FIELD PERFORMANCE OF SLASH PINE FROM FUSIFORM RUST-RESISTANT FAMILIES

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Abstract.--Six families of putatively fusiform-rust resistant slash pine (*Pinus elliottii* Engelm. var. *elliottii*) were planted in four consecutive years at three locations in south Mississippi, and fusiform rust infections were documented according to the calendar year in which they occurred. Each of 24 plots contained 80 trees--13 or 14 established trees of each family in a completely random arrangement. Rankings of the six families tested were highly variable in different trials that separated infection by year of occurrence. Every family ranked well in some trials and poorly in other trials. Much of the variation was apparently due to the low number of trees for computing percentage with infection, but there was some evidence to confirm that relative family performance was probably influenced by the local (plot) environment as well as by differences in the environment among locations. Although there were considerable variations in relative family performance among trials, three or four families performed relatively well with respect to rust infection in a majority of the trials at all locations while two families usually did poorly. Replicating experiments over time on individual locations and separating infection by year of occurrence provides added dimension to field experiments that evaluate relative performance of pine families to fusiform rust.

Keywords: *Cronartium quercuum* f. sp. *fusiforme*, family plots, *Pinus elliottii*, rust-resistance

INTRODUCTION

When families of pine bred for resistance to fusiform rust caused by the fungus *Cronartium quercuum* f. sp. *fusiforme* are planted at different locations, there often seems to be considerable variation in relative rust infection among locations. Some of this variation may be due to differences in the male parent since test materials are usually open pollinated, and seed collections may be made in different years or in different orchards developed from common ortets. But even when plantings are derived from common seed lots there still seems to be considerable variation in relative performance among locations (Goddard and Schmidt 1979, Wells and Wakeley 1966). My purpose in this paper is to examine variations in infection that occurred when common seed lots of six putatively rust-resistant slash pine (*Pinus elliottii* Engelm. var. *elliottii*) families were planted in four consecutive years at three

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locations in south Mississippi and examined for infection occurring in consecutive growing seasons.

METHODS

The data for studying variation in fusiform rust infection were available from a large study in south Mississippi (Froelich, 1988) to evaluate effects of fusiform rust on growth and yield of slash pine and loblolly pine (P. *taeda* L.). Rust infection of susceptible seed lots of slash and loblolly pine, and resistant loblolly pine is given in Froelich (in press). The current study focuses on twenty-four 80-tree plots of putatively rust-resistant slash pine (three locations in Harrison or Hancock counties x four consecutive annual plantings at each location x two replications per year in each annual planting). The rust infection data for the 24 plots are unique in several respects:

(1) The four consecutive annual plantings at each location were developed from common seed lots.

(2) Each plot of 80 trees contained six putatively resistant families (six seed lots), which were randomly planted instead of planted in row plots.

(3) All galls were tallied and year of gall origin was identified, making it possible to compute percent infection by calendar year of occurrence.

The six families were provided by forest industries who considered them to have high degrees of resistance to fusiform rust. The seed lots were obtained from wind-pollinated trees in an orchard developed for resistance. Previous seed collections from these families apparently had developed less rust in field and greenhouse trials. In this study, however, the six families collectively developed only slightly less rust than a seed lot obtained from an orchard that had not been developed for resistance to rust.

Uniform establishment density of 80 trees per plot was ensured by hand planting two trees about 6 inches apart (6-ft x 10-ft intervals) and removing one when necessary at the beginning of the second growing season. Subsequent mortality, almost all rust-related, reduced numbers of trees available for computing percentage of infection, but the number of trees usually exceeded 10 trees of each family per plot even after the fifth growing season. This low number of 10 to 13 trees per plot will be shown to be marginal for estimating family performance. Percentage of infection was computed as the number of trees that developed one or more galls (branch gall or stem gall) in a specified growing season divided by the number of trees living at the end of the growing season. Data from only the two most heavily rust-infected plantings are given in this report. These 2 plantings were about 13 miles apart and the 16 plots of putatively resistant slash pines were of similar site quality; average heights of dominant and co-dominant trees ranged from about 21 to 25 feet per plot at age seven. Annual infection in plots at the third location rarely exceeded 30%, but the data from this location supported the conclusions derived from the two other plantings.

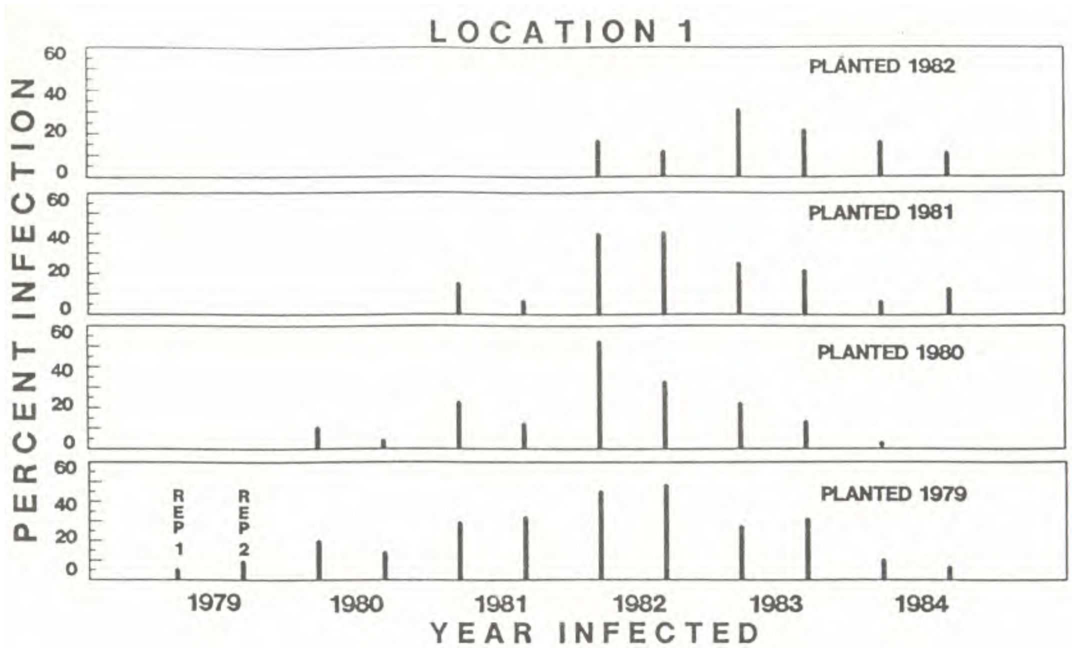

Figure la. Consecutive annual fusiform rust infection in 8, 80-tree plots of putatively rust-resistant slash pine (four planting years x two replication plots per planting year) at Location 1. Pairs of bars indicate Replications 1 and 2.

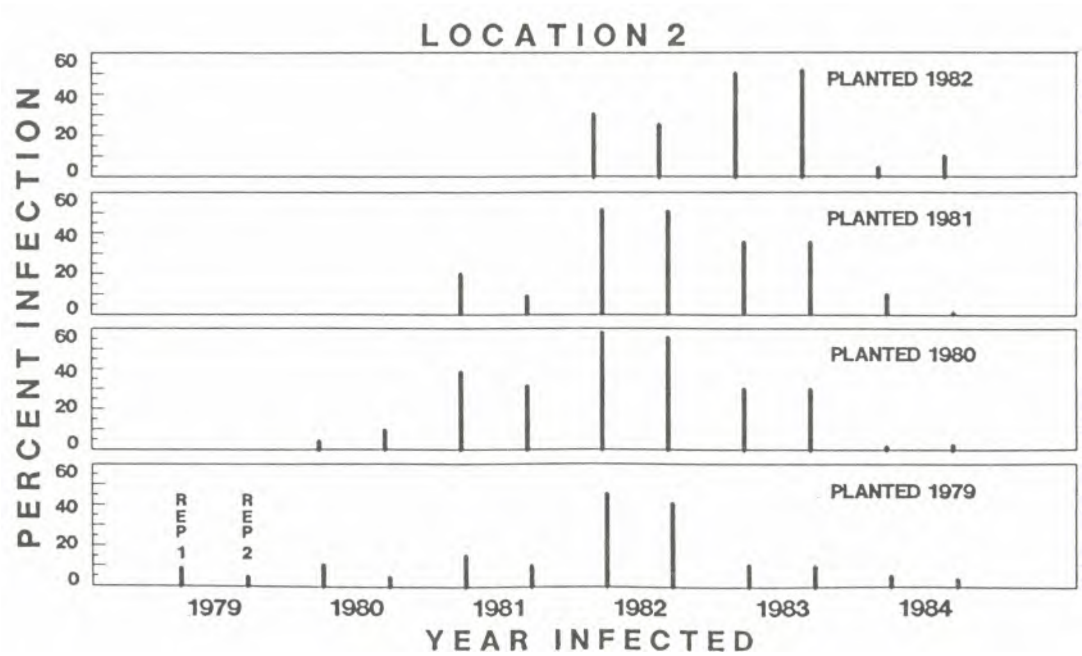

Figure lb. Consecutive annual fusiform rust infection in 8, 80-tree plots of putatively rust-resistant slash pine (four planting years x two replication plots per planting year) at Location 2. Pairs of bars indicate Replications 1 and 2.

RESULTS

Variation in Rust Infection Among 80-Tree Plots.

Variation in annual rust infection in the two plantations developing the most rust is shown in Figures la and lb. These combined data for all six families show that the largest variation in infection between identical 80-tree plots (replications) was 20% (Location 1, year planted = 1980, year infected = 1982). These two plots were located about 150 feet apart. The largest variation in annual infection noted among replications of putatively nonresistant slash pine (not shown in this report) was 24% (range of 16 to 40% among four identical plots). However, the usual variation in infection between replications was less than 10% in both resistant and nonresistant slash pine.

Combined family data indicated considerable variation in infection from year to year in individual plots. In most plots the peak year for infection was 1982. However, in four plots established in 1982 (two each in Locations 1 and 2), most infection occurred in 1983 (Figures 2a, 2b).

All the 80-tree family plot data also showed that infection varied by age class. In general, very little infection developed in the first growing season; this may be the reason why infection was greater in 1983 than in 1982 in some plots. A maximum of 25 to 30% infection was noted in the first growing season (planted and infected in 1982) at Location 2 (Figure lb). This was about one-half the infection noted in 1982 for trees that had been planted one year earlier and were in their second season of growth in 1982. After the first growing season, age-class-related patterns of infection could be observed. For example, in 1983 (Location 2), about 50% infection developed in the second-year age class. The third- and fourth-year age classes ranged from 30 to 35% infection and in the fifth-year age class only 10% infection was observed. Similar age-class-related patterns were not observed in 1983 at Location 1. However, the collective evidence from both resistant and nonresistant plots of slash pine in three locations indicated that probabilities for slash pine infection decreased dramatically after about the fourth or fifth growing seasons.

Performance of Individual Slash Pine Families.

The individual family breakdown of 80-tree plot infection data is shown in Figures 2a and 2b. These data include only the infection years for which at least one family developed 40% or more infection in one of the two replication plots. There is considerable variation in relative rust infection among 34 trials--14 trials at Location 1 (Figure 2a) and 20 trials at Location 2 (Figure 2b)[2]. Every family can be found at the top or bottom of the infection scale in at least one trial. Much of this variation is apparently related to inadequate sample size for computing percentage of infection. Still, several observations merit consideration. Families 1 and 3, for example, commonly

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[2]Each trial shows rust infection by plot and family for individual calendar years.

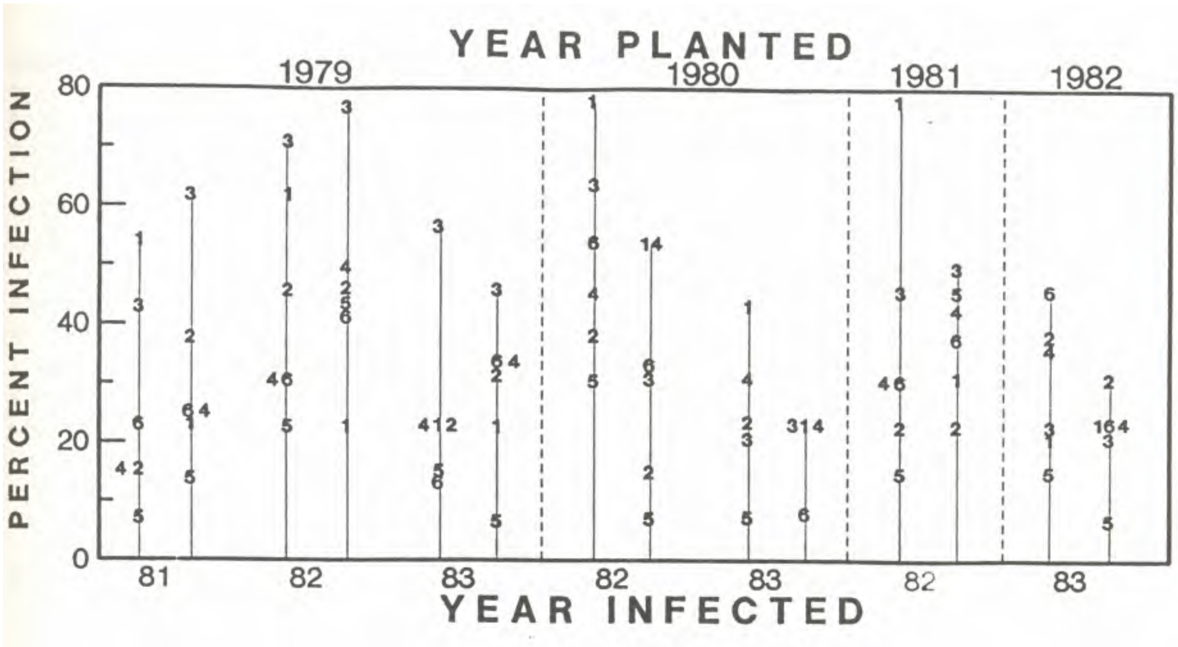

Figure 2a. Annual fusiform rust infection of six putatively rust-resistant families of slash pine at Location 1. Numbers are family identification. Missing data are zero. Pairs of bars indicate Replications 1 and 2.

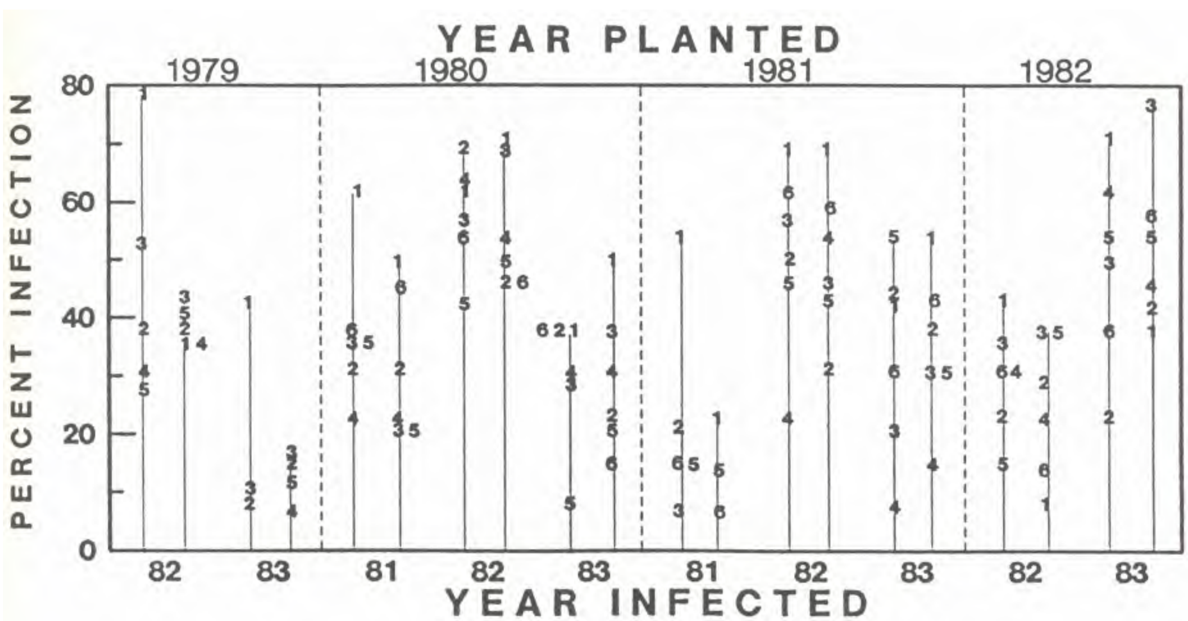

Figure 2b. Annual fusiform rust infection of six putatively rust-resistant families of slash pine at Location 2. Numbers are family identification. Missing data are zero except for family 6 which survived poorly in the 1979 planting and is not presented. Pairs of bars indicate Replications 1 and 2.

developed the most infection. What may be of most importance is that neither of these two apparently most susceptible families occurs at the bottom of the infection range in both replications of the individual trial pairs. Similarly, the four most resistant families seldom occur at the top of the infection range in both replications of trial pairs. With sufficient replication, therefore, it still appears possible to determine relative performance even when sample size is minimal and relative rankings are highly variable among trials.

Although statistical analysis did not seem appropriate because of the marginal sample of trees, several observations may be important relative to possibilities of family x location interactions. To illustrate, in the 1979 planting at Location 1 (Figure 2a), Family 3 developed more rust than Family 1 in five of six trials (exception Replication 1, 1981); the differences in percentage of infection between the two families were quite large in four of the trials. In the 1980 plantings at Location 2 (Figure 2b), however, the pattern was reversed; there was more infection from year to year in Family 1 in all six trials. Another interesting comparison is the 1983 infection of Families 1, 2, and 3 in the 1982 planting at Location 1. Families 1 and 3 developed intermediate levels of infection in both replications; while Family 2, usually with very light infection, developed relatively high infection in both replications.

A final observation suggesting possibility of family x location interaction is that Family 5 emerges clearly as most resistant in Location 1; it was at or near the bottom of the infection range in virtually every trial. At Location 2, however, this family occupied an intermediate position on the infection scale in half of the trials.

Although cumulative infection data are not given, many of the same observations or impressions would have been obtained if only these data had been available. For example, relative cumulative infection of families was just as variable as was the annual infection data. Families 1 and 3 frequently developed the most cumulative infection and Family 5 developed relatively lower infection at Location 1 than at Location 2. The main advantage of separating infection by year of occurrence, therefore, seems to be the added information it gives to field experiments.

DISCUSSION

Although sample size (number of trees of each family per plot and number of replications per annual planting) was too small to permit definite conclusions, there was fairly strong circumstantial evidence to indicate that relative rust infection of six slash pine families was affected by variations in environmental conditions within and between plantings. From the variations in infection observed in various plantings, it is easy to visualize that significant location x family interactions are likely to occur in some field experiments. However, by replicating plantings in time with the same seed lots on each site, and documenting infection by annual year of occurrence, the various interactions seemed to take on questionable practical significance as suggested by Goddard and Schmidt (1979). Specifically, there was no overwhelming consistency to the interactions: one family may have been more suggested by Goddard and Schmidt (1979). Specifically, there was no overwhelming consistency to the interactions: one family may have been more heavily infected from year to year in plantings established In one calendar year, but in plantings established in another year on the same site, that same family may have developed relatively less infection in consecutive growing seasons.

More comprehensive testing would be needed to determine whether location x family interactions are an important biological phenomenon to be given serious consideration by tree breeders, or are more of an artifact associated with inadequate study design, lack of replication, or insufficient numbers of trees of each family per plot. Future field testing might take into account the following suggestions:

(1) Studies of relative family performance in field trials would be more definitive if they were replicated in time on sites high in hazard to fusiform rust, using trees derived from the same seed lots in all consecutive plantings;

(2) Large plots should be considered for evaluating family performance and all families should be randomly located (a scattered arrangement rather than a pure plot arrangement) within each plot to help ensure that family performance is not confounded by variations in the local environment. Experiment size and plot size would be governed by number of families to be evaluated, but there probably should be a minimum of perhaps 30 established trees of each family per plot; and

(3) Infection data could be recorded by year of occurrence for about the first five growing seasons instead of as cumulative infection. Some added costs are involved in obtaining these data, however, because annual height measurements are essential for accurately classifying infection by year of occurrence.

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