FIELD AND GREENHOUSE FUSIFORM RUST SYMPTOMS PREDICT MORTALITY IN PROGENY FIELD TESTS

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Abstract.--Six annual field observations on 43 slash pine families in a progeny test at Jackson County, Florida, showed that gall type was closely related to rust-associated mortality. In the field, the number of galls per family that developed from infection of terminal shoots was the single best predictor variable (r^2 = .85) for rust-associated mortality at 8 years. The proportion of trees with normal stems at age 5 or 6 years ranged from 25 to 100% and appeared to be a good predictor of mortality. Greenhouse inoculations of 21 of the 43 pine families in the progeny test showed purple stem spots without swelling to be the best variable for predicting field infection and mortality. Increasing the number of variables to three gave an r^2 of .64 for predicting field incidence. Differences in virulence of Cronartium quercuum f. sp. fusiforme collections in this progeny test were not related to disease severity among the pine families.

Additional keywords: Pinus elliottii, fusiform rust, disease severity, pathogenic variation.

Slash pines *(Pinus elliottii* Engelm. var. *elliottii)* that are infected by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* exhibit a variety of external symptoms in the field (Froelich et al. 1983). The effects of the rust include innocuous branch swellings, loss of apical dominance, girdling of the main stem, and mortality. Parent trees are considered susceptible to the rust when high numbers of progeny are galled, many cankers occur per tree, and when early infection and a fast rate of disease development occur. Resistant trees are more difficult to define. Both infection and symptom expression should be considered. In this study, the objective was to examine repeatedly a variety of symptoms in a typical progeny test. These symptoms were related to rust-associated mortality in the planting and to greenhouse symptoms for 21 of the 43 families. Also, virulence of the pathogen within the progeny test was measured as a possible variable in disease development.

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METHODS

Definition of Terms

Innocuous branch galls occur on branches 30 cm. or more from the stem. Branch-to-stem galls are branch galls that are within 30 cm of the stem or which contact the stem, there is no swelling of stem tissues. Branch galls in the stem originate from a branch infection and are in the stem; stems are swollen. Distorted stems are trees bent or twisted from gall growth. Normal stems are straight trees with or without galls and with a single dominant terminal. Rust-associated mortality (RAM) is the number or proportion of trees that, in the opinion of the field observer, die from rust compared to the number of trees that survived planting. *True stem galls* are stem swellings that develop from the infected terminal shoot. *Virulence* is the property of the rust fungus isolate that permits it to attack one slash pine family more than another.

Progeny Test Observations

The Jackson County progeny test site, commonly called the "Bumpnose Site," is located near Greenwood, Florida (Goddard and Schmidt 1979). Commercial loblolly pines (P. *taeda* L.) are 95-97% galled in plantings adjacent to the test. Forty-three families of slash pine are planted in 5 replications of 10-tree row plots in this progeny test. Overall survival at age 3 was 62%. High mortality at planting occurred in the 4th and 5th replications. A total of 1,333 trees are being observed yearly for 18 different gall and tree characteristics beginning at age 3 in 1980.

Greenhouse Inoculation

Twenty-one (number based on seed availability) of the 43 slash pine families were inoculated with a standard 30-gall composite (S-6) at the Resistance Screening Center. Ten families had little resistance while 11 had potentially useful resistance. All procedures paralleled those of Laird and Phelps 1975 and Webb et al. 1984. The test had 2 runs of 3 trays of 20 seedlings each. After 6 months, 11 symptoms were read by the author. Resistant checks were included for comparison to former studies (Bey and Walkinshaw 1981, and Walkinshaw and Bey 1981).

Pathogen Variability Assessments

Aeciospores were collected from bright orange, sporulating stem galls on 30 trees. Two random diagonal passes were made for collection. Screened spores were shipped to the Resistance Screening Center to prepare inocula for measuring infection of Georgia bulk seed (susceptible check), 25-61 X W, 179-55 X W, and 18-55 X W (resistant check). These families possess the resistance necessary to measure the virulence of rust isolates (Bey and Walkinshaw 1981). Three runs of 3 trays of 10 seedlings each per family were inoculated. A 30-gall composite made from all the collections, 12 single gall isolates randomly chosen from the 30 collections, and the composite from the 21-family test were the inocula. After 6 months, observations were made by the author.

RESULTS

Progeny Test Observations

Proportion of trees with *branch galls in the stem* at 5 or 6 years was unrelated to RAM at 8 years (Fig. 1). Adding *proportion innocuous branch galls* and *branch-to-stem galls* did not improve the prediction for the 43 families. Proportion of galled trees had an r^2 of 39% with RAM at 8 years. Number of *true stem galls* at age 5 was a good predictor of rust mortality at age 8 (Fig. 2). *Normal stems* and RAM at 8 years had an r^2 of 65% (Fig. 3). Percent true stem galls and percent normal stems at age 5 had an r = -0.79.

Gall length, size of swelling, constriction or sunken areas, and a variety of other tree traits were poor predictors of RAM at 7, 8, or 9 years. Rust-associated mortality at 9 years is given in Table 1. Further mortality is projected on the assumption that existing infected trees may eventually die from rust. Note the good performance of the "C" families. See Goddard et al. 1975, for the basis of these selections.

Families in Table 1 with 1987 RAM values of 50% or higher had a mean of 0.22 for proportion of galled seedlings with witches' broom symptom. Those with lower RAM values had a mean of 0.15. Families C-71 and 25-61 had no witches' broom trees. The projected mortality of 63% for family C-71, which had the lowest RAM 1987, was due to a high incidence of stem galls formed from branch infections. Disease severity in family C-115 was initially more severe than in family C-71. By 1987, 38% of the trees in C-115 had died of rust, but only 3 trees remained with galls in the stems. This pattern was seen in a number of families as evident from present and possible RAM values.

Greenhouse Inoculations

Mean percent galled trees was similar across 21 5-year-old pine families in the progeny test and 6-month-old seedlings at the Resistance Screening Center (Table 2). Ten pine families had more rust infection in the field than at the Center. Proportion with symptoms but no swellings (SYMNO), fat galls, and smooth galls in the greenhouse predicted the Florida rust score with an r^2 of 64 percent (see Walkinshaw et al. 1980 for terms). The best single greenhouse predictor variable for field infection at age 5 and field RAM at age 9 was SYMNO with r-values of -.79 and -.64, respectively.

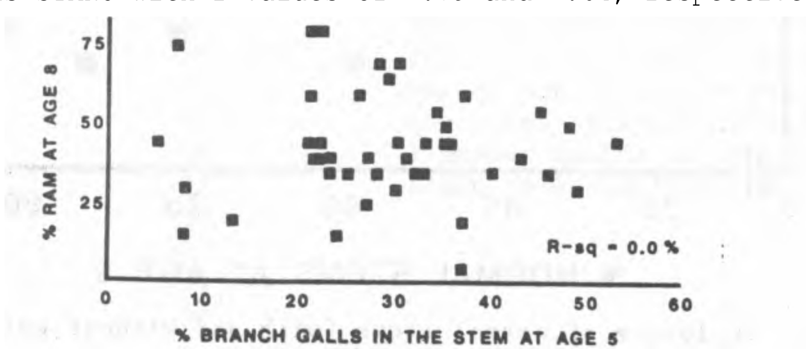

Figure 1. Lack of a relationship between stem galls from branch infections and early mortality.

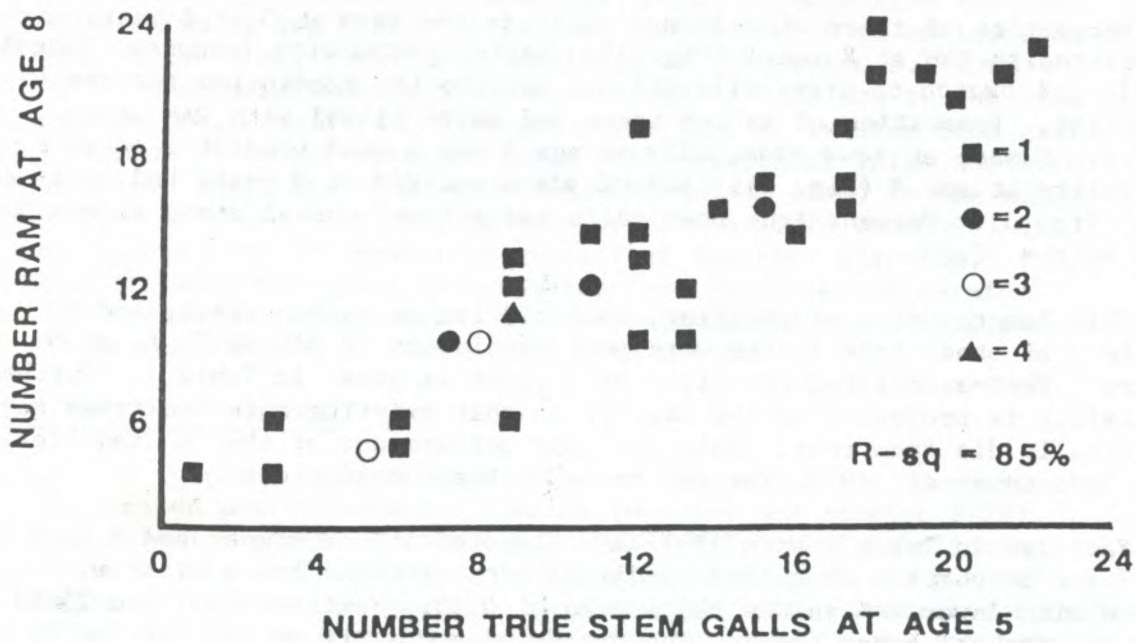

Figure 2. Relationship between early mortality and galls formed from infection of the terminal shoot.

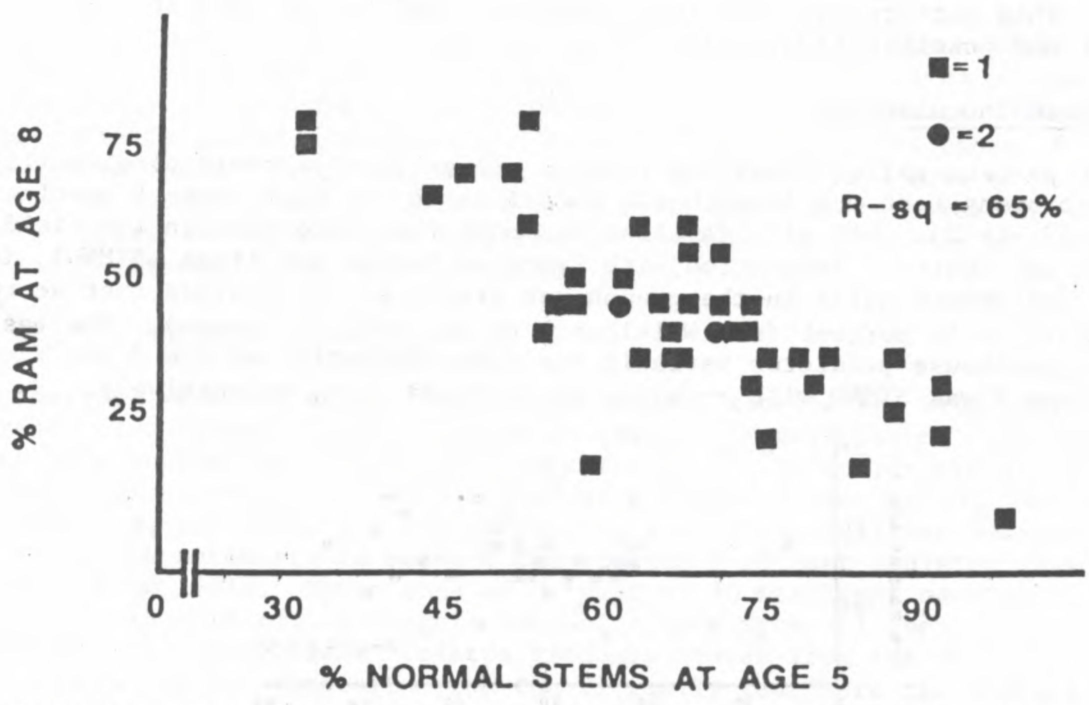

Figure 3. Incidence of normal stems (with and without galls and a single dominant stem) in relation to rust mortality at 8 years.

Table 1.--Existing and projected percent rust associated mortality (RAM) in slash pine planted near Greenwood, Florida

Family	1987 RAM	Possible RAM[1]
M-305	50	97
C-213	27	54
C-184	20	28
262-55	79	84
317-56	68	94
282-55	68	90
C-108	44	68
25-61	16	34
121-56	84	100
M-601	39	58
14-57	48	82
271-56	67	89
103-60	48	90
32-59	29	68
Check	30	65
26-61	55	84
238-56	60	88
B-1008	42	67
100-57	46	75
41-61	57	91
189-57	47	60
C-115	38	54
C-163	37	73
49-57	28	39
58-60	50	100
91-58	60	93
261-55	44	70
41-62	23	31
M-204	50	81
C-200	37	49
27-59	41	64
M-817	26	58
26-58	41	74
C-71	15	63
308-56	68	86
40-61	46	75
B-209	39	69
C-201	25	38
69-56	54	97
M-731	30	82
44-59	63	63
30-62	81	100
8-63	48	67

[1]Includes 1987 RAM (at 9 years) tree plus living trees with stem swellings.

Pathogen Variability Assessments

Infectivity of field isolates was unrelated to the resistance of the source family (Table 3). Differences among inocula were not significant at the 0.01 level. Family x inocula interaction was significant. Inocula separated resistant from susceptible families. Composite SC-30B appeared weaker on susceptible and resistant checks. Percent galled values for the single gall isolates on the resistant check (range 25 to 50%) were within previous values for 6 experiments with rust isolates (Bey and Walkinshaw 1981). Pine family 25-61 had a mean infection of 39% for all inocula, while the percent galled in the progeny test was 40. The highest percent galled for family 25-61 in the greenhouse occurred with an isolate from the most susceptible family. The isolate with the highest infection on family 179-55 also came from a highly susceptible pine family.

DISCUSSION

Results in this paper pertain to a single location and a limited period of tree growth. Studying only one location could certainly affect conclusions, although family X location interactions have not been a serious problem for these tests (Goddard and Schmidt 1979). Nine years appear sufficient to measure accurately early mortality from true stem galls when initial stem infection occurs at 1-3 years. More time is needed to define the effect of branch galls grown into the stem. Possible RAM values in Table 1 appear useful to compare rust among slash pine families. Rating families

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Table 2.--Comparison of percent galled slash pine seedlings after 5 years in the field or 6 months after inoculation in the greenhouse.

Pine family	Florida planting[1]	Greenhouse[2]
C-71	32	21
C-200	45	45
C-213	45	47
41-62	12	35
M-601	57	40
C-115	35	46
189-57	46	54
32-59	65	53
B-209	56	62
317-56	82	73
M-731	66	72
261-55	47	47
26-58	65	63
308-56	72	53
69-56	85	67
271-56	32	73
41-61	80	74
M-305	70	73
14-57	68	27
58-60	67	77
121-56	60	77
Mean	56	56

'Mean of 4 or 5 replications of 10—tree plots.

[2]Mean of 3 replications with 3 trays of 20 seedlings each.

for incidence of true stem galls at age 5 would be of limited value for judging families such as 32-59, C-163, and C-71. This rating system would be more useful applied to resistant families C-184 and 49-57, and especially for susceptible families 262-55 and 121-56.

Data accumulated in this study support the contention that careful classification and early evaluation of gall category are required to evaluate mortality from stem galls (see Lloyd 1982, Nance et al. 1983, and Webb and Patterson 1983). The age of the tree at infection is certainly a critical variable (Froelich et al. 1983).

Comparing greenhouse and field infection of pine families indicates the disease severity at the Bumpnose Site. Generally, greenhouse infection is much higher than field, but this progeny test had a similar disease incidence to that in the greenhouse. Such a consistent level of fusiform rust infection strengthens conclusions made about these 1,333 trees.

The potential problem of rust pathogen variability (Bey and Walkinshaw 1981, Snow et al. 1976, van Buijtenen 1982, and Walkinshaw and Bey 1981) is partially addressed by data in this paper. Bey and Walkinshaw (1981) concluded that the buildup of virulent isolates should not be a serious problem. If the collections in this study were representative of the local population, then resistant families such as pines 179-55 and 25-61 would probably do well on the Bumpnose Site. Rust isolates from the Bumpnose Site did not appear as virulent as others we had collected from commercial plantings in Florida and Louisiana (e.g., FL-4 and LA-7 in Walkinshaw and Bey 1981). Fungus specialization did not seem abnormal in this progeny test. Moreover, incidence of one or more isolates of the fungus that were virulent on the best resistant pine families in this test were not indicated.

Table 3.--Infection of slash pine seedlings inoculated with field isolates of Cronartium quercuum f. sp. fusiforme [1]

Relative Resistance of aeciospore source[2]	Susceptible check	Resistant check	Family 25-61	Family 179-55
	----------------- % galled -----------------			
1.05	83	45	45	37
1.05	73	28	35	32
1.05	68	50	33	32
0.89	62	25	27	13
0.80	78	32	37	37
0.43	55	33	52	20
0.43	70	38	32	15
0.14	72	37	40	23
-0.24	77	42	37	52
-0.37	73	32	63	23
-0.37	72	50	38	25
-0.37	68	38	27	27
SC-30A	80	48	48	28
SC-30B	52	22	35	22

[1]Mean values for 3 replications of 10 seedlings each. Observations were made 6 months after inoculation.

[2]Evaluation from 1986 Florida data as defined in Walkinshaw et al. 1980. Spore source trees were selected at random from sporulating galls in the 5 replications. SC-30A is a composite of 30 galls in the planting; SC-30B is a composite of 30 galls in 5 counties to the northeast of the planting.

CONCLUSIONS

The numbers of stem galls that arise from infection of the terminal shoot appear to be the best field trait to predict rust-associated mortality. This evaluation should be made before branch-to-stem galls cause stem swelling. Combining incidence of true stem galls and stem galls from branches is not warranted for this planting. The proportion of trees with normal stems (straight trees with or without galls) at age 5 is one easy way to approximate mortality at age eight. This proportion is closely related to true stem gall. The high mortality observed in this planting appears to result from an abrupt growth retardation due to true stem galls. The decline is most evident in the sixth and seventh growing seasons when competition is beginning.

Disease incidence in this progeny test parallels incidence in greenhouse inoculations. Such a high infection in the progeny test indicates that conditions are ideal for the fungus at this location. This probably accounts for the strong negative correlation of SYMNO (resistance) in the greenhouse with field infection. Pathogenic variability does not appear to be an important variable in disease development.

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