June 15, 1973

To the Graduate Council:

I am submitting herewith a thesis written by Benjamin Hall Wolcott, Jr., entitled "Epicormic Branching in Southern Red Oak (Quercus falcata Michx)--A Measure of Maximum Degrade Associated with Reduced Stocking in Older Stands." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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We have read this thesis and recommend its acceptance:

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104

EPICORMIC BRANCHING IN SOUTHERN RED OAK (*Quercus falcata* Michx) --A MEASURE OF MAXIMUM DEGRADE ASSOCIATED WITH REDUCED STOCKING IN OLDER STANDS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Benjamin Hall Wolcott, Jr.

August 1973

ACKNOWLEDGMENT

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ABSTRACT

The objectives of the study were: (1) to quantify the relative loss in crop-tree lumber value resulting from increased epicormic branching brought on by stand density reduction, and (2) to quantify the time frame required for this loss to attain economic importance. The study was carried out in West Tennessee and examined the effect of a 13-year-old thinning in a seventy-six-year old hardwood stand dominated by Southern red oak (Quercus falcata Michx). Four sample trees were taken from a stand which had developed at a high level of stocking (127 sq. ft. basal area per acre) and compared to four sample trees from a contiguous part of the same forest stand which had been reduced from 85 to 60 sq. ft. of basal area in 1959. Data were collected regarding site characteristics and the density of surrounding stems, using sample trees as quarter-acre plot centers. Sample trees were logged and sawed, and lumber was graded and indexed to quadrants and log sequence including slab and board position; also, knots were examined to determine the character of their origin.

The first boards sawed from the four quadrants of the lower 34 feet of sample trees were used in the lumber degrade comparison. Total first-board volume was 665 board feet (321 bd. ft. and 344 bd. ft. from the low- and high-density areas, respectively), which was about one-fourth of the total scaled log volume of sample trees.

Epicormic branch knots in sample trees showed a significant (0.05 level) inverse relationship to understory density in all plot quadrants except the southeast. Epicormic branching in all logs above 8-1/2 feet also showed a definite inverse relationship to density of the understory. There were little differences in epicormic branching in the lower 8-1/2-ft. log between stand density areas, but differences began to appear in the second 8-1/2-ft. log and became greater with increasing height in the sample tree.

The value difference per thousand board feet of first-board lumber between the two stand density areas was found to be about $50.00 at current prices, and to have been about one-fourth the market price of No. 1 Common red oak lumber for consecutive five-year periods during the past 25 years.

The number of epicormic knots in lumber from the low-density area (average 111 per tree or nine times as many as in trees from the high stand density area) was felt to be more a result of early low stocking levels than attributable to the 1959 thinning. Because of the already high number of epicormics, devaluation attributable to the thinning was negligible. However, a similar thinning in the high stand density area probably would have resulted in potentially serious devaluation of subsequent wood production, up to $50.00 per MBF. Degrade of this magnitude would take at least 13 years to form, however, and would vary by the diameter growth rate and form of the individual tree, and by current lumber price levels.

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INTRODUCTION

Foresters have long been concerned with epicormic branching because of its insidious effect on the value of many hardwood lumber species. According to Kormanik and Brown (1969), European foresters have been cognizant of epicormic branching since the late 18th century.

Epicormic branches originate from suppressed trace buds and from adventitious buds; their eruption may be triggered by injury to the surrounding stem area, sudden exposure of a portion of the stem to sunlight (as in thinning), or other factors such as inheritance characteristics which are not well known. For some tree species, branch eruption may occur in all logs, while in others, epicormic branches may become more profuse in upper logs; the result being that wood production after thinning will have more defects, though faster growth of the individual tree may be achieved.

The net effect of epicormic branching is the proliferation of small knots which are serious degraders of hardwood lumber[1] or veneer, size notwithstanding. Knots arising from adventitious buds have no vascular connection to the pith (ergo, cause no defect prior to eruption), but are frequently stimulated to erupt by thinning. Dormant trace buds,

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[1]Knots are serious degraders of all hardwood lumber graded under the Standard Rules of the National Hardwood Lumber Manufacturers Association. There are exceptions for some species such as the occurrence of pin knots in black cherry (Prunus serotina L.) (Hanks, 1965).

however, maintain a vascular channel to the pith which may cause a defect in lumber produced before eruption occurs.

The tendency after thinning for residual hardwood trees to "feather out" in numerous epicormic branches has been brought to focus by recent trends in timber management. The present trend toward low-density silviculture with purposes of both shorter rotations and provision of other multiple-use benefits than timber is being practiced. Also, the aversion of the public to clearcutting has brought into use other silvicultural regeneration systems such as seed-tree, shelter-wood, and group selection cutting, all of which are complicated by quality factors involving epicormic branches. Knowledge of the relationship of stand density to epicormic branching in crop trees, and the length of time allowable before an increase in knots will manifest itself in excessive lumber devaluation, is becoming more important.

This study was an attempt to provide some concrete data in these areas. The study objectives were: (1) to quantify the relative loss in crop-tree lumber value resulting from increased epicormic branching brought on by stand density reduction, and (2) to quantify the time frame required for this loss to attain significance. The study was carried out in West Tennessee and examines the effect of a 13-year-old thinning in a stand dominated by Southern red oak (Quercus falcata Michx), which is one of the most widely utilized hardwood species in this area of the state. An attempt was made to compare representatives from a stand which had reached maturity at a high level of stocking (105-110 square feet of basal area) to sample trees from a contiguous

part of the same forest which had been reduced from 85 to 60 square feet of basal area in 1959. Data were collected regarding site characteristics and the density of surrounding stems. The sample trees were logged and sawed, lumber was graded and indexed to quadrants and log sequence including slab and board position; also, knots were examined to determine whether or not they were of epicormic origin.

Price structure of the hardwood lumber market is germane to the present study. Silvicultural treatments which cause an increase in epicormic branching in leave trees may be compared on the value of high-grade lumber lost to this effect. More important, possibly, is the actual spread between prices for the lowest lumber grade and each succeeding higher grade, especially considering possible increased growth rates of leave trees and the overall attractiveness of a desired silvicultural treatment.

I. DESCRIPTION OF THE STUDY AREA

Ames Plantation

The Ames Plantation is comprised of 18,600 acres, located in southwest Tennessee, 45 miles east of Memphis and 45 miles south of Jackson, in Fayette and Hardeman counties. Mr. Hobart Ames began acquiring land in 1903, and the plantation had expanded to its present size by the time of his death in 1945. No timber cutting was allowed during Mr. Ames' lifetime, but considerable logging has been done since 1952, when professional forest management practices were first adopted (Boyd, 1969).

Ames Plantation enjoys a frost-free period of about seven months' duration, from the first of April to the end of October, with mild winters and hot summers. Average high and low temperatures are 95°F in summer and 10°F in winter. Rainfall distribution is fairly uniform and adequate at all seasons, averaging 52 inches per year. Snowfall is four to six inches annually, and hailstorms may occur two or three times per year. Damage from high winds occurs infrequently.

Topography of the Ames Plantation is level to gently rolling, with some severely eroded land. The soil horizon has been penetrated by many deep gullies.

Soils are loess deposits, very fertile but given to erosion when unprotected. Some admixture has taken place with the underlying coastal plain sediment. A few sites are not capable of supporting hardwoods

because of inferior soil quality. Most areas, however, are well suited to hardwoods, and bottomlands are highly productive. Approximately one-half the plantation is currently in forested land. Oak-hickory and oak-pine types predominate, though several thousand acres of pine plantations have been established.

Hardwood Management Demonstration Plots

In 1959, the University of Tennessee initiated a study of the effects of basal-area-controlled thinnings in natural hardwood stands. Determination of optimum basal area to hold under different thinning regimes was a primary objective of this project. In part, the study consisted of thinning three contiguous five-acre plots in a mature[1] hardwood stand to specified residual densities of 110, 80, and 60 square feet of basal area (Figure 1). Thinning was accomplished in the fall of 1959, with no further harvest in the study area since that time. The site has since been utilized as a Management Demonstration Area.

The plots themselves lie on gently rolling ground, with characteristics ranging from mostly upland to some bottomland sites. The land is generally well-drained.

Although a continuous stand of uniform density would seem to be most desirable for the evaluation of basal-area-controlled thinnings, the stand chosen varied from 85 to 110 square feet of basal area per acre. It is possible that site characteristics also vary in uniformity,

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[1]Ages of trees ranged from 44 to 91 years. Mean age was 63 years.

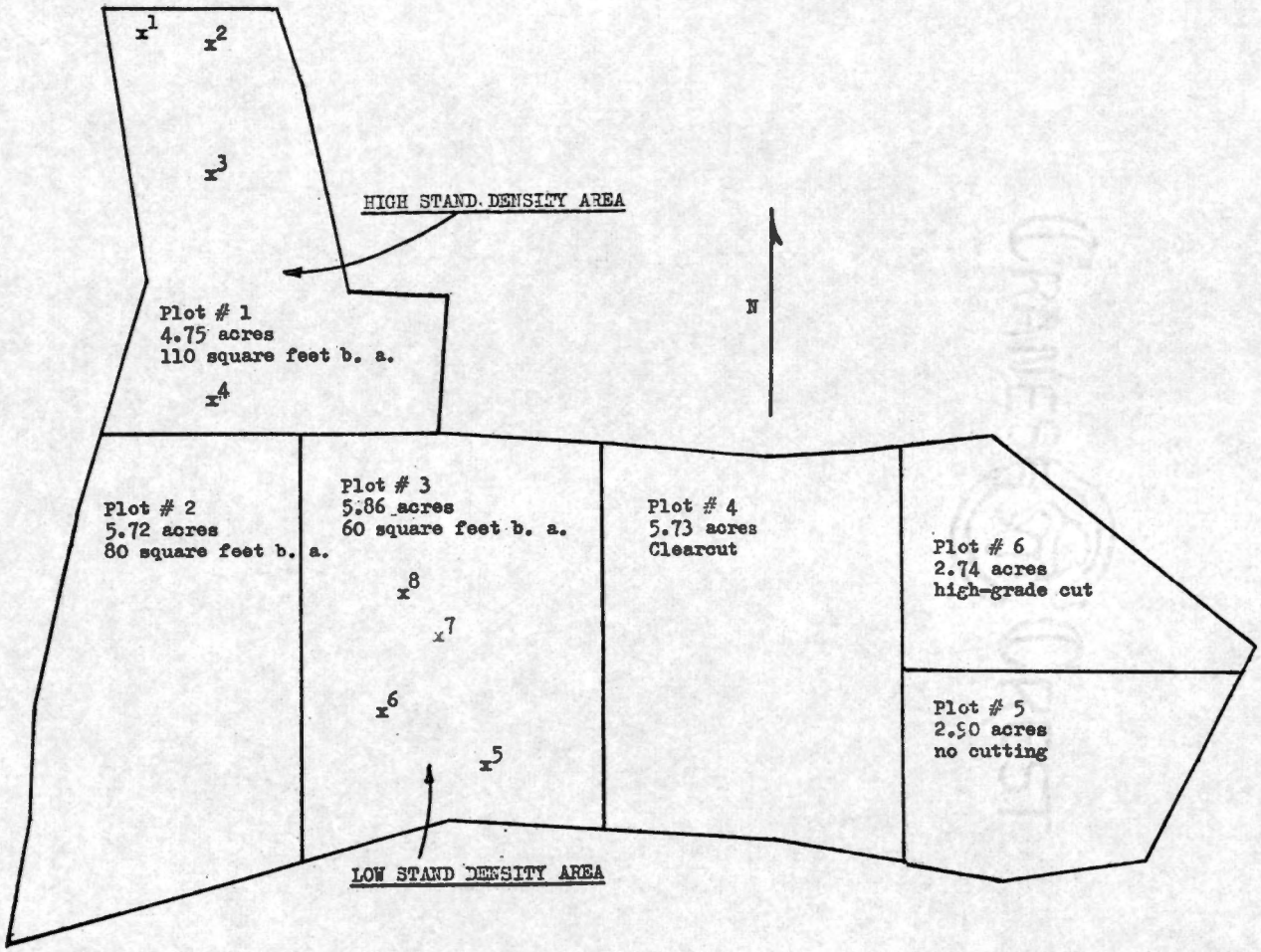


Figure 1. Hardwood management demonstration plots - Ames Plantation.

Location and serial number of Southern red oak sample trees noted by "x ".

and that growth rates of residual crop trees may not exhibit a dramatic response to thinning.

Original and current stocking levels for the two stand density areas examined in the present study are as follows:

	Plot 1	Plot 3
Basal area before thinning in 1959	105 sq.ft./a	85 sq.ft./a
Basal area after thinning in 1959	105 sq.ft./a	60 sq.ft./a
Basal area in 1972	127 sq.ft./a	85 sq.ft./a

Southern red oak was by far the dominant species in the stand, and comprised about 90 percent of the merchantable volume before thinning. Other species found as scattered individuals or small groups were as follows: white oak (Quercus alba L.), post oak (Quercus stellata Wangenh), cherrybark oak (Quercus falcata var. pagodaefolia Ell.), hickory (Carya spp.), yellow poplar (Liriodendron tulipifera L.), and black cherry.

This demonstration area lends itself well to a study on epicormic branching in Southern red oak. In Plot 1, a high density has been maintained throughout the life of the present stand. In Plot 3, basal area was never as high as in Plot 1, though they are part of a continuous tract on which management practices have been uniform, until 1959, when Plot 3 was thinned to a residual density of 60 square feet of basal area per acre (considered quite drastic at that time). Plot 3 is representative of many silvicultural treatments in which a reduced number of stems are carried for some years before final harvest, serving as sources of seed, shelter or as an aesthetic touch.

II. LITERATURE REVIEW

Most writers concur that epicormic branching is of economic importance as a potential source of degrade in hardwood lumber. Hedlund (1964), working in the North Louisiana delta, found that epicormic branches occurred in 72 percent of sawlog-size hardwoods, causing degrade in 40 percent of the sample logs. Of these 23 percent were lowered two or more grades.

Epicormic branching in Southern red oak is related to several environmental factors, the mechanics of which are not precisely known. Sunlight, site fertility, injury, relative dominance class, and the impact of sudden removal of competition are principal among the recognized variables which may affect stimulation of suppressed buds. Recently, the influence of genetic composition of the individual tree has received notice.

Kormanik and Brown (1967a:1) described the origin of epicormic branches as being from suppressed trace buds or from adventitious buds, noting that "Adventitious buds differ from suppressed trace buds in that they lack a vascular connection with the pith and can arise from various tissues in an unpredictable pattern". The writers also stated that ". . . in the oaks, epicormic branches may develop from adventitious buds in sufficient numbers to be of economic importance as a source of lumber degrade". They felt that adventitious buds were frequently stimulated by injury to the stem.

In another work, Kormanik and Brown (1967b:69) observed that basic causes of eruption of epicormics are not understood. They stated:

> Even if the only criterion for plus tree selection was resistance to epicormic branching, we would still have difficulty selecting for this trait . . . . First, we do not understand the mode of inheritance of epicormic branches. Second, we do not understand the mode of development of epicormics. Third, we are sampling at a given period in time when the selection is made, and this presupposes a status quo pattern for epicormic branch development. Evidence, however, points instead to a dynamic or constantly changing pattern which seems to be strongly influenced by tree age and size and by the effect of environmental factors that may partially or completely mask the individual tree's genetic constitution.

The authors found that sweetgum trees (Liquidambar styraciflua L.), partially axe-girdled, showed varying response in epicormic branching and attributed this to inherent genetic differences.

Auchmoody (1972), reporting a West Virginia study, found that fertilization in uncut stands did not stimulate eruption of epicormics within two seasons of application, but that existing branches on high sections of the bole were stimulated as to growth and vigor. He also noted that ". . . red oak was more prone to branching than yellow poplar (6-1/2 times more epicormic branches occurred on the first log, and 3-1/2 times more occurred on the second log of red oak as compared to yellow poplar)". Auchmoody supported the general theory of genetic influence.

Gingrich (1970) recognized the silvicultural implications of epicormic branching as ". . . a dilemma to the silviculturist whose objective is to grow high-quality timber". He pointed out the positive relationship between stand density and stem quality as a management

system. The author suggested, however, that "The best way to avoid epicormic branching is to develop good crowns by thinning and to maintain crop trees as dominants throughout their lives".

Krajicek (1959) found that dominant white oaks in thinned and unthinned stands had fewer epicormics than other classes, with number and location of epicormics related to crown class. Walker (1972), writing on southern upland hardwoods, describes a 95-year-old unthinned stand in which dominant trees had about 3 sprouts on the butt log, codominants 7, intermediates 7-1/2, and suppressed trees 10. He states that "Dominant trees also had the most trunk faces free of sprouting and the greatest distance to the bottommost epicormic branch . . .", and notes that ". . . slow-growing trees are more apt to produce epicormic shoots than more vigorous stems".

Walker (1972:89) also discussed the influence of sunlight: "A few more branches may occur on the warmer southern to southwestern faces where the sun's heat may catalyze bud elongation. . . branches are larger on an open face".

Trimble (1968) imposes the relationship of site characteristics to epicormic branching. On fair sites, he suggests thinning to 45 square feet of basal area, with little or no reduction in quality as long as 15 to 20 square feet of basal area is maintained in stems in the 1-to-5-inch diameter class to shade the first two logs of larger stems. He recommended holding 80 square feet on better sites. Carvell (1971) agreed that, in high-quality stands, epicormic branching is a valid reason for delaying thinnings as long as possible, and pointed out

that a time lag occurs between establishment of epicormics and actual degrade of lumber. Individual tree growth rates are the implied controlling factor.

Carvell (1971) describes past thinning procedures which have been aimed at control of epicormic branching as: (1) selection of dominants as crop trees, (2) light thinnings and low thinnings, and (3) species selection. He reports that the proclivity of individual pole-sized trees toward epicormic branching is indicated by the number of epicormics showing prior to thinning. "Trees with no epicormic branches before cutting generally have few after cutting, and these few shoots are restricted to the area immediately below the crown." Carvell suggests using number of epicormics as a thinning guide, selecting for trees showing low numbers of branches, and describes past success of this method.

A U. S. Department of Agriculture publication reviewing stand response to thinning reported an increase in growth by stagnated dominants and codominants in an overstocked poletimber stand in Arkansas. The report used Trimble's (1968) conclusions to suggest that deterioration in stand quality would not occur. Carvell, (1971:61) however, stated:

> Recent measurements in oak stands that have received previous partial cuttings cause us to question whether the magnitude of response for oaks, and for many other hardwoods, is as great or dramatic as we learned in our silvicultural textbooks.

Gingrich (1971) notes that "Many oaks over 70 years of age have shown no growth response . . . to thinning release".

Jemison and Schumacher's (1948) discussion of epicormic branching in old-growth Appalachian hardwoods is thorough. Their study consisted of sawtimber-volume-reduction thinnings on upper and lower slopes, in a stand which averaged 8.5 thousand board feet (MBF) per acre. They stated:

> The 1944 count of total epicormic branches showed no significant relation either to original differences in volume per acre or to volume removed from the stands in 1936. This was contrary to expectations, for it has been the general observation that branching is greatest in sparse stands and is accentuated by heavy cutting which upsets the natural balance in growing space (1948:253).

As a result of thinning, 44 percent of the residual logs tallied did have more branches 7 years afterward than at time of logging. Analyses of increases in numbers of branches showed significant relations with species, merchantable height, and log position in the tree, but not with site. Increase in shoot occurrence was greatest in stands with the heaviest volume before cutting, and for those with the most volume cut. Increases were greatest for top logs. Jemison and Schumacher observed that second-growth timber is generally more susceptible to epicormic branching than old-growth.

These writers concluded:

> Evaluation of the effect of branching as related to original volume and intensity of cutting show that the monetary loss is so slight that it can be safely ignored in timber management. These results apply only to sawtimber-sized trees 12 inches d. b. h. or larger grown in old-growth stands (1948: 254).

Obviously, not all writers are in agreement on various characteristics of epicormic branching. Individual stems within a forest may

vary from those with clean boles and few epicormics to specimens with a profusion of shoots. These represent the extremes of a wide spectrum which involves all the factors discussed above and possibly others not yet identified.

In the present study, individual trees were selected to provide a comparison between the extremes. On one hand were specimens which showed a minimum of epicormic branches, selected from a high-density stand (average basal area in trees 5 inches D. B. H. and above was 127 square feet per acre in 1972). The four trees selected were highly favorable phenotypes with respect to epicormic branching. A second stand, which had matured at lower density (average basal area per acre 85 square feet in 1959) and sustained a thinning to 60 square feet in 1959, yielded 4 trees for comparison.

III. METHODS AND PROCEDURES

Sampling Design and Tree Selection

One objective of the present study was to quantify lumber degrade resulting from epicormic branching. To provide a basis for comparison, four trees were selected from a stand which had developed at high density (105-110 square feet of basal area per acre). These stems were expected to yield high-quality lumber which would represent the standard by which degrade would be measured. Another part of the same forest had developed at a lower level of stocking (85 square feet of basal area per acre), and had sustained a thinning to 60 square feet residual basal area 13 years prior to the present study. Individual trees in this stand showed numerous epicormic branches. Four additional sample trees were selected from this low-density area, and it was expected that lumber quality from these trees would show the degrading effect of epicormic branching at the extreme level. Sample tree selection in the two divergent stand density areas was consciously biased toward selection of stems which obviously typified the management extremes under consideration, with respect to epicormic branching.

Sample trees were all at least two logs (34 feet) in height and ranged in diameter from 16.1 to 21.7 inches. Large, well-formed trees were chosen to insure recoverability of lumber from all logs, and because the larger trees were considered likely to yield more lumber produced since the 1959 thinning, rather than losing this material in slabs.

Trees from the high-density area were given consecutive serial numbers of 1 to 4, with serial numbers 5 to 8 assigned to trees from the low stand density area. The four cardinal directions were painted on the standing trees with the aid of a staff compass. Color codes used were blue for north, white for east, yellow for south, and black for west. The tree's serial number was also painted on.

The following information was recorded concerning each tree: diameter at breast height; merchantable height; height to form point (both heights obtained by hand-held Abney level); and terrain aspect.

To obtain data regarding stand density immediately surrounding the sample trees, each tree was used as the center of a quarter-acre plot, and plots were divided into compass quadrants. Beginning with the northeast quadrant and proceeding clockwise around the plot, the following data were recorded by quadrant for stems at least 5 inches in diameter: species; diameter; and merchantable length in half-logs.

Selection of trees and data gathering were done during the week of 18-22 July, 1972.

Destructive Felling

Logging procedures. On 29 August, 1972, all trees were felled, bucked, and delivered to the Ames Plantation sawmill. When trees were cut, stump height and total height were recorded. Orientation of cardinal directions was maintained by color on each log as stems were

measured prior to bucking into 8-1/2 foot logs.[1] Each log was coded to insure future identification as to tree number and log sequence. It was presumed that devaluation by epicormic branching would be greatest in the second and third 8-1/2 foot logs of trees containing 34 feet or more merchantable height. Because of the normality of low-grade yield from upper logs, it was judged unlikely that the fourth and subsequent logs would be reduced in value by increased epicormic branching. For this reason, fifth logs (three of the eight sample trees had five 8-1/2 foot logs) were not included in the study.

Milling procedures. Prior to sawing into lumber, both ends of each log were ringed with aluminum paint, indicating growth since 1959. Color orientation was shifted 45° and four color-index marks painted on both ends of each log, with blue indicating northeast, white for southeast, etc.

Logs were turned to align the northeast (blue) index mark adjacent to the plane of the saw for the first slab. The log was then rolled 180° to the southwest face for slab removal, thence 90° to remove the southeast slab. A half-revolution of 180° presented the northwest slab to the saw. The sawyer was directed to continue cutting boards from each face as long as wood produced since 1959 remained in the cant, as evidenced by aluminum paint showing on either end of the cant.

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[1]This length was chosen to provide cants marketable as crossties.

As boards and slabs came off the saw, they were coded to provide identification as to tree number, log number, aspect, and board sequence (slab, first board, second board, etc.). Boards were not edged.

Boards and the inside surface of slabs were graded by Mr. James Warmbrod, an Associate Professor of Forestry at The University of Tennessee. The author recorded the grade, board foot volume, and occurrence of defects. Defects were categorized into the following classifications: pith-originating branches greater or smaller than 1-1/4 inches diameter; epicormic branches of apparent origin prior to 1959; and epicormic branches greater or smaller than 1-1/4 inches, originating after 1959. The grading face of each board and the inside surface of slabs were diagrammed, using the above categories of defects. Knots, branch stubs, and other defect indicators on the outside surface of slabs were also diagrammed and classified as greater or smaller than 1-1/4 inches diameter.

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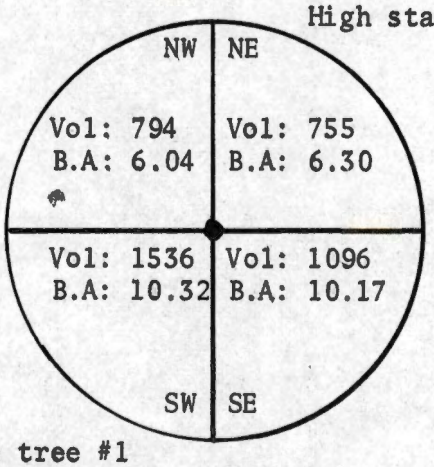
IV. ANALYSIS

Four trees were selected from each of two sites, representing extremes of hardwood management systems relative to epicormic branching. Each of the eight sample trees was used as the center point of a quarter-acre plot. Plots were divided into compass quadrants, and data were collected regarding stems surrounding the sample tree. Figure 2 indicates plot basal area and volume for each tree. Table 1 lists basal areas converted to a per acre basis, including the selected tree. Table 4 in the Appendix shows number of stems per quadrant, according to merchantable size.

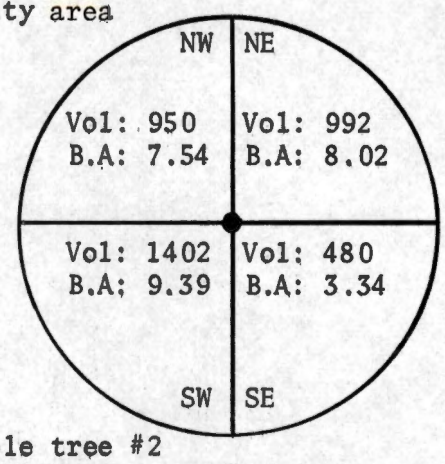
Growth rates were examined by counting rings on the stumps of each of the eight sample trees. Radial growth of the last ten years was measured. Although individual trees varied in growth rates, there was essentially no difference between the stand density areas. Average radial growth for the ten-year period for all trees was 1.50 inches; the slowest-growing tree averaged 1.0 inches for the ten-year period, while the fastest tree averaged 2.3 inches. Radial growth within trees varied almost as much as among trees, possibly due to eccentric growth rings found near ground level.

Wood produced since 1959 was used in comparison of defects and lumber grade between the high and low stand density areas. In nearly all cases, the first board sawn after slabbing contained some wood produced before 1959. In some instances, the slab contained nearly all wood produced after 1959; when this occurred, the inside of the slab

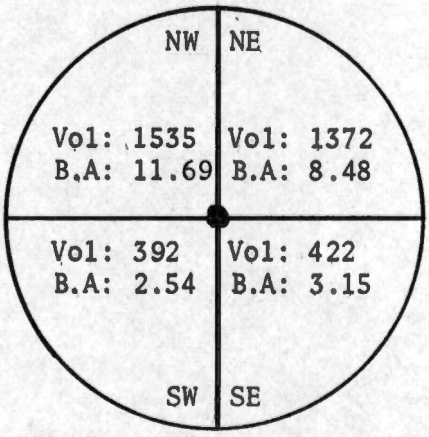
High stand density area



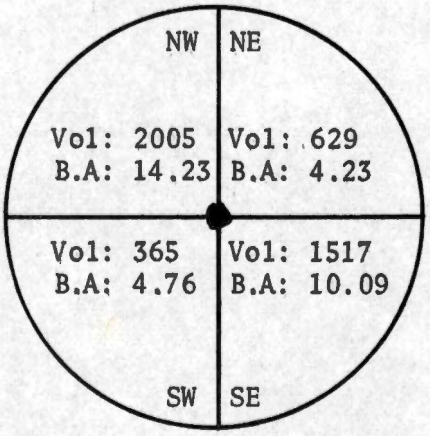
Sample tree #1
tree volume: 200 bd. ft.
tree basal area: 1.50 sq. ft.
plot volume: 4,513 bd. ft.
plot basal area: 34.33 sq. ft.



Sample tree #2
tree volume: 368 bd. ft.
tree basal area: 2.57 sq. ft.
plot volume: 4,258 bd. ft.
plot basal area: 30.86 sq. ft.



Sample tree #3
tree volume: 274 bd. ft.
tree basal area: 1.95 sq. ft.
plot volume: 4,092 bd. ft.
plot basal area: 25.86 sq. ft.

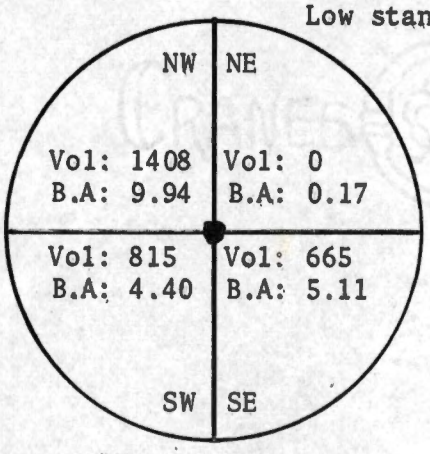


Sample tree #4
tree volume: 410 bd. ft.
tree basal area: 2.45 sq. ft.
plot volume: 5,053 bd. ft.
plot basal area: 35.76 sq. ft.

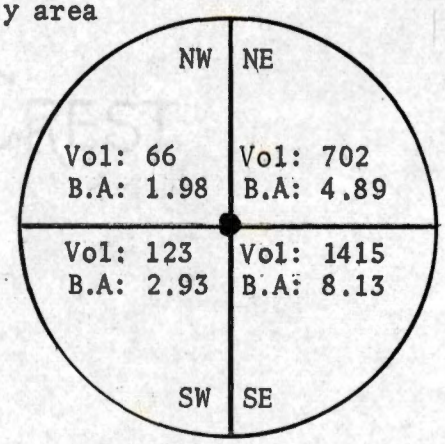
Figure 2. Basal area and volume of sample trees and surrounding stems, by plot quadrant, for high and low stand density areas.

Circles represent quarter-acre plots, divided into compass quadrants, with sample trees as center points. Plot data include volume and basal area of sample tree; quadrant data do not. Board foot volumes computed by International 1/4-inch rule.

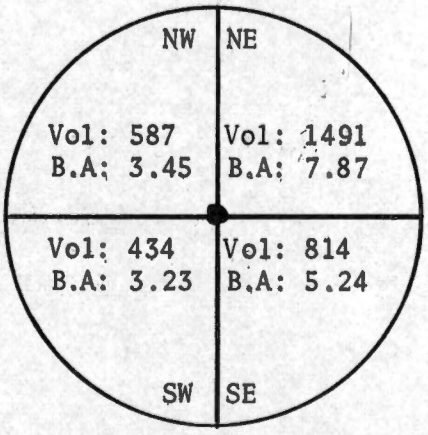
Low stand density area



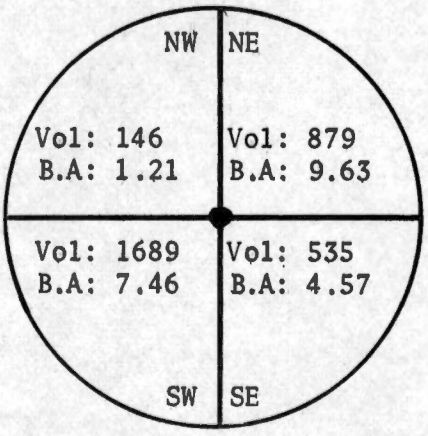
Sample tree #5
tree volume: 231 bd. ft.
tree basal area: 1.41 sq. ft.
plot volume: 3,174 bd. ft.
plot basal area: 21.03 sq. ft.



Sample tree #6
tree volume: 248 bd. ft.
tree basal area: 1.67 sq. ft.
plot volume: 2,683 bd. ft.
plot basal area: 19.60 sq. ft.



Sample tree #7
tree volume: 368 bd. ft.
tree basal area: 2.57 sq. ft.
plot volume: 3.984 bd. ft.
plot basal area: 22.36 sq. ft.



Sample tree #8
tree volume: 501 bd. ft.
tree basal area: 2.54 sq. ft.
plot volume: 3,844 bd. ft.
plot basal area: 22.32 sq. ft.

Figure 2 (continued)

Table 1. Total and mean basal area per acre for the eight sample Southern red oak trees by plot quadrant and stand density area

Sample tree (plot) number	Plot quadrants NE $\frac{1}{4}$	SE $\frac{1}{4}$	SW $\frac{1}{4}$	NW $\frac{1}{4}$	Average[a] per plot
	High stand density area (unthinned)				
1	100.80	162.72	165.12	96.64	137.32
2	128.32	53.44	150.24	120.64	123.44
3	135.68	50.40	40.64	187.04	103.44
4	67.68	161.44	76.16	227.68	143.04
Average basal area per acre, high stand density area:[a]					126.81
	Low stand density area[b]				
5	2.72	81.76	70.40	159.04	84.12
6	78.74	130.08	46.88	31.68	78.40
7	125.92	83.84	51.68	55.20	89.44
8	154.08	73.12	119.36	19.36	89.28
Average basal area per acre, low stand density area:[a]					85.31

[a] In average basal areas, the center (sample) tree was included, while in quadrant basal areas, the sample tree was excluded.

[b] The low stand density area was thinned in 1959 from 85 square feet of basal area to 60 square feet residual basal area.

was used in lieu of the first board. The origin of all knots was traced through subsequent boards far enough to determine their type; i.e., whether bole-branch or epicormic. Epicormic branch knots were classified as to eruption before or after 1959. Log position, exposure, and grade were recorded for all boards and slabs. Figure 3 compares numbers of epicormic branch knots by stand density, quadrant, log position, and time of eruption for first boards.

Numbers of epicormic knots by size (greater or smaller than 1-1/4 inches), time of eruption (before or after 1959), and log position (butt log, second log, etc.), were subjected to correlation analysis. Variables were: quadrant (NE, SE, SW, NW); quadrant volume in cubic feet (stems 5 inches or larger); number of stems by quadrant 1-1/2 logs or less in height (regardless of merchantability); number of stems by quadrant 2 logs or more in height; and quadrant basal area. Bole branch knots by size (greater or smaller than 1-1/4 inches) were also correlated to the above variables. This analysis was performed on the inside surface of slabs and on the grading face of first boards. Defects and defect indicators on the outside surface of slabs were correlated by size (greater or smaller than 1-1/4 inches) and log position to the same above variables.

First boards and the inside surface of slabs were graded and their volumes recorded. Table 2 indicates percent of volume by grade for first boards. Figure 4 illustrates grade distribution by log position.

High stand density area

Tree #: 1				2				3				4				
1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	3	4th log
0	0	4	2	1	1	1	0	2	0	1	2	1	0	3	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3rd log
1	0	3	0	0	1	1	1	2	0	2	1	1	4	1	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2nd log
1	1	0	2	0	0	0	0	0	1	1	0	1	0	0	2	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1st log
0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
NE	SE	SW	NW	NE	SE	SW	NW	NE	SE	SW	NW	NE	SE	SW	NW	Quadrant

Low stand density area

Tree #: 5				6				7				8				
2	2	1	0	1	0	0	0	5	0	3	2	4	1	4	1	4th log
3	6	9	4	3	4	7	4	11	18	11	40	3	5	14	7	
2	0	3	1	0	0	0	0	2	1	2	0	4	0	1	1	3rd log
0	8	7	4	4	2	2	2	13	10	13	13	15	31	16	4	
0	0	2	0	1	1	1	0	3	0	2	0	3	0	4	0	2nd log
0	2	4	0	2	1	1	3	7	4	10	6	5	22	13	0	
0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1st log
0	0	1	1	0	0	1	0	1	0	0	1	3	2	0	0	
NE	SE	SW	NW	NE	SE	SW	NW	NE	SE	SW	NW	NE	SE	SW	NW	Quadrant

Figure 3. Numbers of epicormic branch knots in first board lumber of Southern red oak sample trees by time of eruption, log position, quadrant, and stand density area.

Upper figure indicates epicormics erupting after 1959, lower figure indicates epicormics existing previous to 1959. All logs 8-1/2 feet in length.

Table 2. Board foot volumes and percent yields of first boards sawed from sample trees by lumber grade and stand density areas

Lumber grade	High stand density area[a] (unthinned)		Low stand density area[b] (thinned)	
	Bd. ft.	percent	Bd. ft.	percent
FAS	88	26	40	12
1 C	99	28	39	12
2 C	104	31	90	28
3 A	41	12	76	24
3 B	12	3	76	24
Totals:	344	100	321	100

[a]Basal area 110 square feet per acre.

[b]Thinned in 1959 from 85 square feet per acre to 60 square feet.

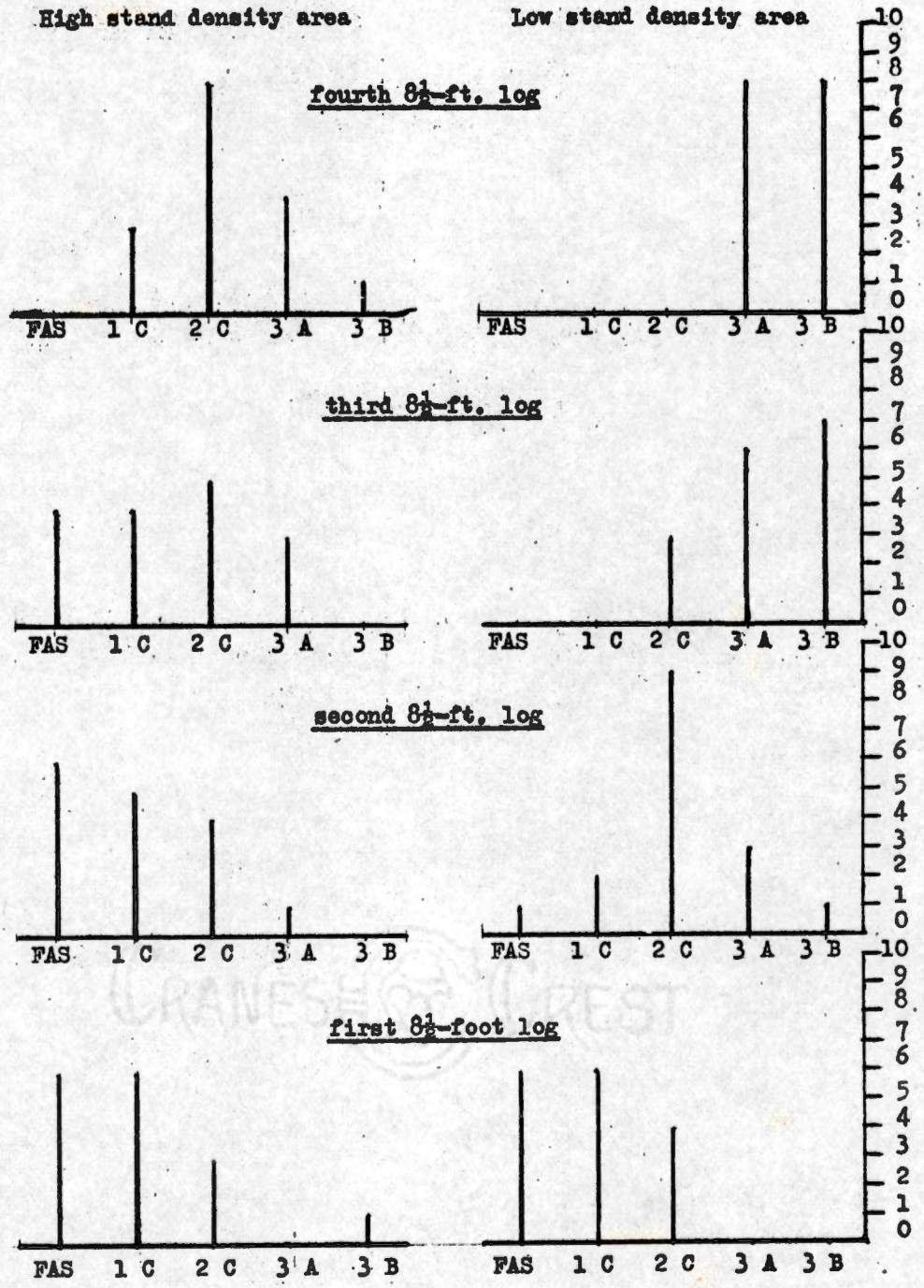


Figure 4. Proportionate grade distribution of first board lumber from eight sample Southern red oaks, by log position and stand density area.

Sixteen boards are represented in each graph.

V. RESULTS AND DISCUSSION

Information from the present study may be characterized as external to the tree or indigenous to the tree. External data consist of plot and stand measurements taken; these relationships will be discussed first. Indigenous data evolved from milling the logs, and consisted of grade-yield relationships among log positions by stand density areas. The economic comparison between stand density areas is treated as a third field of discussion.

Effect of Surrounding Stems

Quadrant data were analyzed to determine the relationships among external plot characteristics and the number, type, and sizes of knots in the sample trees. The first boards and both inside and outside slab surfaces of sample trees were considered because of their relationship to the 1959 thinning. Correlations with significance levels of at least 0.05 are shown in Table 5 in the Appendix.

The variable which showed the highest number of significant correlations for all quadrants was the number of surrounding stems between the limits of smaller trees with 5 inches minimum D.B.H. and no merchantable height, to those larger trees with maximum merchantable heights of 24 feet to a 10-inch top.[1] In the northeast quadrant, this

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[1] Stems with merchantable heights of 24 feet or less included mostly small intermediate trees and nonmerchantable species which surrounded the sample trees. Since the sample trees contained at least 32 feet of merchantable height, these other stems partially shaded the merchantable bole of the sample tree.

variable was inversely related to the following: outside bark knots and defect indicators; old epicormics and post-1959 epicormic knots less than 1-1/4 inches diameter in the first board, and total number of knots both inside the slab and in the first board.

In the southeast quadrant, these small stems (5 inches diameter or larger, 24 feet or less in height to 10-inch top) were inversely related to numbers of bole-originating knots inside the slab.

The southwest quadrant showed a negative correlation of these small surrounding stems to the following: outside bark knots and defect indicators; old epicormics, post-1959[2] epicormic knots less than 1-1/4 inches diameter, and total number of knots inside the slab and in the first board. Bole-branch knots less than 1-1/4 inches diameter inside the slab and on the first board were positively correlated to number of small stems.

Small stems in the northwest quadrant were negatively correlated to outside bark knots and defect indicators less than 1-1/4 inches diameter, and to old epicormic knots and total numbers of knots inside the slab and in the first board.

Quadrant volume in cubic feet, number of surrounding stems with 32 feet or more in merchantable height, quadrant basal area, and total number of stems all had significant but low positive correlations to various knot categories. However, none of the above exhibited a strong relationship to defect numbers or types through all quadrants. A

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[2]Epicormics which appeared to have erupted after the 1959 thinning.

parallel effect between northwest and southwest quadrants was found by total number of stems per quadrant. In both quadrants, negative correlations were found to outside bark defect indicators greater than 1-1/4 inches diameter and old epicormics inside the slab and in the first board. Total number of stems in northwest and northeast quadrants were negatively correlated to outside bark defect indicators greater than 1-1/4 inches diameter.

The relative abundance of stems 5 inches diameter or larger and 24 feet or less to a 10-inch top was found to be a factor strongly related to the numbers of epicormic branches and bole branches in selected trees in all quadrants except the southeast. Several authors (Gingrich, 1970; Walker, 1972; Trimble, 1968) have suggested that epicormic branching will be minimal if crop trees are maintained as dominants and a high percentage of the stand basal area left in the understory. In the present study, all sample trees were dominants. However, small stems comprised 49 percent of the basal area of northeast, southwest, and northwest quadrants in the high-density area, and only 27 percent of the basal area of the same quadrants of the low stand density area.

The southeast quadrant was conspicuous in that the external variables showed no significant correlation to epicormic knots in sample trees. Epicormic knots on southeast faces, however, were compatible in number with those on other portions of the tree within stand density areas, and low-density area trees had more epicormics than high-density area trees. Significant correlations between external variables and

bole-branch knots in the southeast quadrant were not strong and ranged from 0.2994 to 0.3590. There was no observed indication that either bole-branches acted to suppress epicormic branches or that the number of epicormics were affected by shading from surrounding stems, in the southeast quadrant.

Log Position

External data were also analyzed by log position, quadrants not distinguished. Significant correlations are shown in Table 6 in the Appendix. The reader is reminded that 8-1/2 foot logs were used in the present study.

No significant correlations were found between external plot data and defects in the first board or inner and outer slab surfaces of the lower (butt) 8-1/2 foot log.

Concerning the second, third, and fourth logs, the external variable showing highest number of correlations was again the number of surrounding stems 24 feet or less in merchantable height. In the second log, inverse relationships were found between this variable and the following defects: indicators 1-1/4 inches diameter or larger on the outside surface of the slab; and post-1959 epicormics less than 1-1/4 inches and total number of knots, inside the slab. Post-1959 epicormics of both sizes and total number of knots occurring in the first board also showed negative correlations to the number of surrounding small stems. The number of surrounding stems 32 feet or more in merchantable height was positively correlated to post-1959 epicormics less than 1-1/4 inches

diameter inside the slab and in the first board of second logs, and to first-board bole-branch knots 1-1/4 inches diameter or larger.

In the third log, the number of surrounding small stems accounted for all significant correlations. This variable was negatively correlated to defects less than 1-1/4 inches inside slab and in the first board, and to old epicormics in the first board. Number of small stems was directly related to bole-branch knots less than 1-1/4 inches inside the slab and in the first board.

The fourth log showed more significant correlations than others. Again, number of small stems surrounding the sample tree was the variable which seems most important, but several classes of knots were correlated to more than one variable. For example, defect indicators and defects 1-1/4 inches or larger on the outside slab surface were negatively correlated to quadrant volume in cubic feet, number of small stems, quadrant basal area, and total number of stems. Defects less than 1-1/4 inches on the outside slab surface, old epicormics inside the slab, and total number of knots inside the slab were negatively correlated to number of surrounding small stems, quadrant basal area, and total number of stems.

Also, for the fourth log, number of small stems was negatively correlated to defects less than 1-1/4 inches or larger inside slab, post-1959 epicormics less than 1-1/4 inches and old epicormics in the first board, and total number of knots inside the slab.

Finally, total number of surrounding stems showed several negative correlations; these were to post-1959 epicormics less than 1-1/4 inches

inside the slab, and to old epicormics and total number of knots in the first board, in addition to the knot classes mentioned just previously in relation to surrounding small stems.

Standard silvicultural theory of the inverse relationship of stand density to epicormic branching was supported by the above findings, in that understory stems were found to be related to the suppression of epicormic branches in sample trees. Because of this, Trimble's (1968) study on West Virginia hardwoods, which suggested that heavy thinnings (to 45 square feet residual basal area on fair sites) would not cause quality deterioration by increased epicormic branching if about one-third the residual basal area were left in understory stems, may be applicable to the area of the present study.

Grade-Yield Comparison

The net effect of epicormic branching manifests itself in the value yield of lumber. There exists a threshold below which further degrade is impossible - management efforts to suppress epicormic branching must cross this threshold to be effective in increasing lumber value. For example, several boards in upper logs of sample trees from the low stand density area showed 30 or more epicormic knots; it is doubtful that a decrease in epicormic knots of 50 percent would raise the value of these boards.

Jemison and Schumacher (1947) presented tables for predicting the increase in epicormics likely to occur, by log position, for various thinning levels in old-growth stands. However, their calculations are

not directly comparable to the present study, as they did not include Southern red oak among the species measured; their work was carried out some 700 miles from the site of the present study, in an ecologically different forest; and the stand presently examined was not old-growth. The closest comparison that can be made to the predictions of Jemison and Schumacher requires interpolations which lose validity over time and between species. An important conclusion of their study, however, was that increased epicormic branching as a result of thinning was found to have little significance as a source of devaluation in sawlogs, for old-growth Appalachian hardwoods.

The present study compared the value of lumber from diverse management systems: yield from the high-density area was expected to be of high quality, with yield from the low-density area representing about the lowest quality likely to ever be encountered. Table 2 (p. 24) indicates the percent of volume by grade for each stand density area; Figure 4 (p. 25) compares the distribution of grade yield by log position. It is immediately obvious that there was a difference in the grade yield between the two areas, but the actual value difference per thousand board feet depends on the price relationship of the upper and lower lumber grades.

There was essentially no difference shown between the stand density areas in the grade of first boards from the 8-1/2 foot butt log. Where low-grade material occurred, rot was the principal defect, rather than epicormic branching.

Grade-yield differences began to appear in the second 8-1/2 foot log. Board quality from the low stand density area was distributed in all lumber grades, but most prominently in the middle grade of No. 2 Common. Yield from the high stand density area contained a higher proportion of high-grade material, with Firsts and Seconds most abundant.

In third logs, the two stands diverge to a greater extent. High-density area boards were about equally distributed in Firsts and Seconds, No. 1 Common, No. 2 Common, and No. 3A grades. Boards from the low-density third logs fell into the lower lumber grades of No. 2 Common, No. 3A, and No. 3B.

Fourth logs showed the greatest difference in grade yield between study areas. Boards from the low-density area were of the two lowest lumber grades, equally distributed between No. 3A and No. 3B. The high-density area grade yield was predominantly No. 2 Common, followed in frequency by grades No. 3A, No. 1 Common, and No. 3B.

In the high stand density area, 54 percent of the first board volume was Firsts and Seconds and No. 1 Common, with No. 3A and No. 3B comprising only 15 percent of volume. In the low-density area, No. 3A and No. 3B accounted for 48 percent of first board volume, with 24 percent in the highest grades. No. 2 Common comprised the highest percentage of volume from both areas (high-density area - 31 percent; low-density area - 28 percent). First board volume comprised about 25 percent of the total sawlog volume of the sample trees.

No significant relationship was found between grade yield and quadrant for either density area, or for both combined.

A distinct and substantial difference was shown between lumber values of the high and low stand density areas. This is basically attributable to profligate epicormic branching in the low-density area, but it is not possible to ascribe a level of devaluation to the 1959 thinning. First boards used in this study were not totally comprised of post-1959 wood; in any case, the exact year of eruption of epicormics was not discernible.

Numbers of epicormics showing outside the slab showed some variation from numbers found on the outside of first boards. Table 3 shows average numbers of epicormics by log position for first boards and outer slab surfaces for each of the stand density areas. It is apparent that, in the high stand density area, epicormics were increasing when trees were cut for the present study. First boards of logs above the butt showed an average of 13 epicormic knots per tree; however, outside slab surfaces had an average of 24 knots per tree. In the low-density area, epicormic branches were declining slightly, from an average of 108 in first boards to 95 in outside slab surfaces. It is felt that recent windthrow in the high stand density area may have created openings which encouraged development of epicormics, and that normal crown development in sample trees of the low stand density area has slightly inhibited eruption of new branches.

Economic Comparison

Jemison and Schumacher (1948) felt that, in old-growth Appalachian hardwoods, epicormic branches resulting from thinnings were of little

Table 3. Mean epicormic branches in Southern red oak sample trees by stand density area and within-tree location

Log position[c]	High stand density area[a] (unthinned)		Low stand density area[b] (thinned)	
	Slab surface outside bark	Grading face of first board	Slab surface outside bark	Grading face of first board
2nd	4.0	2.3	16.5	24.3
3rd	8.3	4.5	37.0	40.3
4th	11.5	6.0	41.5	43.8
Total:	23.8	12.8	95.0	108.4

[a]Basal area 110 square feet per acre.

[b]Thinned in 1959 from 85 square feet per acre to 60 square feet.

[c]Butt log (first 8-1/2 feet) not computed.

consequence in lowering the value of hardwood sawlogs. This conclusion was based on then-current prices, and was, in effect, determined by the grade of logs before thinning, their predictions of branch increase by log position, and the then-current price relationship of different sawlog grades. The devaluation accruing to lumber will depend upon the probable grade-yield if no thinning is done, the relative proportions of lumber volume in upper and lower grades, and the current price relationship between grades.

There has been an increase in lumber prices for all grades in the last 25 years, with a widening gap in value between higher and lower grades. An important point is that all prices have approximately doubled in this time period, rather than displaying disproportionate increases.

To determine the difference in value of lumber from the high and low stand density areas, prices were examined for the past 25 years and averaged for 5-year periods. Table 2 (p. 24) has shown the grade-yield of first boards from each stand as a percentage of stand volume. Assuming these proportions to be valid as percentages of volume per MBF (thousand board feet) of first boards, the value of one MBF of first board lumber from either study area can be computed for any past price period. This has been done in Tables 7, 8, and 9 in the Appendix.

Comparison of stand values per MBF showed the effect of higher grade material from the high stand density area for all price and time periods. Because all grade prices have increased almost proportionately, the difference in value between the study areas has shown a commensurate increase. Using current (1 April, 1973) prices, the high stand density

area yielded first boards worth $185.86 per MBF; value of the low-density area lumber was $137.90 per MBF, with a difference of nearly $50.00 per MBF ($47.96). The difference in value using average prices for the 1947-1951 period was about $26.00 per MBF. During this time the price of Firsts and Seconds grade material increased from $154.50 to $300.00 per MBF; No. 1 Common increased from $103.00 to $200.00 per MBF; No. 2 Common from $67.98 to $120.00 per MBF; No. 3A from $57.68 to $110.00 per MBF; and No. 3B from $30.00 to $70.00 per MBF.[3]

The concept of "quality index" serves to further substantiate the importance of grade-yield over market price fluctuations for the past 25 years. In the present study, quality index expresses the ratio of lumber value per MBF to the price of No. 1 Common (an accepted indicator of market status) for any given price period. Quality indices were computed for both stand density areas for each price period, as shown in Tables 9 and 10 in the Appendix. Although these indices have fluctuated in response to changes in grade prices, the difference between the indices for stand density areas has shown little change. In the present study, the indication is that the difference in value per MBF between the high and low stand density areas, for the past 25 years, has been approximately one-fourth the market price of No. 1 Common lumber.

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[3]Grade No. 3B is not listed as commonly traded on the national hardwood lumber market. Price for the 1947-1951 period was from a TVA study, with arbitrary advances in price estimated by this writer which attained an orderly progression to a reasonable current price.

VI. SILVICULTURAL IMPLICATIONS

The above analysis of external (plot) data has indicated the strong relationship between understory density and epicormic branching of Southern red oak crop trees at the Ames Plantation. This supports well-established silvicultural principles regarding desirable stand structure in hardwood timber management. In the present study, two extremes of hardwood management were examined, and the individual trees selected for study were considered representatives of the "best" and "worst" quality (with respect to epicormic branching) likely to be encountered. However, in the low stand density area, a smaller population existed from which sample trees could be drawn, considering the requirements of at least 34 feet merchantable height and diameter at breast height of 16 - 22 inches. It is possible that some stems in the low-density area were of lower quality than the sample trees used in the present study.

A cause-and-effect relationship between small surrounding stems and epicormic branching in crop trees has not been definitely established. General opinion is that the shading effect of the understory on the stems of crop trees is one determining factor. The impact of density-reduction thinnings may well be in this province, or in the sudden availability of these and lesser known (possibly genetic) factors. The present study was not designed to test the shading effect of the understory, but data taken indicated a strong relationship between understory density and the apparent suppression of epicormics.

An interesting point that developed in the foregoing analysis was the lack of any correlation regarding surrounding small stems and epicormic branching in the southeast face of crop trees. This possibly was due to the small number of sample trees combined with variability in plot data; however, numbers of epicormics on the southeast face were commensurate with numbers of epicormics on other faces, for individual trees. It is possible that some factor (as yet unidentified) exerts a stronger influence on epicormic branching on the southeast face of crop trees than understory density in that quadrant.

Regarding epicormic branching related to log position, the density of the surrounding understory was again the most important variable measured. High understory density was associated with suppressed epicormics, while an increased proportion of the stand in dominant trees (fewer understory trees) was associated with increased epicormic branches, for all logs above 8-1/2 feet. Epicormic branching on the butt 8-1/2 foot log was not related to any plot variable measured. Stems surrounding the selected study trees were classified as either 24 feet or less or 32 feet or more in height to a 10-inch top. The crown of the smaller stems may be assumed to have exerted a "shading effect" on the stems of sample trees.

Silvicultural treatments dealing with density reduction of the understory in fully-stocked stands may cause an increase in epicormic branching in Southern red oak crop trees, which may or may not have significant economic impact. The shelterwood method of establishing desirable reproduction is a case in point, particularly where

pretreatment elimination of undesirable species in the understory is involved. Where management systems are contemplated which will heavily reduce understory density, or drastically lower stocking, two factors must be considered, viz., the expected growth rate of crop trees; and the economic impact of increased epicormic branching.

There is disagreement as to the increase in growth attainable after thinning in oaks. The U. S. Forest Service (1970), in Arkansas, found a substantial growth rate increase after thinning in a stagnated oak stand, while Carvell (1971) considered such increases to be of doubtful predictability. The growth rate of crop trees will determine how soon increased epicormic branching will be found in the lumber sawn from these trees rather than occurring harmlessly only in slabs and edgings. At the Ames Plantation, due to the slow radial growth of the trees sampled (1.5 inches per decade), the 13-year period after the thinning did not allow sufficient time for trees in the low stand density area to produce lumber completely affected by the thinning. Even after enough time has passed for the value of first boards to be affected by post-thinning wood production, this will be a fraction of the total lumber volume in the sawlog. For example, in the current study, first boards were found to comprise about 25 percent of the sawlog volume, on the average. In addition, the preceding analysis showed first boards from the lower 8-1/2 foot log of crop trees from both high and low stand density areas to be of equal grade yield, with differentiation in grade yield between stand density areas beginning in the second 8-1/2 foot log (the top of the first 16-foot log). Since the greatest proportion

of tree volume is in the lower log, the impact of increased epicormic branching will be predominantly in logs above 17 feet, assuming the upper logs are of at least intermediate quality.

In evaluating the possible devaluation by increased epicormic branching, probably the most important consideration is the value of crop trees before thinning. In many cases, this may well be affected by stocking level, as shown in the preceding analysis. In stands which have matured at low density, and in which dominant trees are predisposed to lumber of the lower grade classes, further degrade by increased epicormic branching is unlikely. The economic impact on crop trees of increased epicormics attributable to a thinning or other reduction of understory density is likely to be negligible in such a stand. Trimble (1968) suggested that devaluation would not occur on fair sites if crop trees were dominants and stems in the 1-to-5 inch diameter class comprised about one-third the residual basal area. (He recommended thinnings to as low as 45 square feet of basal area per acre on fair sites.) Trimble did not comment on the quality of mature dominant oaks in his area, or their likely lumber grade yield.

In a well-stocked, high-quality stand, the opposite may be true. Where dominant trees show long, clear faces well into upper logs, an increase in epicormic branching may very well lower the grade-yield of subsequent wood production. Carvell (1971) observed that the threat of epicormic branching on residual trees in high-quality stands was sufficient grounds for delaying heavy thinnings as long as possible. While it is unlikely that a devaluation would be as severe as the difference

between the high and low stand density areas in the preceding analysis, it is almost certain that some devaluation would occur. A turning point, if such a decision were being considered, would be the expected time interval between thinning and final harvest of crop trees, and the proportion of recovered lumber involved.

The results of the preceding analysis are colored by the effect of original stocking variation between the two study areas. If the two stands had been of equal high stocking, the effect of the 1959 density-reduction thinning would have been more ascertainable. Such was not the case, however, and it is this writer's belief that the low-grade yield from the low stand density area is due more to the low level of stocking throughout the life of this stand than to whatever increase in epicormic branching may have occurred as a result of the 1959 thinning. As shown in Figure 3 (p. 23), in only 2 first boards out of 64 from the low stand density area were all existing epicormic knots classified as post-1959. Of the remaining 62 first boards, only 1 had more post-1959 than pre-1959 epicormic knots. The grade-yield evidenced by first boards from the low-density area, then, is probably a fair representation of quality throughout the tree, rather than a measure of degrade by increased epicormic branching brought on by thinning. Therefore, understocking may be of greater economic importance with respect to degrade than the effect of late thinnings in fully stocked stands.

The data taken on eruption of post-1959 epicormics in the low stand density area cannot be transferred to sample trees from the high-density stand to compute a predicted level of degrade if a similar

thinning had occurred in both stands. In view of the current lack of knowledge regarding epicormic branch physiology, one overriding factor is the possibility that a greater increase in epicormics in the low-density stand was suppressed by an already large number of branches existing before the thinning. Because epicormics were apparently increasing as a result of openings created by windthrow when sample trees were cut from the high stand density area, it is this writer's belief that a heavy thinning would cause a much greater proliferation of branching than was noted in the low stand density area, with greater economic impact on future wood production.

The economic analysis indicated that, for the past 25 years, there have been but small variations in the market price structure of Southern red oak lumber. With the current growth of the pallet industry, however, a greater absolute demand may occur for lower grade material, resulting in changes in the price structure. Such a change would reflect a higher value for lumber from the low stand density area, and a decrease in the economic impact of epicormic branching in high-quality stands.

VII. MAJOR FINDINGS

Four sample trees were taken from a stand which had matured at 85 square feet of basal area, and sustained a thinning in 1959 to 60 square feet residual basal area. A similar stand, which had matured at 110 square feet, yielded four sample trees for comparison. All sample trees served as the center of a quarter-acre plot which was divided into quadrants, and data were collected regarding density of surrounding stems. Data related to epicormic branching were obtained from destructive felling and milling of sample trees.

Relationship of Understory Density to Epicormic Branching in Sample Trees

Epicormic branch knots in sample trees showed a significant inverse relationship to understory density for all plot quadrants, with one exception. Epicormic branch knots in the southeast quadrant of all sample trees showed no correlation to any plot variable measured.

Epicormic branching in all logs above 8-1/2 feet also showed a definite inverse relationship to density of the understory (stems at least 5 inches diameter and 24 feet or less to a 10-inch top). Epicormic branches in the 8-1/2 foot butt log were minimal in number and were not related to any plot variable measured.

Comparison of Epicormic Branch Knots Between High and Low Stand Density Areas

Defects in first-board lumber from sample trees were cataloged by size, type, (i.e., epicormic, bole-branch, or other), and number. For the lower 8-1/2 foot log, there was little difference between stand density areas in numbers of epicormic branch knots showing in first boards. In the upper logs of sample trees, strong differences appeared. Sample trees from the low stand density area averaged 24 epicormic branch knots for the second 8-1/2 foot log, compared to 2 knots per log from the high-density area. In the third 8-1/2 foot log, an average of 40 epicormics was found in low-density logs; in high-density third logs, the average was 4-1/2 knots. Fourth logs from the low-density area averaged 44 epicormic knots, compared to 7 per log from the high-density area. High stand density area trees averaged 14 epicormic branch knots in first boards from the lower 34 feet; for the same logs from the low-density area, the average number of epicormics per tree was 111.

Grade-Yield Differences Between Stand-Density Areas

In the lower 8-1/2 foot logs, there was essentially no difference in first board grade-yield between the high and low stand density areas. In first boards from upper logs, distinct differences in grade-yield began to appear in the second 8-1/2 foot log, and became more apparent with increasing height in the sample trees. First board volume comprised 344 board feet in the high stand density area; of this, 53 percent was in the highest lumber grades of Firsts and Seconds and No. 1 Common, with only 15 percent in No. 3A and No. 3B. In low-density area first

boards (total 321 board feet), 48 percent of the volume occurred in the lowest lumber grades of No. 3A and No. 3B.

Economic Comparison

Southern red oak lumber prices for the past 25 years were averaged for 5-year periods, and the value per thousand board feet of first-board lumber computed for both stand density areas. At current prices, the difference in value was $47.96 per thousand board feet. Because lumber price increases for the past 25 years have been proportional (approximately double for all grades), the difference in stand value has not changed in proportion. This difference is, and has been, equal to approximately one-fourth the market value of No. 1 Common grade material for any price period in the past 25 years. If past trends continue, lumber grade-yield will remain indicative of devaluation and will be a more important determinant of stand value than market price fluctuations.

Economic Impact of Thinning

The increase in epicormic branching which seemed attributable to the 1959 thinning in the low stand density area was probably of little or no importance concerning its effect on grade yield. This is due to the already high number of epicormics existing previous to the thinning; further devaluation was unlikely in this stand because it had matured at a low level of stocking. If, as a result of thinning, the same estimated number of epicormics had occurred in the high-density stand, the degrade would have been more severe.

Silvicultural Implications

The basic criteria affecting silvicultural decisions regarding preliminary thinnings should be the potential value of crop trees and the expected proportion of lumber volume affected by the thinning at final harvest. In Southern red oak stands at the Ames Plantation, increased epicormic branching in crop trees may be expected if heavy thinnings are carried out, or if the stand matures at a low stocking level. Lumber value will be affected by no more than an estimated $50.00 per thousand board feet at current prices.

If a shelterwood system were used in similar Southern red oak stands on the Ames Plantation, the degrading effects of increased epicormic branching would be manifested in most of the first board lumber of final harvest trees by thirteen years after thinning.

CRANES CREST

BIBLIOGRAPHY

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SELECTED BIBLIOGRAPHY

Auchmoody, L. R. 1972. Epicormic Branching: Seasonal Change, Influence of Fertilization, and Frequency of Occurrence in Uncut Stands. U. S. Forest Serv. NE Forest Exper. Sta. Res. Pap. NE-228, 8 p.

Boyd, Wayne M. 1970. Forest Stand Projections Under Conditions of Uncertainty - A Markov Chains Approach. Master's thesis, Univ. Tenn., Knoxville, Tenn., 102 p.

Carvell, K. L. 1971. Silvicultural Aspects of Intermediate Cuttings, p. 60-64. In Oak Symposium Proceedings. U. S. Forest Serv. NE Forest Exper. Sta., 161 p.

Gingrich, Samuel F. 1970. Effects of Density, Thinning, and Species Composition on the Growth and Yield of Eastern Hardwoods, p. 26-35. In The Silviculture of Oaks and Associated Species. U. S. Forest Serv. NE Forest Exper. Sta. Res. Pap. NE-144, 66 p.

_____. 1971. Stocking, Growth, and Yield of Oak Stands, p. 65-73. In Oak Symposium Proceedings. U. S. Forest Serv. NE Forest Exper. Sta., 161 p.

Hanks, Leland F. 1965. Adventitious Bud Clusters Do Not Degrade Black Cherry Logs. U. S. Forest Serv. Central States Forest Exper. Sta. Res. Note CS-44, 6 p.

Hedlund, Arnold. 1964. Epicormic Branching in North Louisiana Delta. U. S. Forest Serv. Southern Forest Exper. Sta. Res. Note SO-8, 3 p.

Jemison, George M. and F. X. Schumacher. 1948. Epicormic Branching in Old-Growth Appalachian Hardwoods. J. For. 46:252-255.

Kormanik, Paul P. and Claud L. Brown. 1967a. Adventitious Buds on Mature Trees. U. S. Forest Serv. SE Forest Exper. Sta. Res. Note SE-82, n.p.

_____ and _____. 1967b. Epicormic Branching: A Real Problem in Plus Tree Selection, p. 69-74. In Proc. 9th Southern Conf. on Forest Tree Improvement, Publ. No. 28, Comm. on Southern Forest Tree Improvement, 138 p.

_____ and _____. 1969. Origin and Development of Epicormic Branches in Sweetgum. U. S. Forest Serv. SE Forest Exper. Sta. Res. Pap. SE-54, 17 p.

Krajicek, J. E. 1959. Epicormic Branching in Even-Aged, Undisturbed White Oak Stands. J. For. 57:372-373.

Mesavage, Clement. 1947. Tables for Estimating Cubic-Foot Volume of Timber. U. S. Forest Serv. Southern Forest Exper. Sta. Occas. Pap. 111, 70 p.

_____ and James W. Girard. 1956. Tables for Estimating Board Foot Volume of Timber. U. S. Government Printing Office, Washington, D. C., 94 p.

The Southern Lumberman. 1 April 1973. Hardwood Prices (Column), 226:28.

Trimble, George R., Jr. 1968. Growth of Appalachian Hardwoods as Affected by Site and Residual Stand Density. U. S. Forest Serv. NE Forest Exper. Sta. Res. Pap. NE-98, 13 p.

Tennessee Valley Authority. 1953. Guide for Improved Forest Management for Sawtimber from the Major Hardwoods in the Tennessee Valley. TVA Div. Forestry Relations, Norris, Tenn., 56 p.

U. S. Forest Service. 1970. A Hardwood Thinning Program for the Ozark National Forest. Southern Region-30, 17 p.

Walker, Laurence C. 1972. Silviculture of Southern Upland Hardwoods. Bull. 22, S. F. Austin State Univ., Nacogdoches, Tex., 137 p.

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APPENDIX

Table 4. Numbers of stems 5" D.B.H. or larger surrounding sample trees, by stem length and plot quadrant

Sample tree no.	Length to 10" top	Quadrant NE 1/4	SE 1/4	SW 1/4	NW 1/4	Total
		High stand density area				
1	≥ 2 logs[a]	1	2	2	2	6
	≤1.5 logs	5	3	4	3	15
2	≥ 2 logs	0	1	3	1	5
	≤1.5 logs	4	3	2	5	14
3	≥ 2 logs	3	1	1	4	9
	≤1.5 logs	1	1	1	2	5
4	≥ 2 logs	2	3	1	3	9
	≤1.5 logs	3	3	2	4	12
		Low stand density area				
5	≥ 2 logs	0	1	2	4	7
	≤1.5 logs	1	2	0	4	7
6	≥ 2 logs	2	4	0	0	6
	≤1.5 logs	1	1	3	4	9
7	≥ 2 logs	0	2	1	1	4
	≤1.5 logs	4	1	1	1	7
8	≥ 2 logs	2	1	3	0	6
	≤1.5 logs	2	3	0	1	6

[a]16-ft. logs.

Table 5. Significant correlations (0.05 level) of plot data with knot classifications in first boards and inner and outer slab surfaces, by quadrant; stand density areas combined

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
Northeast quadrant				
Quad. vol. (cu. ft.)	Pre-1959 epicormics, 1st board	0.3926	31	0.014
"	All knots, 1st board	0.3171	31	0.041
No. stems = 1-1/2 logs	Defect indicators ≤ 1-1/4"	-0.3172	32	0.038
"	Defect indicators ≥ 1-1/4", outside slab	-0.4213	32	0.008
"	Post-1959 epicormics, ≤ 1-1/4", inside slab	-0.4576	32	0.004
"	Pre-1959 epicormics, inside slab	-0.3625	32	0.021
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.3823	31	0.017
"	Pre-1959 epicormics 1st board	-0.3941	31	0.014
"	All knots, inside slab	-0.3035	32	0.046
"	All knots, 1st board	-0.3165	31	0.041
No. stems = 2 logs	Post-1959 epicormics ≤ 1-1/4", inside slab	0.3376	32	0.029
"	Pre-1959 epicormics, inside slab	0.3189	32	0.038
"	Post-1959 epicormics ≤ 1-1/4", 1st board	0.3001	31	0.050

Table 5 (continued)

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
No. stems = 2 logs	Pre-1959 epicormics, 1st board	0.5656	31	0.001
"	All knots, 1st board	0.4244	31	0.009
Quadrant basal area	Pre-1959 epicormics, 1st board	0.3556	31	0.025
Total no. of stems	Defect indicators ≥ 1-1/4", outside slab	-0.3348	32	0.031
Southeast quadrant				
Quad. vol. (cu. ft.)	Bole-br. knots ≤ 1-1/4", inside slab	0.3216	32	0.036
No. stems = 1-1/2 logs	Bole-br. knots ≥ 1-1/4", inside slab	-0.3021	32	0.046
No. stems = 2 logs	Bole-br. knots ≤ 1-1/4", inside slab	0.3590	32	0.022
Total no. of stems	Bole-br. knots ≤ 1-1/4", inside slab	0.2994	32	0.048
Southwest quadrant				
No. stems = 1-1/2 logs	Defect indicators ≤ 1-1/4", outside slab	-0.2960	32	0.050
"	Defect indicators ≥ 1-1/4", outside slab	-0.3969	32	0.012
"	Post-1959 epicormics ≤ 1-1/4", inside slab	-0.3116	32	0.041
"	Pre-1959 epicormics, inside slab	-0.5728	32	0.001

Table 5 (continued)

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
No. stems = 1-1/2 logs	Bole-br. knots ≤ 1-1/4", inside slab	0.3347	32	0.031
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.5791	31	0.001
"	Pre-1959 epicormics, 1st board	-0.5517	31	0.001
"	Bole-br. knots ≤ 1-1/4", 1st board	0.4916	31	0.002
"	All knots, inside slab	-0.4007	32	0.012
"	All knots, 1st board	-0.4312	31	0.008
Total no. of stems	Defect indicators ≥ 1-1/4", outside slab	-0.3969	32	0.012
"	Pre-1959 epicormics, inside slab	-0.3893	32	0.014
"	Bole-br. knots ≤ 1-1/4", inside slab	0.3225	32	0.036
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.3650	31	0.022
"	Pre-1959 epicormics, 1st board	-0.3200	31	0.040
Northwest quadrant				
Quad. vol. (cu. ft.)	Defect indicators ≤ 1-1/4", outside slab	-0.3218	32	0.036
No. stems = 1-1/2 logs	Defect indicators ≤ 1-1/4", outside slab	-0.5043	32	0.002

Table 5 (continued)

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
No. stems = 1-1/2 logs	Pre-1959 epicormics, inside slab	-0.4029	32	0.011
"	Pre-1959 epicormics, 1st board	-0.4090	30	0.012
"	All knots, inside slab	-0.3951	32	0.013
"	All knots, 1st board	-0.4058	30	0.013
Quadrant basal area	Defect indicators 1-1/4", outside slab	-0.3713	32	0.018
"	Pre-1959 epicormics, inside slab	-0.3136	32	0.040
"	All knots, inside slab	-0.3347	32	0.031
Total no. of stems	Defect indicators 1-1/4", outside slab	-0.4670	32	0.004
"	Defect indicators 1-1/4", outside slab	-0.2957	32	0.050
"	Pre-1959 epicormics, inside slab	-0.4001	32	0.012
"	Pre-1959 epicormics, 1st board	-0.3791	30	0.019
"	All knots, inside slab	-0.3791	32	0.016
"	All knots, 1st board	-0.3519	30	0.028

Table 6. Significant correlations (0.05 level) of plot data with knot classifications in first boards and inner and outer slab surfaces, by position; quadrants and stand density areas combined

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
First 8-1/2 ft. log				
NO SIGNIFICANT CORRELATIONS				
Second 8-1/2 ft. log				
No. stems ≤ 1-1/2 logs	Defect indicators ≥ 1-1/4", outside slab	-0.3146	32	0.040
"	Post-1959 epicormics ≤ 1-1/4", inside slab	-0.3917	32	0.013
"	Post-1959 epicormics ≥ 1-1/4", 1st board	-0.5143	31	0.002
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.5073	31	0.002
"	All knots, inside slab	-0.3017	32	0.047
"	All knots, 1st board	-0.3674	31	0.021
No. stems ≥ 2 logs	Post-1959 epicormics ≤ 1-1/4", inside slab	0.3897	32	0.014
"	Post-1959 epicormics ≤ 1-1/4", 1st board	0.3404	31	0.030
"	Bole-br. knots ≥ 1-1/4", 1st board	0.4007	31	0.013
Total no. of stems	Defect indicators ≥ 1-1/4", outside slab	-0.3013	32	0.047
"	Post-1959 epicormics ≥ 1-1/4", 1st board	-0.3971	31	0.013

Table 6 (continued)

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
Third 8-1/2 ft. log				
No. stems ≤ 1-1/2 logs	Defect indicators ≤ 1-1/4", outside slab	-0.3103	32	0.042
"	Post-1959 epicormics ≤ 1-1/4", inside slab	-0.4350	32	0.006
"	Bole-br. knots ≤ 1-1/4", inside slab	0.3556	32	0.023
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.4355	31	0.007
"	Pre-1959 epicormics, 1st board	-0.3137	31	0.043
"	Bole-br. knots ≤ 1-1/4", 1st board	0.3542	31	0.025
Fourth 8-1/2 ft. log				
Quad. vol. (cu. ft.)	Defect indicators ≥ 1-1/4", outside slab	-0.2958	32	0.050
"	Post-1959 epicormics ≥ 1-1/4", 1st board	0.3658	29	0.026
No. stems ≤ 1-1/2 logs	Defect indicators ≤ 1-1/4", outside slab	-0.5409	32	0.001
"	Defect indicators ≥ 1-1/4", outside slab	-0.6624	32	0.001
"	Bole-br. knots ≥ 1-1/4", inside slab	-0.3042	32	0.045

Table 6 (continued)

Independent Variables	Dependent Variable	Corr.	n	Sig. Level
No. stems ≤ 1-1/2 logs	Pre-1959 epicormics, inside slab	-0.5082	32	0.001
"	Post-1959 epicormics ≤ 1-1/4", 1st board	-0.4491	29	0.007
"	Pre-1959 epicormics, 1st board	-0.4520	29	0.007
"	All knots, inside slab	-0.5597	32	0.001
"	All knots, 1st board	-0.4648	29	0.006
Quadrant basal area	Defect indicators ≤ 1-1/4", outside slab	-0.3245	32	0.035
"	Defect indicators ≥ 1-1/4", outside slab	-0.4379	32	0.006
"	Pre-1959 epicormics, inside slab	-0.3337	32	0.031
"	Post-1959 epicormics ≥ 1-1/4", 1st board	0.3573	29	0.029
"	All knots, inside slab	-0.3881	32	0.014
Total no. of stems	Defect indicators ≤ 1-1/4", outside slab	-0.4713	32	0.003
"	Defect indicators ≥ 1-1/4", outside slab	-0.6348	32	0.001
"	Post-1959 epicormics ≤ 1-1/4", inside slab	-0.3377	32	0.029

Table 6 (continued)

Independent Variable	Dependent Variable	Corr.	n	Sig. Level
Total no. of stems	Pre-1959 epicormics, inside slab	-0.4694	32	0.003
"	Pre-1959 epicormics, 1st board	-0.3946	29	0.017
"	All knots, inside slab	-0.5076	32	0.002
"	All knots, 1st board	-0.4066	29	0.014

Table 7. First-board lumber yield by grade and percent of total volume, for high and low stand density areas

Lumber Grade	High stand density area		Low stand density area	
	Yield (Bd. ft.)	Percent	Yield (Bd. ft.)	Percent
FAS	88	25.58	40	12.46
1C	98	28.49	39	12.14
2C	105	30.53	90	28.04
3A	41	11.92	76	23.68
3B	12	3.48	76	23.68
Total	344	100.00	321	100.00

Table 8. Current and average red oak lumber prices[a] by grade, for the past twenty-five years

Lumber Grades	1 Apr, 1973	1968-[b] 1971	1963-1967	1958-1962	1953-1957	1947-[c] 1951
FAS	300.00	234.00	181.00	178.80	181.80	154.50
1C	200.00	137.25	112.00	96.80	99.40	103.00
2C	120.00	80.00	75.20	69.60	71.70	67.98
3A	110.00	70.00	65.20	59.60	62.00	57.68
3B	70.00	55.00	45.00	40.00	35.00	30.00

[a]For 4/4" plain-sawed red oak, estimated mill point average prices to the consuming trade on band-sawn stock in carload quantities, random widths and lengths, rough and air-dried, and graded in accordance with NHLA rules of inspection. Boards used in the present study were sawed 5/4" thick; however, past price information was not available for this thickness. Source of price information was "Hardwood Prices" column in Southern Lumberman.

[b]Price information for 1972 was not available for inclusion in this price period.

[c]From Tennessee Valley Authority, 1953, Guide for Improved Forest Management, TVA div. of Forestry Relations, Norris, Tenn. (p. 10)

Table 9. Value of grade-yield and quality index for current and past price periods, by stand density area

Lumber Grade	1 Apr., 1973	1968-1971	1963-1967	1958-1962	1953-1957	1947-1951
High stand density area						
FAS	76.74	59.86	46.30	45.74	46.50	39.52
1C	56.96	39.09	31.90	27.57	28.31	29.33
2C	36.62	24.42	22.95	21.24	21.85	20.75
3A	13.10	8.34	7.77	7.10	7.38	6.87
3B	2.44	1.91	1.57	1.39	1.22	1.04
Total/MBF	185.86	133.62	110.49	103.04	105.26	97.51
Quality[a] Index	.9293	.9736	.9865	1.0645	1.0590	.9467
Low stand density area						
FAS	37.38	29.16	22.55	22.28	22.65	19.25
1C	24.28	16.66	13.60	11.75	12.07	12.50
2C	33.63	22.42	21.08	19.51	20.07	19.05
3A	26.04	16.57	15.43	14.11	14.68	13.65
3B	16.57	13.02	10.65	9.47	8.28	7.10
Total/MBF	137.90	97.83	83.31	77.12	77.75	71.55
Quality[a] Index	.6895	.7128	.7438	.7969	.7822	.6947

[a]Quality index expresses the value of first-board lumber sawn from either stand density area as a ratio of the price per MBF of No. 1 Common lumber for any price period. (After TVA, 1953, Guide for Improved Forest Management.)

Table 10. Value per MBF of first-board lumber by price periods, and difference in value and quality index, for high and low stand density areas

Price Period	High-density area		Low-density area		Difference in Total Value	Difference in Quality Index
	Value per MBF	Quality Index	Value per MBF	Quality Index		
1 Apr. 73 (current)	$185.86	.9293	$137.90	.6895	$47.96	.2398
1968-1971	133.62	.9736	97.83	.7128	35.79	.2608
1963-1967	110.49	.9865	83.31	.7438	27.18	.2427
1958-1962	103.04	1.0645	77.12	.7969	25.92	.2676
1953-1957	105.26	1.0590	77.75	.7822	27.51	.2768
1947-1951	97.51	.9467	71.55	.6947	25.96	.2520

VITA

Benjamin Hall Wolcott, Jr. was born on 19 May, 1945, in Atlanta, Georgia, and attended elementary schools in that city until 1955. He completed primary and secondary education in Knoxville, Tennessee, and was graduated from Holston High School in 1963.

In the fall of 1963, Mr. Wolcott matriculated at Carson-Newman College, Jefferson City, Tennessee, in the preforestry curriculum. He transferred to The University of Tennessee in 1964, and received a Bachelor of Science degree in Forestry in June of 1968.

Mr. Wolcott entered the Graduate School at Louisians State University in September, 1968, and enlisted in the U. S. Army in March, 1969. He served in the 20th Engineer Battalion at Fort Campbell, Kentucky, and authored Fort Campbell's 1971 Natural Resources Conservation Report.

In January, 1972, he entered graduate school at The University of Tennessee and received a Master of Science degree in Forest Management from that institution in August, 1973. He is a member of the American Forestry Association and Xi Sigma Pi. He served as Forester of the Alpha Kappa chapter of the latter organization for the 1972-73 academic year.

Mr. Wolcott is married to the former Karen Ann Allerup of Atlanta, Georgia. They have one son, Benjamin H. Wolcott, III.

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