at 30 ft² of basal area (Table 5). The number of trees with no epicormics increased between 1961 and 1977 except at the lowest stocking level.

Branch Size

Average diameter of the largest living and dead branch on each 8-foot section is given in Table 6. Live branch size on the second 8-foot section was significantly ($P < 0.01$) related to stocking level. Branch size also appeared to decrease with increasing stocking on the lower sections, but no analyses were attempted because too few trees had branches. Live branches were slightly larger on the second 8-foot section, ranging from 1.0 inch at the lowest stocking to only 0.58 inch at the highest stocking. There was no correlation between stocking and size of dead branches after 10 years. In the future, dead branch size likely will be larger on the lower stocking levels since the live branches present today are now larger on the low-density plots.

We believe that the development of an extremely dense understory on the lower stocked plots (Fig. 2) may help explain some of the changes in branch size and number of dead branches. Initially, the lower bole of sample trees

Table 5.—Percentage of sample trees in 1961 and 1977 by the number of epicormic branches in butt and second section of 16-foot log

Number of epicormics	Residual basal area in 1961 (ft²/acre)									
	15		30		45		60		75	
	1961	1977	1961	1977	1961	1977	1961	1977	1961	1977
BUTT SECTION										
0	30.7	23.0	15.3	53.8	15.3	38.4	—	38.4	—	35.7
1-6	46.2	46.2	69.3	38.5	69.3	53.9	76.9	46.2	71.4	35.7
7+	23.1	30.8	15.4	7.7	15.3	7.7	23.1	15.4	28.6	28.6
SECOND SECTION										
0	7.6	7.6	7.6	7.6	—	7.6	—	—	—	—
1-6	38.5	69.3	20.8	53.9	46.1	53.9	23.0	53.8	14.2	57.1
7+	53.9	23.1	71.6	38.5	53.9	38.5	77.0	46.2	85.8	42.9

Table 6.—Average size (basal diameter) of largest live and dead branch on each tree in 1961 and 1977

Item	Year	Residual basal area after thinning (ft²/acre)				
		15	30	45	60	75
				Inches		
Live limbs Butt 8-foot section	1961	—	—	—	—	—
	1977	0.75	0.58	0.63	—	0.50
Live limbs Second 8-foot section	1961	0.50	0.50	0.50	—	0.50
	1977	1.00	0.80	0.67	0.60	0.58
Dead limbs Butt 8-foot section	1961	—	—	—	—	—
	1977	0.62	0.75	1.00	0.62	0.75
Dead limbs Second 8-foot section	1961	1.04	—	0.94	1.19	0.80
	1977	0.91	0.53	0.70	0.91	0.75

Figure 2.—Typical dense understory on a lower stocking plot in 1977.

was exposed to a great deal of direct sunlight, so epicormics developed and grew rapidly to branch size classification. A few years later, a dense understory was shading the lower 8-foot section, causing branch mortality or restricting growth. After 16 years, the understory is 25 to 30 feet tall and is shading the entire lower 16 feet. Even if branches die as quickly now on the lower as on the higher stocked plots, branches are larger and may require a longer period to drop off and become overgrown by clear wood. Also, the trees already are larger in diameter so even if branches do die shortly, the knotty core will be larger at the lower stocking levels.

Defects Per Square Foot of Surface Area

The number of defects per square foot of stem surface area provides a relative comparison of the effect of stocking on stem quality. Table 7 shows the number of live or dead branch defects per square foot of surface area. The number of such defects per square foot increased on all density levels over the 16-year period, but the greatest increase was on the lowest density plots. The ratio of 1977 to 1961 defects per square foot for the 16-foot log indicates nearly 8 times more defects per square foot in 1977 at the lowest stocking and nearly twice as many at the highest stocking. This ratio decreased as stocking increased from 7.9, 6.2, 4.1, 2.3 and 1.8. Live or dead branches on the second 8-foot section were responsible for most of the increase.

Table 7.—Number of live and dead limb defects per square foot of stem surface area

Item	Year	Residual basal area after 1961 thinning (ft^2/acre)				
		15	30	45	60	75
Butt 8-foot log	1961	—	0.005	—	—	—
	1977	0.056	0.025	0.022	0.012	0.026
Second 8-foot log	1961	0.071	0.032	0.056	0.047	0.102
	1977	0.482	0.223	0.197	0.094	0.156
Entire 16-foot log	1961	0.031	0.018	0.024	0.021	0.045
	1977	0.244	0.112	0.099	0.048	0.083

Summary and Conclusions

The results presented here represent only one age and one size class and apply only to white oak. More comprehensive studies must be completed across a broad range of age, site, and species before specific recommendations can be offered. However, the data suggest that the effect of stocking on potential stem quality may be substantial. The findings in this study indicate that:

1. The number of limb-related defects decreases with increasing residual stand density.
2. The size of live limbs decreases in both upper and lower 8-foot logs with increasing residual stand density.
3. Live limbs generally are larger in the upper log.
4. In this relatively young pole timber stand, there are still more living than dead branches on the 16-foot log, regardless of the residual basal area.
5. The average number of branch-related defects on the butt 16-foot log decreases from a high of nine per tree at the lowest stocking to one to three on the higher stocked plots.
6. The number of epicormic branches on both the lower and upper 8-foot sections generally have decreased since 1961 because many have grown to branch classification size. However, epicormic branches still are numerous on both sections after 16 years, regardless of stand density, and remain a potential source of future defects.

Extremely heavy initial thinning in these young oak stands certainly delays, if not substantially reduces, the potential to develop high-quality stems. Except for extremely heavy thinning, the residual density does not seem to markedly affect stem quality. If sufficient trees are left to fully use the sites (about 60 percent or more stocking, Roach and Gingrich 1968) any slight loss in quality may be compensated for by trees growing faster or reaching maturity sooner than those in unthinned stands. More study is needed on growth, quality, and economic factors before specific thinning regimes can be recommended for the white oak timber type. Meanwhile, it appears from this study that tree quality will not be seriously affected so long as stocking is 50 percent or more after thinning.

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Relative changes in several types of stem defects were studied over a 16-year period to determine the effect of thinning intensity on the development of tree quality. Sixty-six sample white oak crop trees represented each of five density levels created by thinning a young white oak stand in Kentucky in 1961. Occurrence of branch-related and other stem defects on the butt 16-foot section was studied from stereo pairs of photographs taken in 1961 and 1977. The number of live and dead branches greater than 0.3 inch in basal diameter increased on all density plots. Except for extremely heavy thinnings, those below C-level stocking, tree quality was not markedly affected by residual stand density.

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Keywords: Silviculture; thinning; bole quality

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

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