COMPARATIVE PERFORMANCES OF SLASH PINE FOR FUSIFORM RUST RESISTANCE IN HIGH RUST HAZARD LOCATIONS

S. I. Sohn, R. E. Goddard and R. A. Schmidt[1/]

Abstract.--Rust infection of open-pollinated slash pine families, planted at four sites over two years, differed significantly among geographic origins and families. The year and site differences were even greater. Rank correlations of family infections among sites planted in the same year were good but those between the same sites in different years were poor. Correlation between sites was higher with moderately high infection levels at both sites than when there were large differences in average infection percent. Some families showed consistent rust resistance in all plantings while others were highly variable.

Additional keywords: Pinus elliottii, Cronartium fusiforme, geographic variation.

Southern fusiform rust caused by Cronartium fusiforme Hedge and Hunt ex Cumm. is the most serious disease of slash pine (Pinus elliottii var. elliottii) and there are indications (Schmidt et al., 1973) that the average infection rate is increasing in north Florida and Georgia annually. Thus, rust resistance is a trait of critical importance to genetic improvement of slash pine.

Field resistance is essential in the selection of slash pine clones for inclusion in seed orchards for production of rust resistant planting stock. To provide a broad base of data on relative resistance of clones in the Florida Cooperative Program, four geographically diverse test sites were selected on the basis of high fusiform rust incidence in nearby pine plantations. The four sites are located in Escambia County, Alabama, Taylor County, Florida, Webster County and Bulloch County, Georgia (Fig. 1). Starting in 1971, the plan was to plant progenies of all clones in the Florida Cooperative Program at each location at least one time. Annual plantings have been continued at these locations. In this paper, fusiform rust incidence data of 134 slash pine families from the 1971 and 1972 plantings are reported.

MATERIALS AND METHODS

Open-pollinated progenies of slash pine clones established in each location were planted in ten-tree row plots. Spacing was 0.6 m (2 ft) within rows 2.4 m (8 ft) apart. Randomized plots of each family were planted in each of three blocks per location. The 1972 plantings were adjacent to but not randomized

[1/] Graduate Assistant, Associate Professor of Forest Genetics and Associate Professor of Forest Pathology, School of Forest Resources and Conservation, Institute of Food and Agricultural Sciences, University of Florida, Gainesville 32611.

within the 1971 plantings. Although more than 300 families were planted in the two years at the four locations, the design is not balanced. Relatively few families were repeated at the same location both years, but a greater number of families was planted at the several locations during a single year.

Rust infection was assessed in January, 1974 and January, 1975, three years after planting in each case except for the Escambia County, Alabama, site. Because of low infection rates at this site, data for the 1971 planting were recorded after four years and the 1972 planting was not examined in detail. Data were recorded as percent rust per plot. This percentage was based on the number of trees with at least one rust gall expressed as a proportion of the total number of surviving trees in the plot.

Data analysis.--Although the primary objective of these plantings was to determine relative rust resistance of individual families, geographic origins of many parental ortets could be grouped into seven rather discrete areas (Fig. 1). For geographic locations (two or more adjacent counties) represented by five or more families, least squares analysis of variance was computed to partition the effect of geographic origin. Families from the several areas were assumed representative of the native slash pine population of the area in relative resistance to fusiform rust. Effects of the planting locations, year of establishment and several interaction terms were also tested by the least squares analysis of variance method.

Determination of the interactions of families with planting locations and year were accomplished by three separate analyses. The four locations planted in 1971 were compared on the basis of data from sixty-six families commonly represented at all sites. A second group of fifty-four families was used for comparison of three locations planted in 1972. Finally, a separate analysis was run with fourteen families planted at all locations both years. To indicate consistency of relative infection levels of families included in the various analyses, or conversely, the degree of family x environmental interaction, rank correlation tests were applied for each group based on the average infection value of the families at each location and year.

RESULTS

Rust infection differed significantly among the geographic origins represented as well as among families within geographic origin (Table 1). Families from the vicinity of Emanuel County, Georgia and Taylor County, Florida, tended to have the least infection. Families from Baker and St. Johns County, Florida, tended to have the most infection (Table 2).

Infection rates were highly variable among planting locations and years (Fig. 2). However, for most plantings the frequency of families by infection classes appear to fit a normal distribution pattern (Fig. 3). The exceptions were with very high average infection in the 1971 Webster County planting and the low infection at Bulloch County in the 1972 planting.

Significant interactions were observed for geographic origin x planting location, and particularly for family within origin x location for each establishment year. However, rank correlation analyses of family infections in all possible sets of two locations within a given year were significant

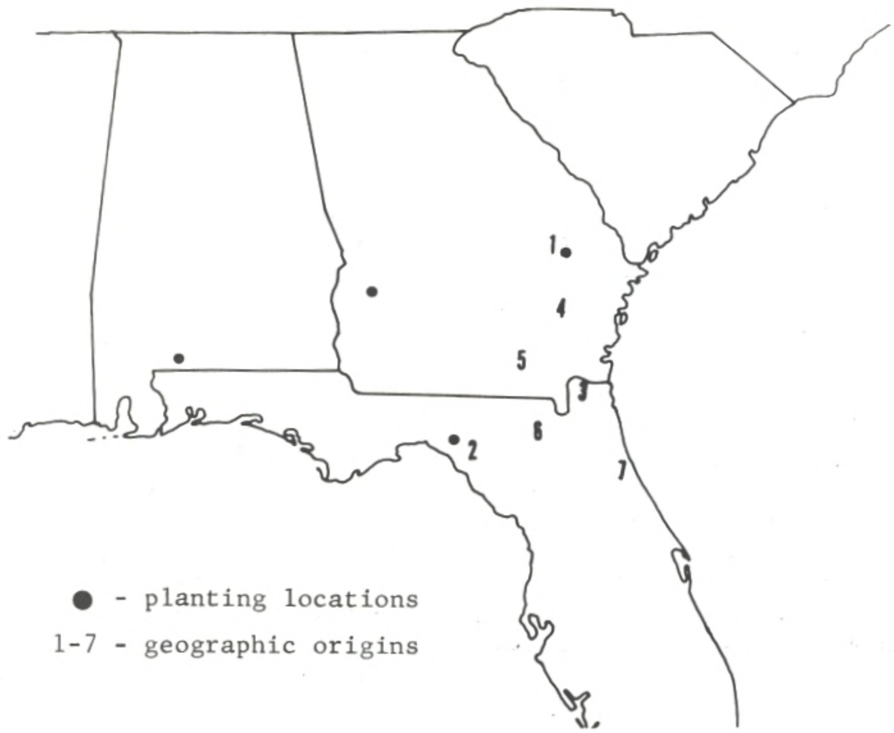

Figure 1.--Location of four planting sites and seven geographic origins.

Table 1.--Least square analysis of variance of rust infection in open-pollinated slash pine families.

Sources	d.f.	M.S.
Year (Y)	1	32230**
Location (Year) (L/Y)	5	130700**
Seed Source (S)	6	6220**
Y x S	6	669
S x L/Y	30	354*
Family (Source) (F/S)	118	1558**
Y x F/S	117	1317**
F/S x L/Y	316	298*
Error	874	193
Total	1473	

* Significant at the 0.05 level
** Significant at the 0.01 level

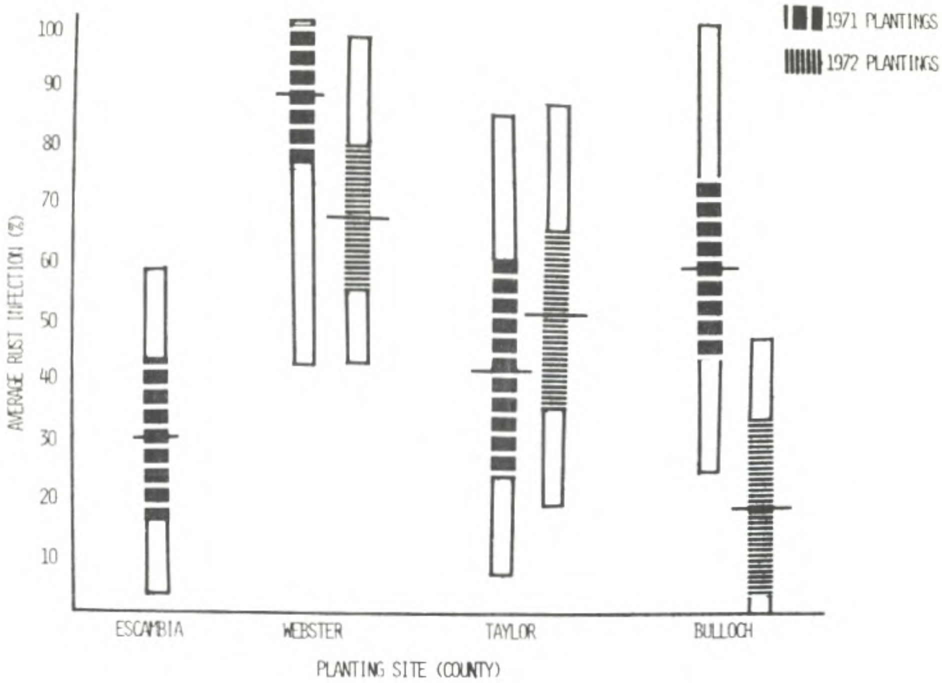

Figure 2.--Effect of planting locations and year of planting on fusiform rust in slash pine (range, mean and standard deviation).

Table 2.--Average percent fusiform rust on slash pine families from different geographic origins planted in high rust hazard locations.

Geographic origin	Average infection (%)[1/]	Number of families
Emanuel-Laurens-Tattnall, Ga.	36.9 ⌉	6
Taylor-Dixie-Lafayette, Fla.	41.9 ⌋	41
Camden, Ga.-Nassau, Fla.	50.3 ⌉	33
Long-Wayne-Appling-Dodge, Ga.	50.9	9
Ware-Clinch, Ga.	51.4	6
Baker-Clay-Union-Columbia, Fla.	55.4	25
St. Johns-Flagler, Fla.	55.7 ⌋	14

[1/] Average infection percents not within the same bracket are significantly different at the 0.05 level.

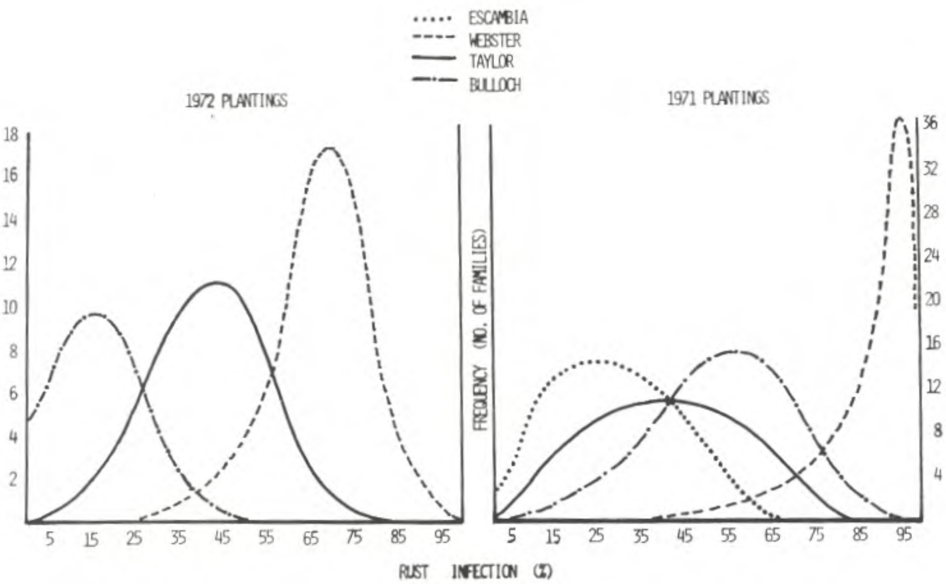

Figure 3.--Frequency distribution of percent fusiform rust on families of slash pine planted in high rust hazard locations in 1971 and 1972.

Table 3.--Rank correlation coefficients (R) of the average rust infection of open-pollinated slash pine families between locations within planting years.

		r[1/]
1971 plantings	N = 66	
Escambia vs. Webster		0.46
Escambia vs. Taylor		0.56
Escambia vs. Bulloch		0.45
Webster vs. Taylor		0.30
Webster vs. Bulloch		0.46
Taylor vs. Bulloch		0.44
1972 plantings	N = 54	
Webster vs. Taylor		0.53
Webster vs. Bulloch		0.52
Bulloch vs. Taylor		0.48

[1/] Correlation coefficients are significant at the 0.01 level when higher than 0.32 with 64 degrees of freedom or 0.35 with 52 degrees of freedom.

(Table 3). Fourteen families planted in all locations both years had poor year to year correlations in the Webster and Bulloch County plantings, while correlation between years at the Taylor County site was significant statistically (Table 4).

DISCUSSION

Geographic origin had an evident effect on resistance to C. _fusiforme_ in open-pollinated slash pine families. Strong seed source effects on rust infection in loblolly pine (Wells and Wakeley, 1966) and in slash pine (Gansel et al., 1972) have been reported. Two geographic origins, Emanuel County, Georgia, and Taylor County, Florida, which showed the lowest infection rate were reported as areas of high rust incidence (Phelps, 1974). In loblolly pine, trees from the provenances of the least infection showed also the least infection. But in slash pine, trees from the geographic areas of the relatively high infection showed the least infection in this study. Goddard et al. (1975) have shown that phenotypic selection of rust-free trees from areas of high rust incidence can provide significant gains in rust resistance of slash pine. The effect of seed source per se, however, does not appear to be as pronounced in slash pine as it is in loblolly pine.

For reliable differentiation of families for rust resistance, moderately heavy infection levels are required. With extremely high infection levels (Webster County, 1971), resistance mechanisms appear to be overcome. In very low infection rates (Bulloch County, 1972), distribution of infection was rather random (Schmidt and Goddard, 1971). Poor correlations of Bulloch County, 1972 planting with three locations in 1971 plantings would be good examples. In the middle range of mean infection level, frequency distribution of rust incidence appears normal and good differentiation of rust resistant families was possible.

Many of the families showed consistent rankings over all locations, while some changed their rankings rather drastically in one location (Table 5). Family 49-61 was ranked as one of the resistant group in three locations but as susceptible in Webster County, 1971 planting. Behavior of these families supports the reports of the pathogenic variability in C. _fusiforme_ (Snow et al., 1972, 1975). This can be also evidence for the possible presence of the vertical resistance to fusiform rust in some slash pines along with the horizontal resistance in other families (i.e. family 316-56).

At least over the three year period of these tests, year to year variation was very high. Rockwood and Goddard (1973) also observed a strong year effect in slash pine. The expectation that open-pollinated families replicated in successive years in the same location would be infected at a relatively consistent level was not substantiated. Correlations between two years in Webster County and Bulloch County were not significant statistically. The high correlation in Taylor County seems to be due to moderately heavy and similar infection levels in both years. Significant correlation between the Bulloch County in 1971 planting and the Taylor County 1972 planting also suggests that moderately heavy infection levels are required for good correlation between years as well as sites. The fourteen families included in plantings at all sites both years however, provide a limited basis for this conclusion.

Table 4.--Rank correlation coefficient (R) of the average rust infection of open-pollinated slash pine families between two years and three locations.

N = 14

	Average Infection level (%)	1971		
		Webster (79%)	Taylor (31%)	Bulloch (43%)
1972	Webster (59%)	0.44	0.39	0.45
	Taylor (46%)	0.41	0.70*	0.66*
	Bulloch (8%)	-0.06	0.18	0.24

* Correlation coefficients 0.66 or higher are significant at the 0.01 level.

Table 5.--Relative resistance of open-pollinated families to fusiform rust in four locations (from 1971 plantings).

Families	Locations			
	Escambia	Webster	Taylor	Bulloch
	- - - relative resistance class[1/] - - -			
49-61	1	5	1	1
316-56	1	1	1	1
262-55	5	1	3	3
191-57	1	1	1	4
296-56	1	4	3	5
94-56	5	5	5	5

[1/] 1 : Resistant (upper 20% in ranking)
2 : Fairly resistant (next 15% in ranking)
3 : Medium (next 30% in ranking)
4 : Fairly susceptible (next 15% in ranking)
5 : Susceptible (next 20% in ranking)

Procedures for testing should be revised to include replication over time as well as over planting sites.

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