Effect of Stem Location of Fusiform Rust Symptoms on Volume Yields of Loblolly and Slash Pine Sawtimber

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ABSTRACT

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The stem location and extent of cankers or galls caused by *Cronartium quercuum* f. sp. *fusiforme* were analyzed for 230 loblolly (*Pinus taeda*) and 217 slash (*P. elliottii* var. *elliottii*) pines of sawtimber-size in the southeastern United States. The average losses of utilizable sawtimber volume, 24–43% for loblolly pine and 23–53% for slash pine, were related inversely to the 10–≥18-in. diameter classes. Symptoms occurring within the initial 8 ft of the first sawlog resulted in the greatest proportional volume loss for either host species.

Additional key words: timber utilization.

Fusiform rust, which is caused by *Cronartium quercuum* (Berk.) Miyabe: Shirai f. sp. *fusiforme*, is the most economically important disease of loblolly pines (*Pinus taeda* L.) and slash pines (*P. elliottii* Engelm. var. *elliottii*) in the southeastern United States (3). Mortality from the disease is highest among seedlings with stem infections, but surviving infected trees exhibit annual growth loss and stem degradation from bole infection (8). Stem degradation from resin-soaking and decay of galled tissue is economically important among pine trees of sawtimber-size due to the high value of the potential product. Resin-soaking associated with stem symptoms is more extensive radially and longitudinally than is revealed by casual observation (Fig. 1).

The impact of stem volume loss due to fusiform rust infection of sawtimber-size loblolly and slash pines has been hampered by the absence of reliable quantitative data (3). Previous analyses of fusiform rust-associated stem volume loss (4–8, and M. A. Veal, *unpublished* internal report, Department of Wood and Paper Science, N.C. State University, Raleigh) either have not concentrated upon a specific product (eg, sawtimber) or have not specifically measured the volume of affected tissue across the range of diameters within the sawtimber classification. Quantitative analysis of stem volume loss of loblolly and slash pine sawtimber, without regard to symptom location, has been accomplished (R. S. Webb, K. M. Portier, H. D. Patterson, and R. T. Luttrell, *unpublished*). Percentage volume losses due to fusiform rust infection was similar for both species and ranged from about 22 to 16% in the 10–≥18-in. diameter classes.

The purpose of the study reported here was to devise an improved method for estimating sawtimber losses due to fusiform rust in loblolly and slash pines by considering symptom location and extent relative to diameter class.

MATERIALS AND METHODS

The radial and longitudinal extent and location of fusiform rust stem symptoms were recorded for 230 loblolly and 217 slash pines from plantations and natural stands across the southeastern United States. A minimum diameter-at-breast-height (d.b.h.) of 9.5 in. was

required for selection as pine sawtimber and diameter classes were created as follows: 10-in. class (9.5–10.4 in.), 11-in. class (10.5–11.4 in.), etc.

A simple visual method was devised to approximate the extent of fusiform rust infection based upon the proportion of stem encircled by the symptom. If the breadth of the symptom at its midpoint was >50% of the host's circumference at the symptom height then the

Fig. 1. Cankered fusiform rust gall on slash pine (left); same gall with bark removed (right) exhibiting the extent of internal decay and resin-soaking.

TABLE 1. Frequency and stem height of fusiform rust symptoms (>50% of host trunk circumference) on sawtimber-sized loblolly and slash pine

Host	Diameter class (in.)	0[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Loblolly	10	2	1					2				1	1		1											1																					
	11					1		1	1	1	2				1																											1					
	12	1	1	1	1	1	1	2	1	1		1	2	1				1																													
	13				1	1		1		1		1	1	1												1																					
	14	1	1		2	1	1	1																		1																					
	15				2	1	2							1																																	
	16				2	1	2							1												1																					1
	17				1	1					1																																1				
	18+				2	2	1																1														1										
Slash	10		1							2	1		3			1																															
	11			6	1	2	3	2	1	2	1			1	1			1						1																							
	12		2	2	1		1	1	3	1		1	1		2	1	1		1						1																						
	13		1		3	4	1			1	2		1		1	1						1				1	1				1							1									
	14		1	1	1			1					1		1	1				1						1											1										
	15		1	1	2	1											1									1																					
	16				1								1		1		1																														
	17													1								1							1																		
	18+					1				2					1																									1							

[a]To convert feet to meters, multiply 3.048×10^{-1}.
[b]A symptom midpoint height of "0" corresponds to the top of a 6-in.-high stump.

TABLE 2. Frequency and stem height of fusiform rust symptoms (≤50% of host circumference) on sawtimber-sized loblolly and slash pine

Host	Diameter class (in.)	0[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Loblolly	10		1	1			2							1				1																													
	11				4		1	3	2		1		1													1						1															
	12				4			1		3	2		1		1	1									1					1																	
	13	1		3	2	1	1	1	2	2		4		2	2	1			1		1		1				1																				1
	14		1		2	4	4	3	3	3			3		3				1		1	2	1				1																				
	15			2	3	1	1	1	2			1	3						1				1					1																			
	16		1	1	2	1	1	5	1	1			1	1	1	1	1	1				1		1														1									
	17			4	1	2	2	1		2	1		1										1																								
	18+				4	1	5	3	3	3	1	3		1	1	1			1				1		1								1			1	1										
Slash	10	1			2			2	1				1		1	1				3	2					1																					
	11				3		1	2	2	1	3	1	1	2	1			1	1		1					1	1			1																	
	12		1	2	2	1	3	2	1	1		3	1	1	2		2	2		2		1	4									1								1							
	13	1	1	3	4		3	1		1	1	2	1	1	4	1	1			2	1		1				1			1	1																
	14		4	7	1	1		2			4		2	1						1	1	1				1	1	2			1																
	15		1	1	1	3		1	3	1			1		2	1	1			1	1																										
	16			1		1							1						1													1															
	17	2												1								1																									
	18+				2	3				1	2	1					1																														

[a]To convert feet to meters, multiply by 3.048×10^{-1}.
[b]A symptom midpoint height of "0" corresponds to the top of a 6-in.-high stump.

TABLE 3. Board-foot and cubic-meter volume losses due to fusiform rust stem symptoms among sawtimber-sized trees of *Pinus taeda* and *Pinus elliottii* var. *elliottii*

Host	Diameter class			Board feet (Intl. rule)				
	cm	in.	n	Average total volume	Average total loss	Corrected[a] volume loss (%)	Average total volume (m³)	Average total loss (m³)
P. taeda	25.4	10	16	60.0	24.2	43.1	0.14	0.06
	27.9	11	23	84.8	29.6	42.7	0.20	0.07
	30.5	12	26	106.9	36.0	35.2	0.25	0.09
	33.0	13	29	147.9	42.6	30.3	0.35	0.10
	35.6	14	36	171.3	50.6	30.9	0.40	0.12
	38.1	15	21	219.3	48.7	25.2	0.52	0.12
	40.6	16	26	253.7	61.3	24.4	0.60	0.15
	43.2	17	18	314.4	62.6	20.8	0.74	0.15
	45.7+	18+	35	513.1	113.8	24.1	1.21	0.27
Total			230					
P. elliottii elliottii	25.4	10	18	50.9	25.3	53.1	0.12	0.06
	27.9	11	35	83.7	28.1	38.6	0.20	0.07
	30.5	12	45	115.7	36.5	32.3	0.27	0.09
	33.0	13	38	142.1	42.2	30.8	0.34	0.10
	35.6	14	31	173.4	46.9	30.0	0.41	0.11
	38.1	15	22	197.1	42.2	21.9	0.47	0.10
	40.6	16	10	254.0	68.6	27.8	0.60	0.16
	43.2	17	5	345.0	76.5	21.3	0.81	0.18
	45.7+	18+	13	364.2	83.1	23.1	0.86	0.20
Total			217					

[a] Corrected for trimming (jump-butting) of the logs due to fusiform rust symptoms in the first 8-ft.

total volume of the infected area was assumed to be resin-soaked and/or decayed and unfit for use as sawtimber. If the circumference of the trunk occupied by the symptom was ≤50% of the host's circumference, the half of the volume of the infected area was assumed to be unusable as sawtimber.

A Barr-Stroud dendrometer was used to measure the stem diameter at the lowest and highest points of each symptom. The dendrometry data were analyzed by using the STX system (2) and volume of sawtimber was computed for each symptom and for the total tree based upon a 6-in. stump height and an 8-in. diameter top.

Optimum sawlog lengths were computed for each tree according to USDA Forest Service log scaling guidelines (1) and were based on total tree height from a 6-in. stump height to an 8-in. diameter top. Deductions in sawtimber wood volume due to fusiform rust symptoms in the first 8-ft. log (the minimal merchantable length) were computed to adjust for trimming (jump-butting) to avoid transporting unusable wood to the mill. For example, if the total height of the bole was 27 ft. and a fusiform rust gall occupied the initial 2 ft. (0.67 m), the usable total height was corrected to 25 ft. Based on log scaling guidelines, the optimum recommended lengths for the first and second logs from a 25-ft. bole were 13 and 12 ft., respectively. The sawtimber volume loss (board feet, International rule) associated with the location and severity of each symptom was subtracted from the total sawlog volume. The average percentage sawtimber volume losses for the (10–≥18 in.) diameter classes were calculated for both species. The frequency and height of each symptom midpoint on the bole was measured to evaluate the frequency and height distribution of symptoms in each diameter class.

RESULTS

The maximum percentage volume losses for both species occurred among the smaller diameter classes, eg, 10–13 in., due to the frequent occurrence of the most severe symptom type (>50% of host circumference) in the first 8-ft. log (Table 1). The frequency of the less severe symptom (≤50% of host circumference) (Table 2) was also maximized in this same height range which added to the proportionately greater sawtimber volume loss among the smaller diameter classes.

Loblolly and slash pine sawtimber volume losses due to the location of stem symptoms caused by *C. quercuum* f. sp. *fusiforme*

are described in Table 3. As the average total volumes of both species increased across the range of diameter classes, the corrected average sawtimber volume loss percentages relative to symptom location decreased, eg, from about 43 to 24% for loblolly and from about 53 to 23% for slash pines in the (10–≥18 in.) classes, respectively.

DISCUSSION

The impact of fusiform rust upon loblolly and slash pine sawtimber yields is twofold: early infection as denoted by symptoms on the lower bole, particularly within the initial 8 ft., maximizes the sawtimber volume loss; and the volume losses incurred among smaller-diameter sawtimber trees can be mitigated by delaying harvest so that diameter and height growth are increased. Infection of seedlings causes the most severe losses throughout the rotation since seedling mortality results in reduced stocking and residual infected seedlings have varying amounts of stem degradation. Mortality declines greatly among trees 5–10 yr old yet residual colonized saplings will exhibit proportionately less volume loss if left to increase in total volume. Trees that are tolerant to stem colonization will continue to increase total volume without a similar proportional increase in average percentage volume loss. Management strategies that delay harvesting stem-infected sawtimber trees will maximize the volume of utilizable sawtimber; however, there will be an increased likelihood that the tree will be lost to breakage or mortality due to stem infection, especially among slash pines.

The computation of stem volume loss without regard for symptom location (R. S. Webb, K. M. Portier, H. D. Patterson, and R. T. Luttrell, *unpublished*) greatly underestimated the volume loss of utilizable sawtimber. Among the smaller-diameter sawtimber classes, the loss of utilizable sawtimber volume may be twice as much as predicted by cu.ft. volume estimates alone.

The greatest average percentage loss to fusiform rust occurs within the first 8 ft. of the butt log. If thinning or timber stand improvement activities are scheduled, then young pines exhibiting basal symptoms are preferred trees for removal. If young trees with lower bole symptoms cannot be removed (eg, due to maintenance of a minimum stocking density etc.), then the total volume losses will decrease with increased tree growth. As Wahlenberg (9) has reported, the costs of producing 1,000 board feet of lumber from

8-in.-diameter loblolly pines are twice as much as from 24-in.-diameter trees, yet the smaller trees are worth only about three-fourths as much. Prior to harvesting, calculated volumes of uninfected sawtimber should be compared with those of infected trees and the effects of a postponed harvest upon profit maximization should be included in the decision whether to cut a particular stand.

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