Comparison of Six Geographic Sources of Loblolly Pine for Fusiform Rust Resistance

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ABSTRACT

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Loblolly pine seedlings grown from seed collected in six geographic areas across the natural range of this species were inoculated with rust fungi collected from each seed source area. There were significant differences in disease susceptibility among seed sources; the Maryland source was the most resistant. The interactions between specific seed sources and rust fungus collections were highly significant, which indicated that seed from several of the sources can be used to reduce the impact of fusiform rust. Seedlings from all seed source areas were most susceptible to infection by their respective local rust fungus isolates.

Additional key words: disease resistance, pathogenic variability, *Cronartium quercuum* f. sp. *fusiforme*, *Pinus taeda*.

Loblolly pine (*Pinus taeda* L.), the most widely planted of the southern pines, is heavily attacked by the fusiform rust fungus (*Cronartium quercuum* [Berk.] Miyabe ex Shirai f. sp. *fusiforme*) in a zone extending from northeastern South Carolina to southwestern Louisiana (6). In this area many plantations average 60% rust infection, with infection reaching 80–95% in high-hazard zones. In addition, the incidence of rust seems to be increasing (9). Resistance to fusiform rust has been demonstrated in loblolly pine (12,13), but few parent trees that transmit high levels of resistance have been found. The resistant selections now available are being used to provide clones for the establishment of rust-resistant seed orchards. Eventually these orchards will provide seed for reforestation in high-rust hazard areas; however, most are quite young and will not produce seed in commercial quantities for at least a few years.

Forest managers, therefore, are using bulk lots of seed from specific geographic areas which are known to have at least a moderate level of resistance. Of four such areas identified in the Southwide Pine Seed Source Study (12), Livingston Parish, Louisiana, currently is the primary seed source. Plantations from these seeds have been established along the Gulf coast and as far north as Savannah, Georgia, on the Atlantic coast. Livingston Parish stock has proved to be reasonably resistant in many field plantings (12).

The objective of this study was to test for interactions between several rust-resistant seed sources and rust inocula from each local area where the seed originated. Results should indicate if resistance to rust is stable for several isolates of the fungus or if seed from certain sources should be considered for planting only in specific geographic areas.

MATERIALS AND METHODS

Loblolly seeds were collected from five geographic areas around the periphery of the natural range of this species: Somerset County, MD; Livingston Parish, LA; Angelina County, TX; Clark County, AK; and Marion County, FL. Seeds from the first four areas had been identified as resistant in the Southwide Pine Seed Source Study (12). Those from the Florida source demonstrated some resistance in some field plantings (1). In Maryland, Texas, Arkansas, and Florida seeds from at least 20 trees at each site were collected after logging operations, and then bulked. Seeds from Louisiana were purchased. Those from Clarke County, Georgia, included as a control, were collected from susceptible trees.

Aeciospores were collected from each seed source county. Aeciospores from 10 individual galls in each area were mixed on an equal basis to provide composite collections representing the area. Seedlings of northern red oak (*Quercus rubra* L.) were inoculated with aeciospores from each collection to produce basidiospores. Basidiospores were harvested after 3 wk and used in a concentrated spray for pine inoculations (5). Seeds from each geographic source were germinated and seedlings transplanted into eight flats containing 20 seedlings each. At 4 wk of age the seedlings were inoculated by spraying with a suspension containing 50×10^3 spores per milliliter (3).In vitro basidiospore viability was at least 91%. Each flat constituted an experimental unit, and 5,760 seedlings were inoculated in the study. The seedlings were then grown in a greenhouse for 9 mo before being examined for infection. Infection data consisted of the percentage of seedlings with actively growing galls. The statistical design was a $6 \times 6 \times 8$ factorial analysis of variance. Means were separated according to Duncan's multiple range test (2).

RESULTS

There were highly significant differences in susceptibility to fusiform rust among the six seed sources of loblolly pine (Table 1). Average infection levels for seed sources ranged from a high of 84% for the control seed from Georgia to a low of 56% for the Maryland seed source. All five of the resistant seed sources had significantly less infection than did the Georgia control; however, the Louisiana seed source was only marginally better (79 vs 84% infection). The Maryland seed source was significantly more resistant than all other sources.

There also were significant differences among the data for rust fungus isolates from the different geographic areas when they were averaged across all seed sources. However, the range of infection was only 66 – 73% (Table 1).

There were highly significant interactions between seed sources and rust fungus collections. The responses ranged from 48% infection on the Arkansas seed source inoculated with the Maryland rust isolate to 89% infection of the Georgia control inoculated with the Maryland rust isolate. Some combinations were particularly striking—for example, the Maryland and Arkansas seed sources with their respective rust isolates. The infection percentages for these two seed sources when inoculated

with Maryland rust were 69 and 48%, respectively (Table 1). With the Arkansas rust pathogen, the results were reversed, 49 and 72%, respectively. For all sources except the control, the infection level for a specific seed source was highest when that source was inoculated with aeciospores from the same geographic area (Table 1). This trend was shown on a broader scale when the two eastern-most resistant sources (Maryland and Florida) were compared with the two westernmost resistant sources (Arkansas and Texas). On trees grown from the two eastern seed sources, eastern rust fungus isolates caused 68% infection, while western isolates caused 54% infection. On trees grown from the western seed sources western rust isolates caused 76% infection, and eastern isolates 58%.

DISCUSSION

Loblolly pine seedlings from all of the geographic sources were significantly more resistant than the control. In the Southwide Pine Seed Source Study these four resistant sources had approximately 50% less infection than a Georgia source in several widely separated plantings (12). The Louisiana seedlings in this study, with 79% infection, were much more susceptible than expected based on previous studies (7). The Louisiana seed used in this test were collected in 1975, while those in the earlier studies were collected prior to that time. The exact geographical source of the 1975 material could not be verified; these seed may not have come from the specific area described by Wells and Switzer (11) which gives the highest levels of rust resistance.

The artificial inoculations undoubtedly produced a higher incidence of rust than is usually found in the field, but even taking this into account, the relative rankings are somewhat different from those in the Southwide Pine Seed Source Study. In that study the most resistant sources, in decreasing order, were Texas, Arkansas, Maryland, and Louisiana. These sources were more resistant than 11 others wherever they were planted. In the current study, the resistance ranking was Maryland, Arkansas, Texas, and Louisiana. Direct comparisons should not be made between the two studies since the seedlots could differ considerably even though they were from the same counties (12). Furthermore, seedlings in the current study were inoculated at the juvenile stage (4 wk old), whereas in the earlier study data were taken over a 10-yr period. Another difference in the current study was that seedlings from each seed source were subjected to severe inoculations with rust collections from each local source; this was not the case in the earlier study. In the Southwide Pine Seed Source Study only the Louisiana planting had high levels of infection (25–98%), while the Arkansas planting had relatively little infection (0–25%), and the Texas and Maryland plantings had none. The one new seed source included in the current study was from Marion County, Florida. Information on field performance of seedling trees from this source is limited; however, it is reported to be at least intermediate in resistance and definitely better than susceptible sources (1). Our results support this evaluation.

Most foresters prefer to use as broad a genetic base as possible in their resistant pine plantations. The Livingston Parish, Louisiana, seed source has been used in most such plantings to date. The data in Table 1 indicate that there are alternative seed sources available for planting in many parts of the South where rust is a serious problem. For example, the Texas and Florida sources could be considered for the lower latitudes of the South, while Arkansas and Maryland sources could be used in areas where cold injury to the southern sources might be a problem. Another possible use of the various geographic sources of resistance would be to combine several in a seed mixture. For example, a mixture of Louisiana, Texas, and Florida seed could be used for planting in the lower South. Use of several alternative sources of resistance would reduce the probability of a buildup in virulence by the pathogen. A single source of resistance should not be relied on, since experience with rust pathogens of other crops (eg, cereals) offers many examples of the development of increased virulence in the pathogen population to certain resistant host cultivars.

Although there were significant differences among the rust collections from the different geographic areas, the infection means ranged only from 66 to 73%. However, the inocula used in this study were composites of 10 individual gall collections from each area, and pathogenic variability within collection areas was not evaluated. It has been shown that the use of a composite of several collections will mask the effect of an individual, highly virulent, collection (4). The results gave a definite indication of higher infection levels when trees grown from any seed source were inoculated with its local rust fungus isolate, as indicated by the underlined figures in Table 1. The higher levels of infection of the seed sources inoculated with local rust fungus collections compared to the mean of the other five collections were large and consistent. These figures were 16, 14, 11, 16, 3, and 4%, respectively, for trees grown from seed sources Maryland to Georgia in Table 1. The two low figures were for trees grown from a seed source of questionable resistance (Louisiana), and for the susceptible control (Georgia). In both cases all infection percentages were very high. These increases in infection levels when local rust fungi were used demonstrated the potential of the pathogen to adapt to resistant hosts. This adaptation has been shown in previous studies for specific families of slash (10), and to a lesser extent, in loblolly (8) pine. These results demonstrate that the pathogen can also adapt to resistance expressed by a mixture of genotypes from a specific geographic area.

Since relatively few resistant loblolly selections are currently available for the development of resistant seed orchards, the resistant geographic sources identified in this study probably will be useful for many years to come. Not only should they provide planting stock to reduce the impact of fusiform rust on forest production in the South, but they also can serve as a source of resistance to enlarge the number of selections available for use in rust-resistant seed orchards.

TABLE 1. Incidence of infection on seedlings of six geographic sources of loblolly pine after inoculation with rust fungus collections from each geographic area

Seed sources	Seedlings (%) with galls 9 mo after inoculation with spores from: GA	MD	AK	FL	TX	LA	Host mean
Maryland	53	69[a]	49	52	56	55	56 A[b]
Arkansas	54	48	72	61	68	61	61 B
Florida	69	74	49	76	61	73	67 C
Texas	58	53	80	68	84	83	71 C
Louisiana	78	73	81	81	81	82	79 D
Georgia (control)	88	89	81	82	80	87	84 E
Mean	66A	68AB	69ABC	70ABC	72BC	73C	(70)

[a] Underlined figures indicate the incidence of infection in trees inoculated with a local source of the rust fungus.

[b] Infection percentages followed by the same letter do not differ significantly ($P = 0.01$ for host means and $P = 0.05$ for spore means) as determined by Duncan's multiple range test.

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