SLASH PINE FAMILIES IDENTIFIED WITH HIGH RESISTANCE TO FUSIFORM RUST

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Abstract.--Fusiform rust readily kills slash pine, *Pinus elliottii* Engelm. var. *elliottii*. When the number of rust-infected trees is high, an investment is altered and fewer trees are available for harvest. As infection reaches 80 to 100%, the healthy trees appear to be a good source of rust resistance. This method of obtaining resistance from selections of such trees has been highly productive. In this study, we have tried an alternative way to identify resistance. We selected rust-free slash pines with good tree characteristics in National Forests where incidence of rust is low (10-30%). Open-pollinated progeny from these trees were inoculated at the Resistance Screening Center (RSC). Parents that had the most resistant progeny at the RSC were then crossed. Their control-pollinated progeny were tested at the RSC. The resistance of some of these was unusually high. Resistance to fusiform rust is relatively common in individual slash pines.

Keywords: *Cronartium quercuum* f.sp. *fusiforme,* selection for resistance to rust, *Pinus* diseases.

INTRODUCTION

Tree-improvement programs initially emphasized growth and form in the selection of southern pines. When rust had obviously become a problem in the 1940's onward, selection procedures aimed to identify trees with rust resistance. Although emphasis is now shifting back to growth and form, fusiform rust remains a serious problem in slash pine *Pinus elliottii* Engelm. var. *elliottii.* But the extensive studies of Sluder (1989 A and B) and others show that genes for resistance to fusiform rust are not difficult to transfer and many trees carry these genes.

Slash pines that are resistant to fusiform rust occur as individuals throughout the range. They are generally identified as asymptomatic trees on high-hazard sites. An example of such a site is given in Walkinshaw (1987). These rust-resistant trees have been useful in forest industry, state forestry, and Forest Service programs. However, many of the rust-resistant trees are slow growers.

In this study good phenotypes for growth and form were identified on low-hazard sites and rust resistance was identified by inoculation. The most resistant trees were crossed. Data in this paper show that these control-pollinated progeny are highly resistant. Moreover, they strongly suggest that high resistance to fusiform rust in slash pine is relatively common in trees on sites with low rust.

METHODS

General Procedure

Four steps were followed in this research:

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1. A total of 223 slash pines with good growth and form were selected from the National Forests in Region 8. Rust infection in the forests within the vicinity of the selected trees was approximately 30%.
2. Open-pollinated seeds of these 223 pines were tested at Asheville (RSC) and Gulfport.
3. The trees with the most rust-resistant progeny and other moderately resistant trees were crossed and the control-pollinated seed were tested at the RSC.
4. Control-pollinated seedlings without swellings after 6 months were planted in the National Forests.

Inoculation Designs

Open-pollinated seedlots at the RSC in Asheville, North Carolina, were tested in two replications of three trays of twenty seedlings per family. Control-pollinated seedlot tests were replicated three times with three trays of twenty seedlings per family. Replications were one week apart and freshly prepared inoculum was used. Trays were arranged in a non-ordered fashion within replications on the greenhouse benches.

The design for inoculations at Gulfport was identical to the description given by Walkinshaw and Bey (1981). These studies were on 211 crosses with forest industry trees.

Inocula Selection

Several hundred field isolates were used to obtain telia from water oak *(Quercus nigra* L.) or northern red oak *(Q. rubra L.).* These provided fusiform-rust inocula for open-pollinated seedlots. In contrast, the inoculum for the control-pollinated families was from one gall on a 10 year-old slash pine in Bogalusa, Louisiana. This gall was selected at random and adopted as the author's standard for ten years of screening at Gulfport, Mississippi and Asheville, North Carolina. To insure that this isolate provided virulent basidiospores for infecting the experimental seedlots, several resistant slash pine seedlots from the Cooperative Forest Genetics Research Program at the University of Florida were first inoculated. Infection was: M-707=42%, 52-56=89%, 6-56=70%, 179-55=33%, and 316-56=67%. A further test with 27 control-pollinated resistant trees at Gulfport insured that the isolate was pathogenic to a wide range of slash pines. Mean infection in this test was 56% and one-third of the putative resistant crosses had galls on more than 70% of their seedlings after 6 months.

Inoculations

Gravity ("tent"), airstream, and water suspensions were used to deposit basidiospores on needles and needle bases of 10-week-old seedlings in flats of soil or in containers. All procedures paralleled those reported previously (Walkinshaw and Bey 1981, Walkinshaw and Roland 1990).

Slash pine 211 was extensively inoculated at the RSC and at Gulfport in an effort to break down its resistance. The other highly resistant slash pines were inoculated only at the RSC.

Observations

Tree and gall traits were taken in detail but are not given in this paper. Resistance is defined as the absence of a visible swelling. Outplanted seedlings were selected from those with purple spots on the stems but no swellings. When this type ran out, those without spots and swellings were planted.

RESULTS

Resistance of Family 211

Family 211 x W had 23% infection in a tent test of 100 seedlings at Gulfport (Table 1). The mean percentage of seedlings with galls for the other Region 8 families in the inoculation was 80. Results of additional tests at Gulfport and Asheville with family 211 x W are given in Table 1. Note the large number of fungal collections that we used to inoculate the progeny of this slash pine family. The ability to resist so many rust isolates was unique among Forest Service and forest industry trees that we had tested.

Histological observations of family 211 that was inoculated at Gulfport showed a large variation in the amount of cambium that was invaded 21 days after inoculation. The range was 110 to 925 microns in stem-circumference for 211 crosses, while the susceptible control ranged from 594 to 1225 microns. The highly resistant University of Florida family (M-707) (Bey and Walkinshaw 1981) averaged 256 microns compared to 294 for the 211 crosses. All measurements of fungal growth were made on a highly virulent rust isolate.

Table 1. Fusiform rust incidence in open-pollinated slash pine progeny of family 211.a

Inoculation code	No. field isolates in inoculum	Percentage of seedlings with galls
"Tent"	many	23
20.42	1 (x9)	32
114-81	150	40
302-82	1	5
3-8-1	30	0
3-8-2	30	3
3-8-3	30	1
108-3	30	24
110-83	30	4
111-83	30	9
113-83	30	20
115-83	30	37
303-85	1 (X12)	12
101-36	120	13

Two or three replications of 60 seedlings were inoculated with 20,000 basidiospores per ml. Test 20.42 and 303-85 used 9 and 12 single isolates, respectively. Susceptible checks had 65 to 88% of their seedlings with galls.

Parallel observations of resistant and susceptible lesion reactions on 211 x W showed a variation in fungal growth within and from the lesion. Periderm formation was rare compared to lesions on the highly resistant Florida trees M-707 and 5-56. Reactions of family 211 were similar to those on Florida tree, 179.55 (Bey and Walkinshaw, 1981). In both families many of the lesions were so small that they were not visible to the unaided eye. Many of the successful infections in these two families developed from invaded needle trace tissue.

Resistance of Other Select Trees

In addition to family 211, several other highly resistant slash pine were identified among the 223 Region 8 selections. The ones used in the crossing experiment and their percentage with galls in the open-pollinated progeny were: 211=14%; 224=35%; 331=42%; 311=50%; 304=50%; and 310=37%. Susceptible check seedlots averaged 88% of their seedlings with galls. Infection of the resistant check was 68%.

Resistance of Crosses

Control-pollinated crosses between slash pine 211 and eleven slash pine families that were being studied at Gulfport were highly resistant at the RSC (Table 2). Infection of the crosses was much lower than in the resistant check families. The gall-free survivors at the beginning of the 12th growing season ranged from 5.0 to 5.7 inches d.b.h.

Table 2. Percentage of control-pollinated progeny of slash pine 211 crosses that were galled six months after inoculation.'

Cross	Galled after 6 mos.	D.b.h. after 11 yrs. (in.)b
211 x 8-4	5	5.0
211 x A-20	8	5.3
211 x J-1-5	2	5.3
211 x JP-1	2	5.3
211 x H-28	0	5.4
211 x H-7	2	5.4
9-2 x 211	1	**5.5**
8-7 x 211	2	5.6
211 x 18-27	2	**5.6**
211 x 21-58	2	5.6
211 x 211-55	3	5.7

[a] Two replications of 60 seedlings were run with each of two single gall isolates. Susceptible check averaged 70% and the resistant check had 55% infection.

[b] D.b.h. for seedlings with stem purple spots but no galls that were planted in the DeSoto National Forest at a 10 x 10 spacing.

Progeny of crosses of Region 8 trees had high resistance when inoculated at the RSC (Table 3). Susceptible families 347, 244, 232, and 214 had 97 - 100% diseased. The RSC susceptible check had 85% infection. All crosses of the resistant trees had less infection than the RSC resistant control seedlot.

DISCUSSION

Our inoculations show that high resistance to fusiform rust exists in slash pines on low-hazard sites. Moreover, the resistance of tree 211 was effective against many field isolates of the rust fungus. The infection of progeny of trees 211, 224, 311, 310, 331, and 304 and others at the RSC was unusually low. The fact that the five susceptible seedlots ranged **85 -** 100 % is proof that the inoculation was effective. As a group these control-pollinated trees are the most resistant ones that I have tested in 25 years.

When one examines the 223 slash pine families that were tested at the RSC by the Forest Service, Region 8, it is interesting to discover that approximately 1 tree of 25 good growers has good resistance. The other 24 trees are susceptible. This pattern appears in the good growers selected for potential rust resistance in the 1950's (Barber, 1961). Clone 243-56 of the University of Florida was one of the good growers with rust resistance when tested at Gulfport and Taylor County, Florida. Other good growers in the top 25, such as 60-56 and 73-56 were susceptible. This somewhat random relationship between growth and rust resistance suggests that the pressure to select for resistance was exerted in prior generations. The period of co-existence of the rust and its host (several million years) would have provided ample opportunity for selection.

Table 3. Low infection in control-pollinated crosses of select slash pines in the USDA Forest Service Region 8 Program.'

Cross	Percentage of seedlings with galls
211 x 211	9
224 x 331	12
311 x 311	18
304 x 304	19
331 x 211	19
224 x 304	26
211 x 304	27
331 x 310	28
310 x 311	32
310 x 331	33
311 x 211 Seedlot A	38
311 x 211 Seedlot B	39
Resistant check **(RSC)**	47
Susceptible families	
RSC	85
Region 8A	100
Region 8B	99
Region 8C	97
Region 8D	97

[a] Three replications of 60 seedlings were inoculated with a single virulent isolate of the rust fungus at a concentration of 20,000 spores per ml.

Microscopy of needle-base lesions on slash pine 211 was interesting. Lesions were unusually small and the fungus was killed before

a periderm was formed. When galls formed, they were similar in size to susceptible controls. These reactions were observed with nine different single-isolates. The ability of a slash pine to restrict fungal growth to a few cells after penetration is common to many of the University of Florida resistant families, e.g., 179-55. Family 211 exhibits reactions much like these and other Florida families but is more effective in killing the rust fungus in the outer cortex.

CONCLUSIONS

Individual rust-resistant slash pines commonly occur in the southern forest. These can be found on both high- and low-hazard sites. Asymptomatic trees on high-hazard sites have been excellent sources of resistance, but their growth and form can be poor. The alternative procedure that was used in this study led to rust-resistant selections that were suitable for planting in high-rust hazard areas. Gains in growth and form can be greater in low-to-moderate-rust areas by utilizing the best families even though they are more susceptible to rust.

In contrast to the pessimistic view in 1960-70, the present study, along with the thorough work of E.R. Sluder (1989 A and B), strongly suggests that obtaining slash pines with good growth and form that also resist fusiform rust is not difficult (Kinloch and Walkinshaw 1991).

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