GALL TYPES FOR PREDICTING FUSIFORM RUST DAMAGE TO LOBLOLLY PINE IN THE FIELD

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Abstract.--A number of rust symptoms and their interrelationships were observed on loblolly pines in 8 locations. In one planting where infection was 90%, rust-associated mortality was 18% at age 12 and its relationship to various rust symptoms could be tested. None of the symptoms observed were highly correlated to rust-associated mortality for individual control-pollinated families. However, the number of galls growing from branches into stems in commercial plantations with 84% and 87% infection was highly correlated to rust-associated mortality. The percentage of trees with damaging galls that had moved into the stem was 83% for some of the more resistant families even though rust infection was less than 50%. The number of BG+S galls in loblolly pines is the most useful symptom to read.

Keywords: Cronartium quercuum f. sp. fusiforme, disease severity, pathogenic variation, Pinus taeda L.

INTRODUCTION

Loblolly pines (Pinus taeda L.) can tolerate rust infection (Goddard and Wells 1977, Geron and Hafley 1988), unless they are infected in the terminal shoot during their first few growing seasons, and they will often survive with rust for decades (Webb and Patterson 1984). Infected loblolly pines from different pine families vary in mortality rates, but prediction of the level of this rust-related death is difficult.

Previous studies, such as those of Geron and Hafley (1988) and Lloyd (1982), have used age, location, site index, measurements of tree growth, number of trees galled, number of galls per tree, and location of galls as possible predictors of rust-associated mortality in loblolly pine. However, death of individual rust-infected loblolly pines is not understood.

In this study, 12-year old loblolly pines with severe rust infection but with low early mortality from true stem galls were selected for describing gall types to correlate with rust damage.

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The objective was to predict mortality and stem damage in loblolly pine families. If the observed symptoms correlated with rust damage, they could be useful for monitoring rust impact in plantations. Moreover, symptoms that predict stem damage or mortality could then be incorporated into growth and yield equations.

METHODS

Definition of Symptoms and Measurements

Symptoms observed were **stunted tree** (shorter than average for the plot); **abnormal stem** (twisted, bent, or double stem, unsuitable for poles or lumber); **galled tree** (tree with one or more fusiform rust galls); **true stem gall** (stem gall from infection of terminal shoot); **branch galls growing toward, and within 30 cm of the stem** (galls on branches that are within 30 cm of the stem which remains unswollen); **branch galls that have grown into the stem (BG+S)** (galls on branches that have grown to the stem causing it to swell); **number of BG+S galls at one whorl; height on the stem of BG+S galls; percentage of the stem circumference girdled by a gall or multiple galls; branch galls** (galls on branches 30 cm or more from the stem); **tree dead from rust** (dead tree with one or more galls in the stem); **tree dead from causes other than fusiform rust;** and **witches' broom** trees (trees without a dominant stem). **Degrade** of stems is assumed to occur when one or more galls grow into the stem from a branch infection.

Heavily Infected Planting

The Bumpnose area near Greenwood, Florida, is planted in pines 10 to 15 years old. The fusiform rust incidence is 95% in loblolly pines planted ajacent to the observation area. Susceptible slash pine nearby are 85% infected. Livingston Parish loblolly pine has 41% rust.

In the observation area, there were 49 full-sib families of loblolly pine planted in five replications of 10-tree row plots at a spacing of 10 x 10 feet. One replication had poor survival and was not used. Each tree was evaluated for fusiform rust at age 12. Trees had been previously assessed by others for mortality at age four.

Low-Rust Plantings

Progeny tests located in Mississippi on the the DeSoto National Forest near Wiggins (1 test), on the Bienville National Forest near Raleigh (2 tests), and on the Homochitto National Forest near Gloster (2 tests), were of low-rust incidence. More than 50 full-sib families of loblolly pines planted in these National Forests were observed; only 20 families were planted in more than one forest. Spacing in all three locations was 8 x 8 feet. Three to four replications of 10-tree row plots were observed at age eight and verified at age nine.

Average infection for susceptible families was 37% for the DeSoto, 12% and 50% for the Bienville, and 26% and 30% for the Homochitto National Forests. The highest infection for any family was 63%. Only 3% of the trees in the progeny tests had died from rust at the time of observation. Of these dead trees, 33% had witches- broom.

Commercial Stands

Measurements of 300 loblolly pines were observed in commercial plantings in Holmes County, Florida, and Stone, Marion, and Pike Counties, Mississippi. Dead and living trees, 12 to 20 cm dbh, were examined for numbers of BG+S galls, branch galls growing toward the stem and within 30 cm of the stem, and branch galls located 30 cm or more from the stem. Random rows of 25 trees were observed. Observations were made during aecial sporulation to increase accuracy of measurements.

Analyses

Analyses of variance (fixed effects model) and regression analyses were done to estimate family effects and to test relationships of symptoms among each other for all observation areas.

RESULTS

Observations in a Heavily Infected Planting

At the time of observation,99% percent of the trees had fusiform rust galls. Only 2% of the trees had died from true stem galls; 38 of the 49 families had no true stem galls. Nearly all the rust-associated mortality occurred after age four. Of the 49 families, 12% of the trees died from causes other than fusiform rust (including mortality at planting). Rust-associated mortality for the families at age 12 ranged from 3 to 41% of trees (Table 1).

Infected trees averaged three BG+S galls. Such galls occurred at heights from 15 cm (6 inches) to 7.6 m (25 feet). The lowest BG+S galls averaged 91 cm (3 feet), and the highest averaged 183 cm (6 feet). When means for BG+S galls and branch galls within 30 cm of the stem were totalled, the average infected tree observed had eight galls growing towards or into the stem.

Table 1.--Fusiform rust symptoms on 12-year-old loblolly pines growing near Greenwood, Florida, for which family effects are significant[1]

Pine cross	Abnormal stems	Trees galled	Branch-to-stem galls	No. of galls[2]	Rust mortality
3-17X1-11	3	71	54	4	17
3-17X1-14	2	83	51	4	3
3-17X1-64	8	78	44	4	5
3-17X3-2	19	86	66	5	5
3-17X3-7	17	76	56	5	5
3-17X3-8	20	92	72	6	8
3-2X1-11	12	95	79	5	18
3-2X11-20	8	92	80	6	27
3-2X1-14	8	88	89	6	28
3-2X12-12	7	100	82	7	23
3-2X12-13	12	94	95	4	22
3-2X1-64	5	90	84	4	26
3-2X5-33	6	98	81	5	34
3-2X5-5	0	91	71	7	28
3-2X7-2	8	97	97	6	21
3-2X7-34	6	97	97	6	24
3-2X7-56	19	95	74	7	16
3-34X1-11	3	100	96	6	39
3-34X1-14	12	94	86	7	22
3-34X3-2	8	100	100	4	26
3-36X1-11	15	90	75	4	8
3-36X11-20	10	78	65	4	11
3-36X1-14	4	87	68	4	17
3-36X12-12	0	78	66	4	8
3-36X12-13	10	92	86	4	24
3-36X1-64	16	77	61	4	15
3-36X3-17	0	92	64	2	10
3-36X5-33	10	77	56	3	6
3-36X5-5	5	92	82	6	10
3-36X7-2	20	81	66	3	11
3-36X7-34	6	83	58	3	16
3-36X7-56	8	86	82	3	5
3-8X1-11	28	92	85	8	13
3-8X11-20	13	59	45	5	14
3-8X1-14	10	94	74	4	14
3-8X12-12	19	97	97	5	28
3-8X12-13	25	100	84	6	20
3-8X1-64	18	90	76	5	31
3-8X5-33	8	97	94	4	6
3-8X5-5	17	100	83	6	10
3-8X7-2	18	89	82	6	6
3-8X7-34	13	90	80	8	18
3-8X7-56	2	92	88	7	10
10-37X3-2	7	94	86	6	33
10-37X3-36	7	94	79	4	18
10-37X3-8	14	98	92	10	23
10-39X10-8	9	100	96	9	26
11-23X10-18	0	96	96	6	41
10-8XW	10	100	91	6	18

[1]Means of 4 replications of 10 trees each; see text for description of symptoms.

[2]Average number of branch galls into the stem and within 30 cm of the stem.

Family effects were significant for five symptoms (Table 1). Signicance probabilities ranged from 0.0094 to 0.0001; replication effects did not differ significantly. Percentage of trees galled explained 71% of the variability of BG+S galls. Neither BG+S galls nor percentage of trees galled explained variation in rust-associated mortality (r^2 =32% and 21%). When percentages of BG+S galls and trees with abnormal stems were combined they accounted for only 37% of the variation in rust associated mortality. Galled trees that died had 4 to 15 BG+S galls per tree; 31% of these trees had 10 or more BG+S galls.

The mean across families and replications for the percentage of tree circumference composed of gall tissue was 55%. Differences in girdling for families and replications were significant (P=0.05). Family 3-34 x 1-11 had the highest mean at 68%; family 3-17 x 1-11 had the lowest at 43%. Variability in stems girdled by gall tissue was not explained by BG+S galls (r2=4.7%).

Branch galls more than 30 cm from the stem occurred on 62% of the trees. Means for the 49 families ranged from 42% to 81%. Family and replication effects were significant (P=0.05). Incidence of branch galls 30 cm or more from the stem accounted for 40% of the variation in percentage of trees galled and 22% of the variation in percentage of BG+S galls.

Observations in Low-Rust Plantings

Families differed significantly (P=0.05) within each test for percentage of trees galled and percentage of BG+S galls in the low-rust plantings. Percentage of galls within 30 cm of the stem was low for all families (Table 2); crosses with 209 as the female parent had low percentage of trees galled and few BG+S galls

Multiple regression analyses did not reveal relationships among symptoms. For example, regression of the family means did not show any relationship between abnormal stems and other symptoms. Only 10% of the variation in percentage of trees galled could be accounted for by other symptoms.

When incidence of gall types for five of the families in Table 2 were compared at Bienville and Homochitto Forests, location had little effect on occurrence of BG+S galls. Family 250 x 238 had means of 70% and 71% for BG+S galls at the two locations, and family 236 x 228 had 86% and 73% BG+S galls. Family 203 x 233 had the highest percentage of branch galls at both locations; however, BG+S galls were correspondingly low.

Table 2. Percentage of rust symptoms on Forest Service loblolly pines growing in southern and central Mississippi.[1]

Pine cross	Abnormal stem	Trees galled	Branch to stem galls	Branch galls within 30 cm of stem	Branch gall more than 30 cm from stem
	....	....			
203X223	2	43	26	2	89
206X231	9	58	48	7	56
209X203	6	4	0	0	100
209X221	6	2	0	0	0
209X239	16	6	40	0	60
213X202	21	23	57	0	36
216X238	4	16	47	13	47
216X245	4	22	83	8	25
217X247	20	36	28	6	44
222X239	12	20	60	0	60
223X221	4	30	25	25	69
236X228	8	35	59	7	48
236X231	11	36	45	4	68
243X227	0	22	67	5	52
250X208	7	30	43	3	54
250X238	6	23	52	8	48
250X242	7	14	0	0	100
250X245	4	20	25	8	75
3-3-2	8	34	36	13	63
3-4-2	16	27	65	14	42

1 Means of 2 to 5 locations and 3 to 4 replications of 10 trees per family. Trees were read at 8 and 9 years after planting.

Observations on BG+S in Commercial Stands

Results from high and low rust plantings suggested that variability of rust mortality might be explained by the number of BG+S galls. To test this hypothesis, galls were observed in commercial loblolly pines that had 60%, 67%, 84%, and 87% infection (Stone, Pike, Holmes, and Marion counties). Rust-associated mortality was 0%, 6%, 12%, and 20% for the four plantings. As shown in Figure 1, variation in this mortality is explained to a large degree by the number of BG+S galls per tree (r^2 =85% and 87% for sites with 84% and 87% infection).

Of the infected trees on the four sites, 87% had BG+S galls. Only 12% of the trees had branch galls and branch galls growing toward the stem but not into the stem. The number of trees with one BG+S gall ranged from 71 to 75 per location. Rust-associated mortality was not observed in trees with one BG+S gall. Moreover, rust mortality was not seen in trees with two BG+S galls except on the site with 8% infection.

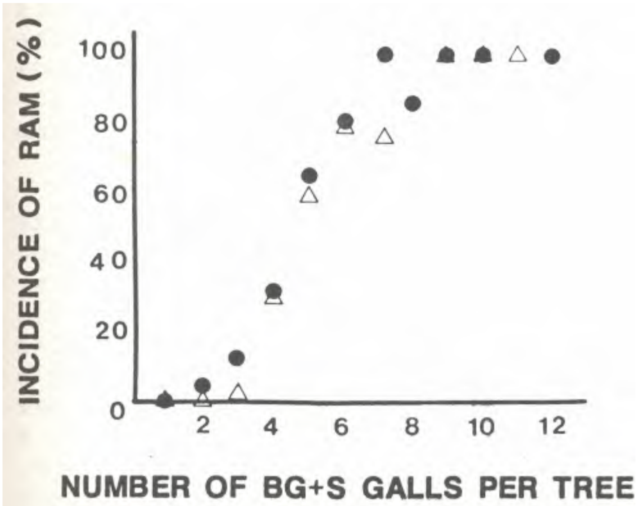

Figure 1. Relationship between rust-associated mortality (RAM,%) and BG+S galls in Mississippi (circles) and Florida (triangles) commercial loblolly pine.

DISCUSSION

The close relationship between high incidence of rust, BG+S galls, and mortality in commercial plantings was unexpected from analysis of family data in Table 1. However, if crosses with the same female (Table 1) are averaged, mortality, galled trees, and BG+S galls (not shown in Table 1) appear related.

Rust-associated mortality in individual families in the full-sib Florida plantation appeared unrelated to symptoms that describe fusiform rust-infected trees at age 12 (Table 1). Had equal numbers of crosses with female 3-17 been tested with females 3-2 or 3-34, the percentage of trees with galls and BG+S galls would have been related to mortality. The mean of 12 crosses with female 3-36 was 12% RAM while the mean for 11 crosses with female 3-2 was 24% RAM. The values for BG+S galls were 69% and 81% for the means of the crosses.

BG+S galls occurred in high percentages in the full-sib plantations studied in Florida and Mississippi. These galls severly damaged the stem and caused degrade, especially when they entered the stem at the heights in the Florida planting. These trees would not be suitable for high value forest products. While occurrence of BG+S galls was correlated to other gall types in the Florida planting, infection in Mississippi forests was too low for correlating symptoms.

Although percentage of abnormal stems in the Florida planting was significant for families, it did not relate to BG+S or other symptoms. Comparison of families 3-17 x 3-8 and 3-2 x 5-5 shows that while incidence of abnormal stems differed by 20%, these families had nearly identical values for trees with galls and BG+S galls (Table 1). Loss of apical dominance (abnormal stems) will be lethal for such trees after crown closure.

Most trees in the full-sib Florida test with BG+S galls had straight stems after repeated invasions, possibly because healthy tissue had formed by the time the fungus entered the stem. Although some trees with BG+S galls had gall tissue in 50% to 90% of their circumferences, gall tissue overlay 4- to 10-year-old normal stem tissues. Thus, invasion of the stem from branches was restricted to part of the trees cross section.

Breeding for resistance should exclude loblolly pine parents that form BG+S galls in large numbers. Crosses 209 x 203 and 250 x 242 might be desirable selections because infections generally occurred more than 30 cm distal to the stem (Table 2). Infected trees of a potentially poor candidate, cross 216 x 245 formed BG+S galls on 83% of the stems. One should examine growth habits of crosses such as 216 x 245 and choose families whose branches elongate rapidly. The highly susceptible Family 203 x 223 and the resistant pine 209 crosses seem to be of this type. Moreover, other studies suggest that selection of trees that form round rather than elongated galls should exhibit fewer BG+S galls (G. A. Snow, personal communication). The high incidence of BG+S galls in infected Mississippi forests shows that degrade may be significant even though the percentage of galled trees is relatively low.

CONCLUSIONS

The number of BG+S galls in loblolly pines is the most useful symptom; it classifies a tree as susceptible either to degrade or rust-associated mortality. Ultimately, BG+S gall data might be incorporated into growth and yield models and recommendations for thinning.

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