RESISTANCE TO THE DEVELOPMENT OF PITCH CANKER IN OPEN-POLLINATED SLASH PINE FAMILIES

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Abstract.--Open-pollinated slash pine (Pinus elliottii Engelm. var. elliottii) families displayed a significant amount of family variation in resistance to the development of pitch canker (Fusarium moniliforme Sheld. var. suhglutinans Wollenw. and Reink). Fertilized slash pine families possessed a significantly greater level of infection than nonfertilized families. Percent infection ranged from 13 to 69 among fertilized and from 6 to 39 percent in nonfertilized families. Slash pine families originating from selections indigenous to Florida were significantly more resistant than families originating from Georgia.

INTRODUCTION

Pitch canker infection of slash pine plantations became a serious forest management problem on Union Camp Corporation land in late 1975 and early 1976 (Broerman, 1976). A survey of pitch canker incidence on company land revealed that 40 to 90 percent of all trees were infected within slash pine plantations in the Florida counties of Clay, Putnam, Flagler, and Volusia. In these highly affected areas, the entire crown of a tree would be infected in contrast to infection of the terminal and perhaps a single branch when pitch canker was present at an endemic level. Losses due to mortality and decreased growth were estimated to he in excess of 1.5 million dollars (Broerman, 1976). In response to the high level of pitch canker infection and the resultant growth loss, the company decided to: (1) document the distribution of the disease and assess the intensity and rate of disease development, (2) develop a management strategy to implement salvage cuttings when necessary, (3) support basic research on the pathogen and means of transmission and (4) screen for potential resistance among open-pollinated slash pine families in the company's first (1.0) generation seed orchards. This paper contains the results of a genetic test to determine the extent of resistance to pitch canker infection among open-pollinated slash pine families.

MATERIALS AND METHODS

An adequate level of inoculum must be present to screen slash pine families for pitch canker resistance. Therefore, a test site was located

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within a high disease incidence area on Union Camp land [1/] in Volusia County, Florida. The slash pine plantation present prior to test establishment was harvested prematurely due to extensive pitch canker induced damage and loss. The slash pine plantations surrounding the test site were also heavily infected. Ninety-two families were available for pitch canker resistance screening from the Union Camp Corporation's first generation seed orchards.

In January 1977, the 92 families were planted in two blocks. Due to space restrictions, Block I and Block II did not receive the same number of families. Block I and Block II were randomly assigned 56 and 36 families, respectively. Four commercial checks were the only "families" common to each block. Each block contains 20 replications with each family planted in five tree row plots. At the time of planting, Block II received 250 lbs./acre of an 18-40-0 fertilizer applied to the planting beds and each tree in both blocks received 7 grams of Furadan 10G.

In summer 1984, height, diameter and pitch canker incidence were measured on each tree. Height was measured to the nearest foot and diameter to the nearest tenth inch. Trees were scored as either being infected with pitch canker or not infected. The magnitude of infection in each tree was not assessed.

Since the commercial checks were the only entities common to each block, a paired t-test was used to compare block means for height, diameter and percent infected trees. Replication, family and family by replication effects were analyzed separately for each block using analysis of variance procedures. The family by replication interaction was not significant in the nonfertilized block, but was significant in the fertilized block. This interaction involved a minor family rank order change of no biological significance. Within each block, the family by replication effect was then pooled with experimental error. Based on family means, height, diameter and percent infected trees were analyzed with families and replications as the sources of variation.

The families tested in this study originated from selections in the Atlantic Flatwoods and Upper Coastal Plain provinces of Georgia and from Florida. Based on the county of origin of the select parent tree, each family in both the fertilized and nonfertilized blocks was clustered into one of four groups: (1) Upper Coastal Plain of Georgia; (2) Northern Georgia Atlantic Flatwoods; (3) Southern Georgia Atlantic Flatwoods and (4) Florida. Duncan's new multiple range test was used to compare mean pitch canker infection, height and diameter among the four groups.

RESULTS AND DISCUSSION

Slash pine families in the fertilized block possessed a significantly higher incidence of pitch canker infection and a significantly larger mean height and diameter than those in the nonfertilized block (table 1).

1/ The test site was subsequently purchased by Container Corporation of America.

Table 1.--Mean tree height and diameter and the proportion of trees infected with pitch canker in the fertilized and nonfertilized blocks. 1/

Block	Height (ft.)	Diameter (in.)	Proportion of trees infected with Pitch Canker
Fertilized	26.3	4.8	40.5
Nonfertilized	24.3	4.0	20.6
	$t=10.40^{ns}$	$t=2.93^{*}$	$t=8.87^{**}$

1/ where ns = not significant
* = significant at five percent level
** = significant at one percent level

Twenty-three percent of the trees in the fertilized block were infected with pitch canker while only twelve percent of the trees were infected in the nonfertilized block. A significantly greater incidence of infection also occurred among the commercial checks in the fertilized block than in the nonfertilized block (table 2). The commercial checks in the fertilized block possessed a significantly larger mean height and diameter. Since the commercial checks were the same in both blocks, the increased rate of infection in the fertilized block was apparently due, in part, to fertilization and is probably not a result of the random assignment of families to each block. A prolonged growing season and an increase in the amount of succulent tissue as a result of fertilization may have predisposed the slash pine to

Table 2.--Degrees of freedom, mean and F-value of height, diameter and proportion of trees infected with pitch canker among the commercial checks between the fertilized and nonfertilized blocks. 1/

Source of Variation	DF	Block	Height(ft.) $\bar{X}$	Height(ft.) F	Diameter(in.) $\bar{X}$	Diameter(in.) F	% Pitch Canker $\bar{X}$	% Pitch Canker F
Block	1	Fert.	24.6		4.5		45.6	
		Nonfert.	23.6	6.48^{**}	4.5	35.80^{**}	20.1	7.39^{**}
C.C.	3			2.07^{ns}		0.68^{ns}		1.39^{ns}
C.C.* block	3			3.15^{*}		1.27^{ns}		0.41^{ns}

1/ where ns = not significant
* = significant at five percent level
** = significant at one percent level
C.C. = commercial check

pitch canker (Dwinell, et al., 1981). In a general way this possibility is corroborated by other work indicating that an imbalance in plant nutrition because of an over abundance or shortage of nutrients can lead to greater levels of infection by a pathogen (Agrios, 1978). The incidence of pitch canker infection has been shown to be associated with increased levels of fertilization (Wilkinson, et al., 1977). Fertilization, applications of pesticides and mechanical wounding may also be associated with the occurrence of pitch canker in loblolly (Pinus taeda L.) and slash pine seed orchards (Dwinell, et al., 1981).

In both the fertilized and nonfertilized block, a weak inverse correlation existed between family mean height and diameter with family percent pitch canker infection (table 3). Although family mean height was

Table 3.--Correlation coefficient (r) of family mean height and diameter with the proportion of trees infected with pitch canker in the fertilized and nonfertilized blocks. 1/

Block	N	Ht	Diameter	
Fertilized	40	-0.45^{**}	-0.26^{ns}	With proportion of trees infected with pitch canker
Nonfertilized	60	-0.47^{**}	-0.246^{ns}	With proportion of trees infected with pitch canker

1/ where ns = not significant
** = significant at the one percent level

significantly correlated with percent pitch canker infection, the correlation accounted for only 20 and 22 percent of the variation between height and percent pitch canker infection in the fertilized and nonfertilized blocks, respectively. The weak height and diameter correlation with percent pitch canker infection suggests that the growth rate of the slash pine families in this study probably did not directly influence the host-pathogen disease complex to any great extent. Growth rate was not correlated with pitch canker resistance in a slash pine screening study conducted by McRae, et al. (1935). Arvanitis, et al. (1984) also found that diameter was not related to pitch canker infection in nonfertilized slash pine plantations.

The proportion of trees infected with pitch canker varied significantly among the slash pine families in both the fertilized and nonfertilized blocks (table 4). In the fertilized block, pitch canker infection among slash pine families ranged from 13.0 to 69.0 percent and from 6.0 to 39.0 percent in the nonfertilized block. Family variation in the fertilized and nonfertilized blocks accounted for 35 and 32 percent, respectively, of the total variation present in each block. Resistance to pitch canker infection

Table 4.--Degrees of freedom and F-value for height, diameter and proportion of trees infected with pitch canker within the fertilized and nonfertilized blocks. 1/

Source of Variation	Fertilized Block DF	Ht	Dia.	% Infect.	Nonfertilized Block DF	Ht	Dia.	% Infect.
Replication	19	10.66**	8.5**	4.3**	19	14.53**	10.5**	6.13**
Family	39	2.34**	1.68**	2.94**	59	1.79**	1.10ns	3.49**

1/ where ns = not significant
** = significant at one percent level

also varies among clones in both slash and loblolly pine seed orchards (Phelps and Chellman, 1976; Dwinell, et al., 1977; Dwinell and Barrows-Broad& 1981; Kuhlman, et al., 1982). The results of this study suggest that the slash pine families in both the fertilized and nonfertilized blocks contain varying levels of resistance to pitch canker.

In both the fertilized and nonfertilized block, slash pine families which were indigenous to Florida displayed a significantly lower level of pitch canker infection than those families which were indigenous to Georgia (table 5). There was no significant difference in the level of pitch canker

Table 5.--Comparison of mean height, diameter and proportion of trees infected with pitch canker among slash pine clones originating from the Upper Coastal Plain, northern and southern Atlantic Flatwoods region of Georgia and from Florida. 1/

Region 2/	Nonfertilized Block Ht. (ft.)	Dia. (in.)	% Infect.	Fertilized Block Ht. (ft.)	Dia. (in.)	% Infect.
U.C.P. Ga.	24.6 ab	4.0 ab	19.7 a	26.0 a	4.7 a	42.2 a
A. Flat. N. Ga.	24.1 b	4.0 ab	23.0 a	26.1 a	4.8 a	45.6 a
A. Flat. S. Ga.	24.2 b	3.9 b	20.8 a	26.6 a	4.7 a	37.5 ab
Florida	24.9 a	4.1 a	13.7 b	26.4 a	4.7 a	30.9 b

1/ Means within a trait and block not sharing the same superscript are significantly different at the five percent level.

2/ U.C.P. Ga. = Upper Coastal Plain of Georgia
A. Flat. N. Ga. = Atlantic Flatwoods Northern Georgia
A. Flat. S. Ga. = Atlantic Flatwoods Southern Georgia

infection among Georgia slash pine families. However, slash pine families which possess good height and diameter growth with pitch canker resistance could be found in selections from Georgia and Florida. In Florida, natural stands of slash pine possess significantly lower levels of pitch canker infection than slash pine plantations; especially those plantations which originated from selections in southern Georgia (Blakeslee and Rockwood, 1978; Dwinell, et al., 1981). This study supports the views of several researchers that slash pine trees indigenous to Florida are, in general, more resistant to pitch canker.

The results of this study suggest that fertilization, directly or indirectly, increases the susceptibility of slash pine families to pitch canker infection. The role of fertilization and perhaps other environmental factors (eg. drought) in the host-pathogen interaction is still unknown. Elucidation of the effect of fertilization and environmental factors on the predisposition of slash pine to pitch canker infection is necessary since pitch canker remains a potential disease of epidemic proportions. The large amount of variation displayed among the open pollinated slash pine families suggests a tree improvement program to enhance pitch canker resistance may be possible. Additional testing is required in order to confirm the repeatability of resistance since the slash pine families employed in this study were only tested in one location. Even though the resistance of the slash pine families was determined in one location, the most resistant families should be preferentially planted in regions of high pitch canker infection.

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