

# FUSIFORM RUST LOSSES, CONTROL COSTS, AND RELATIVE HAZARD IN SOUTHERN FOREST TREE NURSERIES

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Fusiform rust (caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*) is the most serious nursery disease of slash (*Pinus elliotii* Engelm. var. *elliotii*) and loblolly (*P. taeda* L.) pine in the Southern United States (3). Although the disease can be controlled by spraying ferbam, the number, frequency, and formulation of sprays, as well as the degree of rust control, vary from one nursery to another. This paper reports fusiform rust losses and the relative cost of control in southern forest nurseries.

## Methods

In the spring of 1972, a 5-year study was initiated in forest nurseries scattered across the geographic range of fusiform rust. A total of 15 nurseries were selected in North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana.

At each nursery, slash and loblolly pine seeds were sown in March or April of each year on study plots that were three beds wide and 25 feet long. Four plots of each pine species were planted. One plot was left unsprayed (check group), and the

other three were sprayed from the date that seedling emergence began until June 1, June 15, or July 1. Ferbam spray rates and frequencies were routinely used at each study nursery. Rust incidence was based on seedlings lifted from five random 1 by 4-foot areas within each plot during late November or December of each year. A statistical evaluation of the data was not possible because of the lack of replication of study plots. Supplemental data were obtained from each nursery concerning the brand of ferbam used, brand of spreader-sticker used, gallons of spray applied per acre, pounds of ferbam applied per acre, and amount of spreader-sticker applied per acre. The number of ferbam sprays applied at each nursery was recorded annually. Fusiform rust control costs were also computed annually for each nursery, from expenditure data representing the total nursery control program. Seedling grading costs were based on an average hourly rate of \$2.30 per staff hour and previously reported grading rate data (2).

## Results and Discussion

### Rust Hazard.

The risk of nursery infection (rust hazard) was higher at the Davisboro, Georgia nursery than at any of the other nurseries

studied within the fusiform rust range (tables 1, 2).

Although 1972 was the most severe rust year during the 5-year study period (23.7 percent average infection rate in all 15 nurseries and both species), the rust incidence at the Davisboro nursery was greater on slash pine seedlings in 1973 and 1975 than in 1972 (tables 1, 2).

The average incidence of the disease was greater on non-sprayed slash pine than on non-sprayed loblolly pine. This suggests that slash pine is usually more susceptible to fusiform rust. However, because certain slash pine seed sources are more resistant to the disease than are certain sources of loblolly, a lower rust incidence in paired plantings of the two species would result. The different rates of seed germination and seedling growth may also result in a greater rust incidence in loblolly pine than in slash pine seedlings if infections are established when the loblolly seedlings are at a more susceptible growth stage.

### Control With Ferbam

The data in tables 3 through 7 indicate that ferbam sprays will control fusiform rust in forest tree nurseries. Ferbam, however, is a preventative fungicide and, for maximum effectiveness, must completely cover all susceptible seedling tissues. A high rust incidence observed in sprayed

<sup>1</sup>The authors acknowledge the cooperation and assistance of W. H. Pawuk of the Southern Forest Experiment Station and the many personnel at the several forest tree nurseries included in this study.

**Table 1.**—Incidence of fusiform rust (percentage of infection) in non-sprayed slash pine seedlings in 15 southern nurseries from 1972 to 1976

Nursery	Location	1972	1973	1974	1975	1976	Avg.
Hammermill (?) <sup>1</sup>	Alabama	—	—	—	—	—	—
E.A. Hauss (8)	Alabama	0.6	0.5	15.0	1.0	7.5	4.9
J. R. Miller (9)	Alabama	—	0.0	0.0	0.7	4.3	1.3
Buckeye Cellulose (2)	Florida	53.7	1.0	0.2	39.0	—	23.5
St. Regis Paper (?)	Florida	—	4.1	—	—	—	4.1
Davisboro (1)	Georgia	64.3	81.1	2.3	77.9	18.3	48.8
Morgan (4)	Georgia	—	6.6	—	—	—	6.6
Walker (7)	Georgia	—	—	—	4.0	—	4.0
Herty (3)	Georgia	—	29.8	—	—	10.0	19.9
Beauregard (6)	Louisiana	32.5	0.4	—	3.5	1.4	9.5
Columbia (13)	Louisiana	—	0.0	0.0	1.1	0.0	0.3
W. W. Ashe (10)	Mississippi	5.9	0.0	0.2	0.0	1.5	1.5
Waynesboro (11)	Mississippi	—	0.0	—	0.0	4.2	1.4
Claridge (12)	North Carolina	—	0.0	—	1.7	—	0.9
H. L. Tilghman (5)	South Carolina	4.5	10.5	1.1	10.0	—	6.5
Average per year		26.9	10.3	2.7	12.6	5.9	11.2
Overall average for both species		23.7	8.6	1.9	10.1	5.4	9.2

<sup>1</sup>Numbers within parentheses indicate the relative order of fusiform rust hazard in these nurseries.

**Table 2.**—Incidence of fusiform rust (percentage of infection) in nonsprayed loblolly pine seedlings in 15 southern nurseries from 1972 to 1976.

Nursery	Location	1972	1973	1974	1975	1976	Avg.
Hammermill (?) <sup>1</sup>	Alabama	—	—	—	0.0	3.1	1.6
E. A. Hausa (8)	Alabama	4.1	0.0	3.4	0.0	3.1	2.1
J. R. Miller (9)	Alabama	—	0.8	0.0	1.3	7.2	2.3
Buckeye Cellulose (2)	Florida	34.5	1.8	0.3	18.8	2.0	11.5
St. Regis Paper (?)	Florida	—	2.3	—	—	—	2.3
Davisboro (1)	Georgia	72.6	61.0	3.8	40.4	23.0	40.2
Morgan (4)	Georgia	—	4.3	—	28.6	2.6	11.8
Walker (7)	Georgia	—	11.7	1.0	0.5	9.0	5.6
Herty (3)	Georgia	—	—	0.0	0.9	—	0.5
Beauregard (6)	Louisiana	0.0	0.2	0.5	0.9	0.5	0.4
Columbia (13)	Louisiana	—	0.0	0.8	0.5	0.0	0.3
W. W. Ashe (10)	Mississippi	3.8	0.1	0.0	0.0	2.3	1.2
Waynesboro (11)	Mississippi	—	0.0	1.5	0.0	2.9	1.1
Claridge (12)	North Carolina	—	0.0	1.7	1.6	2.7	1.5
H. L. Tilghman (5)	South Carolina	8.1	6.8	0.5	12.0	—	6.9
Average per year		20.5	6.8	1.1	7.5	4.9	7.1
Overall average for both species		23.7	8.6	1.9	10.1	5.4	9.2

<sup>1</sup>Numbers within parentheses indicate the relative order of fusiform rust hazard in these nurseries.

nursery beds is indicative of inadequate spray frequencies or improper spray applications. The decreasing incidence of fusiform rust with extended seasonal spray schedules indicates the value of extending spray applications at least through July 1 (tables 3 through 7). The fact that the majority of rust infections are established before June 1 indicates the need for increased spray applications during this time period. Conversely, the relatively low incidence of rust infections established after June 1 suggests the possibility of decreasing the number of spray applications after this date, thus resulting in control cost savings. The recommended practice of spraying ferbam before rains (1, 5) seems most appropriate during this latter time period.

Manufacturers of ferbam used in this study include Niagara, Woolfolk, Dupont, Stauffer, Allied, and Crown Chemical Companies. Trade names or brands of spreader-sticker or surfactant used include Dupont, Starbar, Spreadhesit, Aquagene, Daly-Herring, Plyac, Triton B-1956, and Santomerse. Although little difference should be expected between brands of ferbam if identical quantities of the active ingredient are applied, there may be a superior brand of spreader-sticker. An evaluation of several brands of spreader-stickers has been published (4).

## Costs

Expenditures for the control of fusiform rust in southern nurseries are summarized in tables 8 and 9. The gradual increase in the cost of ferbam from 1972 to 1976 reflects the overall inflation trend. To help reduce costs, nursery workers are using less labor, less equipment, and cheaper brands of chemicals. For example, the lower average price of spreader-sticker used in 1976 as compared to that used in 1975 reflects a change in brands. The average cost per thousand seedlings for rust control (\$0.12) remained relatively constant during the 5-year period, primarily because of improved nursery management practices.

Although the rust hazard at a particular nursery may be low, the expected disease loss at the same nursery without a rust control program would exceed the cost of the ferbam spray program (table 10). In fact, without rust control, the average nursery could expect to lose \$33,597 per year to fusiform rust (table 10), and the high incidence Davisboro nursery could expect to lose \$144,393 per year if 30 million rust-free seedlings were grown annually without ferbam spray application. The cost of controlling the disease with ferbam sprays averages about 32 percent of the expected losses from growth without a control pro-

**Table 3.**—Incidence of fusiform rust (percentage of infection) in slash and loblolly pine seedlings either not sprayed with ferbam or sprayed from date of emergence until June 1, June 15, or July 1, 1972<sup>1</sup>

Nursery	Slash				Loblolly			
	Check	6/1	6/15	7/1	Check	6/1	6/15	7/1
E. A. Hauss	0.6	0.7	0.6	0.0	4.1	5.3	6.0	6.7
Buckeye Cellulose	53.7	51.0	51.0	44.2	34.5	31.7	27.1	17.1
Davisboro	64.3	6.9	1.6	2.9	72.6	23.0	5.1	2.0
Beauregard	32.5	30.9	25.0	24.0	0.0	0.0	0.3	0.0
W. W. Ashe	5.9	0.9	1.5	1.9	3.8	0.0	0.0	0.3
H. L. Tilghman	4.5	0.6	1.0	1.1	8.1	2.5	1.1	0.2
Average	26.9	15.2	13.5	12.4	20.5	10.4	6.6	4.4

<sup>1</sup>Seeds were sown in March or April.

**Table 4.**—Incidence of fusiform rust (percentage of infection) in slash and loblolly pine seedlings either not sprayed with ferbam or sprayed from date of emergence until June 1, June 15, or July 1, 1973<sup>1</sup>

Nursery	Slash				Loblolly			
	Check	6/1	6/15	7/1	Check	6/1	6/15	7/1
E. A. Hauss	0.0	0.0	0.2	0.0	0.5	0.2	0.0	0.
J. R. Miller	—	—	—	0.0	0.8	1.0	1.5	0.
Buckeye Cellulose	1.0	0.2	0.4	0.1	1.8	0.2	0.2	0.0
St. Regis Paper	4.1	5.8	3.0	5.0	2.3	1.0	1.3	1.4
Davisboro	81.1	57.8	59.0	47.2	61.0	47.0	40.7	34.3
Beauregard	0.2	0.0	0.0	—	0.4	0.9	0.5	—
Columbia	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
W. W. Ashe	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.1
Waynesboro	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Claridge	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3
H. L. Tilghman	10.5	6.8	2.4	1.5	6.8	3.4	1.2	0.7
Average	9.7	7.1	6.6	5.4	7.4	4.9	4.1	3.8

<sup>1</sup>Seeds were sown in March or April.

gram. An average of \$22,771 net savings—the equivalent of saving approximately 84 cents per thousand seedlings—is realized annually per nursery when ferbam is applied (table 10).

## Conclusions

The rust hazard is higher in certain southern forest tree nurseries and in certain years than in others (tables 1, 2).

**Table 5.**—Incidence of fusiform rust (percentage of infection) in slash and loblolly pine seedlings either not sprayed with ferbam or sprayed from date of emergence until June 1, June 15, or July 1, 1974<sup>1</sup>

Nursery	Slash				Loblolly			
	Check	6/1	6/15	7/1	Check	6/1	6/15	7/1
E. A. Hauss	15.0	12.7	3.1	0.4	3.4	2.0	0.5	0.0
J. R. Miller	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Buckeye Cellulose	0.2	0.1	0.0	0.0	0.3	0.3	0.4	0.0
Davisboro	2.3	0.3	0.1	0.0	3.8	0.0	0.0	0.2
Beauregard	—	—	—	0.0	0.5	0.0	0.0	0.0
Columbia	0.0	0.0	0.0	0.0	0.8	0.7	0.5	0.2
W. W. Ashe	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Waynesboro	—	—	—	0.0	1.5	0.6	—	0.6
Claridge	—	—	1.8	2.7	1.7	1.5	0.0	0.0
H. L. Tilghman	1.1	1.2	0.2	0.2	0.5	0.3	0.6	0.0
Average	2.7	2.1	0.7	0.4	1.3	0.5	0.2	0.1

<sup>1</sup>Seeds were sown in March or April.

**Table 6.**—Incidence of fusiform rust (percentage of infection) in slash and loblolly pine seedlings either not sprayed with ferbam or sprayed from date of emergence until June 1, June 15, or July 1, 1975<sup>1</sup>

Nursery	Slash				Loblolly			
	Check	6/1	6/15	7/1	Check	6/1	6/15	7/1
E. A. Hauss	1.0	0.4	0.8	0.2	0.0	1.4	0.5	0.0
J. R. Miller	0.7	0.3	0.0	0.0	1.3	1.1	0.7	0.9
Buckeye Cellulose	39.0	1.9	2.5	1.9	18.8	0.9	0.4	0.9
Davisboro	77.9	19.7	15.7	20.5	40.4	4.6	3.9	2.9
Besuregard	3.5	2.8	4.7	2.8	0.9	0.1	0.5	0.0
Columbia	1.1	1.2	1.2	1.3	0.5	0.2	0.3	0.8
W. W. Ashe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waynesboro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Claridge	1.7	1.4	0.5	0.3	1.6	1.0	1.4	0.9
H. L. Tilghman	10.0	1.8	1.8	2.2	12.0	1.2	2.0	1.7
Average	13.5	3.0	2.7	2.9	7.6	1.1	1.0	0.8

<sup>1</sup>Seeds were sown in March or April.

The observed erratic rust incidence pattern reflects the difficulty of predicting the annual disease incidence in southern forest tree nurseries. Although rust incidence in nursery plantings may be higher in the majority of nurseries during a particular year, there does not appear to be a "cyclical rust wave year" in which rust incidence is greatest in southern nurseries.

The rust hazard at a particular nursery is dependent upon the presence of an adequate supply of fungus inoculum and weather conditions conducive to infection. The incidence of fusiform rust in the nurseries included in this study is significantly correlated ( $r=0.618$ ;  $P=0.05$ ) with the rust incidence in neighboring plantations (6). Because rust incidence in plantations has previously been shown to correlate with the abundance of oak, it should also correlate with oak abundance in nurseries (7). Therefore, it is likely that eradication of susceptible oaks around a nursery would reduce the rust hazard. The oakfree zone should be as wide as practical because basidiospores of the fungus may be airborne for considerable distances.

**Table 7.**—Incidence of fusiform rust (percentage of infection) in slash and loblolly pine seedlings either not sprayed with ferbam or sprayed from date of emergence until June 1, June 15, or July 1, 1976<sup>1</sup>

Nursery	Slash				Loblolly			
	Check	6/1	6/15	7/1	Check	6/1	6/15	7/1
E. A. Hauss	7.5	0.4	0.4	0.2	3.1	0.4	0.1	0.1
J. R. Miller	4.3	1.1	0.8	1.3	7.2	1.0	0.3	0.3
Buckeye Cellulose	—	—	—	—	2.0	0.0	0.2	0.0
Davisboro <sup>2</sup>	18.3 <sup>b</sup>	1.1 <sup>c</sup>	1.3 <sup>c</sup>	0.4 <sup>c</sup>	23.0 <sup>a</sup>	1.4 <sup>c</sup>	1.6 <sup>c</sup>	1.0 <sup>c</sup>
Beauregard	1.4	1.2	1.6	1.3	0.5	0.4	0.1	0.1
Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W. W. Ashe	1.5	0.3	0.6	0.7	2.3	0.0	0.0	0.1
Waynesboro	4.2	3.1	3.2	4.1	2.9	2.3	1.9	2.3
Claridge	—	—	—	—	2.7	2.6	1.3	1.4
Average	5.3	1.0	1.1	1.1	4.9	0.9	0.6	0.6
5-year average <sup>3</sup>	11.2	5.3	4.6	3.9	7.1	3.1	2.3	1.7

<sup>1</sup> Seeds were sown in March or April.

<sup>2</sup> Davisboro percentages are significantly different when followed by different superscript letters ( $P=0.05$ ; Duncan's multiple range test. These study plots were established in a randomized complete block design for purposes of a statistical analysis.

<sup>3</sup> These data represent the overall average infection across all nurseries during the 5-year period, 1972 to 1976.

**Table 8.**—Average cost to control fusiform rust in a forest tree nursery between 1972 and 1976.<sup>1</sup>

Type of expenditure	1972	1973	1974	1975	1976
			\$		
Ferbam	842.10	596.80	857.17	978.19	1,404.75
Spreader-sticker or surfactant	134.61	186.87	194.29	236.81	247.08
Labor	926.63	641.32	729.35	954.97	936.50
Equipment use	292.83	487.50	854.35	669.29	713.07
Equipment depreciation	600.00	600.00	600.00	600.00	600.00
Miscellaneous (electricity, etc.)	75.00	75.00	75.00	75.00	75.00
Total cost per nursery	2,871.17	2,587.49	3,310.16	3,514.26	3,976.40
Total cost per acre	93.33	75.44	77.70	75.09	99.41
Total cost per spray	105.17	105.18	143.30	183.03	162.97
Total cost per M seedlings	0.123	0.099	0.123	0.142	0.121

<sup>1</sup> Data are based on the average expenditures incurred at the Hauss, Miller, Buckeye Cellulose, Beauregard, Columbia, Ashe, Waynesboro, Claridge, and Tilghman nurseries

**Table 9.**—Average annual chemical, labor, and equipment expenditures incurred per nursery for control of fusiform rust.<sup>1</sup>

Item	1972	1973	1974	1975	1976
Acres of seedlings sprayed	29.2	34.3	42.6	46.8	40.0
Number of seedlings shipped (M)	23,373	26,252	26,821	24,756	32,898
Number of sprays applied (range)	27.3 (16-47)	24.6 (8-40)	23.1 (7-43)	19.2 (8-42)	24.4 (7-52)
Ferbam applied (pounds)	1,684.2	1,170.2	1,503.8	1,504.9	1,873.0
Ferbam cost per pound	0.50	0.51	0.57	0.65	0.75
Spreader-sticker or surfactant applied (gallons)	37.6	37.6	37.8	42.9	55.4
Spreader-sticker or surfactant cost per gallon	3.58	4.97	5.14	5.52	4.46
Labor (staff hours)	274.8	210.2	203.9	239.1	244.9
Labor (cost per hour)	3.372	3.051	3.577	3.994	3.824
Equipment operation (hours)	129.0	160.6	175.0	139.0	161.0
Equipment operation cost per hour	2.270	3.035	4.882	4.815	4.429

<sup>1</sup>Data are based on the average expenditures incurred at the nine nurseries listed in table 8.

**Table 10.**—Average annual monetary impact of fusiform rust at each of 10 forest tree nurseries.<sup>1</sup>

Nursery	Nonsprayed seedlings infected (Range) (%)	Sprayed seedlings infected (%)	Sprays applied (no)	Disease control cost (\$)	Expected loss w/o control (\$)	Expected annual savings (\$)
E. A. Hauss	3.5(0 - 15.0)	0.76	20.2	4,894	18,702	13,803
J. R. Miller	1.8(0 - 7.2)	0.42	28.3	5,181	14,062	8,881
Buckeye Cellulose	17.50.2-53.7)	7.13	44.8	26,998	60,058	33,060
Davisboro	44.5(2.3-81.1)	11.14	34.4	38,662	144,393	105,731
Beauregard	5.0(0.5-32.5)	3.53	21.8	12,930	23,174	10,244
Columbia	0.3(0 - 1.1)	0.29	14.0	2,744	9,992	7,248
W. W. Ashe	1.4(0 - 5.9)	0.33	21.5	3,902	12,973	9,071
Waynesboro	1.3(0 - 4.2)	0.88	16.3	4,678	12,721	8,043
Claridge	1.2(0 - 2.7)	0.80	7.5	3,227	12,446	9,219
H. L. Tilghman	6.7(0.5-12.0)	0.95	17.5	5,038	27,444	22,406
Total	—	—	—	108,254	335,965	227,711
Average	8.3	2.6	—	10,825	33,597	22,771

<sup>1</sup>Assumptions are that all nurseries shipped 27 million rust-free trees annually; average cost per spray per year was \$139.93 (table 8); seedlings were valued at \$10 per M; cost of seedlings increased \$0.34 per M over weigh-pack method if rust was not controlled (2).

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