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# Quality Response of Even-Aged 80-Year-Old White Oak Trees After Thinning

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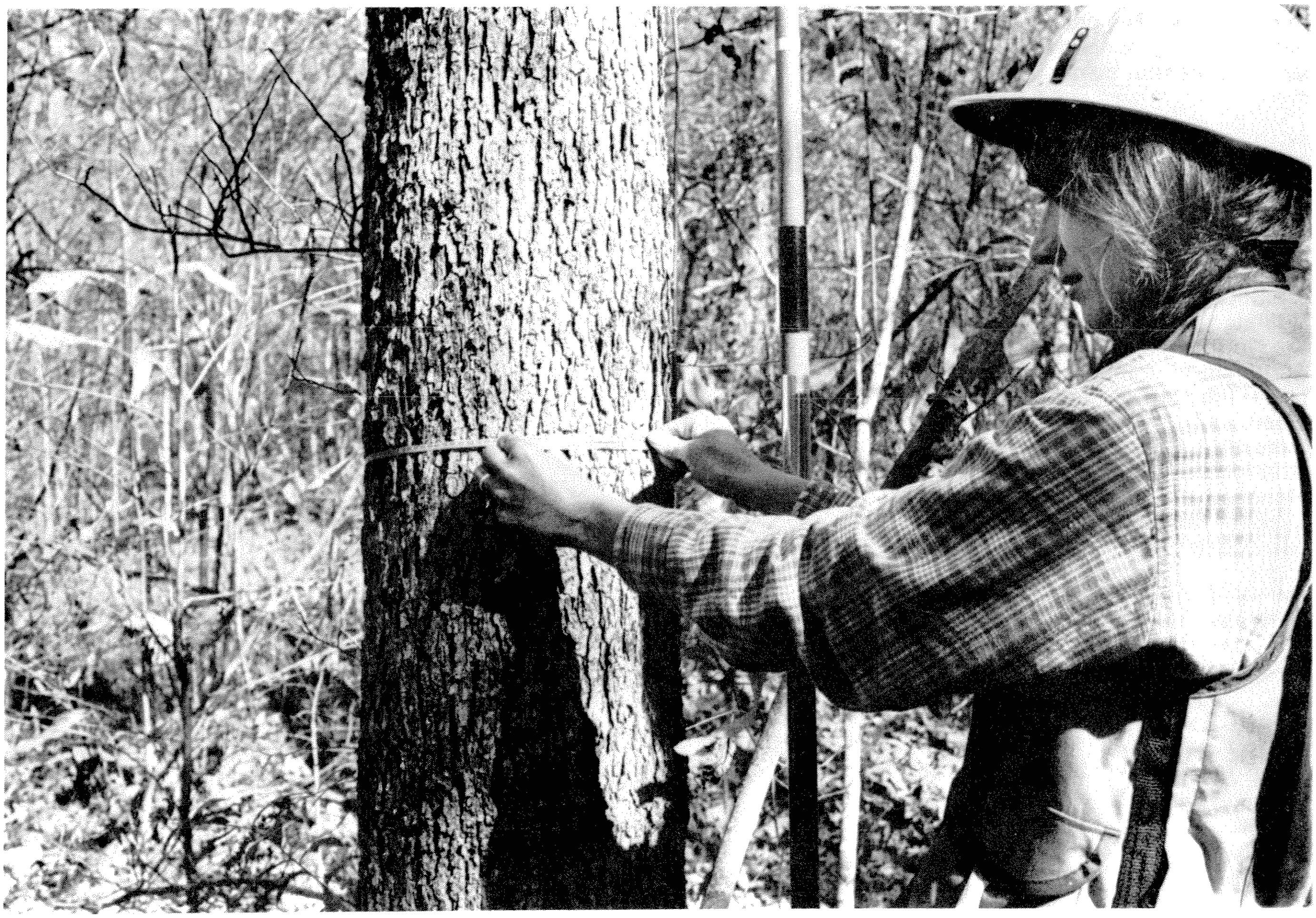

## Abstract

Stem defects were studied over an 18-year period to determine the effect of thinning intensity on quality development of 80-year-old white oak trees. Seventy-nine white oak trees from a thinning study in Kentucky were analyzed from stereo photographs taken in 1960 and 1978. Stem-related defects were measured on the butt 8-foot and second 8-foot sections of each tree. The number of defects per square foot of surface area increased significantly at the heaviest thinning level. The data suggest that heavy thinning has a detrimental effect on potential stem quality.

## The Author

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## Introduction

Forest managers have long been interested in increasing volume growth by the use of various silvicultural treatments. Emphasis has been on increasing tree diameter and height growth by regulating residual stand density, but there has been little regard for tree quality. In fact, tree quality is equally important to good volume growth because it provides high value end-products such as veneers and high-grade lumber.

Documentation of research on the effects of stocking on growth rates is much more frequent than documentation of potential quality development. We found that white oaks responded quite differently from other hardwood species reported on. In one study, the relative change in stem quality of 33-year-old white oaks was affected by thinning intensities after 16 years of treatment. The number of live and dead branches greater than 0.3 inch in diameter had increased for all density levels, with the largest increase at the lowest density plots (Dale and Sonderman 1984).

In a study on the response of young northern hardwoods in New Hampshire, Marquis (1969) found that after 5 years there was no reduction in quality due to treatment. In a study of the influence of stand density on stem quality of pole-size northern hardwoods, Godman (1971) found that during a 15-year period the average number of defects per tree did not change except in the type and position of the defects in the lower tree bole. Smith (1977) found that thinning to various tree-density levels did not influence epicormic branching in yellow-poplar after 8 years.

In most of these studies the responses of individual tree characteristics were observed independently. In this paper, we have included individual tree and quality characteristics that we believe are related to potential end-product classes. We are examining the relationship of time on the development of quality-related surface characteristics of trees grown at different levels of residual stand density. Research on hardwood quality has shown that species, age, crown ratio, and stand density are important factors that affect potential stem quality. Usually, limb-related defects and epicormic branches are the bole characteristics most affected by thinning treatments. In this paper, limb-related characteristics should be considered simultaneously to interpret the effect of stand density on their development.

## Methods

Data were collected on sample trees from a thinning experiment on the Daniel Boone National Forest, Laurel County, Kentucky. In 1960, sixteen 1-acre plots were established in an 80-year old white oak stand; isolation zones of ½ chain surrounded each plot. Four plots each were thinned to a residual basal area of 20, 40, and 60 $ft^2$/acre, leaving four plots with approximately 80 $ft^2$/acre as the control. Minimum diameter of trees thinned from the plots was limited to 3.6 inches. Originally, all plots were about the same in density, age, size class, species composition, and site quality. Before the initial cutting, the average basal area of the plots was 80 $ft^2$/acre. The average age was 78, the average d.b.h. was 8.9 inches, and the average site index was 63. Tree vigor, spacing, size, and apparent quality based on form, straightness, and freedom of stem branches were the factors used for potential crop-tree selection.

Five trees from each plot were selected at random to study the change in potential tree quality by the stereo-photo technique described by Sonderman (1980). Stereo-photographs were taken from the four cardinal directions around each of the study trees; subsequent stereo-photographs were taken after 18 growing seasons. In this analysis, 79 stereo-photo trees were studied from 8 by 10 stereo-photographic enlargements taken in 1960 and 1978. For each tree we recorded the d.b.h., total height, crown ratio, number and diameter of live and dead limbs, and number of epicormic branches. The trees also were classified by relative quality (Sonderman 1979). Only the limb-related defects were recorded from the stereo-photographs. The remaining variables were measured or observed in the field in 1960 and 1978.

Limb-related variables were analyzed by covariance analysis. The value of the variable at the initial time was used as the covariate.

## Results and Discussion

### Growth

Stand density affects the diameter, height growth, and crown ratio of trees in different ways. Heavy stand density (80 $ft^2$ BA) seems to affect diameter growth more than height growth. Average diameter of the study trees after treatment was 10.59 inches in 1960 and 13.38 inches in 1978. Mean diameter growth increased by 2.8 inches on all trees, with a 22-percent increase in diameter in the 80-$ft^2$ plots and a 31-percent increase in the 20-$ft^2$ plots. Hilt (1979) found similar diameter-growth trends in relation to stocking.

In this study, mean height growth was highest in the 60-$ft^2$ plots, but was not significant due to treatment differences in a similar study by Dale and Sonderman (1984).

Average crown ratio, considered one of the best indicators of the effects of stand density, increased in all treatments except the control. The crown ratio in the control plots (80 $ft^2$) decreased by 7 percent and the crown ratio in the 20-$ft^2$ plots increased by 64 percent. The increase in the 20-$ft^2$ plots was due to the development of additional epicormic branches, faster growth, and greater retention of branches. Dale and Sonderman (1984) reported highly significant differences between crown length and treatments.

### Limb Defects Per Square Foot of Surface Area

Limb defects per square foot of surface area include all live and dead limbs and all overgrowths on the butt 16-foot section of the tree. Analyzing the data by the number of defects per square foot of surface area provides a relative comparison of the effects of stocking on stem quality. Normally, expansion of the surface area will result in a decrease in the number of defects per square foot of surface area—if no new defects develop over time. The following tabulation shows the number of defects per square foot of surface area (butt 16-foot section):

| Year | *Residual basal area ($ft^2$/acre)* | | | |
|---|---|---|---|---|
| | 20 | 40 | 60 | 80 |
| 1960 | 0.139 | 0.145 | 0.089 | 0.102 |
| 1978 | 0.185 | 0.153 | 0.095 | 0.088 |

The high-density control plots are the only ones that show a decrease in average number of defects after 18 years. The decrease is due to the effect of natural pruning and to the lack of development of epicormic branches that is associated with dense stands. These plots had a 14-percent decrease in the number of defects per square foot of surface area, and a 16-percent increase in surface area. In the 20-$ft^2$ plots, there was a 33-percent increase in the number of defects per square foot of surface area and a 24-percent increase in surface area.

### Live Limbs

Limbs that were alive and smaller than 0.3 inch in diameter were classified as epicormic branches and those 0.3 inch or larger in diameter were classified as live or dead. The number of limbs was recorded for both the butt 8-foot and second 8-foot sections of each sample tree. In the butt 8-foot section, the number of live limbs and the percentage of trees with live limbs decreased at all density levels between 1960 and 1978 (Table 1). The greatest reduction was in the 60-$ft^2$ treatment, which had no trees with live limbs in the butt 8-foot section after 18 years. When comparing the two log sections, the second 8-foot section increased over the butt section in both the proportion of trees with live limbs and the number of live limbs (Table 1). There was an overall reduction in the percentage of trees with live limbs in the second 8-foot section at every density level from 1960 through 1978.

There was no statistically significant ($P < 0.05$) difference in the number of live limbs per tree on the butt 16-foot section after adjusting for the initial number of live limbs over the 18-year period. However, there was a trend to fewer live limbs per tree as stocking increased. It is apparent that the number of live limbs in the 20- and 40-ft² treatments increased early in the treatment period, because there was an overall increase in the number of dead limbs in these same treatments. This increase in dead limbs developed from an increase in live limbs that subsequently died during the 18-year period.

**Diameter of Live Limbs**

In 1978, the average diameter of live limbs for the butt 8-foot section of the study trees was more than ½ inch. The exception was the 60-ft² plots, which had no live limbs (Table 2). In the second 8-foot section, the size of the live limbs had fluctuated considerably by 1978—from 1.17 inches in the 40-ft² plots to a low of 0.57 inch in the control plots (Table 2). As the density of the stand increased, the number and size of the live limbs decreased because of natural pruning and limited light. In this study, the diameter of live limbs increased by 31 percent in the 40-ft² plots and by less than 1 percent in the control plots.

**Table 1.—Percentage of trees with live limbs in butt 8-foot and second 8-foot sections, 1960-78**

| Number of live limbs | Residual basal area (ft²/acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | |
| | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 |
| | BUTT 8-FOOT SECTION | | | | | | | |
| 1-2 | 20.0 | 10.0 | 15.0 | 5.0 | 10.5 | — | 25.0 | 15.0 |
| 3-4 | 10.0 | 5.0 | — | 5.0 | — | — | — | — |
| | SECOND 8-FOOT SECTION | | | | | | | |
| 1-2 | 60.0 | 65.0 | 25.0 | 20.0 | 63.2 | 31.5 | 50.0 | 35.0 |
| 3-4 | 15.0 | 5.0 | 35.0 | 10.0 | 10.5 | 5.3 | 15.0 | — |
| 5-8 | 5.0 | — | — | — | — | 5.3 | — | — |

**Table 2.—Average diameter of live limbs in butt 8-foot and second 8-foot sections, 1960-78**

| Tree section | Residual basal area (ft²/acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | |
| | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 |
| | *Inches* | | | | | | | |
| Butt 8-foot | 0.62 | 0.58 | 0.50 | 0.75 | 0.50 | — | 0.50 | 0.75 |
| Second 8-foot | 0.75 | 0.98 | 0.85 | 1.17 | 0.73 | 0.65 | 0.53 | 0.57 |

## Dead Limbs

In all treatments, the percentage of trees with dead limbs increased in both 8-foot sections over the 18-year period (Table 3). The 20-$ft^2$ plots had both the largest increase in the percentage of trees with dead limbs and the largest number of defects in both sections. By contrast, the controls had the smallest increase in the percentage of trees with dead limbs in both sections.

The overall increase in number of dead limbs on the lower density plots resulted from the large increase in live limbs early in the treatment period. These live limbs died later in the treatment period. Dead limbs in the butt 16-foot section showed a significant difference between the 20-$ft^2$ treatment and all other treatments ($P < 0.05$). The 20- and 40-$ft^2$ treatments were significantly greater than the 60- and 80-$ft^2$ treatments ($P < 0.1$). There was no significant difference between the 60- and 80-$ft^2$ treatments for the entire 16-foot section.

The development of a dense understory on the lower density plots explains some of the changes in the percentage of trees with dead limbs and the number of dead limbs. Initially, the open condition created in these plots promoted the development of epicormic branches. As the understory developed over the 18 years, it progressively blocked some of the direct sunlight from the butt 8-foot section of the tree, causing limb development to slow. Later, attaining a height of 25 to 30 feet, the understory began blocking sunlight from the entire 16-foot section and suppressing the existing limbs and epicormic branches. This resulted in different limb-related growth rates for each 8-foot section of the tree.

## Diameter of Dead Limbs

The average diameter of the dead limbs on the butt 8-foot section was smaller than the average diameter of the dead limbs on the second 8-foot section (Table 4). The size of dead limbs generally increased as stand density decreased.

The second 8-foot section, which encompassed part of the living crown, received more light and as a result had larger dead limbs than the lower 8-foot section. The second 8-foot section of the trees in the 20-$ft^2$ treatment had the largest dead limbs, increasing from 0.90 inch in 1960 to 1.53 inches in 1978. This 70-percent increase in the size of the dead limbs illustrates the effect of open stocking on limb development. Part of the increase in the size of dead limbs was caused by the lack of natural pruning, which allowed existing live limbs to remain on the tree and develop. By contrast, the size of dead limbs in the control plots was 0.72 inch in 1960 and only 0.83 inch in 1978.

## Epicormic Branches in Both 8-Foot Sections

Table 5 shows the changes in numbers of epicormic branches between 1960 and 1978 for the butt and second 8-foot sections. Three broad categories of epicormic branches were established (Sonderman 1979): (1) trees with no epicormic branches, (2) trees with 1 to 6 epicormic branches, and (3) trees with 7 or more epicormic branches for each 8-foot section.

On the butt 8-foot section, the lowest density treatment had about the same number of epicormic branches per tree after 18 years. The percentage of trees with epicormic branches also remained the same. At all other density levels there was a decrease in the number of epicormic branches per tree, and a similar reduction in the percentage of trees with epicormic branches. In the second 8-foot section, there was a 35-percent reduction in trees with epicormic branches in the lowest density plots.

In the butt 8-foot section, the understory on the 20-$ft^2$ plots began blocking the sunlight soon after thinning, causing epicormic branches to develop more slowly. As a result, the percentage of trees with epicormic branches remained about the same over the 18-year period.

In the second 8-foot section, epicormic branches developed faster because of more light for a longer time. Eventually, the understory attained a height of 25 to 30 feet and began shading the second 8-foot section. However, the extra amount of sunlight had allowed the epicormic branches to grow into measureable live limbs, as evidenced by the significant increase in the number of dead limbs.

**Table 3.—Percentage of trees with limbs in butt 8-foot and second 8-foot sections, 1960–78**

| Number of dead limbs | Residual basal area (ft²/acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | |
| | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 |
| | BUTT 8-FOOT SECTION | | | | | | | |
| 1-2 | 10.0 | 30.0 | 15.0 | 35.0 | — | 10.5 | 10.0 | 20.0 |
| 3-4 | — | 10.0 | — | 5.0 | — | — | — | — |
| 5-8 | — | 5.0 | — | — | — | — | — | — |
| | SECOND 8-FOOT SECTION | | | | | | | |
| 1-2 | 50.0 | 30.0 | 50.0 | 25.0 | 36.8 | 42.1 | 35.0 | 30.0 |
| 3-4 | 10.0 | 20.0 | 20.0 | 15.0 | — | 15.8 | 10.0 | 20.0 |
| 5-8 | 5.0 | 25.0 | — | 35.0 | — | — | — | 5.0 |
| 9-16 | — | 15.0 | — | — | — | — | — | — |

**Table 4.—Average diameter of dead limbs in butt 8-foot and second 8-foot sections, 1960–78**

| Tree section | Residual basal area (ft²/acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | |
| | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 |
| | *Inches* | | | | | | | |
| Butt 8-foot | 0.75 | 1.00 | 0.66 | 0.66 | — | 0.63 | 1.12 | 0.93 |
| Second 8-foot | 0.90 | 1.53 | 0.80 | 1.11 | 0.85 | 0.88 | 0.72 | 0.84 |

**Table 5.—Percentage of trees with epicormic branches, butt 8-foot and second 8-foot sections, 1960–78**

| Number of epicormics | Residual basal area (ft²/acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | |
| | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 | 1960 | 1978 |
| | BUTT 8-FOOT SECTION | | | | | | | |
| 1-6 | 30.0 | 25.0 | 60.0 | 30.0 | 42.1 | — | 45.0 | 5.0 |
| 7+ | 15.0 | 20.0 | 5.0 | 5.0 | — | 10.5 | — | 5.0 |
| | SECOND 8-FOOT SECTION | | | | | | | |
| 1-6 | 65.0 | 35.0 | 40.0 | 50.0 | 73.7 | 42.1 | 55.0 | 40.0 |
| 7+ | 20.0 | 15.0 | 25.0 | 10.0 | 5.3 | 5.3 | 10.0 | 5.0 |

## Summary and Conclusion

The information in this report shows important trends in stem quality and growth as related to different levels of residual stand density for white oak trees over time. It must be remembered that the individual characteristics are not independent of one another. For example, there is a pattern of epicormic branches changing to live limbs, live limbs changing to dead limbs, and dead limbs changing to overgrowths. All branch-related defects must be considered simultaneously to interpret the effect of stocking on their development.

Results from this study indicate that in white oak trees measured over time showed that:

1. The number of defects per square foot of surface area decreased as the residual stand density increased.
2. The second 8-foot section of the tree had more live limbs than the butt 8-foot section.
3. Live limbs were substantially larger in the second 8-foot section of the tree.
4. Both the proportion of trees with dead limbs and the number of dead limbs decreased as residual stand density increased.
5. The average number of dead limbs increased almost 4 times from 1960 to 1978 at the lowest density level.
6. There were more epicormic branches in the second 8-foot section of the tree than in the butt 8-foot section.
7. The percentage of trees with epicormic branches on the butt 8-foot section in the open 20-$ft^2$ plots did not change. Yet, the percentage of trees with epicormic branches decreased in every other treatment for both 8-foot sections between 1960 and 1978.

Because this study was limited to a single species, site class, and age group, the results can be extrapolated to other species, site classes, and age groups only in very broad terms.

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