Breeding Longleaf Pines for Resistance to Brown Spot Needle Blight

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ABSTRACT

In tests with wind-pollinated progenies from 540 parents, heritability of brown-spot resistance was 0.57, and that of height was 0.52, at age 3 years. Infection in progeny of the best 10% of parents averaged 48%, compared to a population average of 63%. This 10%, plus the fastest growing seedlings, were selected for second-generation breeding. In addition, individual seedlings less than 30% infected or more than 1 ft tall were retained.

Tests with exposed and protected progeny indicate that inherent fast height growth is not the major mechanism of resistance.

The frequency of brown-spot resistant genotypes varied by seed source, especially where there were differences in parental exposure to the disease. Offspring from parents selected 30 years earlier from a heavily infected planting averaged 55% taller and had about 10% less brown-spot infection than those from parents with unknown history. Southwestern Alabama was the best of five geographic sources that were sampled for both height growth and brown-spot resistance.

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Derr (2) showed that longleaf pine (*Pinus palustris* Mill.) possessed genetically controlled resistance to brown spot needle blight caused by *Scirrhia acicola* (Dearn.) Siggers. Reported here are results of progeny tests of 540 parents with different disease histories and from several geographic locations. Derr's observations are quantified by heritability estimates, and it is shown that fast growth rate is not the sole mechanism of resistance. On the basis of the tests, resistant and fast-growing genotypes were selected.

MATERIALS AND METHODS.–The frequency of brown spot-resistant individuals in most natural or planted mature longleaf pine stands is unknown. It was assumed for the purposes of study that variation between stands exists, owing to differences in natural selection pressures. Parents were selected in several stands to observe effects of geographic seed source and estimated intensity of stand infection upon progeny performance. To broaden the applicability of results, progeny tests were made in two parts of longleaf pine's range, central Louisiana and southern Mississippi. Also, the influence of inherent seedling vigor on disease resistance was determined by comparing performance of progeny protected from brown spot with that of unprotected progeny.

Brown spot needle blight is a seedling disease, but only 15 of the 540 parents were individually examined in the seedling stage. These were rated in 1928 by Wakeley (7) as among the best 3% for both brown spot resistance and height growth in a Bogalusa, La., plantation established from local seed.

For the balance of the parents, the degree of natural selection for resistance was estimated from stand history. Six trees were selected in an abandoned

Louisiana nursery which had been very severely infected, and from which a tree with outstanding resistance had previously been selected (2). An additional 417 parents were exposed to heavy infection. They are growing in a large natural stand near Bogalusa, La., on land of the Crown Zellerbach Corporation. According to P. C. Wakeley (*personal communication*), the seedlings came from the 1920 bumper seed crop. Densities in some parts of the stand were as high as 200,000 seedlings/acre at 11 years of age. Very few of the seedlings began to grow appreciably in height by age 7 years because of a severe epiphytotic of brown spot not known to have been exceeded since. Selection was made from parts of the stand that had at least 10,000 seedlings/acre initially, no overstory suppression, and no early burning.

On the basis of rapid growth and good form, 102 parents were selected from stands in Louisiana, Mississippi, Alabama, Georgia, and Florida. Their juvenile histories are unknown, but it is probable that, as a group, their exposure to brown spot was less severe than that of the other parent trees. Their progeny furnished data for evaluating geographic seed-source influences on disease resistance. Seeds from some trees in this group were furnished by International Paper Company, Bainbridge, Ga., and the Southeastern Forest Experiment Station, Asheville, N. C.

In 1961, four cones were shot by .22 caliber rifle from each selection. At least 45 seeds from each tree were divided among three plantings. In 1963, after growing 1 year in the nursery, the seedlings were transplanted to milk cartons. Two months later, they were planted in mechanically dug holes in the field (5).

There were three plantings, one at Alexandria, La., and two adjacent plantings at Gulfport, Miss. One of the Gulfport plantings was sprayed with Bordeaux mixture in May, June, and September throughout the experiment to control brown spot. Each planting consisted of a randomized complete block with 10 replications of single-tree plots.

The planting at Alexandria consisted of 5,400 plots covering 3 acres of land. Prior to planting, furrows were made every 8 ft. Weeds were no problem in furrows during the experiment. Within rows, planting holes were 36 inches apart. Numerous well-distributed and infected volunteer seedlings provided inoculum.

The unsprayed planting near Gulfport was similar in size to the Alexandria plantation. The area was initially disked and later periodically cultivated and hoed for weed control. Disease spreader rows 12 ft apart were planted with 16,000 bulk seedlings 1 year prior to the test planting. Test seedlings were interspersed at 18-inch intervals from the older plants, which by that time had become infected and provided inoculum (Fig. 1).

In the Gulfport planting that was sprayed, brown spot was effectively controlled. This area was initially disked and later weeded by strip cultivation along the rows. Rows were 12 ft apart, and planting holes within them were 18 inches apart. Because of a lack of seed, there were only 4,900 plots on 2 acres.

Seedlings were examined for infection in the late fall of 1964 and 1965 after they had been exposed for two and three growing seasons. The needle area killed by brown spot was estimated to the nearest 10%. The highest per cent infection for a given seedling, regardless of year, was transformed to the appropriate arc sin√ percentage prior to analysis. In 1965, heights were measured to the nearest inch. Analyses of variance and unbiased means for height and brown spot infection were computed by a missing-plot technique.

RESULTS AND DISCUSSION.–*Heritabilities and planting location effects.*–Family differences were significant at the .05 level of probability for infection and height in the unsprayed plots at each location. Means for both infection and height were less at Alexandria than at Gulfport (Table 1). Calculated as described in a previous paper (6), heritabilities for infection were 0.30 at Alexandria and 0.57 at Gulfport; those for height were 0.13 and 0.52. In the sprayed plots, height heritability was 0.48. In all

TABLE 1. Means, variance components, and heritability estimates for brown spot (*Scirrhia acicola*) infection and height of progeny of longleaf pine tested at Alexandria, La., and Gulfport, Miss.

Character and statistic	Alexandria	Gulfport	
		Unsprayed	Sprayed
Brown spot infection			
Mean (%)	55	71	
Error df – missing plots	4,851 – 1,217	4,851 – 1,020	
Error variance component	164.9	138.0	
Family variance component ± SE	13.20 ± 2.16	22.87 ± 2.45	
Heritability	0.30	0.57	
Height			
Mean (inches)	3.0	6.4	23.6
Error df – missing plots	4,851 – 1,217	4,851 – 1,021	4,392 – 374
Error variance component	17.86	50.38	216.34
Family variance component ± SE	0.59 ± 0.18	7.55 ± 0.85	29.72 ± 3.44
Heritability	0.13	0.52	0.48

Fig. 1. Longleaf pine seedlings during fourth growing season. Tree at center was selected as resistant to brown spot; those in foreground are heavily infected.

three plantings, the family component of variation was statistically significant.

On the unsprayed plots, there were significant family X location interactions for both brown spot resistance and height growth. Change in ranking of families with moderate to poor disease resistance and height growth was the chief contributor to the interactions, however. Very few families at Alexandria had initiated height growth in 3 years; only 4% of them exceeded the Gulfport mean height. Of those that did, 75% grew well enough or had low enough infection so that their parents were selected for breeding from the combined data. Therefore, conclusions for unsprayed plots are based on combined Gulfport and Alexandria data.

Seed source differences.—Although seed source differences have not been rigorously tested statistically, they are sizable and suggestive. Seeds were collected from trees with unknown early brown-spot history in 5 general areas: central Georgia; northern Florida-southwestern Georgia; southwestern Alabama; Mississippi; and Louisiana. The average number of trees per area was 20. The southwestern Alabama source performed well both in the sprayed and unsprayed plots. In the sprayed plots, seedlings from this source were 17% taller than Louisiana seedlings; and in the unsprayed plots, 32% taller with 13% less brown spot. These results agree with those of Bethune & Roth (1) and Henry & Wells (4).

It was expected that the order of resistance of parental groups would be: (i) those selected as juveniles from a plantation; (ii) survivors in a nursery; (iii) survivors in a heavily infected natural stand; and

TABLE 2. Progeny performance of longleaf pine, by type of selection

	Sprayed plots[a]		Unsprayed plots		
Type of selection	No. families	Mean height growth (inch)	No. families	Mean height growth (inch)	Mean infection (%)
All families					
Mature–juvenile infection unknown	55	22.6	65	3.8	65
Mature–from epiphytotic area	379	23.3	417	4.6	62
Mature–from epiphytotic nursery	5	25.8	6	7.8	62
Juvenile	15	27.1	15	5.9	59
Best 10% of families					
Mature–juvenile infection unknown	6	35.8	6	7.5	56
Mature–from epiphytotic area	38	36.4	42	9.4	44
Mature–from epiphytotic nursery	1	34.0	1	13.6	53
Juvenile	2	36.4	2	11.9	52

[a] Treated with Bordeaux mixture to control brown spot (*Scirrhia acicola*) infection.

(iv) trees in five typical stands. The infections, and especially the heights of the progenies, tended to vary inversely according to our estimates of infection in the area from which they were selected (Table 2).

Wakeley's selections are of particular interest because they verify tentative conclusions about parent-progeny inheritance of resistance, conclusions up to now based on performance of progeny from a single parent (2, 3). Our 15 parents were selected from plantations on the basis of notes Wakeley took for ages 3-6 years, about 30 years prior to our progeny test. The selections were in the best 3% for brown spot resistance. Since the original selections were made in a grassy field, it is surprising that there were gains in resistance and height. We now consider bare ground essential for obtaining severe infection uniform enough for progeny tests.

Height growth as a resistance mechanism.—On a family mean basis, the correlation of −0.66 between height growth and brown spot infection for the 540 entries on the unsprayed sites could suggest merely that, as is well known, the disease decreases height growth. It could also mean that fast-growing families escape the disease; i.e., that fast early height growth is a resistance mechanism. The sprayed planting was installed to examine the second possibility. If height is a resistance mechanism, the heights in the sprayed plots should also have a high negative correlation with brown spot infection in the adjacent unsprayed plots. The correlation was only −0.22, which indicates that many inherently fast-growing types do become infected, and that fast early height growth is not the major mechanism for resistance.

Selections.—We selected parent trees based on three progeny characters independently. Firstly, 54 parent trees (10%) were selected with low family mean infection. The average infection rating of this group was 48% vs. a population average of 63% infection. Secondly, 54 trees were selected for tolerance to infection as indicated by superior progeny height growth (9.4 inches vs. population average of 4.7 inches). Finally, 26 trees (5%) were selected because their progeny grew well in plots sprayed to control brown spot. The mean height of these families was 39 inches as compared to a population average of 24 inches. This last group may be adapted to the eastern 60% of the longleaf pine's range, where brown spot is not a chronic disease.

Because of the correlations among characters, some families were in the upper percentiles for two or three characters. Consequently, actual selection intensity in the epiphytotic plots is 15 instead of 20%, and in the sprayed plots it is 3 instead of 5%, a total selection of 18% of the population. Nine selections did well in both the sprayed and unsprayed plots. These could be valuable where brown spot is sometimes, but not always, important.

Nearly 1,200 seedlings from the progeny tests were released from competition for second-generation breeding. At Gulfport, all seedlings with 30% or less infection were saved. Some that had grown over 1 ft tall in spite of moderate brown spot infection were also saved. Total selection intensity was about 10% (452 seedlings). At Alexandria, where height growth was not so well expressed and infection was lower, seedlings with 20% or less infection were selected. Two hundred eighty-four (7%) of the seedlings were selected. Finally, from the sprayed plots at Gulfport, 458 (10%) were selected because of their superior height or because they belonged to resistant families in the unsprayed test.

Currently, forest managers seldom favor longleaf over other southern pines because of slow initial height growth and brown spot infection. As second-generation breeding could put longleaf pine in a competitive commercial position with other species, the selected seedlings, which have been released from competition, will be carefully evaluated as breeding candidates. Clonal and seedling seed orchards are being established from first- and second-generation selections.

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