STAND QUALITY MANAGEMENT IN A LATE-ROTATION, RED OAK-SWEETGUM STAND IN EAST MISSISSIPPI: PRELIMINARY RESULTS FOLLOWING THINNING

James S. Meadows and Daniel A. Skojac, Jr.

ABSTRACT

Stand quality management is a new management strategy in which thinning prescriptions are based solely on tree quality rather than a quantitative level of residual stand density. As long as residual density falls within fairly broad limits, prescriptions are based on tree quality alone. We applied four thinning prescriptions based on stand quality management, along with an unthinned control, to a late-rotation, red oak-sweetgum (*Quercus* spp.-*Liquidambar styraciflua*) stand in east Mississippi during the fall of 2007. Prior to thinning, stand density averaged 105 trees and 117 square feet of basal area per acre. Quadratic mean diameter of the stand was 14.4 inches. Red oaks comprised 51 percent of stand basal area and had a quadratic mean diameter of 18.0 inches. Residual stand density immediately after application of the four thinning prescriptions ranged from 48 to 69 square feet of basal area per acre. Through the first 3 years after treatment, diameter growth of residual trees increased significantly following all four thinning prescriptions. Thinning had little or no effect on the production of new epicormic branches on the butt logs of residual trees, even among red oaks.

INTRODUCTION

When the primary goal of management in mixed-species hardwood stands is to produce high-quality sawtimber, thinnings often are used to increase growth and enhance bole quality of residual trees and to improve species composition of the residual stand (Meadows 1996). Traditionally, thinning prescriptions in most southern hardwood stands are based on the concept of stand density management. The underlying assumption is that hardwood stands are managed best through regulation of stand density. The strategy of stand density management dictates that stands to be thinned are marked to a pre-determined level of residual density spread uniformly across the stand and that residual trees are spaced more or less evenly throughout the stand.

Stand density management works well and is used frequently in single-species stands. However, most hardwood stands contain a wide range of species that differ greatly in value and desirability. The spatial distribution of trees across a hardwood stand generally is much less than uniform. Trees may be clumped together in small, dense groups or may be so dispersed that small gaps devoid of merchantable trees occur.

Consequently, thinning prescriptions based on stand density management in highly diverse, irregularly distributed hardwood stands are flawed. In these stands, the timber marker often is forced to either leave low-quality trees or cut high-quality trees in order to maintain the target residual density uniformly across the stand. Residual stand quality and value may be compromised. Because the economic value of a hardwood stand is determined primarily by the species and bole quality of the trees in the stand, thinning prescriptions based on stand density management may produce residual stands of less-than-optimum economic value.

Results from a series of thinning studies based on stand density management in red oak-sweetgum (*Quercus* spp.-*Liquidambar styraciflua*) stands revealed that diameter growth rates of dominant and codominant red oaks did not differ statistically across thinning prescriptions with different target residual stand densities (Meadows and Goelz 2002, Meadows and Skojac 2006). Diameter growth responses of upper-crown-class red oaks were very similar throughout the range of residual stand densities evaluated in this series of studies: 58 to 88 square feet of basal area per acre. As long as residual stand density immediately after thinning falls within these broad limits, diameter growth response by dominant and codominant red oaks appears to be independent of residual stand density. Therefore, thinning prescriptions based on stand density management may not be appropriate in southern bottomland hardwood stands, especially those with a large component of red oak.

Stand quality management is a new management strategy designed to replace stand density management as the basis for thinning southern hardwood stands. The goal of stand quality management is to develop and maintain a high level of stand quality, with stand density relegated

James S. Meadows, Principal Silviculturist, and Daniel A. Skojac, Jr., Forestry Technician, Southern Research Station, USDA Forest Service, Stoneville, MS, 38776
Current address for Skojac: Daniel A. Skojac, Jr., Forester, Chattahoochee-Oconee National Forests, USDA Forest Service, Chatsworth, GA, 30705

to a role of secondary importance. Thinning prescriptions based on stand quality management follow one simple rule: leave "good" trees and cut "poor" trees. Stand quality management dictates that, as long as residual stand density falls within fairly broad limits, thinning prescriptions and marking rules are based on tree quality alone.

The hardwood tree classification system developed by Meadows and Skojac (2008) provides a way to identify and separate "good" trees and "poor" trees. The classification system consists of five classes used only for sawtimber-sized trees and two classes used only for poletimber-sized trees. In descending order of desirability and value, the five sawtimber tree classes are (1) preferred growing stock, (2) desirable growing stock, (3) acceptable growing stock, (4) cutting stock, and (5) cull stock. Also in descending order of desirability and potential value, the two poletimber tree classes are (1) superior poletimber stock, and (2) inferior poletimber stock. Preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock represent different degrees of "good" trees. Cutting stock, cull stock, and inferior poletimber stock represent "poor" trees. Each tree class represents a different level of tree quality and therefore categorizes the suitability of each tree in the stand to achieve the goals of management.

Under stand quality management, thinning prescriptions and marking rules are based solely on tree class, such that the various tree classes define the residual component for four different thinning prescriptions. Each prescription is designed to leave all trees of certain tree classes and to cut all trees of the other tree classes. Tree classes that are specified to be retained and tree classes that are specified to be removed differ from one prescription to the next.

To evaluate stand quality management as a new management strategy, we established a series of thinning studies in red oak-sweetgum stands on bottomland sites across the South. The thinning prescriptions evaluated in this series of studies are based on stand quality management. The study reported here is the second in the series. Early results from the first study in the series were reported by Meadows and Skojac (2010).

All studies in the series use the same design, treatments, and methods. Each study will determine the effects of four thinning prescriptions based on stand quality management on both stand-level and tree-level growth, quality, and value. Results from the entire series will be combined to develop a research-based model that will provide guidance to forest managers in the selection of the most appropriate thinning prescription to use in any given southern hardwood stand.

METHODS

STUDY AREA

The study area is located within the floodplain of the Noxubee River on the Noxubee National Wildlife Refuge in Noxubee County, south of the city of Starkville, in east-central Mississippi. The site is nearly flat and is subject to periodic flooding in winter and spring. Urbo silty clay loam (fine, mixed, active, acid, thermic Vertic Epiaquept) is the predominant soil series, with average site indices (base age of 50 years) of 100 feet for cherrybark oak (*Quercus pagoda*), 96 feet for water oak (*Q. nigra*), and 90 feet for sweetgum (Broadfoot 1976).

The study area supports a 65-year-old, red oak-sweetgum stand, in which the primary red oak species are cherrybark oak and water oak, with some scattered willow oak (*Q. phellos*). In addition to sweetgum, other common species in the overstory include hickory (*Carya* spp.), green ash (*Fraxinus pennsylvanica*), swamp chestnut oak (*Q. michauxii*), overcup oak (*Q. lyrata*), and American elm (*Ulmus americana*).

PLOT DESIGN

Plot design followed a standard format for silvicultural research plots.[1] Each treatment was applied across a 2.0-acre rectangular treatment plot that measured 4 by 5 chains (264 by 330 feet). One 0.6-acre rectangular measurement plot was established in the center of each treatment plot. Each measurement plot was 2 by 3 chains (132 by 198 feet), which provided a buffer strip 1 chain (66 feet) wide around each measurement plot within the treatment plot. The entire study covered an area of 30 acres.

TREATMENTS

Thinning treatments represented the four thinning prescriptions based on stand quality management. Marking rules for each thinning treatment consisted of a list of tree classes to be retained after thinning and a list of tree classes to be removed. Rules were applied to all trees within any given tree class, with no regard for residual stand density or uniform spacing of residual trees. The five treatments are listed below:

1) Unthinned Control (Control) – leave all trees

2) Acceptable with Superior Poletimber Thinning (AccSupP) – leave all Preferred, Desirable, and Acceptable growing stock trees, as well as all Superior Poletimber stock trees; cut all trees in the remaining tree classes

3) Acceptable with No Poletimber Thinning

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[1] Marquis, D.; Smith, C.; Lamson, N. [and others]. 1990. Standard plot layout and data collection procedures for the Stand Establishment and Stand Culture Working Groups, Northeastern Forest Experiment Station. 55 p. Unpublished report. On file with: James S. Meadows, Southern Research Station, P.O. Box 227, Stoneville, MS 38776

(AccNoPole) – leave all Preferred, Desirable, and Acceptable growing stock trees; cut all trees in the remaining tree classes, including all Poletimber stock trees

4) Desirable with Superior Poletimber Thinning (DesSupP) – leave all Preferred and Desirable growing stock trees, as well as all Superior Poletimber stock trees; cut all trees in the remaining tree classes, including all Acceptable growing stock trees

5) Desirable with No Poletimber Thinning (DesNoPole) – leave all Preferred and Desirable growing stock trees; cut all trees in the remaining tree classes, including all Acceptable growing stock trees and all Poletimber stock trees

MEASUREMENTS AND STATISTICAL ANALYSIS

Prior to assignment of treatments, we recorded species, diameter at breast height (d.b.h.), crown class, and tree class, as defined by Meadows and Skojac (2008), on all trees of merchantable size (≥ 5.5 inches d.b.h.). We randomly assigned treatments to the plots and marked each 2.0-acre treatment plot for thinning according to the marking rules prescribed for the assigned treatment. We then tallied the number of large epicormic branches, as well as the total number of epicormic branches, on the 16-foot-long butt log of all residual trees. Large epicormic branches are greater than 3/8 inches in basal diameter and are counted as defects in logs of all sizes and species (Rast and others 1973). Three replications of the five treatments were applied in a randomized complete block design to the 15 treatment plots (experimental units) in October 2007. Crown class, d.b.h., and both total number and number of large epicormic branches on the 16-foot-long butt log were measured at the end of each of the first 3 years after thinning.

Data were subjected to a one-way analysis of variance for a randomized complete block design with three replications of five treatments, for a total of 15 experimental units. Treatment effects were considered fixed, while block effects were considered random. Alpha was set at 0.05 for all statistical tests. Plot-level variables represented the mean for all residual trees on each measurement plot. Treatment means were separated through the use of Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

STAND CONDITIONS PRIOR TO THINNING

Prior to thinning, the study area averaged 105 trees and 117 square feet of basal area per acre, with a quadratic mean diameter of 14.4 inches, among trees ≥ 5.5 inches d.b.h. Average stocking across the study area was 97 percent, just slightly below maximum full stocking (100 percent), the point at which thinning is recommended in even-aged stands of southern bottomland hardwoods (Goelz 1995). There were no significant differences among treatments in any preharvest characteristics (n = 3 per treatment; p = 0.78 for number of trees, p = 0.06 for basal area, p = 0.49 for quadratic mean diameter, p = 0.08 for stocking). Symptoms of severe competition among trees were not evident. Most dominant and codominant trees appeared to be healthy.

Red oaks and sweetgum dominated this 65-year-old sawtimber stand. Prior to thinning, these species together accounted for 74 percent of stand basal area. Primary red oak species were cherrybark oak and water oak, with some willow oak scattered throughout the stand. Collectively, these red oak species comprised 51 percent of stand basal area, with a quadratic mean diameter of 18.0 inches, and dominated the overstory. Sweetgum accounted for 23 percent of stand basal area, with a quadratic mean diameter of 11.6 inches, and was found in the overstory, midstory, and understory. Other species, such as swamp chestnut oak, overcup oak, hickory, green ash, and American elm, made up the remaining 26 percent of stand basal area and occurred as scattered individuals throughout the stand.

Prior to thinning, about 65 percent of stand basal area consisted of trees in the preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock tree classes (fig. 1). These classes represent "good" trees that are capable of meeting the goals of management. The remaining 35 percent of stand basal area was comprised of trees in the cutting stock, cull stock, and inferior poletimber stock tree classes. These classes represent "poor" trees that are incapable of meeting the goals of management. This roughly 2:1 ratio of "good" trees to "poor" trees is typical of most previously unmanaged stands of southern bottomland hardwoods.

STAND DEVELOPMENT AFTER THINNING

The Acceptable with Superior Poletimber Thinning (AccSupP) reduced stand density to 29 trees and 69 square feet of basal area per acre, increased quadratic mean diameter to 20.6 inches, and reduced stocking to 54 percent (table 1). Relative to overall stand averages prior to thinning, it removed 72 percent of the trees and 41 percent of the basal area. The Acceptable with No Poletimber Thinning (AccNoPole) reduced stand density to 28 trees and 61 square feet of basal area per acre, increased quadratic mean diameter to 20.2 inches, and reduced stocking to 48 percent. It removed 73 percent of the trees and 48 percent of the basal area. In contrast, the Desirable with Superior Poletimber Thinning (DesSupP) reduced stand density to 26 trees and 57 square feet of basal area per acre, increased quadratic mean diameter to 19.9 inches, and reduced stocking to 45 percent. It removed 75 percent of the trees and 51 percent of the basal area. The Desirable with No Poletimber Thinning (DesNoPole) reduced stand density to 18 trees and 48 square feet of basal area per acre, increased quadratic mean diameter to 22.0 inches, and reduced stocking to 37 percent. It removed 83 percent of the trees and 59 percent of the basal area. Because this older stand contained few superior poletimber stock trees, the two levels of Acceptable thinning (AccSupP and AccNoPole) produced very similar residual stands. Likewise, the residual stands produced after the two levels of Desirable thinning (DesSupP and DesNoPole) were very similar to each other.

All thinning treatments produced stand characteristics significantly different from the unthinned control (table 1). No significant differences in trees per acre, basal area per acre, or stocking were detected among the four thinning treatments immediately after thinning, but minor statistical differences were found in quadratic mean diameter.

Stand conditions 3 years after thinning—Stand-level responses to the four thinning treatments were negligible during the first 3 years after thinning (table 2). For example, cumulative stand basal area growth averaged 3 square feet per acre or less in response to all thinning treatments, whereas cumulative stand basal area growth in the unthinned control averaged 4 square feet per acre. Average increases in quadratic mean diameter ranged from 0.3 to 0.7 inches among the four thinning treatments, while the increase in quadratic mean diameter averaged 0.4 inches in the unthinned control. Minor statistical differences in quadratic mean diameter among the four thinning treatments that existed immediately after thinning disappeared by the end of the third year after thinning.

DIAMETER GROWTH

By the end of the second year after thinning and continuing through the end of the third year, cumulative diameter growth of residual trees increased significantly following all four thinning treatments, when averaged across all trees of all species (table 3). In fact, the rate of diameter growth of residual trees after all thinning treatments was nearly double that of trees in the unthinned control. However, we detected no significant differences in diameter growth among the four thinning treatments during any of the first 3 years after thinning.

To focus the analysis on the more valuable trees in the stand, we separated the diameter growth response data into two species groups: red oak and sweetgum. Through the end of the third year after thinning, we were unable to detect significant differences in cumulative diameter growth among treatments within either the red oak group or sweetgum (fig. 2).

Because most red oaks typically respond quickly to thinning, it was surprising to find no significant differences in cumulative diameter growth among treatments within the red oak group through the first 3 years after thinning (fig. 2). Wide variation in diameter growth response of red oaks within some treatments may have prevented the detection of significant differences. However, cumulative diameter growth of residual red oaks following AccSupP thinning (0.67 inches) was nearly identical to that of residual red oaks following DesSupP thinning (0.68 inches). Both thinning treatments retained superior poletimber stock trees in addition to sawtimber trees specific to each treatment. The same trend was found for cumulative diameter growth of residual red oaks in the AccNoPole and DesNoPole thinning treatments (0.91 inches for both treatments). Both thinning treatments retained only those sawtimber trees specific to each treatment; all poletimber trees were removed during thinning. Although thinning treatments did not significantly increase diameter growth of residual red oaks, relative to red oaks in the unthinned control, diameter growth responses to the AccNoPole and DesNoPole thinning treatments were strong and may produce significant increases in the near future.

Clearly, residual sweetgum trees did not benefit from any of the thinning treatments (fig. 2). Increased diameter growth by sweetgum, in response to thinning, often is delayed while the tree expands its crown to take advantage of the additional growing space and other resources generated by the thinning operation. This response is particularly common among sweetgum trees that are weak codominants, as was the situation in this study prior to thinning. We anticipate that the diameter growth response of residual sweetgum trees will improve in the near future.

PRODUCTION OF EPICORMIC BRANCHES

Thinning operations in hardwood stands sometimes have adverse effects on bole quality of residual trees. New epicormic branches may develop along the merchantable boles of residual trees during the first few years after thinning. Epicormic branches are adventitious twigs that develop from dormant buds along the bole (Brown and Kormanik 1970). Standard grading rules for hardwood factory logs stipulate that epicormic branches greater than 3/8 inches in diameter at the bark surface are defects on logs of all sizes, grades, and species (Rast and others 1973). Meadows and Burkhardt (2001) surmised that, in general, as few as five epicormic branches, somewhat evenly distributed along a 16-foot-long hardwood log, may reduce the grade of that log. Because epicormic branches greater than 3/8 inches in basal diameter produce defects in the underlying wood, their presence also may reduce both lumber grade and value. Consequently, production of epicormic branches along the merchantable boles of residual trees may become a serious problem associated with thinning in hardwood stands.

Meadows (1995) hypothesized that tree health controls the release of dormant buds that develop into epicormic branches, such that healthy, upper-crown-class trees are much less likely to produce epicormic branches than are unhealthy, lower-crown-class trees. Consequently, thinning prescriptions that retain healthy sawtimber trees and remove unhealthy sawtimber trees, as well as most poletimber trees, can minimize production of new epicormic branches in most hardwood stands. In contrast, thinning prescriptions that fail to retain healthy trees may result in the development of numerous epicormic branches along the boles of residual trees.

To assess the impact of thinning on epicormic branch production, we counted the number of large epicormic branches on the 16-foot-long butt log of all residual trees immediately after thinning and at the end of each of the first 3 years after thinning. We defined large epicormic branches as those branches greater than 3/8 inches in basal diameter.

When averaged across all trees of all species, the four thinning treatments had no significant effects on the number of large epicormic branches on the butt logs of residual trees at the end of each of the first 3 years after thinning (table 4). Immediately after thinning, however, residual trees in these four treatments actually had significantly fewer large epicormic branches than did trees in the unthinned control. Because the prescriptions evaluated in this study are based on tree quality and tree health, trees with numerous epicormic branches prior to thinning generally were removed from the stand during the thinning operation. Trees with no epicormic branches and trees with few epicormic branches generally were retained, thus effectively reducing the mean number of large epicormic branches on residual trees immediately after each of the four thinning treatments. During the first 3 years after thinning, the number of large epicormic branches on the butt logs of residual trees in thinned plots increased gradually, to the extent that there no longer are significant differences in the number of large epicormic branches between each of the four thinning treatments and the unthinned control. This same pattern was observed in thinning studies based on stand density management (Meadows and Goelz 2002, Meadows and Skojac 2006). In those studies, the number of epicormic branches on residual trees increased steadily for the first 3 years after thinning, remained stable for the next several years, and then declined slowly. Results in this study followed the same trend, at least through the first 3 years after thinning.

Because hardwood species vary widely in their susceptibility to the production of epicormic branches (Meadows 1995), data were partitioned by species groups: red oak and sweetgum (table 5). Meadows (1995) classified water oak, willow oak, and sweetgum as highly susceptible to the production of epicormic branches, but classified cherrybark oak as only moderately susceptible. However, none of the four thinning treatments had a significant effect on the number of large epicormic branches on the butt logs of residual red oaks or sweetgum by the end of the third year after thinning. Residual red oaks averaged fewer than two large epicormic branches on the butt log, while residual sweetgum trees averaged less than one large epicormic branch on the butt log, regardless of treatment.

Yet, there often is a proliferation of epicormic branches along the boles of hardwood trees in response to thinning (Stubbs 1986, Ward 1966). We believe the reason this proliferation of epicormic branches did not occur in this study is because our thinning prescriptions are based on stand quality management, which places strong emphasis on retention of healthy, high-quality trees. Our prescriptions did not force us to leave unhealthy, low-quality trees simply to maintain a target residual stand density, which would have been required if our prescriptions were based on stand density management. Because healthy trees are much less likely to produce epicormic branches than are unhealthy trees, retention of healthy, high-quality trees, even of susceptible species like red oak and sweetgum, minimized the production of epicormic branches in response to the four thinning treatments evaluated in this study.

Based on the general rule that as few as five epicormic branches on a 16-foot-long hardwood log may reduce the grade of that log (Meadows and Burkhardt 2001), we expect that the number of large epicormic branches observed on residual red oak and sweetgum trees in this study will not result in log grade reductions. We also anticipate that there will be no reductions in timber value or lumber value associated with epicormic branches. Previous research indicates that production of epicormic branches generally ceases by the end of the third year after thinning and the number of branches usually stabilizes after that (Meadows and Goelz 2002, Meadows and Skojac 2006). Thus, it is unlikely that significantly more epicormic branches will be produced on residual trees in the near future. Rather, it is likely that the number of epicormic branches on residual trees will remain relatively stable for the next several years. Consequently, it is clear that our stand quality management prescriptions minimized production of epicormic branches and had no adverse effects on bole quality of residual trees.

PRELIMINARY REMARKS

Generally, 3 years is not long enough to draw definitive conclusions about a thinning study. So, we offer the following preliminary remarks for consideration:

1. Diameter growth of residual trees increased significantly following all four thinning prescriptions, when averaged across all trees of all species. However, we were unable to detect significant differences among treatments in cumulative diameter growth of red oaks.

2. Thinning had little or no effect on the number of large epicormic branches on the butt logs of residual trees, even among red oak species that are moderately to highly susceptible to production of epicormic branches.

3. Statistically, it does not appear that thinning benefitted residual red oaks after 3 years. However, diameter growth of residual red oaks in the AccNoPole and DesNoPole prescriptions is vigorous, while epicormic branch production across all four thinning prescriptions has been negligible.

ACKNOWLEDGMENTS

The U.S. Fish and Wildlife Service, Noxubee National Wildlife Refuge, provided the study site and cooperated in all phases of study installation and measurement. We specifically thank Henry Sansing, Refuge Manager, and Richard Smith, Refuge Forester, for their cooperation and assistance. Tim Huggins, Ben Maddox, and Sam Maddox assisted with field measurements over the course of the study. John Adams and Andy Ezell provided helpful comments on earlier drafts of this manuscript.

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Table 1—Treatment means (± SE) for stand conditions immediately after application of five thinning treatments. Means followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p < 0.01 for all variables)

Treatment	Trees	Basal area	Quadratic mean diameter	Stocking
	no./ac	ft^2/ac	inches	%
Unthinned Control	93 ± 14 a	108 ± 7 a	14.8 ± 0.7 c	89 ± 7 a
Acceptable/Superior	29 ± 2 b	69 ± 8 b	20.6 ± 0.5 ab	54 ± 6 b
Acceptable/No Pole	28 ± 2 b	61 ± 3 b	20.2 ± 1.0 ab	48 ± 2 b
Desirable/Superior	26 ± 3 b	57 ± 11 b	19.9 ± 1.0 b	45 ± 9 b
Desirable/No Pole	18 ± 2 b	48 ± 3 b	22.0 ± 0.3 a	37 ± 3 b

Table 2—Treatment means (± SE) for stand conditions 3 years after application of five thinning treatments. Means followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p < 0.01 for all variables)

Treatment	Trees	Basal area	Quadratic mean diameter	Stocking
	no./ac	ft^2/ac	inches	%
Unthinned Control	91 ± 13 a	112 ± 6 a	15.2 ± 0.7 b	92 ± 6 a
Acceptable/Superior	28 ± 2 b	68 ± 6 b	20.9 ± 0.4 a	53 ± 5 b
Acceptable/No Pole	27 ± 2 b	64 ± 2 b	20.9 ± 1.1 a	50 ± 2 b
Desirable/Superior	25 ± 3 b	59 ± 11 b	20.5 ± 1.0 a	46 ± 8 b
Desirable/No Pole	18 ± 2 b	51 ± 4 b	22.7 ± 0.3 a	39 ± 3 b

Table 3—Cumulative diameter growth (± SE) of residual trees 1, 2, and 3 years after application of five thinning treatments. Means within each year followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p = 0.12 for year 1, p = 0.03 for year 2, p = 0.01 for year 3)

	Years after thinning		
Treatment	1	2	3
	inches		
Unthinned Control	0.12 ± 0.01 a	0.22 ± 0.02 b	0.33 ± 0.02 b
Acceptable/Superior	0.18 ± 0.03 a	0.43 ± 0.07 a	0.59 ± 0.07 a
Acceptable/No Pole	0.17 ± 0.02 a	0.43 ± 0.05 a	0.62 ± 0.07 a
Desirable/Superior	0.15 ± 0.01 a	0.38 ± 0.02 a	0.56 ± 0.02 a
Desirable/No Pole	0.19 ± 0.01 a	0.48 ± 0.04 a	0.69 ± 0.06 a

Table 4—Number (± SE) of large epicormic branches found on the butt logs of residual trees immediately after thinning (year 0) and 1, 2, and 3 years after application of five thinning treatments. Means within each year followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p < 0.01 for year 0, p = 0.17 for year 1, p = 0.30 for year 2, p = 0.46 for year 3)

	Years after thinning			
Treatment	0	1	2	3
Unthinned Control	1.3 ± 0.2 a	1.3 ± 0.2 a	1.3 ± 0.3 a	1.2 ± 0.2 a
Acceptable/Superior	0.4 ± 0.2 b	0.7 ± 0.4 a	0.7 ± 0.4 a	1.1 ± 0.6 a
Acceptable/No Pole	0.4 ± 0.1 b	0.9 ± 0.1 a	1.0 ± 0.1 a	1.3 ± 0.1 a
Desirable/Superior	0.2 ± 0.1 b	0.7 ± 0.3 a	0.8 ± 0.3 a	1.2 ± 0.3 a
Desirable/No Pole	0.1 ± 0.1 b	0.2 ± 0.2 a	0.3 ± 0.2 a	0.4 ± 0.3 a

Table 5—Number (± SE) of large epicormic branches found on the butt logs of residual trees, by species group, 3 years after application of five thinning treatments. Means within each species group followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p = 0.09 for red oak, p = 0.54 for sweetgum)

	Species group	
Treatment	Red oak	Sweetgum
Unthinned Control	0.7 ± 0.1 a	0.7 ± 0.1 a
Acceptable/Superior	1.6 ± 0.6 a	0.9 ± 0.7 a
Acceptable/No Pole	1.2 ± 0.3 a	0.2 ± 0.2 a
Desirable/Superior	1.9 ± 0.6 a	0.3 ± 0.3 a
Desirable/No Pole	0.1 ± 0.1 a	0.6 ± 0.1 a

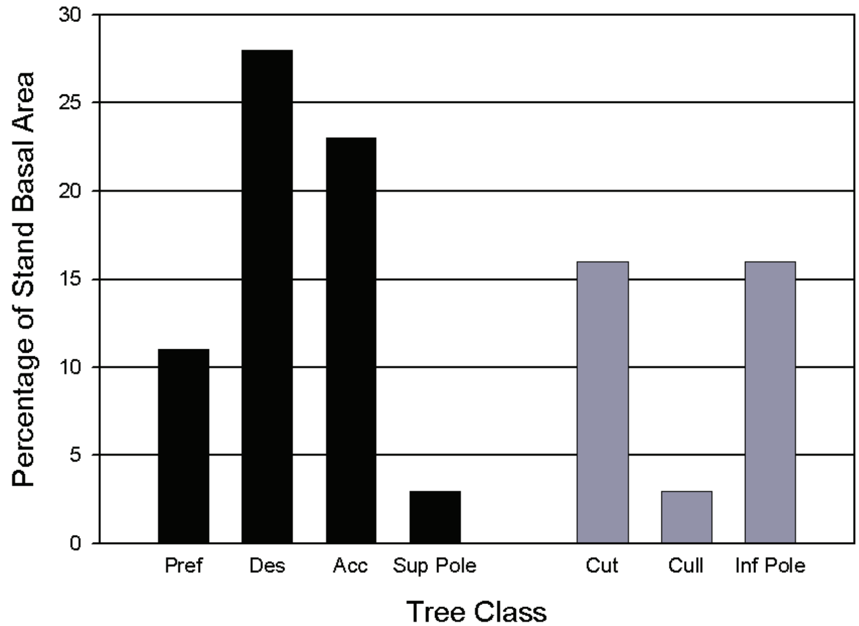

Figure 1—Tree class distribution, expressed as the percentage of stand basal area in each tree class, prior to application of five thinning treatments.

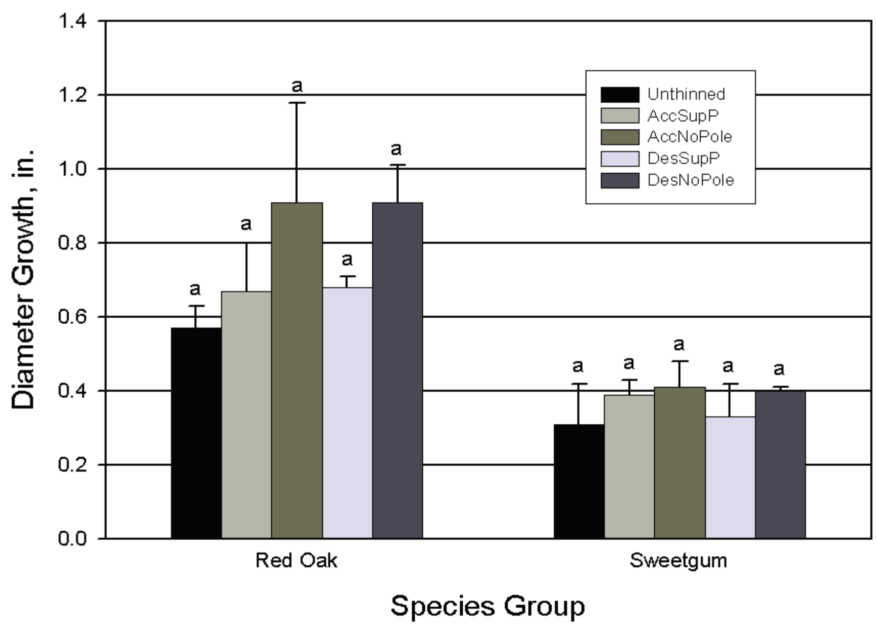

Figure 2—Cumulative diameter growth (± SE) of residual trees, by species group, 3 years after application of five thinning treatments. Means within each species group followed by the same letter are not significantly different at the 0.05 level of probability (n = 3 per treatment; p = 0.45 for red oak, p = 0.89 for sweetgum).