PRELIMINARY RESULTS OF FUSIFORM RUST RESISTANCE FROM FIELD PROGENY TESTS OF SELECTED SLASH PINES

R. A. Schmidt and R. E. Goddard 1/

Southern fusiform rust incited by the fungus *Cronartium fusiforme* Hedgc. & Hunt ex Cum. is of prime importance to the management of slash pine *(Pinus elliottii* Engeim. var. *elliottii)* in many areas of the Southeast. This is especially so since intensive cultural practices which enhance growth appear to predispose pines to infection by C. *fusiforme.* Results of a recent unpublished survey of 1290 slash pine plantations (age 5-22 years) in 39 counties in Florida and Georgia indicate that in the average county 31.8% of the trees have fusiform rust. Counties with average values over 50% are not uncommon. Although these results include branch and stem galls, the extent of stem damage and mortality appears proportional to the total incidence of the disease. Within high-hazard rust areas the advisability of continued use of susceptible slash pine for commercial wood production is questionable.

Believing that genetic disease resistance offers a feasible control method, slash pine selections in the Cooperative Forest Genetics Research Program at the University of Florida are being screened for resistance to C. *fusiforme.* Hopefully, the extent and nature of such resistance will be determined so that plans can be made for its utilization in the tree improvement program. Rust data resulting from natural inoculation of pines of known parentage are presented in this paper. Select families and other seed sources were examined for differential response to C. *fusiforme* and for consistent performance among tests.

METHODS

Selection of slash pine.--Within the Florida program, approximately 1200 slash pines were selected from the species range, primarily on the basis of growth parameters and form quality. Trees with fusiform rust were avoided, but upon re-examination galls were found in crowns of a few selections. In total, few ortets used in seed orchards had any indication of rust. Selection against rust in certified seed production areas was equally or more stringent. For certification by the Georgia Crop Improvement Association, there must be no rust galls in the seed production area or the isolation zone. However, neither select trees nor seed production areas were necessarily in high-rust hazard areas. Also, the trees in both cases were normally over 25 years old at time of selection and galls that may have been present on lower limbs were shed before selections were made.

1/ Assistant Professor of Forest Pathology and Associate Professor of Forest Genetics, respectively, School of Forestry, University of Florida, Gainesville.

Progeny test designs.--Progeny resulting from open-pollination within seed orchards or control-pollination were established in field tests to evaluate their select tree parents. Open-pollinated tests were a randomized block design having 5 to 10 blocks **of 7 to** 10-tree row plots. Check lots consisted of 1 to 4 different bulk seed lots repeated twice in each block. Progeny tests of control-pollinated crosses were similar except that there were only 4 blocks. Approximate locations of these progeny tests are shown in figure 1.

Figure 1.--Locations of select tree progeny tests in Fla., Ga., and Miss.

With regard to seed production areas, Continental Can Company established tests in five locations using progeny from several certified seed sources. Four randomized blocks of 25-tree plots were planted in each location. Also included in these tests were progeny from trees in the rust-free isolation zone around the seed production area and bulk seed lots from adjacent stands.

Analyses of rust data.--In each instance data are given as percent rust, i.e., the percent of trees with a rust gall, branch or stem, and represent a 100% sample. Differential response among families within individual tests was determined by an analysis of variance, using variance among plots of check lots as a measure of experimental error.

Linear correlation analysis was used to evaluate consistency of performance of families included in two or more progeny tests.

Comparisons between means of select families and check lots were made with Student's paired "t" test.

RESULTS

Select slash pine progeny tests.--The incidence of fusiform rust in 26 progeny tests is presented in table 1. Averages of select families range from 3.0 to 59.8% and those of check lots from 1.3 to 55.8%.

Table 1.--Results of analyses of the incidence of fusiform rust in progeny tests of select slash pine

Progeny Test No.21	No. of Select Families	Ave. % Trees With Rust: Select Families	Ave. % Trees With Rust: Check Lots	Results of ANovd/: Block Means	Results of ANovd/: Family Means
1	7	43.6E/	34.6E/	NS	NS
2	5	30.8E/	25.2E/	NS	**
3	12	43.4	32.0		
4	35	34.3E/	28.5.E/	NS	*
5	34	23.1E/	13.6E/	NS	**
6	56	4.6	1.3		
7	56	4.6	6.0		
8	42	28.9	15.6		
9	42	25.7	17.5		
10	23	6.3	4.6	**	NS
11	22	13.1	11.7	*	**
12	19	3.7	2.3	NS	NS
13	2812/	58.2	41.2	NS	**
14	19.W	56.8	38.2	*	**
1	1.1)/	58.9	35.0	**	**
16		9.5	8.8	NS	*
17	27	59.8	55.8	NS	**
18	21	3.0	3.0		
19	20	6.0	3.4		
20	14	4.0	1.3		
21	9	42.2	33.1		
22	10	31.3	19.5		
23	4912/	8.2	8.2		
24	4712/	9.7	5.9		
25	15	12.7	14.5		
26	15	11.3	9.9		
	Ave.	24.37	18.10		

a/ Numbers correspond with figure 1.
b/ Control-pollinated families; all others are open-pollinated.
C/Fifth-year data; all others are third-year data.
d/ Analysis of variance; **,*, and NS = significant at .01, .05, and non-significant, respectively.

The average for all tests is 24.37% for select families and 18.10% for check lots. Check lots had significantly fewer diseased trees (5% level) than select families.

A summary of the analysis of variance of percent rust of 12 progeny tests is also given in table 1. In most instances block means were not significantly different and, more important, select family means were significantly different. Sample data for test #4 (Brunswick Pulp and Paper Company test #6) were as follows. The average percent rust for the 35 select families was 34.3%, ranging from 8.6 to 71.4%. Check lots were 28.0, 32.4 and 25.0% diseased. Differences among select family means were significant at the 5% level.

Consistency in family performance, as judged by the correlation coefficient (r) between percent rust of families located in two or more progeny tests, was examined. A portion of these data, i.e., those tests having at least 14 families in common (12 degrees of freedom), are given in figure 2. As expected, test pairs with less than 12 degrees of freedom gave erratic "r" values and were deleted from the figure. A preliminary analysis (Goddard and Strickland 1970) suggested that "r" values were positively related to the mean percent rust for the two progeny tests being compared. Thus, the statistical significance or non-significance of the "r" values are shown in relation to the progeny test means.

In general, significant "r" values occurred when both progeny test means were relatively high, e.g., 20% or greater. Comparisons of family performance when one or both progeny test means were low usually yielded non-significant "r" values. Two notable and, perhaps, predictable exceptions occurred. One comparison of control-pollinated families yielded a significant "r" value regardless of the fact that both progeny test means were quite low. Comparisons of control-pollinated families in several progeny tests with high percentages of rust yielded very high "r" values. Second, comparisons of third- and fifth-year data from a single test yielded a significant "r" value in spite of low test means.

A noteworthy result not evident from figure 2 was that progeny test #7 (table 1) was unlike other tests with which it had families in common. Of eighteen such comparisons, including both third- and fifth-year rust data, all "r" values were near zero; several were negative.

Percent rust in one control-pollinated progeny test of four males and thirteen females is given in table 2. This test, one of several established by ITT-Rayonier, was measured 5 years after planting. In spite of low rust incidence specific combinations have substantially more rust than others. One male and several females have progeny with above average percent rust, regardless of the other parent. When these "high-rust" parents were crossed with one another relatively high rust percentages resulted. The amount of rust on these crosses was significantly correlated with that present on the same crosses established on different sites in the same year.

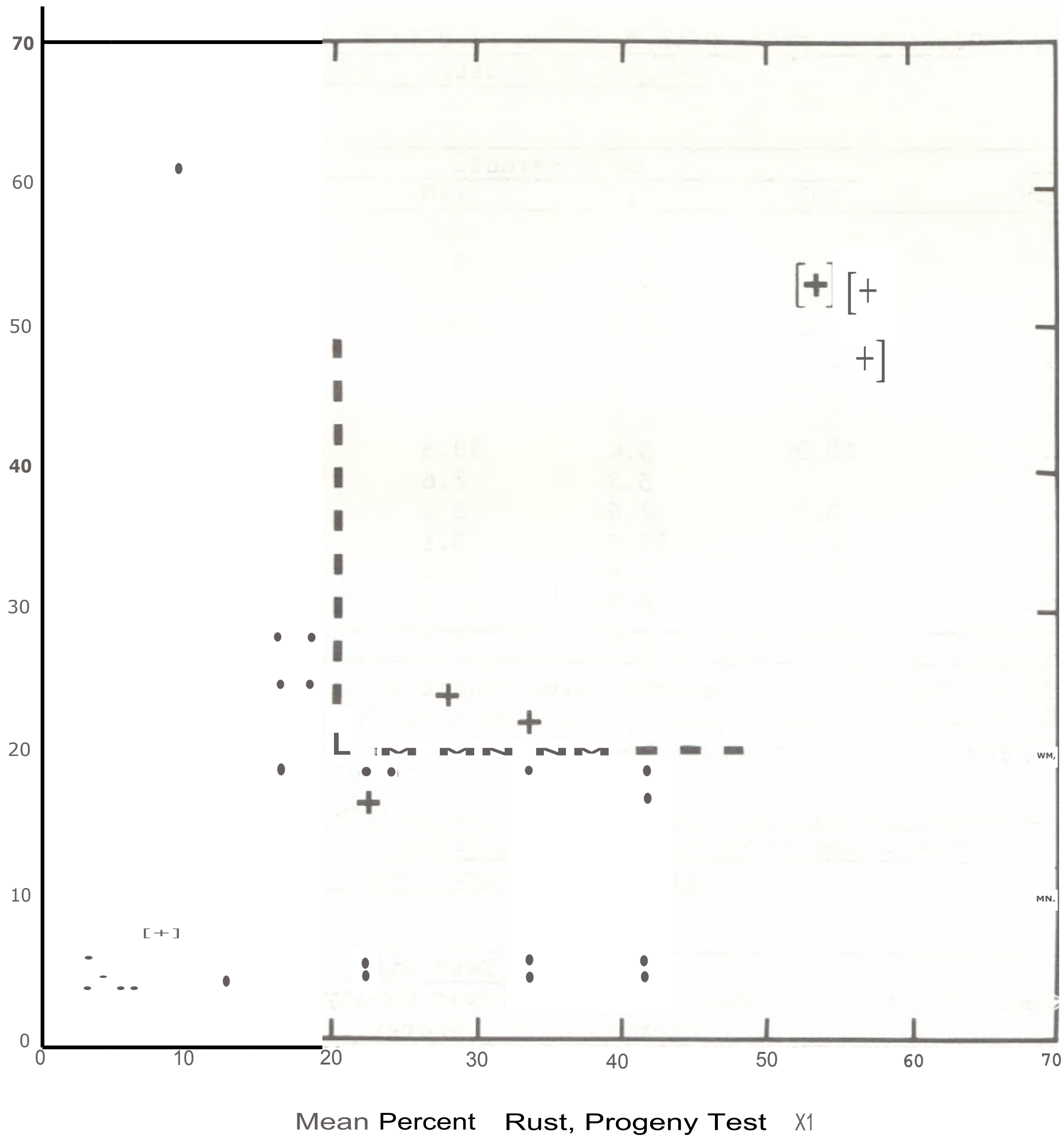

Figure 2.--Results of linear correlation analyses of mean percent rust for families located in two progeny tests shown in relation to the mean percent rust in the two progeny tests, X_1 and X_2. + = statistically significant at the 5% level, • = non-significant, O =3rd vs 5th year rust data for a progeny test, and [ ] = control-pollinated progeny test.

<u>Seed production area progeny</u> tests.--Of the five tests of seed production area progeny established by Continental Can Company, three having substantial amounts of rust are summarized in table 3. These data, taken at age five, give percent rust for progeny of the seed production area, the surrounding rust-free isolation zone, and bulk seed from an adjacent stand. There was no significant difference among combined means for the three test sites and no improvement in rust resistance of the progeny from the seed production area.

Table 2.--Percent of trees with fusiform rust in a control-pollinated progeny test after 5 years

Female Parent[a]	Male Parent[b]				Mean[c]
	101	118	110	502	
101			10.3	2.7	6.5
104		5.1	8.3	2.6	5.3
105	0.0	10.8	21.6	28.2	15.2
107	16.7	12.8	10.5	23.7	15.9
109	5.9	2.6	5.4	10.8	6.2
501	7.9	2.6	2.7	16.1	7.3
602	5.3	7.7		20.5	11.2
1104	10.3	5.4	13.5	13.5	10.7
1201		5.3	2.6	11.1	6.3
12 04	0.0	2.6	2.8	12.5	4.5
6104	7.5	10.5	5.1		7.7
6107	8.1	2.8	5.4	10.3	6.6
6117		10.3	10.8	2.5	7.9
Mean	6.9	6.5	8.2	12.9	8.6

a/ F value for female parents significant at 1% level.
b/ F value for male parents significant at 1% level.
c/ The means for the two check lots were 3.8 and 10.3%.

Table 3.--Average .ercent trees with rust in o•en- ollination ro•en from a seed production area, isolation zone and adjacent stand planted in three locations

Seed Source	Test Site			Mean
	Emanuel County Georgia	Bryan County Georgia	Jasper County South Carolina	
Long County Certified Seed Production Area	48	50	59	52.0
Isolation Zone	34	53	50	46.8
Adjacent Stand	31	50	55	46.0

DISCUSSION AND CONCLUSIONS

Data from natural inoculations of open- and control-pollinated families show that the average percent rust was greater on progenies of select slash pine than on bulk seed check lots. This is not surprising in that (i) selections were not necessarily made from high-hazard rust areas,' (ii) branch galls could have been naturally pruned from selected trees prior to selection, and (iii) selection for vigor could be positively related to susceptibility to an obligate parasite such as C. *fusiforme.* Nevertheless, there were significant differences among select families as some had substantially less rust than other families and check lots. Results similar to these have been reported (Barber 1961; LaFarge and Kraus 1967; Webb and Barber 1966) although the latter paper found select tree progeny to have less rust than check lots.

Comparisons of percent rust between families established in two or more progeny tests indicate that (i) open-pollinated families were consistent between tests when both progeny tests had relatively high mean rust percentages, (ii) control-pollinated families were more consistent than open-pollinated families even when the former were established in progeny tests with low mean percent rust and (iii) third- and fifth-year rust percentages were positively correlated. Thus, it appears that reliable identification of rust resistant families can be made from control-pollinated tests at low levels of disease while identification of resistant families in open-pollinated tests is more feasible at relatively high levels of rust.

The one example of a strong genotype x site interaction is difficult to explain solely on the basis of racial variation in the fungus as the locations are near to one another. Perhaps, it is, in part, due to the low level of disease incidence. In general, these data agree with those of others (Kinloch and Stonecypher 1969) who reported little genotype x site interaction.

An analysis of the amount of rust on full-sib progeny in a control-pollinated test indicated that progeny of certain male or female parent trees have more rust, regardless of the other parent, than do other progeny. Crosses between these high-rust parents yielded progeny that had more rust than progeny having only one high-rust parent. Similar conclusions were reached (Kinloch and Stonecypher 1969) for loblolly pine.

Further evidence of the failure of phenotypic selection to increase rust resistance of progeny is indicated by the lack of difference in the amount of rust among the progeny of the seed production area, the isolation strip and adjacent stand.

In conclusion these data suggest the following with regard to rust resistance.

1. The average rust resistance of half-sib families of the select slash pine in the Florida program is less than that of bulk seed check lots.

2. Half-sib families of some selections are substantially more rust resistant than others and more so than bulk seed check lots.

3. Consistent disease ratings for half-sib families were evident at relatively high levels of rust.

4. Consistent disease ratings for full-sib families were evident at low levels of rust and, in general, their ratings were more consistent than those of half-sib families.

5. Disease ratings of half-sib families were similar for third- and fifth-year measurements.

6. One instance of a site-genotype interaction was evident although generally few such interaction occurred.

7. Full-sib families from male and female parents which consistently yielded rust susceptible progeny were more susceptible than families having only one high-rust parent.

8. Progeny from a rust-free seed production area gave no evidence of increased rust resistance when compared with check lots from adjacent stands.

LITERATURE CITED

Barber, J. C. 1961. Growth, crown form, and fusiform rust resistance in open-pollinated slash pine progenies. Proc. Sixth South. Conf. For. Tree Improv., p. 97-104.

Goddard, R. E. and R. K. Strickland. 1970. Cooperative forest genetics research program. 12th Prog. Rept., Univ. Fla., School of For., Res. Rept. No. 18, 36 p.

Kinloch, B. B., Jr. and R. W. Stonecypher. 1969. Genetic variation in susceptibility to fusiform rust in seedlings from a wild population of'loblolly pine. Phytopathology 59: 1246-1255.

LaFarge, Timothy and J. F. Kraus. 1967. Fifth-year results of a slash pine polycross test in Georgia. Proc. Ninth South. Conf. For. Tree Improv., p. 86-91.

Webb, C. D. and J. C. Barber. 1966. Selection in slash pine brings marked improvement in diameter and height growth plus rust resistance. Proc. Eighth South. Conf. For. Tree Improv., p. 67-72.