SECOND-YEAR GROWTH AND BOLE QUALITY RESPONSE OF RESIDUAL POLETIMBER TREES FOLLOWING THINNING IN AN EVEN-AGED BOTTOMLAND HARDWOOD SAWTIMBER STAND

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

Abstract—Poletimber trees were classified as either superior or inferior poletimber stock, and then retained on separate plots receiving identical thinning treatments. Differences in post-treatment response were used to evaluate the potential of the two poletimber classes to produce grade sawtimber in the thinned sawtimber stand. Treatments included: an unthinned control, two levels of the Desirable treatment (retained preferred and desirable sawtimber and either superior or inferior poletimber), and two levels of the Acceptable treatment (retained preferred, desirable, and acceptable sawtimber and either superior or inferior poletimber). Thinning increased the likelihood that poletimber trees we initially classified as superior will yield sawlogs in the thinned sawtimber stand. Sawtimber production from inferior poletimber seems unlikely. The Desirable treatment yielded the greatest 2 year cumulative diameter growth response by superior poletimber trees (0.49 inches), but also adversely affected the bole quality of these potentially more valuable stems (10.1 new epicormics). The Acceptable treatment yielded significant diameter growth by superior poletimber trees as well (0.31 inches), and reduced epicormic branching by nearly 60 percent of that observed in the Desirable treatment during the 2-year period. Superior red oak poletimber trees in the Acceptable treatment grew at a rate equivalent to 2 inches per decade while averaging fewer than five defect-causing epicormic branches after the first 2 years. Our preliminary conclusions are that the Acceptable treatment may provide the best combination of growth and maintenance of bole quality for growing high quality sawtimber from poletimber, particularly from the potentially more valuable red oak poletimber trees.

INTRODUCTION

Poletimber trees are usually abundant in previously unmanaged even-aged, bottomland hardwood sawtimber stands. During stand development, these poletimber trees grow slower than their contemporary sawtimber neighbors and therefore, usually occupy the mid-canopy in subordinate crown positions. Most of these trees are of poor form, in declining health, and do not contain potential for development into grade sawtimber. To improve stand health and quality, these weaker poletimber trees are usually removed for pulpwood during thinning operations in these stands. Fewer scattered poletimber trees in these even-aged sawtimber stands are of good form and quality and exhibit potential sawtimber merchantability. Premature removal of these vigorous poletimber trees during thinning underutilizes this potential and could represent substantial losses in potential sawtimber revenue by the end of the rotation. Their retention, however, does not guarantee their ascendance into the sawtimber product class. Sawtimber production will hinge greatly on three factors: improvement in diameter growth, preservation or improvement of bole quality, and achievement of both within the time remaining in the rotation.

Poletimber trees selected for retention in these thinned sawtimber stands must grow and compete for site resources with much larger sawtimber neighbors. Unfortunately, residual poletimber trees are often an overlooked and underutilized component in thinned sawtimber stands, and therefore, we know very little of their post-thinning growth response potential. Several studies, however, indicated that hardwood poletimber trees have the ability to respond vigorously in diameter growth following other forms of partial cutting in bottomland stands (Johnson 1950, Johnson 1968, Meadows 1988). General findings from these earlier experiments indicated that diameter growth was highly correlated with tree health and vigor, as characterized by crown shape and size (Meadows 1988); pre-release diameter and diameter growth rates (Johnson 1968, Meadows 1988); species (Johnson 1968, Meadows 1988); and degree of release (Johnson 1950, Johnson 1968).

Unfortunately, increases in diameter, volume, and potential value may be completely offset by epicormic branching and subsequent reduction in future log grade. Most poletimber trees in these sawtimber stands are at a competitive disadvantage due to their subordinate crowns. Consequently, they are less vigorous than their sawtimber neighbors and generally are more susceptible to epicormic branching, especially when exposed to higher levels of light such as following thinning (Meadows 1995). To develop grade sawtimber from poletimber trees, we need practical guidelines to help identify vigorous poletimber trees that will not be degraded following thinning in these sawtimber stands.

A newly developed tree classification system for southern hardwoods (Meadows and Skojac 2008) separates hardwood poletimber trees into two broad classes based on several characters that may indicate their potential to produce grade sawtimber. This system could be used as a guide when selecting poletimber trees for retention following thinning in sawtimber stands. The new system expands Putnam's

[1] Forester, U.S. Forest Service, Chattahoochee-Oconee National Forests, Chatsworth, GA; Principal Silviculturist, U.S. Forest Service, Southern Research Station, Southern Hardwoods Laboratory, Stoneville, MS; Professor of Forestry, College of Forest Resources, Mississippi State University, Starkville, MS, respectively.

Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

(Putnam and others 1960) set of four tree classes to five tree classes used exclusively for sawtimber (in descending order of desirability): (1) preferred growing stock, (2) desirable growing stock, (3) acceptable growing stock, (4) cutting stock, and (5) cull stock; and creates two additional classes for poletimber: (1) superior poletimber stock and (2) inferior poletimber stock. Superior poletimber stock consists of poletimber trees of a desirable or acceptable commercial species, which are of good form and quality, and currently contain the potential for a Grade 2 butt log once size requirements are met. Comparatively, inferior poletimber stock consists of poletimber trees that do not contain the potential for a Grade 2 butt log because of poor form or quality. Inferior poletimber trees should be removed during the next entry into the stand.

The classification of poletimber trees used in this new system is a qualitative assessment of their current health and condition, but actual differences in thinning response and grade sawtimber development have not been tested, nor have levels of thinning which may improve diameter growth while preserving bole quality been identified. Therefore, the objectives of this study were to (1) compare the growth and quality responses of trees within the two poletimber classes to several levels of thinning to determine their potential for sawtimber production, and (2) to identify a level of thinning which may successfully promote sawtimber production from residual poletimber trees in thinned sawtimber stands.

SITE DESCRIPTION

The experiment was conducted in an even-aged bottomland hardwood stand within the alluvial floodplain of the Red River, on Barksdale Air Force Base in southwestern Bossier Parish, in northwestern LA. The study site is part of a larger 188-acre stand that was approximately 60 to 65 years old at the time of study establishment. Prior to treatment, the stand averaged 119 trees (75 poletimber trees) and 110 square feet (30 square feet in poletimber) of basal area per acre in trees 5.5 inches and larger d.b.h. Quadratic mean d.b.h. was 13.1 inches. Average stand stocking was 92 percent (Goelz 1995). Stand basal area consisted of 47 percent red oak [cherrybark oak (*Quercus pagoda* Raf.), Nuttall oak (*Q. nuttallii* Palmer), water oak (*Q. nigra* L.), and willow oak (*Q. phellos* L.)], 38 percent sweetgum (*Liquidambar styraciflua* L.), and 15 percent other species, primarily pecan [*Carya illinoensis* (Wangenh.) K. Koch] and American elm (*Ulmus americana* L.). The study area contained nearly equal areas of both Perry clay (very-fine, smectitic, thermic Chromic Epiaquerts) and Gallion silt-loam (fine-silty, mixed, superactive, thermic Typic Hapludalfs) (USDA Soil Conservation Service 1962, USDA Natural Resources Conservation Service 2003). Site indices based on the Baker and Broadfoot (1979) site evaluation method were estimated as 104 feet for cherrybark oak, 97 feet for water and willow oak, 94 feet for Nuttall oak, and 107 feet for sweetgum.

PROCEDURE

In December of 2003, the following five treatments were applied to 2.0-acre treatment plots measuring 5 by 4 chains and replicated three times in a randomized complete block design: (1) unthinned control, (2) desirable growing stock with superior poletimber (DesSupP), (3) desirable growing stock with inferior poletimber (DesInfP), (4) acceptable growing stock with superior poletimber (AccSupP), and (5) acceptable growing stock with inferior poletimber (AccInfP). Tree classes (see footnote[2]) were used to form the cutting priority within treatments, such that each treatment was defined by the tree classes to be retained (table 1). Treatments 2 and 3 are collectively referred to as Desirable and 4 and 5 as Acceptable. Although inferior poletimber trees would generally be removed during commercial hardwood thinnings, we retained inferior poletimber trees in two of the four thinned treatments in order to compare responses between superior and inferior poletimber trees, particularly within treatments of similar overstory removal.

Prior to treatment, species, d.b.h., tree class, and crown class were recorded for every tree greater than or equal to 5.5 inches d.b.h. on 0.6 acre interior measurement plots of 3 by 2 chains. Sawtimber tree classes were assigned to trees greater than or equal to 12.5 inches d.b.h., and poletimber tree classes were assigned to trees between 5.5 and 12.4 inches d.b.h. Immediately after thinning, we recorded the number of epicormic branches on the 16-foot butt log of the residual poletimber trees. Individual epicormic branches were tallied according to their location by height (at half-foot intervals) and cardinal direction on the butt log section so that new epicormic branches could be detected in subsequent years. Individual epicormics were also classified as either non-defect (less than 3/8 inches basal diameter) or defect causing branches (greater than 3/8 inches basal diameter) (Rast and others 1973). In cases where the number of epicormic branches on the 16-foot butt log exceeded 30, only a count was taken. Diameter growth and epicormic branching were assessed annually during the two years following treatment. First year results were reported in Skojac and others (2007).

RESULTS AND DISCUSSION

Residual Stand Conditions

The intensity of removals within each of the four thinning treatments was defined by initial stand quality, expressed by the tree class distribution in the pre-thinned stand. Treatments were not intended to reduce stand density to predetermined post-harvest levels. Post-harvest stand conditions are summarized in table 2. By design, Desirable treatments were thinned more heavily than Acceptable treatments. Within both levels of sawtimber retention (i.e., Desirable and Acceptable), reduction in stand density was greater in those treatments retaining superior poletimber than in corresponding treatments retaining inferior poletimber. Therefore, thinning was heaviest in the DesSupP treatment and lightest in the AccInfP treatment. All four levels of thinning significantly reduced residual stand density relative to the unthinned control (table 2).

Residual Poletimber Characteristics

Prior to thinning, the stand contained many weak, poorly formed, or otherwise defective poletimber trees that we classified as inferior poletimber. A smaller number of poletimber trees met our criteria for the superior class. Therefore, following thinning, inferior poletimber trees were 3 to 4 times more numerous than superior poletimber trees in corresponding thinning treatments (table 3). Within the

Table 1—List of five thinning treatments, including tree classes to be retained

Tree class	Treatments: Control	DesSupP[a]	DesInfP	AccSupP	AccInfP
Preferred	X[b]	X	X	X	X
Desirable	X	X	X	X	X
Acceptable	X			X	X
Cut	X				
Cull	X				
Superior poletimber	X	X		X	
Inferior poletimber	X		X		X

[a]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

[b]X indicates tree classes to be retained following application of thinning treatment.

thinned treatments, superior poletimber trees were nearly equally distributed between the red oaks and sweetgum, whereas sweetgum accounted for over 65 percent of residual inferior poletimber trees. Residual superior poletimber trees in this stand were approaching minimum sawtimber size (12.5 inches d.b.h.) and were no more than 2.6 inches below sawtimber d.b.h. at the post-harvest evaluation (table 3). In contrast, residual inferior poletimber trees were nearly 2.0 inches smaller in diameter than their superior poletimber counterparts, and averaged over 4.0 inches below minimum sawtimber d.b.h. Residual superior poletimber trees also averaged fewer than 4 epicormic branches on the butt log, a level acceptable for grade sawtimber production (table 3). In contrast, residual inferior poletimber trees in corresponding thinning treatments averaged two to three times more epicormic branches than their superior poletimber counterparts, but these differences were not statistically significant.

Table 2—Residual stand conditions immediately following application of treatments

Treatment	Trees Per Acre	Basal Area	Quadratic Mean DBH	Stocking
	number	*feet²/acre*	*inches*	*percent*
Control	113 a[a]	117 a	13.8 b	98 a
DesSupP[b]	34 d	42 d	15.0 b	35 d
DesInfP	64 c	59 c	13.1 b	50 c
AccSupP	38 d	65 c	17.7 a	52 c
AccInfP	87 b	80 b	13.1 b	67 b

[a]Means followed by the same letter within a column are not significantly different at the 0.05 level of probability using Duncan's New Multiple Range Test.

[b]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

Diameter Growth

Cumulative diameter growth of superior poletimber trees varied significantly following the two levels of thinning (table 4). During the 2 years following thinning, superior poletimber trees in the Desirable treatment (DesSupP) grew 58 percent more in diameter than superior poletimber trees in the Acceptable treatment (AccSupP). Both levels of thinning, however, yielded significant increases in cumulative diameter growth of the superior poletimber trees compared to the diameter growth of poletimber trees in the unthinned control. Thus far, only the superior poletimber trees in the DesSupP treatment have grown significantly more than their inferior poletimber counterparts in corresponding thinning treatments. Cumulative diameter growth of superior poletimber trees in the DesSupP treatment averaged 2 to 2.3 times the average cumulative diameter growth of inferior poletimber trees in either treatment during the first 2 years. Cumulative diameter growth of inferior poletimber trees 2 years following treatment has been uniformly low following both levels of thinning (DesInfP and AccInfP), and did not differ significantly from growth of poletimber trees in the unthinned control.

Within the superior poletimber class, average cumulative diameter growth during the first 2 years following thinning has been greatest among the red oaks (table 4). Slightly less growth was observed among superior sweetgum poletimber trees. Within the inferior poletimber class, average cumulative diameter growth of the red oaks and sweetgum

Table 3—Post-harvest attributes of residual poletimber trees, by treatment

Treatment	Trees per acre	Diameter	Epicormics
	number	*inches*	*number*
Control	68.9	8.4 b[a]	8.6 a
DesSupP[b]	10.6	9.9 a	3.0 a
DesInfP	35.6	8.1 b	7.3 a
AccSupP	10.6	10.3 a	3.6 a
AccInfP	45.9	8.4 b	10.6 a

[a]Means followed by the same letter within a column are not significantly different at the 0.05 level of probability using Duncan's New Multiple Range Test.

[b]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

was similar 2 years following both the Desirable and Acceptable treatments. Because we observed wide variation in cumulative diameter growth response within individual species groups, differences within species groups were not significant across the five levels of thinning after the second year (table 4).

Though preliminary, it appears that we have been successful in identifying poletimber trees capable of rapid diameter growth response following thinning. Thinning increased diameter growth of superior poletimber trees by 138 to 277 percent compared to growth of poletimber trees in the unthinned control. Thinning did not significantly improve the growth of inferior poletimber trees in the 2 years following treatment. The largest increases in diameter have been observed among the superior red oak poletimber trees (0.48 and 0.40 inches in the DesSupP and AccSupP treatments, respectively). If these growth rates can be maintained, it is conceivable that the superior red oak poletimber trees will yield small sawlogs within a decade after thinning in this sawtimber stand. A slightly longer period of time may be required for superior sweetgum poletimber trees to yield sawtimber products.

Table 4—Average 2-year cumulative diameter growth of all residual poletimber trees, residual red oak poletimber trees, and residual sweetgum poletimber trees, by treatment

	2-Year Cumulative Diameter Growth		
Treatment	All Trees	Red oaks	Sweetgum
	---------------------*inches*---------------------		
Control	0.13 c[a]	0.19 a	0.14 a
DesSupP[b]	0.49 a	0.48 a	0.41 a
DesInfP	0.25 bc	0.36 a	0.31 a
AccSupP	0.31 b	0.40 a	0.28 a
AccInfP	0.21 bc	0.23 a	0.27 a

[a]Means followed by the same letter within a column are not significantly different at the 0.05 level of probability using Duncan's New Multiple Range Test.

[b]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

Epicormic Branching

The production of new epicormic branches on the 16 foot butt log of superior poletimber trees in the DesSupP treatment increased during the second year, exceeding the rate observed during the first year by nearly two branches (table 5). Production of new epicormic branches remained consistent from year 1 to year 2 across the other treatments, and was roughly 1/3 the rate observed in the DesSupP treatment during the second year. As a result, the cumulative number of new epicormic branches (i.e., new branches in year 1 and year 2 less mortality of new branches from year 1) produced by superior poletimber trees in the DesSupP treatment was significantly greater than the cumulative number of new epicormic branches produced by poletimber trees in the other four treatments (table 5). Two years following treatment, superior poletimber trees in the DesSupP treatment averaged four times as many new epicormic branches as poletimber trees in the unthinned control, and two to nearly four times as many new epicormic branches as inferior poletimber trees in either treatment. It is important to note that superior poletimber trees in the AccSupP treatment averaged 57 percent fewer new epicormic branches than superior poletimber trees in the DesSupP treatment at the end of the second year.

The total number of epicormic branches increased four-fold on superior poletimber trees in the DesSupP treatment during the 2 years following thinning (table 6). In contrast, superior poletimber trees in the AccSupP treatment averaged a net increase of less than three total epicormic branches (less than a two-fold increase) during the same time period. Inferior poletimber trees experienced a moderate net increase in total epicormic branches during the first 2 years, but still contain too many branches for high quality sawtimber production. Poletimber trees in the unthinned control averaged a slight net decrease in total epicormic branches during the 2-year period.

Red oak poletimber trees have been most affected by the production of epicormic branches during the 2 years since thinning. For example, 86 percent, or approximately 11 of the nearly 13 epicormic branches on superior red oak poletimber trees in the DesSupP treatment were large enough to cause defects on a small sawlog (fig. 1). Large, defect-causing epicormic branches on inferior red oak poletimber trees were also prominent, averaging nearly 13 and over 7.5 branches in the DesInfP and AccInfP treatments, respectively. It should be noted that superior red oak poletimber trees in the AccSupP treatment averaged less than five defect-causing epicormic branches 2 years following thinning. In general,

Table 5—Average number of new epicormic branches produced during Year 1 and Year 2, and the cumulative number of new epicormic branches produced by residual poletimber trees, by treatment

	New Epicormic Branches		
Treatment	Year 1	Year 2	Net-Cumulative
	--------------------*number*--------------------		
Control	1.2 c[a]	1.5 b	2.5 b
DesSupP[b]	4.3 a	6.0 a	10.1 a
DesInfP	3.1 ab	2.4 b	5.0 b
AccSupP	2.2 bc	2.2 b	4.3 b
AccInfP	1.4 c	1.5 b	2.8 b

[a]Means followed by the same letter within a column are not significantly different at the 0.05 level of probability using Duncan's New Multiple Range Test.

[b]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

sweetgum poletimber trees have been less susceptible to epicormic branching during the 2 years following thinning (fig. 1). Epicormic branches on sweetgum poletimber trees were also smaller than those on the red oaks. In fact, sweetgum poletimber trees averaged no more than four defect-causing epicormic branches across the five levels of thinning after the second year.

Table 6—Average total number of epicormic branches, immediately post-harvest and at Year 2, on residual poletimber trees, by treatment

	Total Epicormic Branches	
Treatment	Post-harvest	Year 2
	----------------- *number* -------------------	
Control	8.9 a[a]	8.6 a
DesSupP[b]	3.1 a	12.2 a
DesInfP	6.7 a	10.1 a
AccSupP	3.7 a	6.5 a
AccInfP	10.4 a	12.1 a

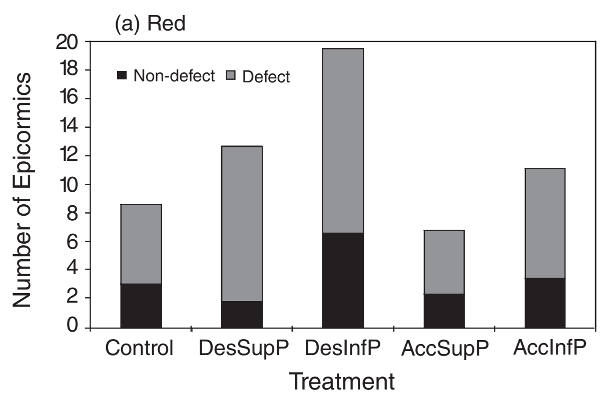
[a]Means followed by the same letter within a column are not significantly different at the 0.05 level of probability using Duncan's New Multiple Range Test.

[b]DesSupP = Desirable Growing Stock with Superior Poletimber Stock, DesInfP = Desirable Growing Stock with Inferior Poletimber Stock, AccSupP = Acceptable Growing Stock with Superior Poletimber Stock, and AccInfP = Acceptable Growing Stock with Inferior Poletimber.

It is clear that thinning adversely affected the bole quality of superior poletimber trees in the DesSupP treatment, particularly superior red oak poletimber trees (see fig. 1). The DesSupP treatment was the most severe of the thinning treatments applied, removing nearly 2/3 of the preharvest basal area. These severely reduced residual conditions spawned significantly higher levels of epicormic branching on the superior poletimber trees in this treatment. Net cumulative production of new epicormic branches within the DesSupP treatment was over twice that observed by superior poletimber trees in the AccSupP treatment over the 2 year period studied. Nearly 90 percent of the epicormic branches on superior red oak poletimber trees in the DesSupP would cause defects on a small log. The more moderately thinned AccSupP treatment appeared to minimize the production of epicormic branches on the potentially more valuable superior red oak poletimber trees. Defect-causing epicormic branches on superior red oak poletimber trees in this treatment were below levels believed capable of causing a reduction in log grade on red oak sawtimber trees (Meadows and Burkhardt 2001). Though preliminary, retention of the acceptable growing stock sawtimber class, as specified by the marking rules for the AccSupP treatment, seemed to create residual stand conditions more favorable for protecting the boles of the superior poletimber trees.

CONCLUSIONS

Thinning increased the likelihood that the poletimber trees we initially classified as superior will yield quality sawlogs in



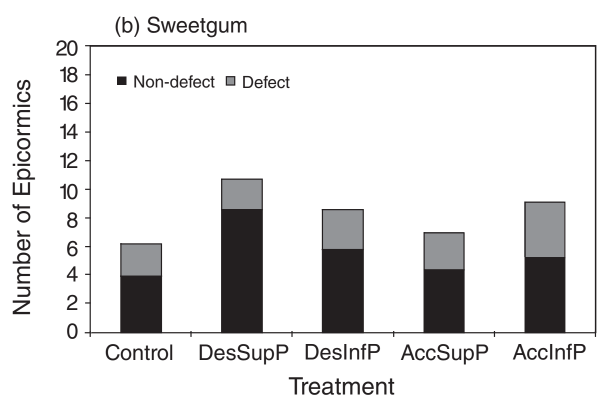


Figure 1—Average number of non-defect and defect causing epicormic branches on residual (a) red oak and (b) sweetgum poletimber trees 2 years following thinning, by treatment.

the thinned sawtimber stand. Quality sawtimber production from their inferior poletimber counterparts seems unlikely. The DesSupP treatment yielded the greatest diameter growth response of the superior poletimber trees, but also adversely affected the bole quality of these potentially more valuable stems. The AccSupP treatment yielded significant diameter growth by superior poletimber trees as well, and reduced epicormic branching by nearly 60 percent of that observed in the DesSupP treatment during the 2-year period. Superior red oak poletimber trees in the AccSupP treatment grew at a rate equivalent to 2 inches per decade while averaging fewer than five defect-causing epicormic branches after the first 2 years. Based on these preliminary results, it appears that the AccSupP treatment may provide the best combination of diameter growth and maintenance of bole quality for growing quality sawlogs from residual superior poletimber trees in thinned sawtimber stands, particularly from the potentially more valuable red oaks.

ACKNOWLEDGMENTS

This research was initiated while Skojac was a graduate student at Mississippi State University. The authors wish to thank the U.S. Air Force and Barksdale Air Force Base for providing the study site and Matthew Stroupe, forester, for his help during the initial installation of this study. We also thank the technicians at the Southern Hardwoods Laboratory for their continued help in the field.

LITERATURE CITED

Baker, J.B.; Broadfoot, W.M. 1979. A practical field method of site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO-26. U.S. Forest Service, Southern Forest Experiment Station, New Orleans, LA: 51 p.

Goelz, J.C.G. 1995. A stocking guide for southern bottomland hardwoods. Southern Journal of Applied Forestry. 19: 103-104.

Johnson, J.W. 1950. Release speeds growth of bottomland hardwoods. Southern Lumberman. 181: 41-42.

Johnson, R.L. 1968. Thinning improves growth in stagnated sweetgum stands. Res. Note SO-82. U.S. Forest Service, Southern Forest Experiment Station, New Orleans, LA: 5 p.

Meadows, J.S. 1988. Response of suppressed cherrybark oak and green ash trees to release from overstory competition. Ph.D. dissertation, Mississippi State University, Mississippi State, MS: 191 p.

Meadows, J.S. 1995. Epicormic branches and lumber grade of bottomland oak. In: Lowery, G.; Meyer, D. (eds.) Advances in hardwood utilization: following profitability from the woods through rough dimension: Proceedings of the twenty-third annual hardwood symposium. National Hardwood Lumber Association, Memphis, TN: 19-25.

Meadows, J.S.; Burkhardt, E.C. 2001. Epicormic branches affect lumber grade and value in willow oak. Southern Journal of Applied Forestry. 25: 136-141.

Meadows, J.S.; Skojac, Jr., D.A. 2008. A new tree classification system for southern hardwoods. Southern Journal of Applied Forestry. 32(2): 69-79.

Putnam, J.A.; Furnival G.M.; McKnight, J.S. 1960. Management and inventory of southern hardwoods. Agriculture Handbook No. 181. U.S. Forest Service Washington, DC: 102 p.

Rast, E.D.; Sonderman, D.L.; Gammon, G.L. 1973. A guide to hardwood log grading. Rev. Gen. Tech. Rep. NE-1. U.S. Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA: 31 p.

Skojac, Jr., D.A.; Ezell, A.W.; Meadows, J.S. [and others]. 2007. First year growth and quality response of residual hardwood poletimber trees following thinning in an even-aged sawtimber stand. Res. Note SRS-13. U.S. Forest Service, Southern Research Station, Asheville, NC: 6 p.

United States Department of Agriculture, Natural Resources Conservation Service, Soil Survey Division. Official soil series descriptions. http://ortho.ftw.nrcs.usda.gov/osd/. [Date Accessed: October 15, 2003].

United States Department of Agriculture, Soil Conservation Service. 1962. Soil survey of Bossier Parish, Louisiana. U.S. Government Printing Office, Washington, DC: 144 p.