BULLETIN 304 MARCH 1957

Southern FUSIFORM RUST

AGRICULTURAL EXPERIMENT STATION
of the ALABAMA POLYTECHNIC INSTITUTE
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FIRST PRINTING 4M, MARCH 1957

SOUTHERN FUSIFORM RUST

Some factors affecting its incidence in Alabama's Coastal Plain Region

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LONG, SPINDLE-SHAPED SWELLINGS on limbs and stems of slash, loblolly, and longleaf pines are a common sight to farmers and other landowners. These swellings are caused by the fungus *Cronartium fusiforme*, (A. and K.) Hedgc. and Hunt. This disease is commonly called southern fusiform rust. In the last 20 years, the incidence of this rust has increased greatly. Cankers have become so common that many people have become concerned about the economic soundness of planting pines. While it is believed that this fear is not justified, the disease is certainly a factor to be considered when planting pines in the Coastal Plain.

THE DISEASE and HOW IT SPREADS

Like many other rusts, *Cronartium fusiforme* must have an alternate host. It cannot spread from pine to pine. Oak trees are the alternate hosts. Water, willow, and laurel oaks are the most important hosts; however, blackjack, bluejack, southern red, turkey, and live oaks may be hosts.

The infection cycle, from pine to oak and back to pine, is usually completed in the spring. First signs of this infection cycle appear on pines early in March. The cankers on pine trees produce masses of orange-colored spores resembling powder. These spores are wind-disseminated. The spores that come in contact with oak leaves produce brownish, hair-like bristles on the lower surface of leaves. These bristles bear small dark spores that can infect pines. Spores produced on oaks are also wind-disseminated. Infection of the pine usually takes place on new needles or on the tender, new stem and branch tips.

REVIEW of LITERATURE

Since 1945 *Cronartium fusiforme* has been studied by many research workers in southern states. The life history and requirements of this fungus are well known and have been reported in numerous publications *(5, 7, 10, 11, 13, and 14)*. Many factors affect the incidence of *Cronartium fusiforme* infection in forest stands. Among the most important are weather, fire, soil cultivation, tree species, genetic strain, stand age, rate of height growth, and density of stocking. The incidence of infection in a stand on a particular site may also be affected by microclimate and the amount of rust in the general area.

Siggers *(10 and 11)* reported that conditions favorable for abundant infection of pines include temperatures between 60° and 79° F. and atmospheric humidity maintained close to the saturation point for at least 18 hours. Since there are definite temperature and humidity requirements for infection, late winter and early spring weather of a locality will affect the amount of infection occurring during a given year.

Many articles published in the past indicate that some pine species are more susceptible to infection with *Cronartium fusiforme* than others. In 1940, Lamb and Sleeth *(7)* reported that where slash pine *(Pinus caribaea Morel.)* and loblolly pine *(Pinus taeda* L.) were growing together slash pine was apparently more susceptible than loblolly pine. In 1947, Siggers and Lindgren *(14)* recommended that in areas of high hazard loblolly pine be favored over slash pine and that longleaf pine be grown on what the authors call typical sites for the species. Lindgren *(8)* stated that the order of greatest to least resistance to infection and serious damage is shortleaf, longleaf, loblolly, and slash pine. He further stated that shortleaf pine is immune for all practical purposes and longleaf pine usually is highly resistant. Goggans *(3)*, in a study of slash and loblolly pine plantations in the Alabama Piedmont, found no important difference between the amount of infection on slash and loblolly pine in pure plantations. In 1955, Siggers *(13)* stated, "Loblolly appears to be more susceptible to infection than slash pine, but once infected, slash pine seems to be more sensitive to invasion of the living bark by the rust. Pitch and pond pines are also attacked. Longleaf pine is relatively resistant to infection." He stated further, "in pine tree nurseries there is usually more fusiform rust infection on slash than on loblolly pine receiving similar cultural treatment. Al-

though this has been accepted as evidence of the greater susceptibility of slash pine, a better explanation is based on difference in germination between the two species."

The age of a stand apparently affects the percentage of infection. Goggans *(3)* observed that infections generally decrease as stand age increases. Siggers and Lindgren *(14)* indicated that infections grow less common as the stand ages.

Literature indicates that the rate of height growth of trees may affect the amount of rust infection. Siggers and Lindgren *(14)* stated that the influence of quality of site on the prevalence of rust is not fully known; however, there is evidence that the fungus is more likely to attack vigorous than slow-growing pine trees. Goggans *(3)* found an indication that infection increased as rate of height growth increased. Lindgren *(8)* stated that trees of vigorous growth appear to be more susceptible to cankering than slower growing ones. Closely associated with the effect of rate of height growth is the effect of cultivation and fire. Balthis and Anderson *(1)* reported that cultivation increased rust infection on planted slash pine. Boggess and Stahelin *(2)* also reported that cultivation increased infection on planted slash pine. They could establish no correlation between the frequency of infection and height growth of infected trees during the first three growing seasons. Siggers *(12)* reported that fire causes an increased number of infections on young trees. He explained this increase in infection by stating that the fire had altered the periodicity of spring growth, causing an early break in dormancy. This increased the amount of susceptible new needle and shoot growth during the high infection period of early spring. This belief has also been used to explain the increase in infection caused by cultivation. In 1955, Siggers *(13)* restated his belief, "Vigorous growth itself does not predispose pines to infection, but any factor or treatment that causes an early break in winter dormancy seems to have that effect."

Muntz *(9)* reported that close spacing reduces the percentage of southern fusiform rust infection.

Evidence is mounting to show that genetic strain is a factor affecting the incidence of southern fusiform rust on loblolly pine. Henry and Coyne *(6)* reported southern fusiform rust infection percentages in loblolly pine plantations established in Washington Parish, Louisiana, and Pearl River County, Mississippi, as part of the "Southwide Pine Seed Source Study." This report showed that loblolly pines from certain seed sources have

fewer rust infections than loblolly pines from other seed sources. Loblolly pine plantations established in Coosa County, Alabama, by the Agricultural Experiment Station of the Alabama Polytechnic Institute as part of the southwide study also show that loblolly pine from certain seed sources have much less rust infection than loblolly pines from other seed sources.

METHODS and RESULTS of INVESTIGATION

This study of the incidence of southern fusiform rust in the Alabama Coastal Plain Region was part of a project designed to investigate the establishment, growth, and yield of pine plantations in Alabama. Figure 1 shows the Coastal Plain Area covered by this portion of the investigation.

Old field plantings of longleaf, loblolly, and slash pine from 5 to 16 years old were examined. One-tenth-acre, square study plots were used. Plot locations were selected so that all plots would present a good distribution of the well-drained, upland sites found in the study area. Most plots were on gentle slopes and hilltops. None were in bottoms. Rust infection was not considered when plot locations were selected. However, none of the plots included in this study showed evidence of burning that could have influenced the amount of rust infection. None of the slash pine plantations studied was within the natural range of the species. Table 1 presents general information concerning plots used in this study.

An extensive description of each plot was recorded. The history of the land before and after planting was investigated. Physical site factors were recorded. The diameter at breast height of each tree was measured and the height of each tree was estimated. The heights of 10 of the tallest trees were measured. The average of these 10 measurements was used as the height figure for the plot. The average height figure was also used as a criterion of site quality.

All southern fusiform rust infections observed on each tree were recorded. Each infection (or canker) was classified, with

TABLE 1. GENERAL INFORMATION CONCERNING PLOTS STUDIED

Species	Number of plots	Average survival	Trees per plot	Average age
		Per cent	*Av. no.*	*Years*
Slash pine	70	54	64	10.5
Loblolly pine	47	72	82	10.2
Longleaf pine	33	39	42	11.4

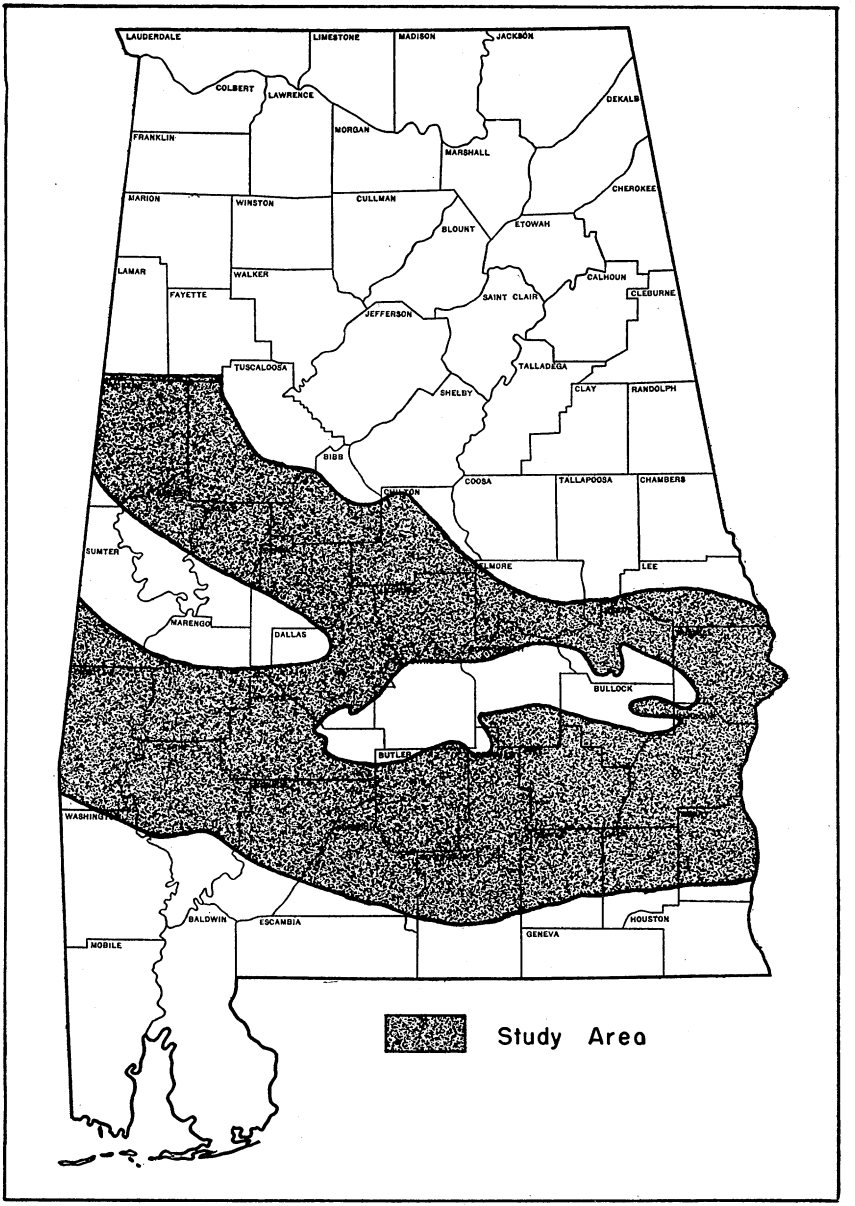

Figure 1. Shaded area on map is Coastal Plain Region of Alabama where study of incidence of southern fusiform rust was conducted.

modifications, according to a system reported by Lindgren *(8)*. Branch cankers were reported as occurring either more or less than 18 inches from the stem. Stem cankers and limb-stem cankers (those stem cankers that definitely came from a limb) were recorded in three categories. A number 1 stem canker was one occupying less than 50 per cent of the stem circumference. A number 2 stem canker was one occupying more than 50 per cent of the stem circumference. A number 3 stem canker was one of either extent with a deeply sunken canker face or a bend in the stem at the canker.

These infection data were summarized in two ways for different purposes.

First, to study some factors thought to affect the incidence of southern fusiform rust, the average number of infections per tree regardless of type and category of cankers was determined for each plot.

Second, with each tree described by its worst or most limiting canker, the percentage of trees in each canker category was computed for each plot. This information was used to study the amount of rust infection occurring in each category.

Factors Affecting Incidence of Southern Fusiform Rust

For each plot the infection data were used to determine the average number of infections per tree, disregarding type and category of cankers. Year of planting, species, age, height-over-age ratio, and number of trees per plot were studied to determine importance of their effect on the number of infections per tree. Infection data as summarized for the analysis are presented in Appendix Table 1.

Evaluation of the infection data and of the effects of the given variables was accomplished by use of a covariance analysis of multiple classification tables with unequal subclass numbers as described by Hazel *(4)*.[1] This particular type of analysis was selected because it permitted investigation of the effect of each of several variables (or sets of discrete variables) when each variable (or set) was adjusted for the effects of all other variables and because it allowed unequal subclass numbers.

[1] The author expresses his appreciation to E. Fred Schultz, Jr., Associate Biometrician, Agricultural Experiment Station of the Alabama Polytechnic Institute, for suggesting this type of analysis and for supervising the statistical computations.

The analysis of variance, Appendix Table 2, shows that each of the independent variables investigated had a significant effect on the number of infections per tree with allowance made for the effects of all other variables. In the course of the analysis, an equation showing the multiple regression of number of infections per tree on the several independent variables was developed. Relative size and direction of the effect of each independent variable may be noted in Appendix Table 3, which shows the regression coefficient for each variate.

While year of planting affected the number of infections per tree, the number of infections occurring on trees planted in the various years varied greatly. The number of infections occurring on trees planted during one year might be very low, whereas trees planted during the next year might have a very high number of infections. Whether the number of infections occurring on trees planted during a given year were high or low, the effect of the given year was the same on all species. A statistical test was made that showed there was no interaction between year of planting and species. Varying infection conditions created by the late winter and early spring weather of each year may explain the erratic effect that year of planting has on the amount of infection.

There were differences in the incidence of infection found on the different species studied. Longleaf pine definitely had less infection than either slash pine or loblolly pine. However, there was no appreciable difference between the amount of infection on slash and loblolly pines, Appendix Table 1.

As plantation age increased, the observed number of infections per tree decreased significantly.

Height-over-age ratio was used to represent the rate of growth of the planted trees. The effect of height-over-age ratio on the incidence of infection was highly significant. Infection increased as the ratio (hence the growth rate) increased.

The effect of the number of trees per plot was important. As the number of trees per plot increased, number of infections per tree decreased.

Occurrence of Southern Fusiform Rust by Infection Category

Only the most limiting infection on each tree from the standpoint of chance of salvage or future use of the tree was considered

in this phase of the study. Trees having their most limiting infection in the same category were grouped together and expressed as percentage of total trees on the plot, and also as percentage of infected trees on the plot. These data are presented in Table 2. A breakdown of this information by stand age group is presented in Appendix Tables 4, 5, and 6. When examining these tables, the reader is reminded that the data are from observed infections in plantations of varying age and that the data have not been adjusted for any factors that have been found to affect amount of infection.

Generally speaking, slash and loblolly pine had approximately the same amount of infection. Furthermore, the proportional part of the total infection occurring in each of the various categories was roughly the same for both species. Longleaf pine, on the other hand, had much less infection than either slash or loblolly pine. The variation in percentage of infection found on the longleaf plots was much greater than that found on the slash and loblolly pine plots. Perhaps because of this variation and the small number of plots, trends observed with the other species were not apparent in the longleaf data.

Data in Appendix Tables 4 and 5 show general trends in southern fusiform rust infection on slash and loblolly pines. Total infection percentage decreased with increasing stand age. This is in agreement with findings of the previously described statistical study of factors affecting the incidence of infection. As stand age increased, the percentage of trees with stem infections increased slightly and the proportion of infected trees having stem infections increased. The percentage of trees having limb-stem infections decreased with stand age, and the proportion of infected trees having limb-stem infections decreased. The percentage of trees in the combined stem and limb-stem infection category and their proportion of the infected trees decreased with increasing stand age. With increase in age the proportion of infected trees having branch infections increased. Much of this increase was in branch infection more than 18 inches from the stem, which may not be considered limiting so far as use of a tree is concerned.

A further breakdown of slash and loblolly pine infection data by percentage infection groups revealed no major differences in proportions of various infection categories between low and high amounts of infection.

TABLE 2. AVERAGE PERCENTAGE, BY SPECIES, OF TREES HAVING SOUTHERN FUSIFORM RUST INFECTIONS OF INDICATED DEGREE, BASED BOTH ON ALL TREES AND INFECTED TREES

Classification of most limiting rust infection[1]	Species					
	Slash pine		Loblolly pine		Longleaf pine	
	All trees	Infected trees	All trees	Infected trees	All trees	Infected trees
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Stem infection, No. 1	3.96	9.1	3.81	9.7	1.40	8.6
Stem infection, No. 2	3.00	6.9	4.27	10.8	2.94	18.1
Stem infection, No. 3	4.61	10.5	2.25	5.7	1.86	11.4
Stem infection, total	11.57	26.5	10.34	26.3	6.21	38.2
Limb-stem infection, No. 1	11.38	26.0	9.35	23.8	3.98	24.5
Limb-stem infection, No. 2	4.65	10.6	3.50	8.9	0.53	3.3
Limb-stem infection, No. 3	2.69	6.2	2.85	7.2	0.82	5.0
Limb-stem infection, total	18.72	42.8	15.71	39.9	5.35	32.9
Both stem & limb-stem infection, No. 1	15.34	35.1	13.17	33.5	5.39	33.2
Both stem & limb-stem infection, No. 2	7.65	17.5	7.78	19.8	3.47	21.4
Both stem & limb-stem infection, No. 3	7.30	16.7	5.10	13.0	2.69	16.6
Both stem & limb-stem infection, total	30.29	69.3	26.05	66.2	11.55	71.1
Branch infection, less than 18"	8.41	19.2	6.42	16.3	4.15	25.6
Branch infection, more than 18"	4.99	11.4	6.85	17.4	0.53	3.3
Branch infection, total	13.40	30.7	13.28	33.8	4.69	28.9
Total infection, minus branch > 18"	38.70	88.6	32.47	82.6	15.71	96.7
Total infection	43.70	100.0	39.33	100.0	16.24	100.0

[1] Key to meaning of categories:
Stem or limb-stem infection, No. 1—canker occupying < 50 per cent of stem circumference, face not deeply sunken, stem straight at canker.
Stem or limb-stem infection, No. 2—canker occupying > 50 per cent of stem circumference.
Stem or limb-stem infection, No. 3—a canker with a deeply sunken face or at a bend in the stem.

Income Loss

While this study was not designed to make possible the calculation of income loss caused by southern fusiform rust infection, the information presented should help forest managers in estimating their individual risk.

Many factors affect the amount of southern fusiform rust infection on a particular site. With any given amount of infection, there are additional factors that determine how much loss of income will result. Generally these additional factors that determine loss of income may be associated with management practices and utilization practices.

For example, with any given amount of rust infection, the length of time between thinnings would affect the number of infected trees salvaged. Where management objectives allow, a forest manager might modify his practices so that loss from rust infection would be minimized. These modifications might take the form of early pruning or more frequent early thinnings. Data in text Table 2 and Appendix Tables 4, 5, and 6 indicate how much rust infection might be prevented by early prunings. Certainly, much of the infection recorded as limb-stem infection and some branch infection less than 18 inches from the stem could have been prevented. Along with individual stand information on average tree size and an estimate of percentage total rust infection, these tables will also help to estimate the amount of material that it might be necessary to remove in thinnings or salvage cuts.

Stands on good sites need to be watched closely, especially those that are open, because the statistical study of factors affecting the amount of infection showed that fast growing trees and trees in open stands have more infection than slow growing trees and trees in dense stands. A percentage of rust infection that is relatively unimportant in a dense stand may cause a serious loss of income in an understocked stand because the latter will have far too few healthy trees to fully occupy the site. Since the plantation project, of which this rust study was a part, showed that understocked slash and longleaf pine plantations are more likely to occur than understocked loblolly pine plantations, forest owners should be alert to avoid infection losses in open slash and longleaf pine plantations. In areas of high rust hazard, it might be advisable to plant slash pine at a closer spacing than loblolly

pine, particularly if one has experienced poor slash pine survival in previous plantings.

SUMMARY and CONCLUSIONS

The incidence of southern fusiform rust in pine plantations in the Alabama Coastal Plain and some factors affecting this incidence have been investigated during a 6-year period.

A statistical study showed that year of planting, species planted, stand age, height-over-age ratio, and number of trees per plot affected the number of rust infections per tree. From this statistical study the following conclusions can be made:

1. Effect of year of planting on the number of infections per tree was important. The year-to-year change was highly erratic.
2. Relative effect of any given year was the same on all species.
3. No important difference was shown in the number of infections per tree on slash pine and loblolly pine. Longleaf pine definitely had fewer infections than either slash or loblolly.
4. Number of infections per tree decreased as stand age increased.
5. As height-over-age ratio increased, the number of infections per tree increased.
6. Number of infections per tree decreased as the number of planted trees per plot increased.

In a study of the occurrence of southern fusiform rust by infection category, trees were grouped according to their most limiting infection. The number of trees in each group was expressed as percentage of total trees on the plot and as percentage of infected trees on the plot. Slash and loblolly pines had approximately the same amount of rust infection. Longleaf pine had much less infection than either slash or loblolly. Although no broad trends were apparent in the longleaf data, the slash and loblolly pine data showed these trends:

1. Total infection percentage decreased with increasing stand age.
2. As stand age increased, the percentage of trees with stem infections increased; also the proportion of infected trees having stem infections increased.
3. The percentage of trees with limb-stem infections decreased with increasing stand age as did the proportion of infected trees having limb-stem infections.

4. The percentage of trees in the combined stem and limb-stem infection category decreased with increasing stand age, as did the proportion that these trees made of all infected trees.

5. With increase in age, the proportion of infected trees having branch infections increased.

6. The proportion of infected trees in each category appeared to be unrelated to total infection percentage.

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APPENDIX

APPENDIX TABLE 1. SOUTHERN FUSIFORM RUST INFECTION DATA SUMMARIZED FOR STATISTICAL ANALYSIS

Year planted	Slash pine		Loblolly pine		Longleaf pine	
	Plots	Infections per tree	Plots	Infections per tree	Plots	Infections per tree
	Number	*Av. no.*	*Number*	*Av. no.*	*Number*	*Av. no.*
1936	5	0.589	1	0.449	0	--
1937	11	.558	7	.748	0	--
1938	3	.678	1	.112	9	.238
1939	4	.963	1	.150	3	.271
1940	8	.856	4	.336	4	.496
1941	16	.887	15	.800	9	.214
1942	5	.980	3	.800	3	.433
1943	5	1.025	3	1.413	1	1.895
1944	0	--	1	.535	1	.000
1945	1	1.224	1	.578	0	--
1946	1	1.156	0	--	2	.038
1947	0	--	2	1.964	0	--
1948	1	.262	2	.835	1	.022
1949	9	.544	6	.638	0	--
Total all years	69	.776	47	.776	33	.308

APPENDIX TABLE 2. SUMS OF SQUARES AND DEGREES OF FREEDOM ASSOCIATED WITH THE SEVERAL CONTINUOUS VARIABLES AND THE SETS OF DISCRETE VARIABLES WHEN EACH VARIABLE, OR SET, IS ADJUSTED FOR THE EFFECTS OF ALL OTHER VARIABLES

Source of variation	d.f.	Sum of squares[1]	Mean square	Variance ratio (F)	Probability P
Year of planting	13	.00056122	.00004317	1.95	<.025
Species	2	.00127186	.00063593	28.78	<.005
Age	1	.00010962	.00010962	4.96	<.05
Height/age	1	.00022662	.00022662	10.25	<.005
Number of trees per plot	1	.00024494	.00024494	11.08	<.005
Error	130	.00287260	.00002210		

[1] Due to the type of analysis, sums of squares are not additive as in the usual analysis of variance. See Hazel *(4)*.

APPENDIX TABLE 3. REGRESSION COEFFICIENTS FOR EACH VARIATE

Variate	Classification	Coefficient
Year of planting—1936	y_1	.1584235
Year of planting—1937	y_2	.2102858
Year of planting—1938	y_3	.0714285
Year of planting—1939	y_4	.0115775
Year of planting—1940	y_5	.0245495
Year of planting—1941	y_6	−.0069270
Year of planting—1942	y_7	.0144739
Year of planting—1943	y_8	.3900210
Year of planting—1944	y_9	−.3838811
Year of planting—1945	y_{10}	−.0411326
Year of planting—1946	y_{11}	−.4417836
Year of planting—1947	y_{12}	.9044320
Year of planting—1948	y_{13}	−.4979869
Year of planting—1949	y_{14}	−.4134807
Species—slash	s_1	.0903522
Species—loblolly	s_2	.1994053
Species—longleaf	s_3	−.2897576
Age	x_1	−.07832891
Height/age	x_2	.28374621
Number of trees	x_3	−.00546401

APPENDIX TABLE 4. AVERAGE PERCENTAGE, BY AGE GROUP, OF LOBLOLLY PINE HAVING SOUTHERN FUSIFORM RUST INFECTIONS OF INDICATED DEGREE, BASED BOTH ON ALL TREES AND INFECTED TREES

Classification of most limiting infection[1]	Infection percentage by age group					
	5-8 years old (14 plots)		9-12 years old (25 plots)		13-16 years old (8 plots)	
	All trees	Infected trees	All trees	Infected trees	All trees	Infected trees
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Stem infection, No. 1	2.41	4.9	4.36	12.6	4.57	12.4
Stem infection, No. 2	4.73	9.6	3.48	10.1	5.96	16.2
Stem infection, No. 3	1.36	2.8	2.49	7.2	3.09	8.4
Stem infection, total	8.50	17.2	10.33	29.9	13.62	36.9
Limb-stem infection, No. 1	12.52	25.4	8.78	25.4	5.60	15.2
Limb-stem infection, No. 2	7.26	14.7	1.96	5.7	1.73	4.7
Limb-stem infection, No. 3	7.80	15.8	.60	1.7	1.20	3.2
Limb-stem infection, total	27.58	55.9	11.35	32.8	8.54	23.2
Both stem & limb-stem infection, No. 1	14.92	30.2	13.14	38.1	10.18	27.6
Both stem & limb-stem infection, No. 2	11.99	24.3	5.45	15.8	7.69	20.8
Both stem & limb-stem infection, No. 3	9.16	18.6	3.09	9.0	4.29	11.6
Both stem & limb-stem infection, total	36.08	73.1	21.68	62.8	22.16	60.1
Branch infection, less than 18"	8.23	16.7	5.93	17.2	4.79	13.0
Branch infection, more than 18"	5.02	10.2	6.90	20.0	9.92	26.9
Branch infection, total	13.26	26.9	12.83	37.2	14.72	39.9
Total infection, minus branch > 18"	44.31	89.8	27.61	80.0	26.95	73.1
Total infection	49.34	100.0	34.51	100.0	36.88	100.0

[1] Key to meaning of categories:
Stem or limb-stem infection, No. 1—canker occupying < 50 per cent of stem circumference, face not deeply sunken, stem straight at canker.
Stem or limb-stem infection, No. 2—canker occupying > 50 per cent of stem circumference.
Stem or limb-stem infection, No. 3—a canker with a deeply sunken face or at a bend in the stem.

APPENDIX TABLE 5. AVERAGE PERCENTAGE, BY AGE GROUP, OF SLASH PINE HAVING SOUTHERN FUSIFORM RUST INFECTIONS OF INDICATED DEGREE, BASED BOTH ON ALL TREES AND INFECTED TREES

Classification of most limiting infection[1]	Infection percentage by age group					
	5-8 years old (18 plots)		9-12 years old (30 plots)		13-16 years old (22 plots)	
	All trees	Infected trees	All trees	Infected trees	All trees	Infected trees
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Stem infection, No. 1	3.38	6.9	4.07	8.9	4.27	11.6
Stem infection, No. 2	2.32	4.3	3.14	6.8	3.38	9.2
Stem infection, No. 3	3.60	7.4	4.07	8.9	6.18	16.7
Stem infection, total	9.30	19.1	11.28	24.6	13.82	37.6
Limb-stem infection, No. 1	16.52	34.0	12.60	27.5	5.52	15.0
Limb-stem infection, No. 2	9.67	19.9	3.34	7.3	2.32	6.3
Limb-stem infection, No. 3	5.49	11.3	1.93	4.2	1.43	3.9
Limb-stem infection, total	31.67	65.2	17.90	39.1	9.22	25.1
Both stem & limb-stem infection, No. 1	19.88	40.9	16.67	36.4	9.78	26.6
Both stem & limb-stem infection, No. 2	11.99	24.7	6.48	14.1	5.70	15.5
Both stem & limb-stem infection, No. 3	9.08	18.7	6.04	13.2	7.56	20.6
Both stem & limb-stem infection, total	40.98	84.3	29.18	63.7	23.05	62.7
Branch infection, less than 18″	7.00	14.4	10.85	23.7	6.24	17.0
Branch infection, more than 18″	0.63	1.3	5.78	12.6	7.49	20.4
Branch infection, total	7.63	15.7	16.63	36.3	13.74	37.4
Total infection, minus branch > 18″	47.97	98.7	40.04	87.4	29.29	79.6
Total infection	48.60	100.0	45.82	100.0	36.78	100.0

[1] Key to meaning of categories:
Stem or limb-stem infection, No. 1—canker occupying < 50 per cent of stem circumference, face not deeply sunken, stem straight at canker.
Stem or limb-stem infection, No. 2—canker occupying > 50 per cent of stem circumference.
Stem or limb-stem infection, No. 3—a canker with a deeply sunken face or at a bend in the stem.

APPENDIX TABLE 6. AVERAGE PERCENTAGE, BY AGE GROUP, OF LONGLEAF PINE HAVING SOUTHERN FUSIFORM RUST INFECTIONS OF INDICATED DEGREE, BASED BOTH ON ALL TREES AND INFECTED TREES

Classification of most limiting infection[1]	Infection percentage by age group					
	5-8 years old (4 plots)		9-12 years old (22 plots)		13-16 years old (7 plots)	
	All trees	Infected trees	All trees	Infected trees	All trees	Infected trees
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Stem infection, No. 1	1.13	45.9	1.59	8.8	0.97	5.2
Stem infection, No. 2	1.32	54.1	3.52	19.6	2.03	10.8
Stem infection, No. 3	0	0	1.87	10.4	2.91	15.5
Stem infection, total	2.46	100.0	6.98	38.9	5.92	31.6
Limb-stem infection, No. 1	0	0	4.08	22.7	5.94	31.7
Limb-stem infection, No. 2	0	0	0.27	1.5	1.67	8.9
Limb-stem infection, No. 3	0	0	1.09	6.1	0.46	2.4
Limb-stem infection, total	0	0	5.45	30.4	8.07	43.1
Both stem & limb-stem infection, No. 1	1.13	45.9	5.68	31.6	6.91	36.9
Both stem & limb-stem infection, No. 2	1.32	54.1	3.78	21.0	3.70	19.8
Both stem & limb-stem infection, No. 3	0	0	2.96	16.5	3.38	18.0
Both stem & limb-stem infection, total	2.46	100.0	12.43	69.2	13.99	74.7
Branch infection, less than 18″	0	0	5.01	27.9	3.83	20.4
Branch infection, more than 18″	0	0	0.51	2.8	0.91	4.8
Branch infection, total	0	0	5.52	30.8	4.74	25.3
Total infection, minus branch > 18″	2.46	100.0	17.44	97.2	17.82	95.1
Total infection	2.46	100.0	17.95	100.0	18.73	100.0

[1] Key to meaning of categories:
Stem or limb-stem infection, No. 1—canker occupying < 50 per cent of stem circumference, face not deeply sunken, stem straight at canker.
Stem or limb-stem infection, No. 2—canker occupying > 50 per cent of stem circumference.
Stem or limb-stem infection, No. 3—a canker with a deeply sunken face or at a bend in the stem.