THIRD-YEAR RESULTS OF A SHORTLEAF X LOBLOLLY PINE HYBRID PROGENY TEST IN GEORGIA

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Abstract.--A 3-year progeny test of shortleaf X loblolly pine hybrids bred to recombine the high resistance of shortleaf pine to fusiform rust with the rapid growth rate of loblolly pine confirms the findings of an earlier artificial inoculation study. Progeny of selected F2 hybrids backcrossed to loblolly pine were significantly more resistant than loblolly but equalled, and in some backcrosses exceeded, it in growth rate. Similarly, Fl hybrids and progeny of wind-pollinated F2 hybrids were significantly faster growing than shortleaf pine but retained the same high level of resistance to rust.

Additional keywords: Backcross, *Pinus echinata*, P. *taeda*, *Cronartium fusiforme*, recombine.

In 1975 we reported promising results from an artificial inoculation test of hybrid crosses between loblolly pine (*Pinus taeda* L.) and shortleaf pine (P. *echinata* Mill.). That study was designed to determine growth and resistance of the hybrids to fusiform rust (*Cronartium fusiforme* Hedgc. and Hunt ex Cumm.) (La Farge and Kraus 1975). Those results indicated that rust resistance and growth rate might be recombined. However, since the seedlings were only 9 months old when measured, inferences concerning growth rate were inconclusive. This paper reports supporting evidence from a progeny test after 3 years in the field.

The present study is larger than the former; it consists of 30 seedlots representing 3 different hybrid types and both parent species. The former study comprised only 12 seedlots representing 3 hybrid groups and one parent species (loblolly). The original 12 seedlots are included in the present study. Since this is a field test, it also offers an opportunity to compare natural infection with artificial inoculation on those seedlots which were common to both studies.

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MATERIAL AND METHODS

The material consists of the following five groups; (1) Group 1, open-pollinated shortleaf; (2) Group 2, shortleaf X loblolly Fl hybrids; (31 Group 3, the progeny of wind-pollinated shortleaf X loblolly F2 hybrid selections; (4) Group 4, the progeny of selected shortleaf X loblolly F2 hybrids back-crossed to loblolly; and (5) Group 5, open-pollinated loblolly. Crosses included in each group are shown in table 1.

Table 1.--Summary of traits measured at age 3 years in a progeny test of short-leaf X loblolly pine hybrids in Houston County, Georgia

Groups and seedlots in groups	Height	Trees free of rust
	Feet	Percent
Group 1 (Progeny of Wind-pollinated shortleaf)		
TVA X Wind	4,6	100
Z15 X Wind	4.2	100
Piedmont Commercial	3.9	100
Group mean	4.3	100
Group 2 (Fl Hybrids)		
Z15 X 541	5.2	100
Z15 X 536	5.0	100
Z15 X 631	5.3	94
Group mean	5.1	98
Group 3 (Progeny of Wind-pollinated F2 Hybrids)		
HH 8 X Wind	5.6	100
HH 20 X Wind	4.9	100
HH 5 X Wind	4.9	100
HH 6 X Wind	4.7	98
HH 15 X Wind	5.2	92
Group mean	5.1	98

Table 1.--(Cont'd)

Groups and seedlots in groups	Height	Trees free of rust
	Feet	Percent
Group 4 (Progeny of F2 Hybrids Backcrossed to Loblolly)		
HH 19 X 624	5.6	97
HH 19 X 607	6.0	94
HH 5 X 624	6.5	97
HH 5 X 520	5.7	88
HH 11 X 607	4.8	95
HH 11 X 515	5.6	85
HH 17 X 518	6.0	92
HH 17 X 541	5.5	83
HH 15 X 541	5.9	94
HH 15 X 600	5.5	79
HH 8 X 520	6.5	86
HH 8 X 600	6.4	85
HH 30 X 603	6.2	71
HH 13 X 603	5.8	71
HH 13 X 518	5.6	71
HH 6 X 617	6.0	78
HH 6 X 515	6.0	45
Group mean	5.8	83
Group 5 (Progeny of Wind-pollinated Loblolly)		
GCIA 2G-9-5-3	5.9	47
GCIA 2G-65-D1	6.0	38
Group mean	6.0	42

The wind-pollinated parents of the trees in Group 1 had three origins:

1. Z15, a superior tree in Harris County, Georgia. This tree's progeny have demonstrated superior resistance to littleleaf disease, caused by *Phytophthora cinnamomi* Rands, in tank tests (Zak 1955) and in the laboratory (Bryan 1965). Its offspring have shown some resistance to adverse soil conditions plus P. *cinnamomi* as well as P. *cinnamomi* alone, and Z15 progeny had exceptional height growth in field tests (Bryan 1973).

2. Three clones in the Georgia Forestry Commission (GFC) seed orchards. These clones originated from ortets selected by the Tennessee Valley Authority.

3. Shortleaf pine seed commercially collected from the Georgia Piedmont.

Group 2 consists of three single crosses between Z15 and three GFC seed orchard clones of loblolly pine as pollen parents.

Group 3 comprises the progeny of five wind-pollinated mother trees which were selected F2 hybrids. The Fl parents of these hybrids were the offspring of shortleaf from North Carolina and loblolly from Virginia and were grown by the Institute of Forest Genetics in Placerville, California.

Group 4 is composed of 17 single crosses between selected F2 hybrids (those comprising Group 3 and others from the same source) and selected loblolly GFC seed orchard clones as pollen parents.

Two Georgia Crop Improvement Association (GCIA) commercial check lots of loblolly pine make up Group 5 (table 1).

In November 1973 the seeds were germinated in the laboratory, and within 2 days after germination each seedling was transplanted to a peat pot in the greenhouse. The peat pots were placed in cedar flats so as to form 4 x 5 = 20-seedling rectangular plots. The study occupied five benches in the greenhouses, each bench representing one replication.

The seedlings were planted in late June 1974 in Houston County, Georgia, south of Route 26. The site is typical of the Upper Coastal Plain. The use of peat pots made such a late planting possible. After three growing seasons survival was 94.7 percent.

The plantation was measured in late January 1977. Total height and the numbers of stem and branch galls were recorded for each tree.

The variables analyzed were height and arcsin percent of trees free of rust. The test was arranged in a randomized complete-block design with 5 replications. There were 30 seedlots and 16 trees in each square plot. Differences tested among groups and among seedlots within groups were planned orthogonal comparisons. These differences were tested for statistical significance at the 0.01 level, and the results of these tests are summarized in table 2.

RESULTS AND DISCUSSION

As in the artificial inoculation test, the loblolly controls in Group 5 had by far the lowest percentages of trees free of rust (table 1). In the 3-year field test the larger sample of 17 progenies of F2 hybrids backcrossed to loblolly (Group 4) still maintained essentially the same average growth rate as the loblolly controls. In fact, table 2 shows that Groups 4 and 5 did not differ significantly for height growth but were statistically different at the 1% level for the percentage of trees free of rust.

Table 2.--Analysis of variance of orthogonal comparisons among progenies and groups of hybrids in a progeny test of shortleaf X loblolly ine hybrids in Houston County, Georgia

Source of variation	Degrees of freedom	Mean squares	
		Height	Trees free of rust
Block	4	7.48**	117.64
Progeny	29	2.09**	839.41**
Within Group 1	2	0.64	0.30
Within Group 2	2	0.11	47.28
Within Group 3	4	0.54	68.76
Within Group 4	16	0.87**	483.26**
Within Group 5	1	0.04	61.31
Group 1 vs. Groups 2 + 3	1	7.54**	35.20
Group 2 vs. Group 3	1	0.06	1.20
Groups 1 + 2 + 3 vs. Groups 4 + 5	1	35.15**	9,409.92**
Group 4 vs. Group 5	1	0.16	6,732.91**
Block X Progeny (Error)	112	0.25	60.78

** Difference is statistically significant at the 0.01 level.

The differences among families within Group 4 were also highly significant for both traits (table 2). Four of the families in Group 4 exceeded the loblolly controls in height, and three of these exceeded the group average in the percentage of trees free of rust. There is only one family, HH 6 X 515, which performed as poorly for this trait as the loblolly controls. The other 16 families exceeded the controls by at least 24 percent. Conversely, only two of the six families in Group 4 that had at least 90 percent of trees free of rust were surpassed by the loblolly controls in height growth. This was the only group within which differences were significant.

Gains in resistance to rust and growth rate were not limited to the backcrosses in Group 4. The Fl hybrids (Group 2) and the progeny of wind-pollinated F2 hybrids in Group 3 were significantly taller than the pure shortleaf in Group 1 but did not differ from that group in resistance to fusiform rust. However, the Fl hybrids of Group 2 did not differ significantly from the progeny of the wind-pollinated F2 hybrids of Group 3 for height growth or rust resistance.

One other planned orthogonal comparison was statistically significant for each trait. The progeny of wind-pollinated shortleaf, the Fl hybrids, and the progeny of wind-pollinated F2 hybrids (Groups 1, 2 and 3) collectively were slower growing and more rust resistant than the progeny of F2 hybrids backcrossed to loblolly and the loblolly controls (Groups 4 and 5). The only meaningful result of this comparison is that it places Group 4 in association with the loblolly control. Yet, as we have already seen, most of the crosses in Group 4 had considerably less rust than the loblolly controls. Hence, the progeny of F2 hybrids backcrossed to loblolly (Group 4) seem to represent the desired products of the hybrid breeding strategy. They are the beginnings of a new strain of loblolly pine with that species' desirable growth but also with resistance to fusiform rust.

These results were generally similar to those of the smaller inoculation study (La Farge and Kraus 1975). To determine more precisely the degree of similarity, we ran simple correlations between the percentages of trees that were galled in the inoculation test and the percentages of trees free of rust in the field test. Only the 12 crosses common to both tests were included. Note that a favorable correlation will be negative because of the difference in the way the same trait was measured in each test. For all 12 families, representing Groups 2, 3, 4 and 5, the test-to-test correlation was r = -0,83 (significant at the 1% level). When we based the correlation on only those 8 families in Group 4, the progeny of F2 hybrids backcrossed to loblolly, the correlation coefficient was r = -0.80 (significant at the 5% level). These correlations agree with results reported by Dinus (1972), who obtained a very close similarity in relative responses to artificial inoculation and field infection of six half-sib slash pine (P. *eliiottii* Engelm.) families.

CONCLUSIONS

The results of this study support the conclusion of the earlier inoculation test: resistance to fusiform rust may be transferred from shortleaf to loblolly pine without reducing growth rate. Since the present study is older and contains more groups and seedlots within groups, this conclusion is more firmly established by the existing data. However, such a conclusion cannot be considered fully reliable until these trees are at least 10 years old. By then we will have additional hybrid material in the field to supplement our backcrossing program.

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