STAND QUALITY MANAGEMENT OF A WATER OAK PLANTATION IN LOUISIANA: PRELIMINARY RESULTS FOLLOWING THINNING

James S. Meadows and Daniel A. Skojac, Jr.[1]

Abstract—Stand quality management is a new guiding principle in which thinning prescriptions are based on tree quality rather than on residual stand density. We recently initiated a series of hardwood thinning studies to determine the effects of four stand quality management thinning prescriptions on both stand-level and individual-tree-level growth, quality, and value: (1) no thinning, (2) Acceptable with Superior Poletimber, (3) Acceptable with No Poletimber, (4) Desirable with Superior Poletimber, and (5) Desirable with No Poletimber. The first study was installed during the summer of 2004 in a 35-year-old water oak (*Quercus nigra* L.) plantation at the Red River Wildlife Management Area near Shaw, LA. Prior to thinning, stand density averaged 122 trees and 101 square feet of basal area per acre. Quadratic mean diameter of the stand was 12.4 inches. All four thinning prescriptions significantly increased diameter growth of individual water oak trees during the first two years after thinning. However, thinning also stimulated the production of new epicormic branches on the butt logs of residual trees. The Acceptable with Superior Poletimber thinning prescription produced the best combination of (1) acceptable residual stand density, (2) improved diameter growth, and (3) least adverse effect from the production of epicormic branches in this previously unmanaged, mid-rotation water oak plantation.

INTRODUCTION

Profitable management of hardwood stands for sawtimber production demands not only satisfactory rates of tree growth, but also requires the development and maintenance of high-quality, high-value logs. Thinnings often are used to fulfill these goals. Specifically, thinnings in southern bottomland hardwood stands should be designed to improve growth of residual trees and to maintain and enhance bole quality of residual trees (Meadows 1996).

Thinning regulates stand density and increases diameter growth of residual trees, as has been reported for several hardwood forest types in the Eastern United States (Hilt 1979, Lamson and Smith 1988, Sonderman 1984a). Generally, diameter growth of residual trees increases as thinning intensity increases. However, recent research in natural, mixed-species, bottomland hardwood stands indicates that residual dominant and codominant red oaks (*Quercus* spp.) exhibit similar diameter growth responses to thinnings in which residual stand densities range from 64 to 86 square feet of basal area per acre (Meadows and Goelz 2002, Meadows and Skojac 2006). Significant increases, of nearly identical magnitude, in diameter growth of these valuable red oaks can be achieved through thinning, as long as residual stand density falls within this fairly broad range.

However, over-thinning may reduce residual stand density to the point where stand-level basal area growth and volume growth are greatly diminished, even though diameter growth and volume growth of individual residual trees are greatly enhanced. Minimum residual density levels necessary to maintain satisfactory stand-level growth after thinning have been reported for different types of upland hardwood stands (Hilt 1979, Lamson and Smith 1988), but no recommended minimum residual stand density levels have been identified for southern bottomland hardwood stands. Meadows and Goelz (2001), however, observed that a residual basal area of 52 square feet per acre in a 28-year-old water oak (*Quercus nigra* L.) plantation was sufficient to promote adequate stand-level growth following thinning, but that a residual basal area of 34 square feet per acre created severely understocked conditions that likely will depress stand-level growth for many years.

Degradation of bole quality, specifically in the form of increased production of epicormic branches along the boles of residual trees, often occurs as a result of thinning in hardwood stands. For example, Sonderman (1984b) found that the number and size of epicormic branches on the boles of upland oak trees increased significantly as residual stand density decreased. However, this adverse effect of thinning on bole quality most often is associated with poorly planned thinning operations, in which high-value trees are harvested to provide income for the landowner and low-value trees are retained to form the residual stand. This form of high-grading is not conducive to profitable management of hardwood stands for high-quality sawtimber production.

In contrast, well-designed hardwood thinning operations strive to increase the proportion of high-value trees and to decrease the proportion of low-value trees. Trees that are damaged or diseased, have low-quality boles, or are undesirable species should be removed; trees that are healthy, have high-quality boles, and are desirable species should be retained. Because thinning should favor healthy, sawtimber-sized trees of desirable species, the proportion of dominant and codominant trees in the residual stand typically increases as thinning intensity increases. Vigorous, upper-crown-class trees are much less likely to produce epicormic branches than are less vigorous, lower-crown-class trees (Meadows 1995). Consequently, production of epicormic branches along the boles of residual trees actually may decrease as thinning intensity increases (Sonderman and Rast 1988). In fact, well-designed thinnings should improve average bole quality throughout the residual stand.

[1]Principal Silviculturist and Forestry Technician, USDA Forest Service, Southern Research Station, Stoneville, MS, respectively. (Current address for Skojac is USDA Forest Service, Ozark-St. Francis National Forest, Russellville, AR.)

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Stand Density Management

Traditionally, thinning operations in southern hardwood stands are guided by the practice of stand density management. The stand is marked to a predetermined level of residual stand density. Trees to be removed and trees to be retained are selected on the basis of individual tree quality and value. Goelz and Meadows (1997) provided guidelines for the implementation of stand density management in southern bottomland hardwood stands. A stocking guide developed by Goelz (1995) for natural stands of southern bottomland hardwoods forms the basis for these guidelines. In the practice of stand density management, thinnings are designed to reduce stocking to the B-line, which, as described by Goelz (1995), represents the desired level of stocking to be retained after thinning, as recommended by Putnam and others (1960). The B-line ranges from 55 to 60 percent of maximum full stocking in poletimber stands (average diameter of 9 inches) to 80 to 85 percent of maximum full stocking in large-sawtimber stands (average diameter of 30 inches). The first commercial thinning in most natural stands of southern bottomland hardwoods is conducted when average diameter reaches 12 to 14 inches. The corresponding B-line for this stand is 65 to 70 percent of maximum full stocking, equivalent to a residual stand density of 75 to 85 square feet of basal area per acre (Goelz 1995). A reasonable thinning prescription under the guiding principle of stand density management thus might be to thin the stand to a target residual density of 80 square feet of basal area per acre.

The practice of stand density management leads to two serious problems. First, it is difficult for the timber marker to accurately and consistently visualize the prescribed residual density as he/she marks the stand. Second, 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. Consequently, overall stand quality and value frequently are compromised by strict adherence to stand density management.

Stand Quality Management

Due to the problems associated with stand density management, and because bole quality and species play such significant roles in setting the value of hardwood timber, we recently developed the concept of stand quality management as the new guiding principle for management of southern hardwood forests. The basic tenet of stand quality management is that the stand should be managed to maintain a high level of residual stand quality, with residual stand density relegated to a role of secondary importance. In its simplest terms, stand quality management is expressed as "If it's a good tree, leave it; if it's a poor tree, cut it!" Less emphasis is placed on the idea that hardwood stands must be thinned to a target level of residual stand density. Rather, quality dictates which trees will be cut and which trees will be left during a thinning operation. As long as residual stand density falls within fairly broad limits, prescriptions and marking rules for thinnings are based on tree quality alone.

We also recently developed a new hardwood tree classification system that can be used as a tool to implement stand quality management. Definitions for the tree classes are based on five characteristics that affect future performance and value growth potential of individual hardwood trees: (1) species, (2) crown class, (3) current condition of the tree and future risk of mortality or degrade in merchantability, (4) bole quality, and (5) expected change in value over time.

The first component of our new system consists of five tree classes used only for sawtimber-sized trees, in descending order of desirability and value: (1) preferred growing stock, (2) desirable growing stock, (3) acceptable growing stock, (4) cutting stock, and (5) cull stock. Two additional tree classes are used only for poletimber-sized trees, in descending order of desirability and potential value: (1) superior poletimber stock, and (2) inferior poletimber stock. Trees in the preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock classes are currently or potentially suitable for the production of high-quality sawtimber and are collectively referred to as "growing stock." Conversely, trees in the cutting stock, cull stock, and inferior poletimber stock classes are unsuitable for the production of high-quality sawtimber and are collectively referred to as the "overburden."

In stand quality management, the quality of each individual tree determines which trees are left and which trees are cut in a thinning operation. The maxim is to leave "good" trees and to cut "poor" trees. Our new tree classification system can be used to identify "good" trees and "poor" trees, and then to segregate them into distinct tree classes. Thinning prescriptions and marking rules are based on tree class alone, such that the tree classes actually define the residual component of four different thinning prescriptions under stand quality management (table 1). Even though most trees removed under stand quality management have low value, the volume removed should be sufficient to warrant a commercial thinning operation, particularly in areas with a viable hardwood pulpwood market.

Selection of the most appropriate thinning prescription to use in any given stand of southern hardwoods depends on two factors: (1) initial stand quality, and (2) stage of stand development. Initial stand quality is estimated from the tree class distribution of the stand prior to thinning, expressed as the proportion of basal area in each tree class. A stand of medium initial quality contains a relatively high proportion of acceptable growing stock trees and a relatively low proportion of preferred growing stock and desirable growing stock trees. This distribution of tree classes is typical of previously unmanaged stands. In contrast, a stand of high initial quality contains a relatively high proportion of preferred growing stock and desirable growing stock trees and a relatively low proportion of acceptable growing stock trees. This distribution of tree classes is typical of previously thinned stands.
We hypothesize that the two "Acceptable" prescriptions (AccSupP and AccNoPole in table 1) are best suited for stands of medium initial quality, whereas the two "Desirable" prescriptions (DesSupP and DesNoPole in table 1) are best suited for stands of high initial quality and may be unsuited for stands of medium initial quality. The decision to retain or to remove the superior poletimber stock trees depends on the stage of stand development, expressed as the length

Table 1—Marking rules for four thinning prescriptions associated with the practice of stand quality management

Thinning prescription		Marking rules
Acceptable With Superior Poletimber (AccSupP)	LEAVE:	preferred growing stock desirable growing stock acceptable growing stock superior poletimber stock
	CUT:	cutting stock cull stock inferior poletimber stock
Acceptable With No Poletimber (AccNoPole)	LEAVE:	preferred growing stock desirable growing stock acceptable growing stock
	CUT:	cutting stock cull stock superior poletimber stock inferior poletimber stock
Desirable With Superior Poletimber (DesSupP)	LEAVE:	preferred growing stock desirable growing stock superior poletimber stock
	CUT:	acceptable growing stock cutting stock cull stock inferior poletimber stock
Desirable With No Poletimber (DesNoPole)	LEAVE:	preferred growing stock desirable growing stock
	CUT:	acceptable growing stock cutting stock cull stock superior poletimber stock inferior poletimber stock

of time remaining in the rotation before final harvest of the stand. The timber marker retains superior poletimber stock trees in early-to-mid-rotation stands because there is ample time left in the rotation for these trees to develop into quality sawtimber. Conversely, the timber marker removes superior poletimber stock trees in late-rotation stands.

Objectives

To evaluate this new concept of stand quality management, we recently initiated a series of thinning studies in hardwood stands across the South. All individual studies within the series use the same experimental design, treatments, and methods. The study reported here is the first in the series. Each individual study within the series is designed to determine how the four thinning prescriptions associated with stand quality management affect (1) stand-level growth, development, yield, and value; and (2) growth and bole quality of individual trees. Results from the entire series of studies will be combined to develop a research-based model that will provide guidance to forest managers in the selection of the most appropriate stand quality management thinning prescription to use in southern hardwood stands with different levels of initial stand quality and at different stages of stand development.

METHODS

Study Area

The study is located on the Red River Wildlife Management Area between the Mississippi River and the Red River in southern Concordia Parish, near the community of Shaw, LA. The land is managed by the Louisiana Department of Wildlife and Fisheries. The Mississippi River mainline levee protects the site from major flooding, but backwater flooding from nearby canals and bayous may occur periodically during the winter and spring.

Soils across most of the study area are Commerce silt loam or Commerce silty clay loam, but there is a relatively small area of Tunica clay that occupies the western portion of the study site. The Commerce soils are somewhat poorly drained, have very high available water capacity, are moderately slowly permeable, and formed from loamy alluvium. The Tunica soil is poorly drained, has high available water capacity, is very slowly permeable, and formed from clayey alluvium deposited over a layer of loamy alluvium. Broadfoot (1976) reported average site indexes for water oak to be 104 feet at 50 years on the Commerce soils and 88 feet at 50 years on the Tunica soil.

The study area is located entirely within a 160-acre water oak plantation. There are also a few planted cherrybark oak (*Quercus pagoda* Raf.) and willow oak (*Q. phellos* L.) trees scattered throughout the plantation, as well as occasional rows of Nuttall oak (*Q. nuttallii* Palmer) and of pecan [*Carya illinoensis* (Wangenh.) K. Koch]. Volunteer individuals that seeded into the plantation are primarily sycamore (*Platanus occidentalis* L.) and sugarberry (*Celtis laevigata* Willd.). The plantation was 35 years old at the time of study installation. There was no evidence of previous harvesting activity in the plantation. Details, such as site preparation, initial spacing, and early cultural treatments, were not documented at the time of plantation establishment.

Plot Design

Plot design follows the recommendations for standard plots for silvicultural research, as described by the U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station (Marquis and others 1990). We applied each treatment uniformly across a 2.0-acre rectangular treatment plot that measures 4 by 5 chains (264 by 330 feet). We established a 0.6-acre rectangular measurement plot in the center of each treatment plot. Each measurement plot is 2 by 3 chains (132 by 198 feet), which provides a 1-chain-wide (66 feet) buffer strip around each measurement plot. The entire study area is 30 acres.

Treatments

Treatments consist of the four thinning prescriptions associated with stand quality management (table 1) and an unthinned control. Trees were retained or removed from the plantation solely on the basis of tree class. All trees assigned to tree classes designated as “leave” for each given prescription were retained; all trees assigned to tree classes designated as “cut” for each given prescription were removed. No consideration was given to residual stand density or to spacing of residual trees. Treatments were assigned randomly to treatment plots after preliminary data, including tree class of each tree, were collected.

Three replications of the five treatments were applied in a randomized complete block design to the 15 treatment plots (experimental units) during early autumn of 2004. A contract logging crew directionally felled all marked trees with a mechanized feller equipped with a continuously running cutting head. Felled trees were topped and delimbed in the woods. Tree-length logs were removed from the woods with rubber-tired skidders.

Measurements

Before assigning treatments, we conducted a preharvest survey to determine initial stand quality and initial stand density on each 0.6-acre measurement plot. We recorded species, diameter at breast height (d.b.h.), crown class, and tree class on all trees ≥ 5.5 inches d.b.h. We defined sawtimber as trees ≥ 12.0 inches and poletimber as trees ≥ 5.5 inches but < 12.0 inches d.b.h. After marking the treatment plots for thinning according to the marking rules associated with each prescription (table 1), we collected additional data on all designated “leave” trees: (1) the number of epicormic branches > 3/8 inches in basal diameter (designated “large” epicormic branches) on the 16-foot-long butt log, and (2) the total number of epicormic branches, regardless of size, on the 16-foot-long butt log. “Large” epicormic branches are counted as defects on logs of all sizes, grades, and species (Rast and others 1973). Basal diameters of epicormic branches were estimated ocularly. We recorded pulpwood merchantable height on all poletimber “leave” trees and sawtimber merchantable height on all sawtimber “leave” trees. We also recorded log grade, as defined by Rast and others (1973), of the 16-foot-long butt log on all sawtimber “leave” trees. We measured total height on the two largest codominant trees on each measurement plot. All heights were measured using a clinometer. Crown class, d.b.h., the number of “large” epicormic branches, and the total number of epicormic branches on the 16-foot-long butt log were measured annually for the first two years after thinning.

RESULTS AND DISCUSSION

Plantation Conditions Prior to Thinning

Prior to thinning, the plantation averaged 122 trees and 101 square feet of basal area per acre, with a quadratic mean diameter of 12.4 inches, among trees ≥ 5.5 inches d.b.h. The plantation contained 3,729 board feet of sawtimber per acre, Doyle scale, and 4.4 cords of pulpwood per acre. Water oak accounted for 84 percent of the trees, 90 percent of the basal area, 80 percent of the pulpwood volume, and 99 percent of the sawtimber volume. Quadratic mean diameter of the water oak component was 12.8 inches. There were no significant differences among treatment plots in any of the preharvest characteristics.

Although the plantation was relatively dense, most dominant and codominant water oak trees appeared healthy and exhibited few symptoms of poor vigor, such as crown deterioration, loss of dominance, or the presence of numerous epicormic branches along the bole. Small gaps created by the death of scattered trees were interspersed throughout the plantation. Generally, conditions indicated that the plantation needed to be thinned, but overall stand health had not yet begun to decline visibly.

Most trees in the plantation prior to thinning had short merchantable boles of relatively low quality. In fact, average merchantable height of sawtimber trees was only 21 feet. For most trees, merchantable height was limited by the base of the live crown, rather than by excessive sweep and/or crook, abundant defects, damage from insects and/or diseases, or other log abnormalities. Many trees had a few epicormic branches large enough to be counted as defects on the butt log. Across all trees in the plantation, we found an average of 3.8 “large” epicormic branches on the butt log, compared to only 1.7 “large” epicormic branches on the butt log of dominant and codominant water oak. Overall bole quality was relatively poor on most trees, primarily due to existing defects in the form of overgrown knots. Approximately 84 percent of all sawtimber trees in the plantation contained Grade 3 butt logs, the least valuable log grade assigned to hardwood factory-lumber logs, as defined by Rast and others (1973). However, several trees with Grade 3 butt logs actually had high-quality boles, but had not yet attained the minimum size requirements for higher-grade logs.

Prior to thinning, only 54 percent of the total plantation basal area and 55 percent of the water oak basal area consisted of trees in the “growing stock” category (preferred, desirable, and acceptable growing stock sawtimber trees plus superior poletimber stock trees). Conversely, 46 percent of the total and 45 percent of the water oak basal area consisted of trees in the “overburden” category (cutting and cull stock sawtimber trees plus inferior poletimber stock trees). The overburden represents a fairly large component in this previously unmanaged water oak plantation. As a general rule, the overburden should account for less than 40 percent of total basal area. Based on the tree class distribution of the plantation prior to thinning and the expected length of time remaining in the rotation, we classified this water oak plantation as an early-to-mid-rotation stand of medium initial quality.

Plantation Development Following Thinning

Treatments were applied during the early autumn of 2004, using the marking rules established in table 1. The Acceptable With Superior Poletimber thinning prescription (AccSupP) reduced stand density to 52 trees and 54 square feet of basal area per acre, increased quadratic mean diameter to 13.8 inches, and reduced sawtimber volume to 2,480 board feet per acre. It removed 57 percent of the trees, 45 percent of the basal area, and 33 percent of the sawtimber volume. The Acceptable With No Poletimber thinning prescription (AccNoPole) reduced stand density to 39 trees and 47 square feet of basal area per acre, increased quadratic mean diameter to 14.8 inches, and reduced sawtimber volume to 2,702 board feet per acre. It removed 68 percent of the trees, 56 percent of the basal area, and 28 percent of the sawtimber volume. The Desirable With Superior Poletimber thinning prescription (DesSupP) reduced stand density to 30 trees and 33 square feet of basal area per acre, increased quadratic mean diameter to 14.2 inches, and reduced sawtimber volume to 1,447 board feet per acre. This more radical treatment removed 76 percent of the trees, 67 percent of the basal area, and 61 percent of the sawtimber volume. The Desirable With No Poletimber thinning prescription (DesNoPole) reduced stand density to 23 trees and 30 square feet of basal area per acre, increased quadratic mean diameter to 15.6 inches, and reduced sawtimber volume to 1,393 board feet per acre. Our most radical treatment removed 82 percent of the trees, 70 percent of the basal area, and 63 percent of the sawtimber volume.

All four thinning prescriptions produced stand characteristics significantly different from the unthinned control. Residual basal areas associated with the two “Acceptable” prescriptions (AccSupP and AccNoPole) were significantly greater than the residual basal areas associated with the two “Desirable” prescriptions (DesSupP and DesNoPole). However, residual basal area did not differ significantly between the AccSupP prescription and the AccNoPole prescription or between the DesSupP prescription and the DesNoPole prescription. The AccSupP and AccNoPole prescriptions produced residual stand densities that closely correspond to the C-10 and C-15 lines of stocking, respectively, as described by Goelz (1997). These two C-lines of stocking represent stands that will achieve B-line stocking, or minimum full stocking, after 10 and 15 years of growth, respectively. In contrast, the DesSupP prescription produced a residual stand density that corresponds to the C-25 line of stocking, as described by Goelz (1997), whereas the DesNoPole prescription resulted in a residual stand density well below the C-25 line of stocking. The C-25 line of stocking represents a stand that will achieve B-line stocking only after 25 years of growth. By definition, all stands below B-line stocking are, at least to some extent, understocked. Goelz (1997), however, asserted that stands at or below the C-20 line of stocking are so severely understocked that immediate regeneration of the stand is recommended.

The two “Acceptable” prescriptions produced residual stands that are suitable for continued management. In contrast, the two “Desirable” prescriptions clearly removed too many trees and reduced stand densities to levels unacceptable for continued management. These results support our initial hypothesis that the “Acceptable” prescriptions are best suited for stands of medium initial quality, such as this previously unmanaged water oak plantation, whereas the “Desirable” prescriptions are best suited for stands of high initial quality, typical of previously thinned stands, and actually may be unsuited for stands of medium initial quality.

Two years after thinning, 1.7 trees per acre died in the unthinned control plots, but none died in any of the thinned plots. Cumulative mortality in the unthinned control plots was 1.5 percent. All mortality occurred as a result of suppression of individual trees, rather than from some type of major disturbance.

Stand-level basal area growth did not differ significantly among the five treatments during the first two years following thinning, but all four thinning prescriptions produced significant increases in quadratic mean diameter, relative to the unthinned control (table 2). However, increases in quadratic mean diameter did not differ significantly among the four thinning prescriptions. Because it is generally too soon to expect significant stand-level responses to thinning, our stand-level results are inconclusive. Speculation on future stand development would be premature.

Diameter Growth of Water Oak Trees

All four thinning prescriptions significantly increased cumulative diameter growth of residual water oak trees during each of the first two years following thinning (fig. 1). In fact, by the end of the second year after thinning, all four prescriptions had more than doubled the diameter growth of residual water oaks, relative to water oaks in the unthinned control plots. Cumulative diameter growth of residual water oaks in the DesNoPole prescription more than tripled—0.74 inches in just two years. However, there were no significant differences in cumulative diameter growth among the four thinning prescriptions through the first two years following thinning.

The data presented in figure 1 include all water oak trees, regardless of tree size or crown class. However, we are more interested in the response of the larger trees in the stand. To

Table 2—Stand conditions 2 years after application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Means within a column followed by the same letter are not significantly different at the 0.05 level of probability

Treatment	Trees	Basal area	Cumulative basal area growth	Quadratic mean diameter	Increase in quadratic mean diameter
	no./ac	----------- ft^2*/ac* -----------		---------- *inches* ----------	
Control	113 a	105 a	3.5 a	13.0 c	0.32 b
AccSupP	52 b	58 b	4.5 a	14.4 bc	0.58 a
AccNoPole	39 bc	50 b	3.4 a	15.3 ab	0.55 a
DesSupP	30 cd	36 c	2.9 a	14.8 ab	0.62 a
DesNoPole	23 d	33 c	2.8 a	16.3 a	0.73 a

evaluate this response, we separated the data by tree size class—sawtimber versus poletimber (fig. 2). For purposes of this study, we defined sawtimber as trees ≥ 12.0 inches d.b.h. and poletimber as trees between 5.5 and 11.9 inches d.b.h., inclusive.

By the end of the second year after thinning, all four thinning prescriptions had approximately doubled the diameter growth of sawtimber-sized water oaks, relative to sawtimber-sized water oaks in the unthinned control plots (fig. 2). There were no significant differences in cumulative diameter growth among the four thinning prescriptions, but all of them exhibited significantly greater diameter growth than did sawtimber-sized water oaks in the unthinned control plots.

The AccSupP and DesSupP prescriptions more than tripled the diameter growth of poletimber-sized water oaks, relative to water oak poletimber in the unthinned control plots (fig. 2). Cumulative diameter growth did not differ significantly between these two prescriptions. The AccNoPole and DesNoPole prescriptions were not included in this part of the analysis because, by definition, all poletimber trees in these plots were removed from the plantation.

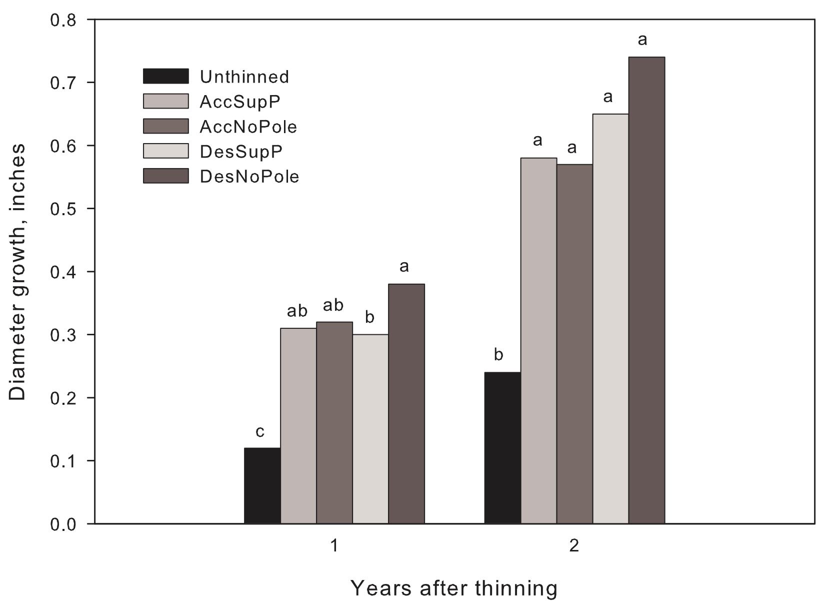

Figure 1—Cumulative diameter growth of residual water oak trees at the end of the first and second years following application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Bars within a year followed by the same letter are not significantly different at the 0.05 level of probability.

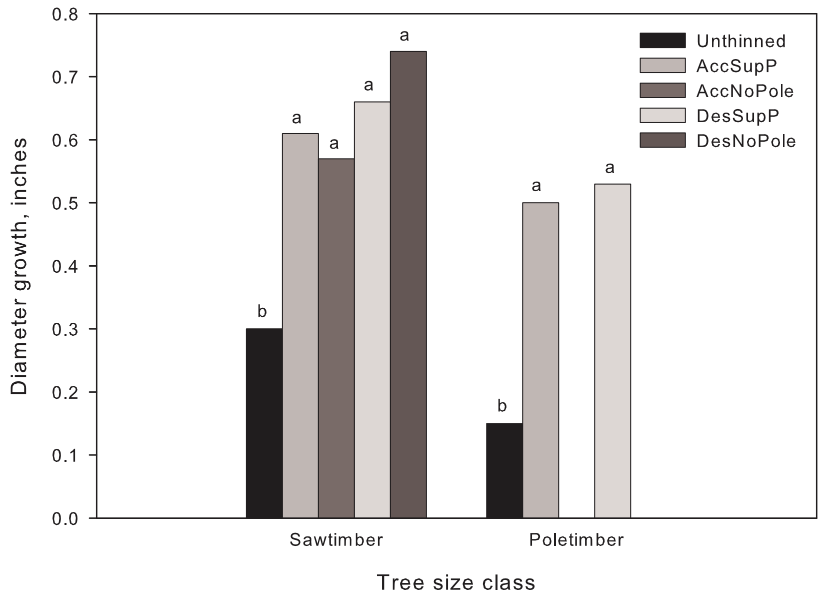

Figure 2—Cumulative diameter growth of residual water oak trees, by tree size class, at the end of the second year following application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Bars within a tree size class followed by the same letter are not significantly different at the 0.05 level of probability.

Recent research indicates that diameter growth of residual, dominant and codominant bottomland red oaks following thinning in natural stands is independent of residual stand density, at least within the range of 64 to 86 square feet of basal area per acre (Meadows and Goelz 2002, Meadows and Skojac 2006). It is unknown if the relationship between diameter growth response and residual stand density observed in mixed-species, natural stands also holds true in single-species plantations. Stand dynamics may be quite different between these two types of forests. However, our results in this study generally support the assertion advanced by Meadows and Goelz (2002) and by Meadows and Skojac (2006).

Because all four thinning prescriptions produced stands with residual densities well below the ranges evaluated by Meadows and Goelz (2002) and by Meadows and Skojac (2006), we speculate that differences in residual stand density between the two "Acceptable" prescriptions and the two "Desirable" prescriptions eventually may lead to significant differences in cumulative diameter growth between these two broad types of prescriptions. Using the C-lines of stocking developed by Goelz (1997) as a guide, the residual stands produced through the two "Acceptable" prescriptions are marginally understocked, but still manageable, whereas the residual stands produced through the two "Desirable" prescriptions are severely understocked and should be regenerated. In fact, sawtimber-sized trees retained following "Desirable" thinning are essentially open-grown. As these four stands continue to develop over time, we expect that cumulative diameter growth will be significantly greater on the essentially open-grown, sawtimber-sized, residual water oaks in the "Desirable" stands than on the sawtimber-sized, residual water oaks in the more manageable "Acceptable" stands.

Production of Epicormic Branches on Water Oak Trees

Thinning operations in hardwood stands, while producing positive effects on diameter growth, also may have negative consequences on bole quality of residual trees, particularly in the form of epicormic branches. The production of epicormic branches along the merchantable boles of residual trees can be a serious problem in thinned hardwood stands. Epicormic branches create defects in the underlying wood and can reduce both log grade and subsequent lumber value. In one case study in Alabama, defects from epicormic branches reduced the value of willow oak lumber by 13 percent (Meadows and Burkhardt 2001).

Immediately after thinning, residual water oaks in the thinned plots averaged fewer than two "large" epicormic branches (>3/8 inches in basal diameter) on the butt log, whereas water oaks in the unthinned control plots averaged nearly four branches (fig. 3). These statistically significant reductions in the number of large epicormic branches were the direct result of the thinning operation. All thinning prescriptions discriminated against trees that had numerous pre-existing epicormic branches. Those trees were removed from the plantation during thinning; most trees retained during the thinning operation had few pre-existing epicormic branches.

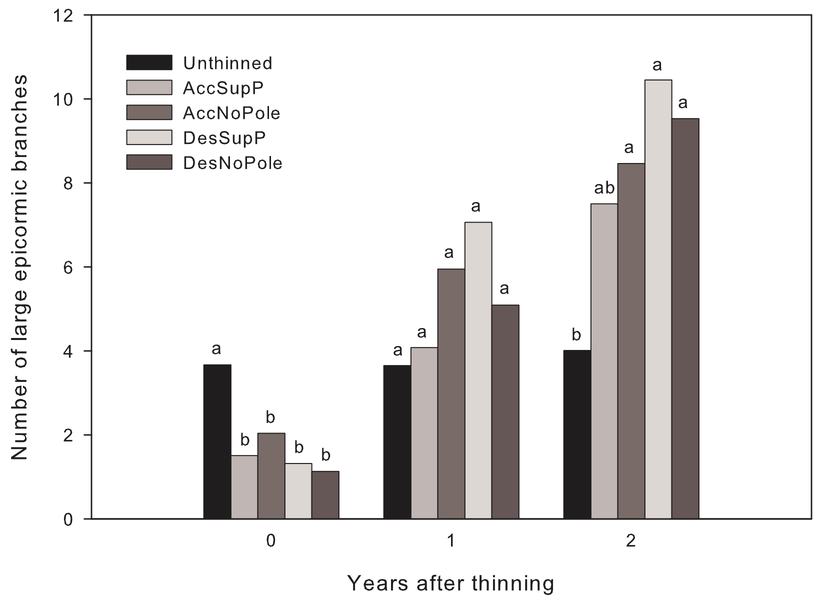

Figure 3—Number of large epicormic branches on the butt logs of residual water oak trees immediately after treatment and at the end of the first and second years following application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Bars within a year followed by the same letter are not significantly different at the 0.05 level of probability.

The number of large epicormic branches on the butt logs of water oaks in the unthinned control plots remained fairly stable (at about four branches) during the two years after thinning (fig. 3). However, there were notable increases in the number of large epicormic branches on the butt logs of residual water oaks in all thinned plots during the same two year period. By the end of the second year after thinning, residual water oaks in all four thinning prescriptions, except AccSupP, had significantly more large epicormic branches than did water oaks in the unthinned control. The number of large epicormic branches on residual water oaks in the AccSupP prescription did not differ significantly from the number of large epicormic branches on water oaks in either the unthinned control or the other three thinning prescriptions.

To evaluate the response of the larger water oak trees in the plantation to the five thinning treatments, we partitioned the epicormic branch data by tree size class—sawtimber versus poletimber (fig. 4). Among sawtimber-sized trees at the end of the second year after thinning, there were more than twice as many large epicormic branches on the butt logs of residual water oaks in the thinned plots, relative to water oaks in the unthinned control plots. These differences in response between the thinned plots and the unthinned control plots were statistically significant. However, the number of large epicormic branches on residual sawtimber-sized water oaks did not differ significantly among the four thinning prescriptions.

There appears to be a separation in the level of the epicormic branch response between the two "Acceptable" prescriptions and the two "Desirable" prescriptions (fig. 4). Residual sawtimber-sized water oaks in the two "Acceptable" prescriptions averaged 7.3 to 7.9 large epicormic branches on the butt log at the end of the second year after thinning, whereas residual sawtimber-sized water oaks in the two "Desirable" prescriptions averaged 9.0 to 9.3 branches, although this separation was not statistically significant. Residual superior poletimber stock trees in the DesSupP prescription had significantly more large epicormic branches on the butt log than did residual superior poletimber stock trees in the AccSupP prescription (fig. 4).

The apparent separation in the level of the epicormic branch response between the two "Acceptable" prescriptions and the two "Desirable" prescriptions becomes more distinct when we limit the analysis to crop trees—preferred growing stock and desirable growing stock trees only (fig. 5). The two "Desirable" prescriptions resulted in significantly more large epicormic branches on the butt logs of high-value preferred and desirable growing stock trees at the end of the second year after thinning than did the two "Acceptable" prescriptions. Depending on the specific thinning prescriptions compared, the average increase ranged from 2.2 to 3.2 branches.

The two "Desirable" prescriptions apparently had a greater effect on the production of epicormic branches than did the two "Acceptable" prescriptions, especially among high-value preferred and desirable growing stock trees. The separation in the level of epicormic branch response between the "Acceptable" and the "Desirable" prescriptions most likely is due to differences in residual stand density after application of these two types of thinning prescriptions, as discussed in the previous section. Residual basal areas in the two "Acceptable" prescriptions were 47 and 54 square feet per acre, indicative of a marginally understocked, but still manageable, stand. Residual basal areas in the two

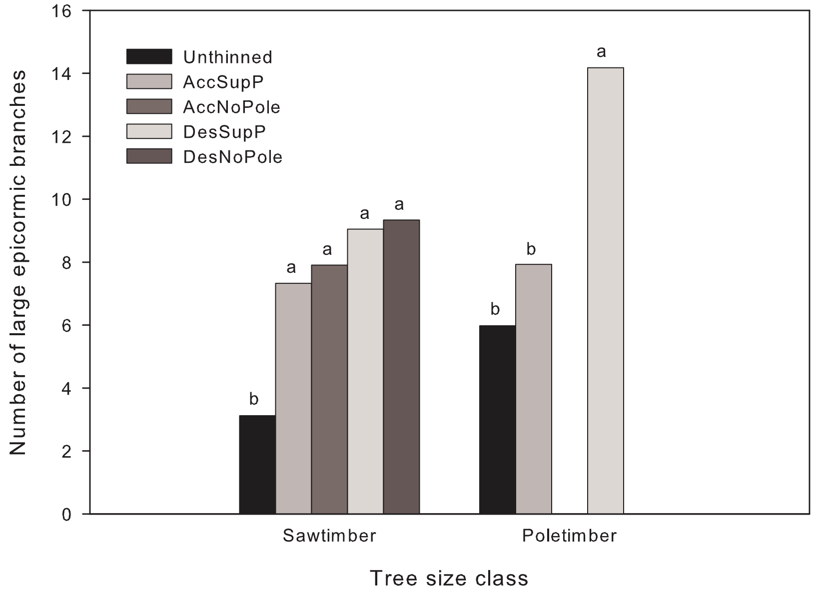

Figure 4—Number of large epicormic branches on the butt logs of residual water oak trees, by tree size class, at the end of the second year following application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Bars within a tree size class followed by the same letter are not significantly different at the 0.05 level of probability.

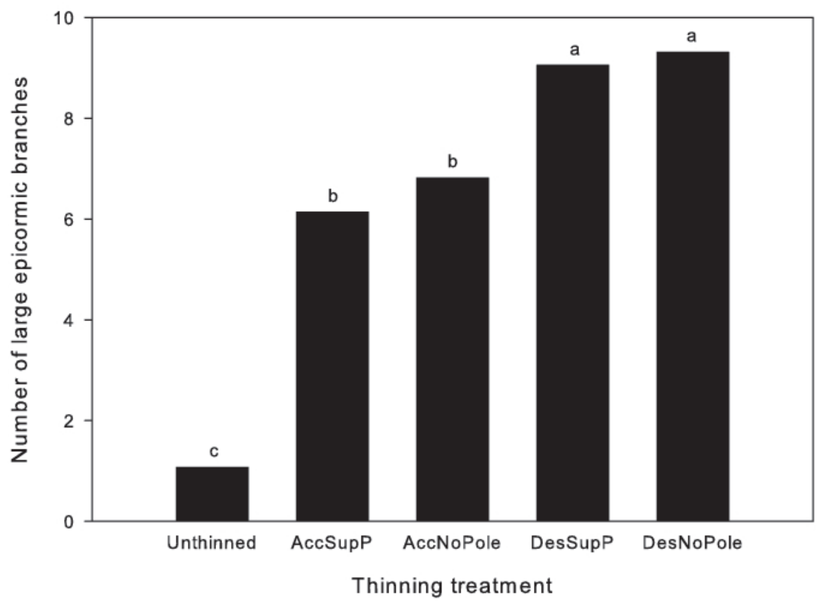

Figure 5—Number of large epicormic branches on the butt logs of residual water oak trees, in the preferred growing stock and desirable growing stock tree classes only, at the end of the second year following application of five thinning treatments in a 35-year-old water oak plantation in Louisiana. See table 1 for an explanation of treatment descriptors. Bars followed by the same letter are not significantly different at the 0.05 level of probability.

“Desirable” prescriptions were 30 and 33 square feet per acre, indicative of a severely understocked stand in which residual trees are essentially open-grown.

The DesSupP and DesNoPole prescriptions removed too many trees, reduced stand densities to unacceptable levels, and, consequently, stimulated the production of new epicormic branches on the butt logs of residual trees. On the other hand, retention of the acceptable growing stock trees in the AccSupP and AccNoPole prescriptions maintained residual stand density at a more favorable level, reduced the amount of sunlight to the boles of residual trees, and minimized the production of new epicormic branches, especially on the butt logs of high-value preferred and desirable growing stock trees. In stands of medium initial quality, such as this 35-year-old water oak plantation, acceptable growing stock trees should be retained after thinning to serve as “shelter” trees for the more valuable preferred and desirable growing stock trees.

Regardless of the manner in which we partitioned the data to examine the epicormic branch response by various stand components, the bottom line is that the number of large epicormic branches produced on the butt logs of residual trees in this water oak plantation was greater than that generally associated with well-designed thinnings in natural, mixed-species stands of bottomland hardwoods (Meadows and Goelz 2002, Meadows and Skojac 2006). The number of branches produced following thinning in our study was, at best, only marginally acceptable for the goal of high-quality sawtimber production.

Three factors likely contributed to the production of numerous epicormic branches along the boles of the residual trees in this study. First, water oak is highly susceptible to the production of epicormic branches (Meadows 1995). Second, bottomland red oaks do not compete well with other oaks when grown in pure stands (Aust and others 1985), such as this water oak plantation, whereas they are generally able to gain a competitive advantage over other species when grown in even-aged, natural stands of mixed species composition (Clatterbuck and Hodges 1988). As a result of long-term oak versus oak competition, individual trees in this water oak plantation may have been more stressed than was visibly apparent at the time of thinning. Hardwood trees, especially most bottomland red oaks, growing under stressful conditions exhibit an increased tendency to produce epicormic branches following thinning (Meadows and Goelz 2001). Third, all of our thinning prescriptions produced residual stand densities well below the acceptable range for natural stands proposed by Meadows and Goelz (2002) and by Meadows and Skojac (2006). The combination of a highly susceptible species subjected to the intense stress of oak versus oak competition in this single-species plantation and the low residual densities to which the plantation was thinned produced adverse effects on bole quality, in the form of numerous epicormic branches along the boles of residual trees.

CONCLUSION

Even though all four thinning prescriptions had negative impacts on bole quality of residual trees, the early results presented here indicate that the Acceptable With Superior Poletimber thinning prescription produced the best combination of (1) acceptable residual stand density, (2) improved diameter growth, and (3) least adverse effect from the production of epicormic branches in this previously unmanaged, mid-rotation water oak plantation.

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