Epicormic Branches Affect Lumber Grade and Value in Willow Oak

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ABSTRACT: *A case study was conducted in a 50-yr-old bottomland oak stand in central Alabama to investigate the relationship between epicormic branches and lumber grade and value in willow oak (*Quercus phellos *L.). The stand had been thinned from below 7–10 yr earlier, resulting in a wide variety of epicormic branch conditions on the residual trees. A sample of 41 willow oak trees was selected before the stand was clearcut in late 1991. All merchantable logs in each tree were graded prior to felling. Average dbh of sampled trees was 19.1 in. Each tree averaged 9.5 epicormic branches on the sawlog portion of the bole. From these 41 trees, a random sample of 57 logs (31 butt logs and 26 upper logs) was shipped to a sawmill where they were sawn into lumber and graded. Epicormic branching had a large detrimental effect on log grade of individual trees. In general, as few as five epicormic branches somewhat evenly distributed on a 16 ft log was enough to cause a reduction in log grade. More importantly, defects caused by epicormic branches had a serious effect on lumber grade, particularly in the higher grades. Over 50% of the lumber volume that would have been graded as either First and Seconds or Select in the absence of epicormic branches was downgraded to No. 1 Common or below due to defects caused by epicormic branches. Based on lumber prices prevailing at the time of the study, defects caused by epicormic branches resulted in a 13% reduction in the value of the lumber produced in the final harvest. South. J. Appl. For. 25(3):136–141.*

Key Words: Epicormic branches, log grade, lumber grade, lumber value, willow oak, *Quercus phellos*, thinning.

Profitable management of southern bottomland hardwood stands for sawtimber production depends on successful development and maintenance of high-quality logs. Bole quality, i.e., log grade, is a major determinant of the value of hardwood sawtimber. The value of a log decreases rapidly in the progression from Grade 1 to Grade 3. Any silvicultural practice or other phenomenon that results in log grade reduction significantly reduces the value of the stand. Thinning hardwood stands sometimes stimulates development of epicormic branches from dormant buds located on the main bole. These adventitious twigs are frequent contributors to log grade reduction. Consequently, epicormic branching is a serious problem in the management of southern bottomland hardwood stands for high-quality sawtimber production.

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According to USDA Forest Service standard grading rules for hardwood factory logs (Rast et al. 1973), epicormic branches greater than 3/8 in. diameter at the bark surface are defects on logs of all sizes, grades, and species. For hard hardwoods, such as oaks, smaller branches (3/8 in. diameter or less) are defects in all logs less than 14 in. scaling diameter, but only every other one is counted as a defect in logs larger than 14 in. scaling diameter (Rast et al. 1973). Consequently, the grade and subsequent value of the log may be significantly reduced due to the presence of sufficient epicormic branches. For example, Stubbs (1986) found that epicormic branching following a seed-tree cut in South Carolina was prolific enough to cause a grade loss in 44% of the cherrybark oak (*Quercus falcata* var. *pagodifolia* Ell.) butt logs. In a survey of epicormic branches on upper logs in bottomland oak stands in northeastern Louisiana, Hedlund (1964) reported that the presence of epicormic branches caused a log grade reduction in nearly 40% of the logs, with a two-grade reduction in 23% of the logs.

Furthermore, the grade and subsequent value of the lumber produced from a log with several epicormic branches may also be drastically reduced. Because hardwood lumber grade is determined by the spacing rather than the size of knots, defects caused by epicormic branches can greatly affect the length and number of clear cuttings obtained from the lumber. Hardwood lumber grades are delineated on the basis of the minimum yield of defect-free material contained in each board. High-grade boards, such as those classified as First and Seconds (FAS) or Select (SEL), will yield high percentages of clear cuttings in relatively large sizes. Low-grade boards, such as those classified as No. 2 Common or No. 3 Common, will yield small percentages of clear cuttings in relatively small sizes (Rast et al. 1973). The value of high-grade lumber is approximately 2 to 3 times greater than the value of low-grade lumber. No. 1 Common is an intermediate lumber grade of moderate value. Unfortunately, there are no published reports that assess the reduction in lumber value as a consequence of epicormic branching. Therefore, this case study was initiated to investigate this relationship and to determine the effects of epicormic branches on lumber grade and value in a willow oak (*Q. phellos* L.) stand.

Methods

The study was conducted on a privately owned, 60 ac bottomland tract of mixed red oaks along the Alabama River near Selma, Alabama. The 50-yr-old, even-aged stand was predominantly willow oak, but also contained scattered Nuttall oak (*Q. nuttallii* Palmer), water oak (*Q. nigra* L.), laurel oak (*Q. laurifolia* Michx.), and swamp chestnut oak (*Q. michauxii* Nutt.). Stand age was determined after final harvest by counting rings on stumps of approximately 25 trees scattered across the tract. To provide income to the landowner, the stand had been thinned from below about 7–10 yr earlier, but the owner was unsure of the date of thinning and had no information on pre-existing stand conditions. Most of the material removed in the thinning was marketed as pulpwood. Through destructive sampling, we verified that many of the epicormic branches existing along the boles of residual trees originated about the time of this thinning. It is likely that most of these epicormic branches developed as a result of the thinning operation. Epicormic branches were numerous on willow oak, which McKnight (1958) described as being particularly susceptible to epicormic branching.

To investigate the relationship between epicormic branches and lumber grade and value, 41 willow oak trees were selected from across the study site prior to final harvest in late 1991. Sample trees were selected to represent a range of tree size, tree vigor, and degree of epicormic branching. Observations on crown size, shape, and density were used to assess tree vigor. Each tree was numbered, and its dbh was recorded.

The merchantable bole of each standing tree was graded according to USDA Forest Service standard hardwood log grading rules (Rast et al. 1973). After felling, trees were skidded tree-length to a landing and bucked into sawlogs of various lengths (10, 12, 14, or 16 ft) to maximize the grade and value of each log. A total of 94 logs were cut from the 41 sample trees for an average of 2.3 logs per tree. After bucking, each log was labeled with the corresponding number of the tree and was designated as a butt log, second log, or third log (second and third logs were later grouped as upper logs). Actual log length, scaling diameter, and the number of epicormic branches on each log were recorded at the landing. Only those epicormic branches large enough to be considered defects according to standard log grading rules (Rast et al. 1973) were counted. Those smaller than the minimum size were ignored. Multiple epicormic branches arising in a clump or cluster from a single location on the log were counted as one branch. However, two branches arising from two adjacent, but distinct, locations on the log were counted as two branches. The actual grade of each log (with existing epicormic branches counted as defects, where applicable) was verified at the landing. Each log was then graded a second time, ignoring all existing epicormic branches. The log grade obtained from this second grading is referred to as the "potential" grade of the log. In other words, "potential" log grade refers to the grade that would have been obtained in the absence of epicormic branches, whereas "actual" log grade refers to the grade obtained in the presence of applicable epicormic branches. All other defects, such as bark distortions, bumps, knots, wounds, and scars, were counted as defects when assigning both actual and potential log grades. A random sample of 57 logs (31 butt logs and 26 upper logs) was then hauled to a sawmill in Aliceville, Alabama, and sawn into lumber.

Lumber cut from each log was graded and tallied for actual board-foot volume by lumber graders at the sawmill. However, the graders combined First and Seconds (FAS) and Select (SEL) into one grade class and combined No. 2 Common and No. 3 Common into one grade class. Consequently, all references to the volume of FAS lumber in this article also include SEL lumber volume, and all references to the volume of No. 2 Common lumber also include No. 3 Common lumber volume. Individual boards cut from each log were marked as they were processed through the sawmill so that the volume and grade of the boards could be matched with the corresponding log number. "Actual" lumber grade of each board was the grade assigned by the lumber graders, taking into account all defects, including those caused by epicormic branches (Figure 1).

Ideally, to determine the grade of each board in the absence of epicormic branch defects, the lumber graders would have graded each board a second time and ignored those defects caused by epicormic branches. Unfortunately, the graders were unable to perform this second

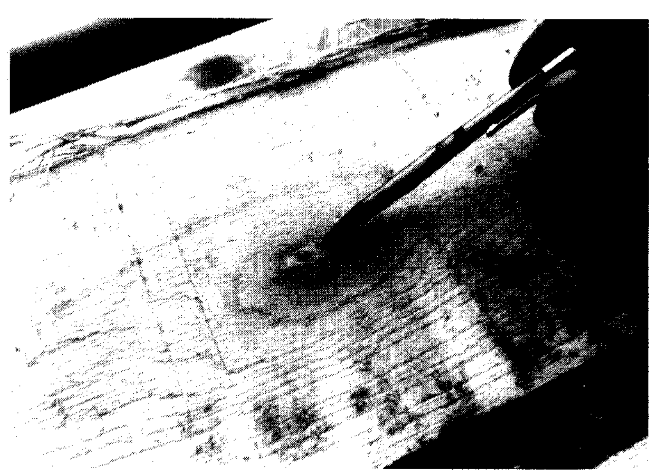

Figure 1. Epicormic branch defect in a willow oak board.

grading due to time and safety considerations in the sawmill. As a substitute for this second grading of the lumber, we used tables developed by the USDA Forest Service for bottomland red oak (Hanks et al. 1980) to estimate percentage lumber grade yields for each log. The scaling diameter and the potential grade of each log (defined above as the log grade that would have been obtained in the absence of epicormic branches) were used as independent variables in these tables to predict the percentage yield, by lumber grade, of the total lumber volume cut from the log. Percentage yield values from the tables for FAS and SEL were combined into one grade class referred to as FAS. Similarly, values for No. 2 Common and No. 3 Common were combined into one grade class referred to as No. 2 Common. Estimated percentage lumber grade yields derived from these tables for each log are referred to as "potential" lumber grades and are indicative of the lumber grades that would have been expected if epicormic branch defects were not present.

To illustrate the use of the Hanks et al. (1980) tables for bottomland red oak, the lumber volume cut from a Grade 1 log with a scaling diameter of 14 in. would be expected to consist of 36% FAS, 27% No. 1 Common, and 37% No. 2 Common and below. The lumber cut from a Grade 2 log with the same scaling diameter would be expected to consist of 12% FAS, 28% No. 1 Common, and 60% No. 2 Common and below. The lumber cut from a Grade 3 log of the same size would be expected to consist of 2% FAS, 13% No. 1 Common, and 85% No. 2 Common and below.

Actual and potential lumber volumes were then summed by lumber grade for the 57 sample logs to develop actual and potential lumber grade distributions. As defined previously, "actual" lumber grade refers to the grade assigned by the lumber graders in the presence of epicormic branch defects. In contrast, "potential" lumber grade is a predicted grade derived from the Hanks et al. (1980) tables, using the scaling diameter and the potential grade of the log. Potential lumber grade is thus indicative of the grade that would have been assigned in the absence of epicormic branch defects.

A simple economic analysis was performed on the lumber grade distributions to determine the reduction in lumber value as a result of the defects caused by the presence of epicormic branches. Lumber prices prevailing at the time of the study for 4/4 in. red oak lumber in the South (Southern Lumberman 1992) were used for this economic analysis. Actual and potential lumber values were determined (1) per mbf, (2) per acre, based on an average sawtimber volume of 5,000 bd ft (Doyle)/ac (R.M. Loughridge, Buchanan Timber Co., Selma, AL, pers. comm., Sept. 1991), and (3) for the entire 60 ac tract.

The research reported here was a case study designed to investigate the relationship between epicormic branches and lumber grade and value in a willow oak stand. Stand-level variance was not estimated because no subplots were established. Consequently, statistical analyses and tests of significance were not performed. Only descriptive statistics were used to present the data.

Table 1. Average scaling diameter, log length, and number of epicormic branches per log, by actual log grade, of 41 willow oak trees in a 50-yr-old bottomland stand in central Alabama.

Log grade	Scaling diameter (in.)	Log length (ft)	Number of epicormics
1	15.4	15.4	0.5 (0–1)*
2	14.8	14.3	5.1 (0–9)
3	12.2	13.6	7.1 (0–24)
All logs	13.5	14.1	5.4 (0–24)

* Range of data

Results And Discussion

The dbh of sample trees ranged from 14.7 to 23.5 in. and averaged 19.1 in. Average merchantable height for sawtimber was 33 ft. Sample trees averaged 9.5 epicormic branches on this merchantable sawlog portion of the bole. All trees in the study had either dominant or codominant crowns.

Log Grade

Grade 1 and 2 logs were larger in both diameter and length and had fewer epicormic branches than Grade 3 logs (Table 1). As expected, the number of epicormic branches on each log increased as log grade and quality decreased. In fact, as few as five epicormic branches somewhat evenly distributed on a 16 ft log was enough to cause a grade reduction.

Of the 31 butt logs sampled in this study, 68% were potentially Grade 1, and only 3% were Grade 3 (Table 2). However, when existing epicormic branches were counted as defects, only 35% of the butt logs were actually Grade 1, whereas 30% were Grade 3. In hardwood factory-lumber logs, the butt log is typically the most valuable log in the tree because it yields higher grades of lumber than upper logs. Consequently, this large reduction in the percentage of high-value Grade 1 logs and accompanying increase in the proportion of low-value Grade 3 logs, as a result of epicormic branches, had a substantial effect on the value of the standing timber.

Potentially, well over half (58%) of the upper logs in this study would have been Grade 2 logs in the absence of epicormic branches (Table 2). However, with epicormic branches counted as defects, nearly all (88%) of the upper logs were Grade 3. None of the upper logs were potentially Grade 1, primarily because most did not meet minimum

Table 2. Actual and potential log grade distributions for butt logs, upper logs, and all logs combined for 41 willow oak trees in a 50-yr-old bottomland stand in central Alabama.

Log position	Log grade	Log grade distribution Actual	Potential
		(%)	
Butt	1	35	68
	2	35	29
	3	30	3
Upper	1	0	0
	2	12	58
	3	88	42
All logs	1	19	37
	2	25	42
	3	56	21

size requirements. This reduction in grade of the upper logs as a consequence of epicormic branches reduced the value of the standing timber, but not nearly to the extent observed through reduction of grade in the butt logs.

When all sample logs were considered, nearly 80% were potentially Grade 1 or 2, whereas less than half (44%) of all logs actually graded out at one of these higher value grades (Table 2). A stand with this potential log grade distribution (in the absence of epicormic branches) contains a significant proportion of high-value logs. It would be attractive to timber buyers and would command a competitive price in the market. Interest among buyers and the number of probable bidders would be high, which would likely increase the stumpage price paid to the landowner. On the other hand, a stand with the actual log grade distribution observed in our study contains a significant proportion of low-value logs and would not attract top-dollar bids from timber buyers. The presence of numerous epicormic branches on the boles of standing trees reduces the stumpage value of the timber and results in a significant loss of potential revenue to the landowner.

Epicormic branching was severe enough to cause a one-grade reduction in 45% of the butt logs and 46% of the upper logs. Moreover, 7% of the butt logs had sufficient epicormic branches to be downgraded two log grades, from Grade 1 to Grade 3. These results are very similar to those reported in other bottomland oak stands in the South (Hedlund 1964, Stubbs 1986). Because log grade has a major influence on the value of hardwood sawtimber, log grade reduction caused by epicormic branches, particularly on butt logs, greatly reduces the value of the stand.

Epicormic branches develop along the boles of hardwood trees in response to a variety of stimuli, one of which is sudden exposure to direct sunlight following a partial cut, such as occurred in this study. However, Brown and Kormanik (1970) maintained that sudden exposure to sunlight serves only as a triggering mechanism to release those dormant buds that develop into epicormic branches rather than as the direct cause of the phenomenon. Several researchers have noted that tree vigor also plays a major role in determining the propensity of an individual tree to produce epicormic branches following partial cutting (Wahlenberg 1950, Skilling 1957, McKnight 1958, Erdmann et al. 1985). Meadows (1993) speculated that tree vigor is the primary controlling mechanism for the production of epicormic branches, while sudden exposure to sunlight, or some other disturbance, is the primary triggering mechanism that begins the process of epicormic branching. In fact, several researchers have recommended that, to minimize the production of epicormic branches on residual trees, partial cuts should retain trees with large, healthy, fully developed crowns (McKnight 1958, Meadows and Stanturf 1997). Observations in our case study support this concept that epicormic branches are less prevalent on high-vigor, upper-crown-class trees than on low-vigor, lower-crown-class trees of the same species (Table 3). The number of epicormic branches per log generally increased as tree vigor decreased.

Table 3. Effects of vigor class on average log grade and number of epicormic branches per log, for butt logs and upper logs, of 41 willow oak trees in a 50-yr-old bottomland stand in central Alabama.

Vigor class	Number of trees/class	Average log grade		Number of epicormics	
		Butt	Upper	Butt	Upper
High	12	2.1	2.8	4.3	4.4
Medium	14	2.2	2.9	5.8	7.0
Low	15	2.4	3.0	7.9	8.7

Lumber Grade

The Hanks et al. (1980) tables were very accurate in predicting the actual lumber grade yields for sample logs that had no epicormic branches. The actual lumber grade distribution for the seven sample logs with no epicormic branches consisted of 33% FAS, 32% No. 1 Common, and 35% No. 2 Common and below, whereas the potential lumber grade distribution for these same seven logs, as predicted from the Hanks et al. (1980) tables, consisted of 34% FAS, 29% No. 1 Common, and 37% No. 2 Common and below. Consequently, it is reasonable to conclude that potential lumber grade distribution is indicative of the lumber grade distribution that would have resulted in the absence of epicormic branch defects.

The following example from the data is provided to illustrate the use of the Hanks et al. (1980) tables to produce the potential lumber grade distribution for a sample log. The butt log of Tree No. 28 was 16 ft long, had a scaling diameter of 16 in., contained seven epicormic branches, and was assigned an actual log grade of Grade 2 in the presence of epicormic branches. However, when epicormic branches on the log were ignored, the log's potential grade was Grade 1. When the log was cut into lumber, 14 boards were produced for a total volume of 140 bd ft. The actual lumber grade yield from this log, as assigned by the lumber graders in the presence of epicormic branch defects, consisted of 16 bd ft FAS (11%), 50 bd ft No. 1 Common (36%), and 74 bd ft No. 2 Common and below (53%). In contrast, the potential lumber grade yield from this log, as estimated from the Hanks et al. (1980) tables for a Grade 1 log, consisted of 40 bd ft FAS (29%), 44 bd ft No. 1 Common (31%), and 56 bd ft No. 2 Common and below (40%).

Defects caused by epicormic branches (Figure 1) had a serious effect on lumber grade, particularly in the higher grades. As estimated from the Hanks et al. (1980) tables, 72% of the lumber volume would have been graded at No. 1 Common or better in the absence of epicormic branch defects, but when those defects were considered in the grading process, only 54% of the lumber actually received these higher grades (Table 4). More importantly, over 50% of the volume that would have been graded as FAS in the absence of epicormic branches was downgraded to No. 1 Common or below due to the defects caused by epicormic branches. Because FAS lumber is much more valuable than lower grade lumber, this 50% reduction in the volume of FAS had a very detrimental effect on the subsequent value of that lumber.

Table 4. Actual and potential lumber values, based on actual and potential lumber grade distributions and prevailing prices for 4/4 in. red oak lumber in the South (Southern Lumberman 1992), of 41 willow oak trees in a 50-yr-old bottomland stand in central Alabama.

Lumber grade*	Price ($/MBF)	Lumber grade distribution Actual	Potential	Lumber value Actual	Potential
		(%)		($/MBF)	
FAS	810	9	19	69	157
#1C	540	45	53	244	286
#2C	320	46	28	148	88
Total	—	—	—	461	531

* FAS—First and Seconds (also includes Select); #1C—No. 1 Common; #2C—No. 2 Common (also includes No. 3 Common).

Lumber Value

To determine the reduction in lumber value as a result of the defects caused by epicormic branches, we performed a simple economic analysis on the actual and potential lumber grade distributions developed previously. Willow oak lumber produced in this study, in the absence of epicormic branch defects, was potentially valued at $531/mbf (Table 4). However, the actual value of the lumber was only $461/mbf. This reduction in value was caused by the presence of epicormic branch defects. These differences in lumber grade distributions magnified the large price discrepancies associated with the various lumber grades. For example, the value of FAS red oak lumber, at the time of this study, was approximately 2.5 times greater than the value of No. 2 Common lumber. This difference in price, coupled with differences in grade distributions, led to a large disparity between actual and potential value of the willow oak lumber produced in this study.

To carry this analysis one step further, we took the current stand's average sawtimber volume of 5,000 bd ft (Doyle)/ac and made the appropriate calculations to determine the actual and potential lumber values per acre and for the entire 60 ac tract (Table 5). Based on these calculations, defects caused by epicormic branches resulted in a loss of $70/mbf of lumber, a loss of $354/ac, and a total loss of approximately $21,000 for the entire tract. Epicormic branching on the boles of these willow oak trees led to a 13% reduction in the value of the lumber produced from this stand.

Because potential lumber grades were estimated from the Hanks et al. (1980) tables rather than measured directly, there is a possibility that some portion of this loss in lumber value may be due to some unusual defects in the sample logs, other than epicormic branches, that make them atypical of the logs used to produce the tables. However, as demonstrated in the previous section, the actual and potential lumber grade yields for logs of the same size and grade were very similar. Consequently, it can be assumed that the sample logs used in this study were typical of the ones used to derive the Hanks et al. (1980) tables. Under this assumption, it is reasonable to conclude that epicormic branch defects caused the 13% reduction in lumber value observed in this case study.

Table 5. Reduction in lumber value as a consequence of defects caused by epicormic branches on 41 willow oak trees in a 50-yr-old bottomland stand in central Alabama.

	Per mbf	Per acre*	Per tract†
		[Value ($)]	
Potential	531	2,658	159,498
Actual	461	2,304	138,261
Loss	70	354	21,237

* Based on an average sawtimber volume of 5,000 bd ft (Doyle)/ac.
† Based on the 60 ac tract in central Alabama used in this case study.

Because we are unaware of any other published reports that calculated actual dollar losses in lumber value from epicormic branching, it is difficult to assess the accuracy of the results obtained in this case study. However, the 13% reduction may be a conservative estimate of the loss in lumber value associated with epicormic branching in willow oak. The presence of epicormic branches on the logs would likely increase both logging costs and milling costs, such that the value of lumber produced from these logs would be even further reduced. On the other hand, the earlier thinning that led to the development of most of these epicormic branches also undoubtedly promoted increased diameter and volume growth of the residual trees. The degree to which these positive effects of the thinning operation offset the negative effects of epicormic branching could not be determined.

Other studies may yield estimates of loss that are higher or lower than ours, but it is important to note that the magnitude of the loss is significant to those whose forest management objectives include economic benefit. In general, the degree of economic loss from epicormic branching depends on the age and size of the epicormic branch. Defects caused by older epicormic branches run deep into the log and degrade a relatively high proportion of the volume of lumber cut from that log. The degree of economic loss is also affected by the diameter of the log. Epicormic branches are a larger problem on small-diameter logs because they degrade a greater proportion of log volume.

Conclusions

High-vigor trees tended to have fewer epicormic branches than low-vigor trees. Trees with large, dense, well-developed crowns generally produced fewer epicormic branches following partial cutting than trees with small, sparse, poorly developed crowns. Consequently, to reduce epicormic branching on residual trees, high-vigor trees of desirable species should be favored over low-vigor trees and retained in partial cuttings.

Epicormic branching appeared to have a detrimental effect on log grade. In general, as few as five epicormic branches on a 16 ft log was enough to cause a reduction in log grade. In hardwoods, particularly in the more valuable oaks, log grade reduction caused by the presence of numerous epicormic branches significantly reduces the stumpage value of the stand and represents a loss of potential income to the landowner.

Defects caused by epicormic branches had a serious effect on both lumber grade and value. Over 50% of the lumber volume that would have been graded as FAS in the absence of epicormic branches was downgraded to No. 1 Common or below due to defects caused by epicormic branches. This reduction in lumber grade caused by epicormic branch defects decreased lumber value by 13%.

Epicormic branches are a serious problem in the management of hardwoods for high quality sawtimber production. They cause significant reductions in both log and lumber grade and a subsequent loss of value in the stand and the lumber produced from it. Additional research is needed to more accurately determine the magnitude of that economic loss. However, the production of epicormic branches along the boles of hardwood trees can be minimized through sound management practices. Improvement cuttings and thinnings can be used to maintain healthy stands composed of vigorous, high quality trees of desirable species. Hardwood stands, especially those with a high component of oak, should not be allowed to become overstocked. Trees severely stressed from competition are highly susceptible to epicormic branching. Land managers should use carefully planned partial cuttings to not only improve species composition, regulate stand density, and increase growth, but also to reduce the risk of epicormic branching (Meadows 1996).

Literature Cited

Brown, C.L., and P.P. Kormanik. 1970. The influence of stand disturbance on epicormic branching. P. 103–112 *in* Silviculture and management of southern hardwoods: 19th annual forestry symp., Hansbrough, T. (ed.). Louisiana State Univ. Press, Baton Rouge.

Erdmann, G.G., R.M. Peterson, Jr., and R.R. Oberg. 1985. Crown releasing of red maple poles to shorten high-quality sawlog rotations. Can. J. For. Res. 15:694–700.

Hanks, L.F., G.L. Gammon, R.L. Brisbin, and E.D. Rast. 1980. Hardwood log grades and lumber grade yields for factory lumber logs. USDA For. Serv. Res. Pap. NE-468. 92 p.

Hedlund, A. 1964. Epicormic branching in north Louisiana Delta. USDA For. Serv. Res. Note SO-8. 3 p.

McKnight, J.S. 1958. Thinning stands of water oaks. P. 46-50 *in* Management of bottomland forests: 7th annual forestry symp. School of For, Louisiana State Univ., Baton Rouge.

Meadows, J.S. 1993. Logging damage to residual trees following partial cutting in a green ash–sugarberry stand in the Mississippi Delta. P. 248–260 *in* Proc. of the 9th central hardwood forest conference, Gillespie, A.R., et al. (eds.). USDA For. Serv. Gen. Tech. Rep. NC-161.

Meadows, J.S. 1996. Thinning guidelines for southern bottomland hardwood forests. P. 98–101 *in* Proc. of the Southern forested wetlands ecology and management conf., Flynn, K.M. (ed.). Consortium for Res. on South. For.Wetlands, Clemson University, Clemson, SC.

Meadows, J.S., and J.A. Stanturf. 1997. Silvicultural systems for southern bottomland hardwood forests. For. Ecol. Manage. 90:127–140.

Rast, E.D., D.L. Sonderman, and G.L. Gammon. 1973. A guide to hardwood log grading. USDA For. Serv. Gen. Tech. Rep. NE-1. 31 p.

Skilling, D.D. 1957. Is the epicormic branching associated with hardwood pruning wounds influenced by tree crown class? USDA For. Serv. Lake States Exp. Sta. Tech. Notes No. 510. 2 p.

Southern Lumberman. 1992. Hardwood price index. South. Lumberman. 1992(March):39.

Stubbs, J. 1986. Hardwood epicormic branching—small knots but large losses. South. J. Appl. For. 10:217–220.

Wahlenberg, W.G. 1950. Epicormic branching of young yellow-poplar. J. For. 48:417–419.