RESISTANCE OF SHORTLEAF X LOBLOLLY PINE HYBRIDS TO INOCULATION WITH FUSIFORM RUST

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Abstract.--A breeding program to recombine the high resistance of shortleaf pine to fusiform rust with the more rapid growth rate of loblolly pine has been initiated by the U. S. Forest Service in Macon, Georgia. Early results from progenies artificially inoculated with fusiform rust indicated that wind-pollinated progenies from F_2 hybrids were significantly more resistant than F_1 hybrids and F_2 hybrids backcrossed to loblolly, and that all three hybrid types were significantly more resistant than seed orchard loblolly clones. Early observations also indicated that some backcrossed hybrid full-sib families equalled or exceeded the height growth of the loblolly control.

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

Hybridization between loblolly pine (Pinus taeda L.) and shortleaf pine (P. echinata Mill.) as a method of obtaining resistance to fusiform rust Cronartium fusiforme Hedgc. and Hunt ex Cuinm.) has already shown some promise (Henry and Bercaw 1956). Better still, Sluder (1970) showed that certain shortleaf x loblolly hybrid combinations could combine very high rust resistance with high volume per acre due to good growth rate and high survival.

The present study comprises the full-sib progenies of F_2 shortleaf x loblolly hybrids backcrossed to progeny tested seed orchard loblolly clones, the progenies of wind-pollinated F_2 hybrids, F_1 hybrids, and a bulk lot from a loblolly seed orchard as a control. The hybrids were compared with the loblolly control in a test of their resistance to fusiform rust by means of artificial inoculation. This study is a portion of a new advanced-generation hybrid breeding program.

MATERIAL AND METHODS

The material consists of the following four groups: (1) F_1 hybrids; (2) the progeny of wind-pollinated F_2 hybrids; (3) the progeny of F_2 hybrids backcrossed to loblolly; and (4) the progeny of wind-pollinated seed orchard loblolly clones.

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The F_1 hybrids are the progeny of a cross between a selected and progeny tested shortleaf parent and a loblolly seed orchard clone (Group 1 in table 1). The shortleaf parent, Z15, is located in Harris County, Georgia and is included in a clone bank in the Whitehall Forest at Athens. Z15 was selected for resistance to littleleaf disease (Phytophthora cinnamomi Rand.), and progeny tests have shown it to have superior growth rate compared to other selected shortleaf families (personal communication, Dr. Charles R. Berry).

Table 1.--Seedlot and group means for height, diameter, percentage of trees with galls and gall volume

Groups and seedlots in groups	Height	Diameter	Trees with galls	Gall volume
	mm	mm	Percent	mm^3
Group 1 (F_1 Hybrid)				
Z15 x 541	138	2.7	42	58
Group 2 (F_2 x Wind)				
HH8 x Wind	170	2.9	7	138
HH15 x Wind	129	2.4	30	162
Group mean	150	2.6	18	150
Group 3 (F_2 x Loblolly)				
HH19 x 624	138	2.0	24	41
HH17 x 518	162	2.9	44	158
HH17 x 541	170	2.8	44	126
HH15 x 541	125	2.2	44	87
HH8 x 600	174	2.6	47	87
HH8 x 520	166	2.6	63	83
HH13 x 518	146	2.7	66	132
HH6 x 617	153	2.4	69	135
Group mean	154	2.5	50	106
Group 4 (S.O. Loblolly x Wind)	153	2.7	86	251

The second group of hybrids consists of seedlings derived from wind-pollinated seed collected from two F2 hybrid trees (Group 2 in table 1). The F2 hybrid trees are two of 40 hybrid trees selected on a one-acre block on the Hitchiti Experimental Forest. These "Hitchiti Hybrids," which comprised one of several hybrid types reported on by Sluder (1970), are the wind-pollinated offspring of crosses between a North Carolina shortleaf source and a Virginia loblolly source. The F_1 hybrid parents of the F2 hybrids were produced at the

Institute of Forest Genetics in Placerville, California. The F_1 trees were allowed to cross-pollinate among themselves at Placerville to produce the F2 seed, so that there was no possibility of contamination from other shortleaf or loblolly pine.

When the F_2 block on the Hitchiti Forest was measured in 1971 at age 20, the trees had virtually no fusiform rust, in contrast to the loblolly trees in the surrounding heavily infected natural stands. Six F2 hybrid trees selected for good size and form were backcrossed to six seed orchard loblolly clones to produce eight seedlots (Group 3 in table 1). The half-sib progenies of the seed orchard loblolly clones had been shown to have good growth rate.

The loblolly control consists of the progeny of a random sample of wind pollinated clones from the Arrowhead Seed Orchard of the Georgia Forestry Commission (Group 4 in table 1).

In December, 1973 the seeds were germinated in the laboratory and transplanted into plastic containers measuring 13" x 5" and 4.5" deep in Macon. Twenty seedlings were planted into each container in two 10-seedling rows. Each 20-tree container represented one plot, and each seedlot was replicated four times. When the seedlings were 8 weeks old, they were transferred to Athens, Georgia, where they were inoculated by the Fusiform Rust Research and Development Program of the Southeastern Forest Experiment Station.

The seedlings were returned to Macon in late August and measured in September. Measurements made were: (1) height; (2) basal diameter; (3) presence of fusiform rust galls; (4) gall length; and (5) gall diameter.

The variables analyzed were: (1) height; (2) diameter; (3) arcsin percent of trees with galls; and (4) the logarithm of gall volume. Gall volume was calculated by subtracting the volume of the stem cylinder estimated to be within the gall, so that only the swelling of the stem due to the gall was analyzed. Gall volume was used to obtain some measure of resistance to severity of infection.

A good gauge of the overall severity of this inoculation test is the percentage of trees with galls of group 4, the loblolly control (table 1). This figure of 86 percent is typical of many 3-year-old progeny test plantations of loblolly pine studied by the authors in the Lower Piedmont and Upper Coastal Plain of Georgia.

The experimental design was completely randomized. Differences between groups and seedlots within groups were planned orthogonal comparisons. Differences were tested for statistical significance, and the results of those tests are shown in table 2.

Table 2.--Mean squares and significance of differences of orthogonal comparisons

Source	Degrees of freedom	Mean squares[a/] Height	Diameter	Trees with galls	Gall volume
Among lots	11	1,119.58*	505.24**	770.68**	0.184**
Groups (1) vs. (2)	1	322.67	28.17	713.95**	.451**
Within Group (2)	1	3,280.50*	840.50**	667.95**	.009
Group (3) vs. Group (4)	1	3.12	205.03	1,886.00**	.591**
Groups (1) + (2) vs. Groups (3) + (4)	1	650.25	169.00	2,935.83**	.002
Within Group (3)	7	1,151.27*	616.42**	324.82**	.138*
Within lots	36	492.74	101.31	59.24	.049
Total	47				

[a/] * Significant at 5% level.
** Significant at 1% level.

RESULTS AND DISCUSSION

Group 4, the seed orchard loblolly control, had the highest percentage of trees with galls and by far the greatest gall volume of any group (tables 1 and 2). Moreover, the mean height of Group 3, the F2 hybrids x loblolly, was essentially the same as that of Group 4, the loblolly control.

Certain specific comparisons of interest were not tested statistically. Group 1 seedlings, the F_1 hybrids, were 15 mm shorter than those in Group 4 on the average. This difference was expected. Assuming no heterosis, F_1 shortleaf x loblolly hybrids will probably be intermediate in height growth between shortleaf and loblolly.

Since the crosses in Group 3 represent a third generation of hybrid breeding, they offer the best opportunity to evaluate the possibilities of recombining growth rate with rust resistance. Four of the progenies of Group 3 exceeded the mean height of Group 4 (table 1). If these differences are real,

then some hybrids can be expected to grow faster than loblolly. But even if the differences occurred by chance, we still have good growth rate in hybrids that are significantly superior to loblolly in rust resistance. In fact, two of the four Group 3 progenies having better height growth than the loblolly control also have low percentages of trees with galls and very low gall volumes. Although it is too early to be certain that these differences are reliable evidence of segregation for growth and resistance traits, there is some basis for believing that inoculation test results will accurately predict relative rust resistance in the field. Dinus (1972) found very close correlations between artificial inoculation and field infection of six half-sib slash pine (P. elliottii Engeim.) families. Rankings among families changed very little between inoculation tests and field tests. The large variation among hybrid types for rust resistance in the present tests suggests that these rankings will remain relatively unchanged in the field.

Of the hybrid types, the wind-pollinated progenies of F2 hybrids (Group 2) had significantly fewer trees with galls but greater gall volumes than the F1 hybrids of Group 1 (tables 1 and 2). Evidence of increased rust resistance is probably to be expected in the Group *2* wind-pollinated hybrids. Observed flowering times in most of these hybrid trees overlap more with shortleaf than with loblolly flowering times. Further, Hicks (1974) has found evidence in suspected shortleaf x loblolly hybrids that backcrossing among natural hybrids in east Texas is probably more in the direction of shortleaf than of loblolly. Although gall volumes were larger in Group 2 than in Group 1 or 3, they were still much smaller than the loblolly control.

Differences within Group 2 and Group 3 were significant for all traits except for gall volume in Group 2. The variability in Group 3 suggests considerable specific combining ability among hybrid crosses.

CONCLUSIONS

This initial study demonstrates the potential use of advanced-generation hybridization among southern pines. It suggests that resistance to fusiform rust may be transferred from shortleaf into the loblolly pine genome without reduction in growth. In fact, some backcrosses of F_2 hybrids x loblolly exceeded the height growth of the seed orchard loblolly control.

It goes without saying that continued observations of the rust resistance and growth rate of these hybrid types in the field will be needed to fully evaluate the possibilities of an advanced generation hybrid breeding program. All of the seedlots which comprised the present inoculation test have been included in a larger field progeny test. This field test also includes additional hybrid crosses in all groups, a loblolly commercial check, and two shortleaf provenances. Other field progeny tests with new hybrid material are also being prepared. Hence, in three to five years we will begin to obtain data which will confirm or refute the present results.

These promising early results should encourage breeders to establish more plantations of shortleaf x loblolly hybrids. Continued selection and back-crossing should ultimately produce trees which combine the rapid growth rate of the best loblolly pines with the high rust resistance of shortleaf pine.

LITERATURE CITED

Dinus, R. *J.* 1972. Testing for rust resistance in slash pine. In Biology of rust resistance in forest trees, p. 331-339. Proc. of a NATO-IUFRO Adv. Study Inst. USDA Misc. Publ. 1221.

Henry, B. W., and Bercaw, T. W. 1956. Shortleaf-loblolly hybrid pines free of fusiform rust after 5 years exposure. J. For. 54: 779.

Hicks, R. R., Jr. 1974. Comparisons of seedlings from east Texas loblolly, shortleaf and suspected hybrid pines. Texas Forestry Pap. No. 24, 6 p. Stephen F. Austin State Univ., Sch. of For., Nacogdoches, Tex.

Sluder, E. R. 1970. Shortleaf x loblolly pine hybrids do well in central Georgia. Ga. Forest Res. Pap. 64, 3 p. Ga. For. Res. Counc., Macon, Ga.