1994

Characterizing Fusiform Rust Incidence and Distribution in East Texas

J. David Lenhart
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University

Gary D. Kronrad
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University

A. Gordon Holley
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University

T.G. Gregoire

Characterizing Fusiform Rust Incidence and Distribution in East Texas

J. David Lenhart, *College of Forestry, SFASU, Nacogdoches, TX 75962-6109,* **Timothy G. Gregoire,** *Department of Forestry, VPI&SU, Blacksburg, VA 24061-0324,* **Gary D. Kronrad** *and* **A. Gordon Holley,** *College of Forestry, SFASU, Nacogdoches, TX 75962-6109.*

ABSTRACT. *Three measurement cycles were completed on an extensive network of loblolly* (Pinus taeda *L.*) *pine and slash* (Pinus elliottii *Engelm.*) *pine plots in industrial plantations throughout East Texas in 1984, 1987, and 1990. Because the incidence of fusiform rust caused by* Cronartium quercuum *[Berk.] Miyabe ex Shirai f. sp.* fusiforme *had been recorded at each measurement , it is possible to characterize the temporal and geographic distribution of fusiform rust among these industrial pine plantations in East Texas. Average rust incidence for each species by two year age classes is presented. For loblolly pine, there is no apparent change in overall average incidence between 1987 and 1990 , whereas for slash pine, there is an apparent overall average decline of about 7-8 percentage points. For some slash pine age classes, the incidence decline is 20–30 percentage points. Loblolly and slash pine rust incidence maps depict the geographic distribution of rust infection by plantation age groups in East Texas. South. J. Appl. For. 18(1):29–34.*

Management of loblolly (*Pinus taeda* L.) and slash (*Pinus elliottii* Engelm.) pine plantations in East Texas is affected by the occurrence of fusiform rust (*Cronartium quercuum* [Berk.] Miyabe ex Shirai f. sp. *fusiforme*). Thinnings may need to be scheduled, or rotation ages modified in order to salvage infected stems or utilize stems likely to become infected (Dinus and Schmidt 1977). Also, rust-associated mortality can significantly reduce stocking levels (Shoulders and Nance 1987, Nance et al. 1981, Wells and Dinus 1978), and as a result, planned revenues may not materialize.

Information on fusiform rust incidence in East Texas loblolly and slash pine plantations is available from five surveys made over a 19 yr period from 1969–1987 (Mason and Griffin 1970, Walterscheidt and Van Arsdale 1976, Texas Forest Service 1982, Hunt and Lenhart 1986 and Lenhart et al. 1988). The first three papers presented average rust percentages based on separate surveys, while the last two papers combined the earlier rust incidence data with East Texas Pine Plantation Research Project[1] (ETPPRP) information.

As part of the ETPPRP, a network of 246 permanent plots in loblolly and slash pine plantations has been measured on a 3 yr cycle since 1984. Because these plantations are representative of typical industrial practices with respect to plantation establishment and silviculture methods in the East Texas region, information garnered from their repeated measurement may be useful in the detection and better understanding of geographic and temporal trends in fusiform rust incidence in East Texas. With the completion of the third cycle of plot measurements in 1990, it is timely now to update previously reported information on rust incidence and distribution.

The purpose of this report is to present the collected data in tabular and graphical formats in order to disseminate it to (1) forest managers in the region, who may use it as a basis for silvicultural decisions, and (2) researchers elsewhere in the South, who may benefit from comparative analyses to the pattern of rust incidence in other regions.

Plantation Measurements

Information on the incidence of fusiform rust in planted stands of loblolly and slash pine trees in East Texas was available from the ETPPRP. The ETPPRP was initiated in 1982 by the College of Forestry at Stephen F. Austin State University. ETPPRP data consist of repeated measurements of 246 permanent plots located within loblolly and slash pine plantations throughout East Texas. Measurements are on a 3 yr cycle: 1982–1984, 1985–1987,1988–1990, etc., because it takes 3 yr to measure all plots.

[1] The continuing support of the participating industries—Champion International Corporation, International Paper Company, Louisiana-Pacific Corp. and Temple-Inland Forest Products Corporation—is appreciated.

Each plot is located in a different plantation and consists of two adjacent subplots separated by a 60 ft buffer zone. Latitude and longitude coordinates are known for each plot. One subplot is designated for model development and the other for model evaluation. Data from development subplots were utilized in this study. A subplot is 100 × 100 ft in size, and all planted pines within a subplot are tagged and numbered. Seed source information is not available for the research plots. Typical site preparation methods for establishing the plantations in which ETPPRP plots are located involved various combinations of shearing, pushing down, piling and/or chopping, plus burning.

At each measurement cycle, among other tree attributes, each planted pine was examined for fusiform rust and recorded as having an infected stem if a gall occurred on a stem or on a live branch within 12 in. of the stem. ETPPRP field crews were able to reliably tabulate galls occurring on trees in plantations 5 yr or older. Thus, for both species, rust incidence analyses were limited to data from plantations 5 yr or older. For each measurement cycle, stem rust incidence was calculated for each plot as the proportion of living trees with stem galls, irrespective of branch galls.

A characterization of ETPPRP plots as of the third measurement cycle is listed in Table 1. For both species, the majority of plots are 10 yr old or less with an average age of about 11 yr. Average surviving trees per acre are listed by plantation age. In general, trees per acre values are relatively low, with the overall average number of trees per acre calculated as 476 and 388 for loblolly and slash pine, respectively. Average site index (base age 25 yr) was 73 ft for loblolly and 69 ft for slash pine.

Table 1. East Texas Pine Plantation Research plots characterized by species, age, and average trees per acre, as of the 1990 measurement cycle.

Plantation age (yr)	Number of plots		Ave. trees/ac	
	Loblolly	Slash	Loblolly	Slash
5	1	—	566	—
6	11	3	624	541
7	22	9	576	530
8	24	12	505	469
9	25	12	463	493
10	22	3	387	279
11	5	9	354	308
12	3	9	429	286
13	13	6	407	141
14	11	—	488	—
15	6	1	465	924
16	7	3	366	232
17	11	1	499	247
18	4	4	476	368
19	1	—	395	—
20	2	3	514	278
21	2	1	342	334
Totals	170	76		

Rust Incidence

Average incidence of stem infection observed in the ETPPRP plots by species, age classes, and measurement cycles is presented in Table 2. At the bottom of Table 2, averages across all age classes are listed for all plots, and for the subset of plots (65 loblolly, 33 slash) that have been tabulated on all three measurement cycles. Not all plots were measured three times due to ages less than 5 yr or inadvertent plot destruction.

Loblolly Pine Rust Incidence

The average incidence of rust within the loblolly pine plots at 1984, 1987, and 1990 measurement cycles was fairly stable overall and within the various age classes (Table 2). Comparison of rust incidence within age classes across the three measurement cycles in Table 2 indicates that as different loblolly pine plots entered and departed a specific age class at each measurement cycle, rust incidence was relatively constant. This implies that as loblolly pine trees in different plots attain a common age level at various points in time, the incidence of rust is relatively unchanged.

Also, it appears that the 1990 rust incidence in an age class is very close to the 1987 incidence of the preceding age class (Table 2). This suggests that for a given set of plots, the incidence of rust has not changed noticeably over the past few years. Examination of individual plot rust histories indicated variability, but the general sense of the trend lines indicated slight increases in rust incidence between 1984 and 1990 measurements, which may reflect a relatively low mortality rate for infected trees coupled with fewer trees becoming infected.

Slash Pine Rust Incidence

On the average, there has been considerably greater incidence of rust and more fluctuation between measurement cycles for slash pine than for loblolly pine (Table 2). Examination of individual age classes indicates that as time passes, rust incidence is not stable. From measurement cycle to measurement cycle, as different slash pine plots entered and departed specific age classes, rust incidence increased and then decreased. The typical situation for a given age class is an eventual reduction in rust incidence in a slash pine plot

To investigate these average changes in rust incidence over time, individual plot rust histories across three successive measurement cycles were studied. From the 1984 measurement cycle to the 1987 measurement cycle, rust incidence increased for almost every plot. However, from the 1987 to 1990 cycles, rust incidence tended to decrease. The rust incidence decrease may have been caused by infected trees dying at a faster rate than uninfected trees, and/or fewer trees becoming infected.

Rust Incidence Trends in a Data Subset

As mentioned earlier, average incidence values are shown in the lower part of Table 2 for that subset of ETPPRP plots that were in plantations at least 5 yr old during the 1984 measurement cycle, and, as a result, have each been measured on three occasions. For the 65 loblolly pine plots in this

Table 2. Average incidence of fusiform rust stem galls[a] in East Texas Pine Plantation Research plots at each measurement cycle by species and age classes.

Age class (yr)	Loblolly			Slash		
	1984	1987	1990	1984	1987	1990
			(%)			
5 – 6	4	7	3	32	29	21
7 – 8	7	13	6	53	47	27
9 – 10	6	12	3	54	62	34
11 – 12	10	13	12	31	63	48
13 – 14	10	10	15	63	62	64
15 – 16	6	17	8	40	65	58
17 – 18	19	10	11	—	70	50
19 – 20	—	25	10	—	—	63
21 – 22	—	—	10	—	—	58
All	7	10	10	46	48	41
All[b]	6	12	12	42	60	52

[a] May or may not also have rust-infected branches.
[b] Percentages based on subset of plots (65 loblolly, 33 slash) that have been measured on all three occasions.
NOTE: These are plots in plantations that were at least 5 yr old in 1984.

subset, the average rust values are close to the averages computed from all available plots, and indeed are probably not different by an amount that can be meaningfully attributed to a cause other than sampling variation. However, for the 33 slash pine plots in this subset, the differences are large enough to suspect that sampling variation is not the only causal agent. Evidently as the younger plantations attain the minimum age threshold of 5 yr, and enter the slash pine data set, they have substantially lower incidences than the older plots.

Comments on Analyzing Rust Distribution and Variation

The averages shown in Table 2 may give an unwarranted impression of stability and precision within age classes at the different measurement occasions. In fact, there is substantial variation in rust incidence values among plots by age classes. For example, individual rust incidence percentages calculated in 1990 for each of the 170 loblolly and 76 slash pine plots are shown in Figure 1. Within an age class, for either species, rust incidence is wide-ranging. The precision of an average value is usually expressed by an estimate of standard error. In the present case, the usual estimate of standard error, which is based upon the observed variation of incidence values among plots, is not a statistically valid measure of precision.[2] The incidence proportions can be modeled in a manner that permits statistical comparisons to be made;

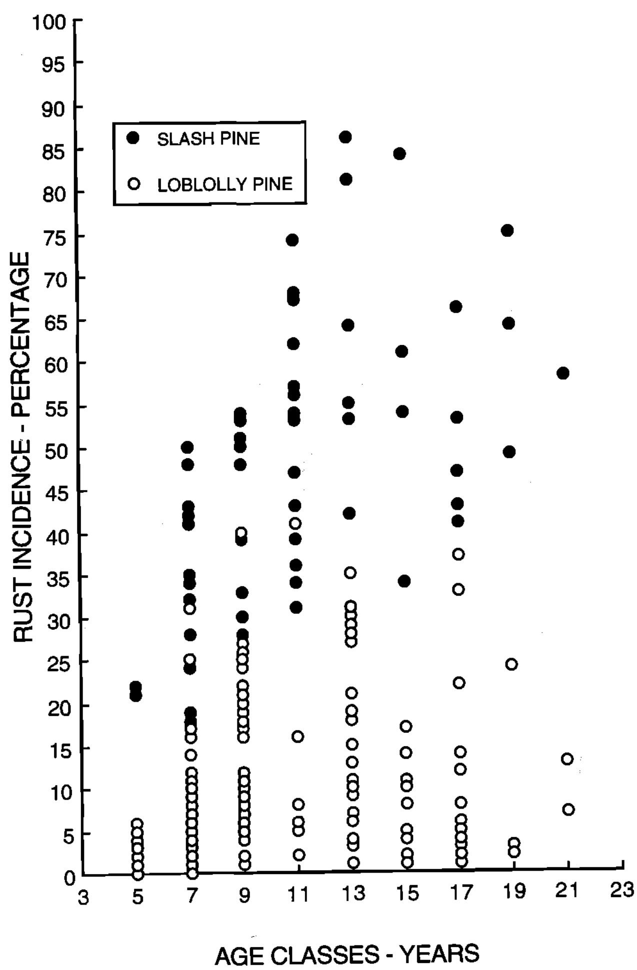


Figure 1. Distribution of rust incidence as of 1990 for individual East Texas Pine Plantation Research Project plots by age classes.

[2] An observed proportion of infected trees on a plot is subject to extrabinomial variation, due to correlation among trees on a plot. Furthermore, and owing to the varying numbers of trees among plots, each observed proportion will have a different distribution. Lastly, it is likely that distributional differences arise due to age differences among plots. To compare incidences between two age classes in different measurement cycles, a further complication may arise when the same plot contributes to two average incidence values that are compared.

outside of forestry, the beta-binomial distribution has been used frequently for this purpose. However, the relatively complicated statistical analyses that are required are beyond the scope of this paper.

Rust Incidence Maps

As stated earlier, our intention here is to present the currently available data in an informative and useful fashion for the benefit of managers and scientists. Another procedure for illustrating rust incidence is through the creation of maps showing the geographic distribution of fusiform rust across a region. In 1974 and 1976, maps with isograms showing the geographic distribution of fusiform rust throughout the south were developed (Phelps 1974, 1977, Squillace 1976, Squillace and Wilhite 1977). These analyses were the first Southwide examination since a survey in 1938–1939 (Lamb and Sleeth 1940). Based on the maps in Squillace and Wilhite (1977), rust hazard rating maps were developed showing the probability of various infection levels occurring within rust hazard zones (Anderson et al. 1986). Isograms showing contours of fusiform rust incidence in loblolly pine plantations in Virginia, North Carolina, South Carolina, and Georgia, and slash pine plantations in Georgia and Florida were developed in 1988 by Anderson et al. (1988). After independent checks and reviews, the isograms were converted into fusiform-rust-hazard zone maps.

The Southwide fusiform rust isograms developed in the 1970s extended from the Atlantic Ocean across the South to the Texas border but not into East Texas. However, the three earlier surveys in East Texas did attempt to depict average rust levels by six broad geographic regions (Mason and Griffin 1970) and average rust incidence by several locations within certain counties (Walterscheidt and Van Arsdel 1976, Texas Forest Service 1982). Preliminary maps approximating the fusiform rust hazard for planted and natural loblolly and slash pines in the south have been developed by the USDA Forest Service as part of the National Forest Health Monitoring program.[3] The slash pine map does not extend into East Texas, but the loblolly pine map includes the East Texas region and indicates "hot spots" of rust incidence in the north, southwest and southeast regions of East Texas.

Rust incidence maps can assist land managers in determining the need to use rust-resistant nursery stock and the timing of silvicultural practices for maximizing utilization of the stand (Phelps 1977). For each species, the stem rust incidence for each plot from the three ETPPRP measurement cycles was combined and sorted by age. Age classes of 5-6, 9-10 and 13-14 were selected as representative of the data set.

The stem gall frequency plus latitude and longitude coordinates for each plot within each of the three age data sets for each species were analyzed using the Contour plot program within SYGRAPH (Wilkinson 1989). A distance weighted least squares smoothing procedure in the Contour plot program was used to draw isograms. To better understand the geographic/age distribution of average stem gall incidence across East Texas, each isogram was converted into an incidence level map by selective use of fill patterns and overlayed on an East Texas county outline map to produce the final set of maps.

Each map indicates areas of expected rust incidence levels. An individual plantation within a map area may have a percentage of infected trees quite different from the level expected within that map area. Unfortunately, it was impossible to estimate probabilities of infection values for individual plantations within a map area, because latitude and longitude coordinates for the map contour lines were not known. The ETPPRP plots could not be stratified by map areas. Nonetheless, the maps do present the incidence of rust in general terms (Anderson 1988).

Loblolly Pine Rust Incidence Maps

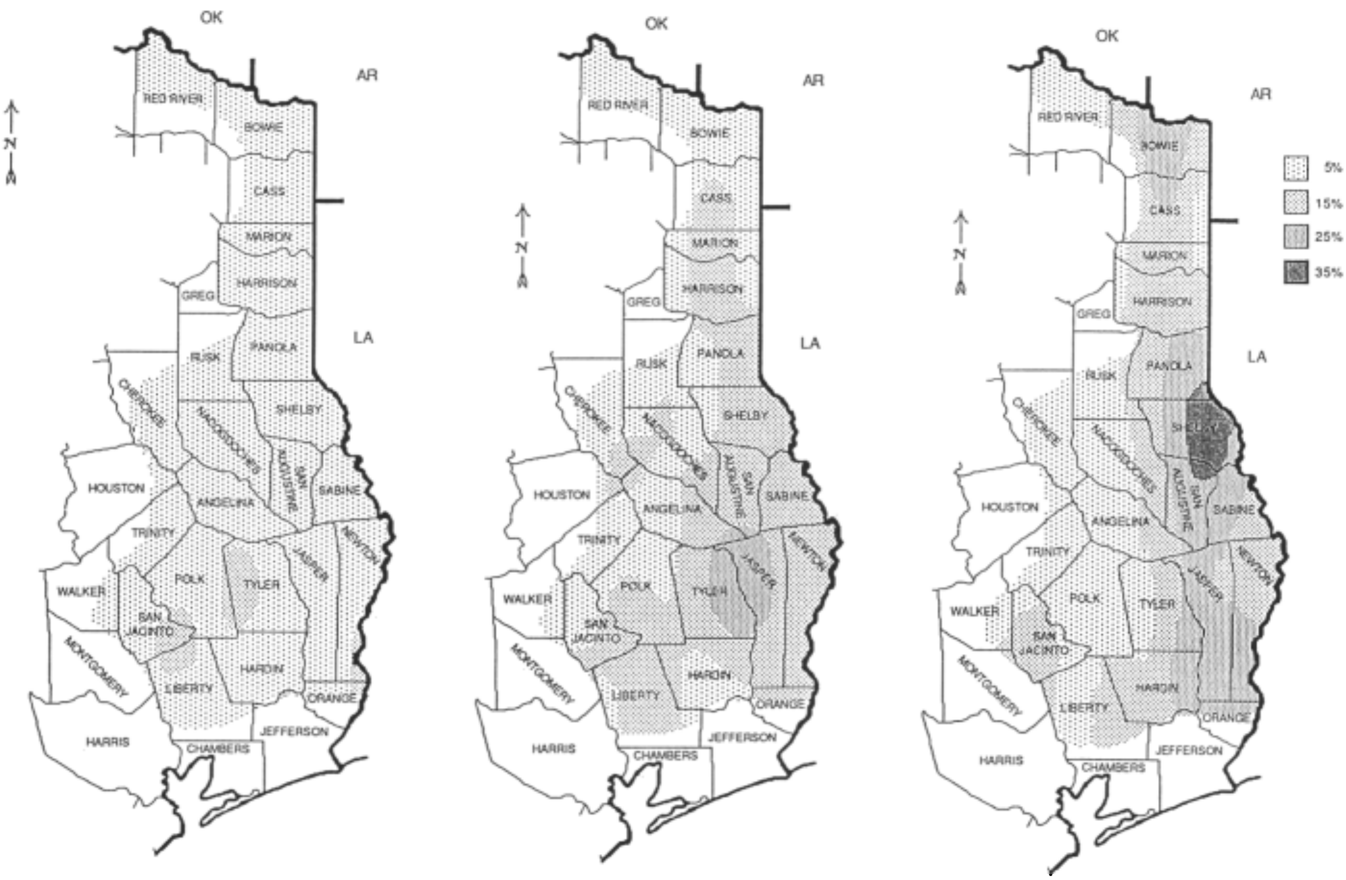
The occurrence of stem galls in 5- to 6-year-old loblolly pine plantations throughout East Texas is expected to be about 5%, except for two areas, where rust incidence averages about 15% (Figure 2). However, in the 9–10 yr age class, expected rust incidence of 15% has increased, while the 5% area has decreased in size. A 25% "hot spot" has surfaced in Tyler and Jasper counties. By age 13–14, when plantations may be approaching initial thinnings, rust incidence is expected to be 15% and 25% on north-south strips of the far eastern part of East Texas. There is a 35% "hot spot" in Shelby county.

Geographic rust incidence information might be helpful in deciding where to establish loblolly pine plantations, and then, determining the timing of intermediate and final harvests. For example, owners of loblolly pine plantations 12 yr or younger within the 25% incidence map area might consider management strategies that will minimize anticipated future financial losses and downgrading of their growing stock (Dinus and Schmidt 1977). Specifically, a forest manager contemplating establishing loblolly pine plantations in Shelby county might want to use rust-resistant loblolly stock. It is interesting that these loblolly pine rust incidence maps based on the ETPPRP plots indicate relatively low rust incidence along the western edge of the East Texas region.

Slash Pine Rust Incidence Maps

Figure 3 shows areas of expected rust incidence for three slash pine age classes. Five- to six-year-old slash pine plantations located in the center of southeast Texas are expected to have 30% rust incidence. Within and around this area, there are pockets of expected 10% levels and areas of expected 50% rust incidence. Most 9- to 10-yr-old slash pine plantations are expected to have rust incidences of 50% or more. However, in Polk county, a typical 9- to 10-yr-old slash pine plantation may have galls on 70–90% of the stems. Owners of young slash pine plantations in this county may see a noticeable increase in infection levels as their 5- to 6-yr-old plantations grow to 9- and 10-yr-old plantations. There may be financial losses incurred by these landowners due to possible product downgrading. Elsewhere in the region for the 9- to 10-yr-old plantations, expected stem gall incidence has increased relative to the 5- to 6-yr-old plantations, except for the northern edge and the southeastern corner of the region.

[3] Pers. comm., Starkey, D.A., USDA Forest Service, South. For. Exp. Stn., Pineville, LA, 1991.



5-6 YEARS 9-10 YEARS 13-14 YEARS

Figure 2. Geographic trends of expected fusiform rust incidence in loblolly pine plantations by three age classes in East Texas.

By age 13–14, rust incidence areas appear as a saddle pattern. In this age group, rust incidence is averaging 50% or more with highest values at the northeast and southwest corners of the region. For example, by this age, a slash pine plantation in Hardin county is expected to have stem galls on 90% of the standing trees. As existing slash pine plantations are harvested in this area, it may be advantageous to consider re-establishment with a different species or rust-resistant slash pine.

Forest managers with young slash pine plantations in southeast Texas might decide to implement silvicultural practices to slow the increase of rust or even convert the plantations to another more rust-resistant species (Dinus and Schmidt 1977). If future intermediate or final harvests of the slash pine plantations were intended to provide wood for utilization into lumber or plywood, intensive silvicultural measures may be necessary. Otherwise, unplanned wood shortfalls may occur. Figures 2 and 3 can provide information to assist forest managers in planning which pine species to plant and where to plant the trees. The rust incidence maps coupled with the overall rust incidence information can assist East Texas forest landowners to make correct silvicultural and financial decisions concerning their loblolly and slash pine plantations in East Texas.

Literature Cited

ANDERSON, R.L., N.D. COST, J.P. MCCLURE, and G. RYAN. 1986. Predicting severity of fusiform rust in young loblolly and slash pine stands in Florida, Georgia, and the Carolinas. South. J. Appl. For. 10(1):38–41.

ANDERSON, R.L., T.C. MCCARTNEY, N.D. COST, H. DEVINE, and M. BOTKIN. 1988. Fusiform-rust-hazard maps for loblolly and slash pines. USDA For. Serv. Res. Note SE-351. 7 p.

DINUS, R.J., and R.A. SCHMIDT, eds. 1977. Management of fusiform rust in southern pines. Symp. Proc. Univ. Fla., Gainesville. 163 p.

HUNT, E.V., JR., and J.D. LENHART. 1986. Fusiform rust trends in East Texas. South. J. Appl. For. 10(4):215–216.

LAMB, H., and B. SLEETH. 1940. Distribution and suggested control measures for the southern pine fusiform rust. USDA South. For. Exp. Stn. Occas. Pap. No. 91. 4 p.

LENHART, J.D., W.T. MCGRATH, and T.L. HACKETT. 1988. Fusiform rust trends in East Texas: 1969-1987. South. J. Appl. For. 12(4):259–261.

MASON, G.N., and J.K. GRIFFIN. 1970. Evaluating the severity of fusiform rust in East Texas pine plantations. For. Farm. 29:8–9.

NANCE, W.L., R.C. FROELICH, and E. SHOULDERS. 1981. Effects of fusiform rust on survival and structure of Mississippi and Louisiana slash pine plantations. USDA For. Serv. Res. Pap. SO-172. 11 p.

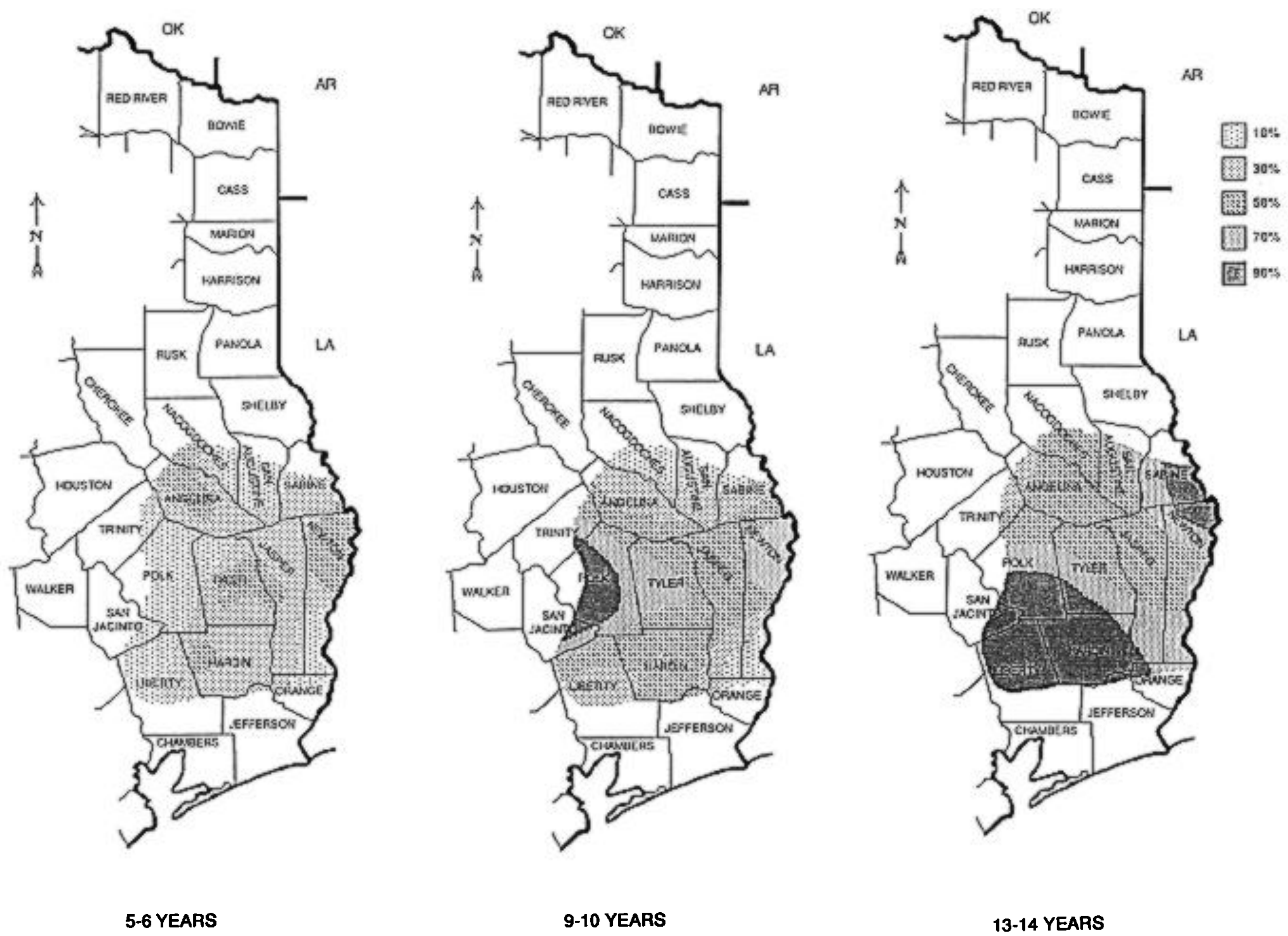


Figure 3. Geographic trends of expected fusiform rust incidence in slash pine plantations by three age classes in East Texas.

Phelps, W.R. 1974. Evaluation of fusiform rust incidence on loblolly and slash pine in the south. Plant Dis. Rep. 58(12):1137–1141.

Phelps, W.R. 1977. Incidence and distribution of fusiform rust. P. 25–31 *in* Management of fusiform rust in southern pines, Dinus, R.J., and R.A. Schmidt (eds.). Symp. Proc. Univ. Fla., Gainesville. 163 p.

Shoulders, E., and W.L. Nance. 1987. Effects of fusiform rust on survival and structure of Mississippi and Louisiana loblolly pine plantations. USDA For. Serv. Res. Pap. SO-232. 11 p.

Squillace, A.E. 1976. Geographic patterns of fusiform rust infection in loblolly and slash pine plantations. USDA For. Serv. Res. Note SE-232. 4 p.

Squillace, A.E., and L.P. Wilhite. 1977. Influence of oak abundance and distribution on fusiform rust. P. 59–69 *in* Management of fusiform rust in southern pines, Dinus, R.J., and R.A. Schmidt (eds.). Symp. Proc. Univ Fla., Gainesville. 163 p.

Texas Forest Service. 1982. Texas forest pest activity 1980-1981 and Forest Pest Control Section Biennial Report. Publ. 127. 39 p.

Walterscheidt, J.J., and E.P. Van Arsdale. 1976. Distribution of fusiform rust on slash and loblolly pines in Texas. Plant Dis. Rep. 60:718–720.

Wells, O.O., and R.J. Dinus. 1978. Early infection as a predictor of mortality associated with fusiform rust of southern pines. J. For. 77:8–12.

Wilkinson, L. 1989. SYGRAPH: The system for graphics. Systat, Inc, Evanston, IL. 600 p.