VARIATION IN RUST RESISTANCE IN MISSISSIPPI LOBLOLLY PINE

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Abstract.--Stands with a high degree of resistance were located in the Florida parishes of Louisiana and southwestern Mississippi. Stands nearest the Gulf Coast in Alabama and Mississippi were least resistant, and resistance increased gradually to the north and west. There were more highly resistant stands along the western margin of the range in Mississippi than along the Mississippi-Alabama border. Attempts to correlate these results with the distribution of shortleaf pine (Pinus echinata Mille) were only partially successful.

The among-stand effect was about nine times larger than the withal-stand effect. Therefore, in development of resistant loblolly (P. taeda L.) strains for planting, first priority should be given to selection of geographic areas and stands.

Range-wide provenance tests have demonstrated that genetic resistance to southern fusiform rust (Cronartium fusiforme Hedgc. and Hunt ex Cumm.) exists in parts of the loblolly pine range, specifically (1) west of the Mississippi River, (2) in the Florida parishes of Louisiana (that part of Louisiana directly south of Mississippi and north of New Orleans), and (3) on the eastern shore of Maryland (Henry 1959, Wells and Wakeley 1966). In tests over a smaller geographic area Crow (1964) has found genetic variation in resistance within the Florida parishes, and studies within two or three counties in Mississippi (Dinus 1969) and Georgia (Kinloch and Stonecypher 1969) have identified individual trees whose progenies have a high degree of resistance.

This paper describes in detail the pattern of geographic variation in rust resistance in that part of the loblolly pine range within Mississippi, the Florida parishes of Louisiana, and the parts of Alabama and Tennessee immediately adjacent to Mississippi. The main strength of the work lies in the intensity of the sampling. Progenies from 561 parent trees were tested.

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The collection locations were planned by dividing the State into 20 latitudinal transects, 15 minutes of latitude apart, and mapping a collection point every 30 miles along the transects. Collections were made within 10 miles of these points. Cones were taken from five trees at each of 115 locations during 1962, 1963, or 1964. Six locations west of the Mississippi River were also sampled to provide a basis of comparison with previous work. Loblolly pine is ubiquitous within the study area, and criteria for selecting the parent trees were undemanding. The first five trees that were sighted from the road within the specified location were chosen provided that they had cones and were easy to climb. The latter provision meant a maximum of about 30 feet to the first limb. It also meant that most of the trees were young and less than 50 feet tall. Presence or absence of cankers was not considered. In addition, the selected trees were between 200 feet and one-fourth mile apart and were within 100 feet of other cone-bearing loblolly pines. Obvious hybrids with longleaf pine (P. palustris Mill.) or shortleaf pine were bypassed, and if trees of other species occurred in mixture, their presence was noted.

Planting stock was grown in a three-replicate design near Gulfport, Mississippi, during 1965. Fungicide was applied five times to exclude rust infection in the nursery, and no galls were observed on the stock. The seedlings were planted during the winter of 1965-66 in three locations: 15 miles east of Baton Rouge, Louisiana, central Mississippi, and northwestern Alabama. Stock at each location was from a single nursery replication. The design was a 10-replicate, compact family block with two-tree (family) plots (Panse and Sukhatme 1954). "Family" as used here means the wind-pollinated progeny of a single tree. This design grouped the five two-tree family plots representing a single stand (the five trees in each collection area) rather than distributing the family plots at random over each replication. Spacing was 8 by 8 feet and replication size was about 1.7 acres. A single border row was used to offset edge effects.

Rust infection in the Louisiana planting has been heavy. Forty-three percent of the trees have either a branch or a stem gall. This, coupled with good survival and growth, prompted us to score the planting for rust infection during the winter of 1969-70, when it was 4 years old. The average number of both trunk and branch cankers per tree was determined. Results from the remaining two plantations will be reported as they are developed.

Analyses.--The data were transformed to $\sqrt{X + 1/2}$, and $\sqrt{X}$ $(\sqrt{X + 1})$. Raw and transformed data from several stands were plotted, and $\sqrt{X + 1/2}$ approached normality closest; therefore analysis of variance was done with this transformation.

First, 115 separate analyses of variance were conducted on the five families from each stand. Degrees of freedom for typical analysis were: blocks--9, families--4, error--36, total--49.

Then, an analysis combining data from all stands was made as follows:

Source of variation	D.f.	S.S.	M. Sq.	Variance components
Blocks	9	27.46	3.051	
Stands	104	149.82	1.440*	$S_{e(a)} + 10 (S$
Error (a): stands x blocks	936	135.82	.145	$6_{e(a)}^2$
Families within stands	401	130.54	.326*	q(b) + 10 Si
Error (b): families within stands x blocks	3,238	577.79	.178	Se(b)

The 0.05 level of significance was used.

The "families within stands" and "error b" in the combined analyses terms were determined by pooling the "family" and "error a" terms from each stand analyses. Prior to pooling, tests of homogeneity were conducted and data from four stands were removed because of excessive heterogeneity. The six stands west of Mississippi were also removed,because of their geographic isolation from the population east of the Mississippi River.

RESULTS

The geographic pattern of variation is shown in figure 1 **in** terms of cankers per tree averaged over the five families from each collection area. The values range from near 2.4 for the progenies from the collection areas immediately west of Mobile Bay to 0 for one of the progenies from east-central Arkansas.

The most obvious geographic effect is the relative resistance of the progenies from west of the Mississippi River compared to those from east of it. This confirms earlier evidence that resistance in loblolly pine is widespread west of the Mississippi River.

The most important new aspects of the variation pattern **are** (1) the distribution of stands with a high degree of resistance in the Florida parishes of Louisiana and southwestern Mississippi, and (2) the lack of resistance in the progenies from the southeastern part of the study area and the general increase in resistance to the north and west. Inherent resistance is higher along the western margin of the range in Mississippi than it is along the Alabama-Mississippi border.

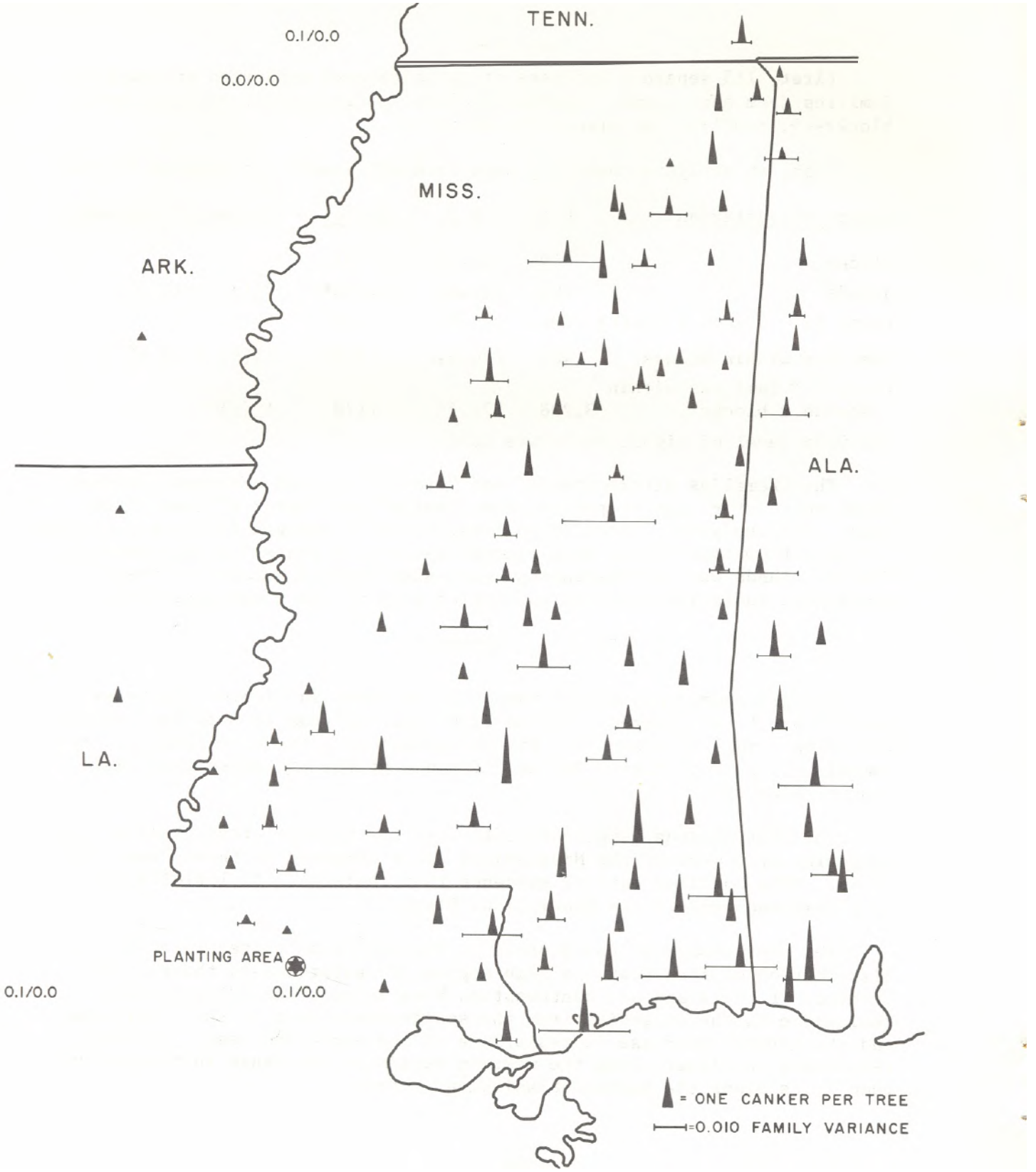

Figure 1.--Average number of cankers per tree (vertical triangles) for the progenies of 115 stands of loblolly pine. The horizontal bars represent variation among the (usually) five families from each stand. The fractions state canker/variance values too small to depict grapically.

It is easier to report these variations than to explain them. One possibility is hybridization between loblolly and the resistant shortleaf pine.

Introgression with shortleaf is almost certainly important in the development of resistance in loblolly pine (Hare and Switzer 1969). However, correspondence between the distribution of shortleaf pine (fig. 2) and the geographic variation in resistance of loblolly is only fair. Shortleaf is absent or rare within about 30 miles of the Mississippi Gulf Coast where resistance is low, and it is common in southwestern Mississippi where resistance is high. Concentrations of shortleaf are particularly heavy and resistance particularly high west of the Mississippi River. On the other hand, resistance in loblolly is fairly high in parts of northeastern Mississippi where shortleaf is relatively scarce.

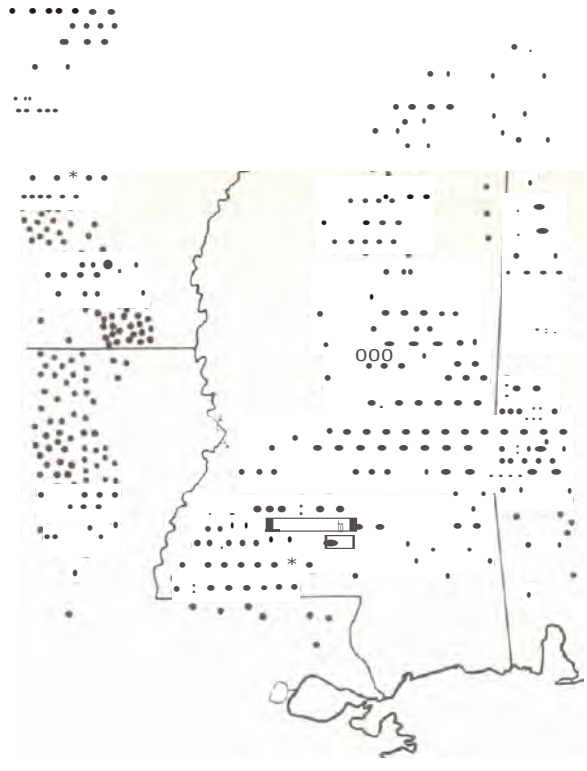

Figure 2.--Distribution of shortleaf pine in and near the study area. Each dot signifies 5,000,000 cubic feet of timber volume in trees at least 5.0 inches in diameter at breast height. (Adapted from Janssen and Weiland 1960.)

The presence of shortleaf was noted for each collection area where it occurred; the notes agreed very well with the shortleaf distribution map shown in figure 2 but revealed nothing further about the relationship between resistance in loblolly and the distribution of shortleaf.

Introgression may also be at least partly responsible for the very large differences in amount of family variance within stands (fig. 1). Large family variance would be expected in early stages of introgression before resistant genes become evenly distributed throughout the population.

Still other factors may contribute to the pattern of resistance. Climatic characteristics of the environment or introgression with longleaf may be involved, either singly or in combination. Resolution of the problem would undoubtedly be greatly aided by a fuller knowledge of the genecology of the rust.

Variance within stands was 0.0148, and variance among stands (the geographic effect) was 0.1294, or 8.75 times as great. This result provides a guide for efficient selection for rust resistance in loblolly within the study area and probably outside it as well, since the area covered is representative of most of the loblolly range. First priority should be given to selection of resistant stands. Once this has been done, individual trees may be selected within the best stands.

The large variation attributable to stands simplifies the problem of making use of resistance once it is located. Seed can be collected from resistant natural stands in large quantities, whereas resistant individual trees must be propagated and multiplied in orchards. Collecting seed from a stand should also ensure a broader genetic base than could be had by picking a few individual trees, and would thus reduce the chances of heavy loss if the pathogen evolved new races capable of infecting the presently resistant selections.

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