RESPONSE OF FOUR SOURCES OF LOBLOLLY PINE TO SOIL ACIDITY EXTREMES

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Abstract--Four sources of loblolly pine from Florida and adjacent regions were grown on two soil regimes, one very acidic and the other nearly neutral, in a greenhouse. All sources had greater height, root collar caliper, and dry weight on the acidic soil. There was no significant interaction of sources or families within sources with acidity levels. The Gulf Coast source was significantly shorter in height than the other three sources. While no important differences were found between the two Florida sources, some Gulf Hammock families performed well on the soil with acidity level of pH 6 to 7.

Additional keywords: Marion County, edapic ecotypes, G X E interaction, Pinus taeda.

INTRODUCTION

Much interest has been expressed in Florida loblolly pine (Pinus taeda L.) because of its status as the southern-most source and its repu

planting as an exotic in more tropical regions of the world.

Over the years, foresters have come to refer to Florida loblolly pine as either the Marion County or Gulf Hammock source. The Marion County material is typically found on deep sandy sites with soil acidity levels of pH 4 to 5. In contrast, Gulf Hammock refers to Levy and Dixie Counties on the Gulf Coast and is typified by wet marl soils with soil acidity of pH 6 to 7. Since soil acidity is such a dominant factor in soil chemistry and the Florida sources are under intense selection pressure by virtue of the fact they are on the edge of species' natural range, an interesting question is whether the two sources have evolved differently into edaphic races.

Another concern involving Florida Loblolly pine is the restricted breeding population and dim prospects for locating more select phenotypes. Presently, about 140 selections have been located by the organizations working with Florida loblolly pine. This is far below the 200 to 400 genotypes generally suggested as the minimum for a base breeding population (Krug, 1979; Burdon, et al., 1977; and McKeand and Beineke, 1980). The dearth of natural stands precludes more mass selection to bolster the breeding population.

This paper reports on a greenhouse study to determine if the two Florida sources are distinct genetically and whether they could be combined with adjacent sources of loblolly pine in an expanded breeding population.

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MATERIALS AND METHODS

Fifteen half-sib families were chosen from seed orchard seed lots to represent ortets originally selected in each of the following geographical seed sources: Gulf Hammock, Florida (GH); Marion County, Florida (MC); the Gulf Coastal Plain of Mississippi - Alabama (GCP); and the Atlantic Coastal Plain of Georgia - South Carolina (ACP). The GH seed was collected from Georgia - Pacific's Gulf Hammock orchard and the MC seed came from clonal collections at Brunswick Pulp Land Company's Florida Loblolly Seed Orchard. The other seed lots were selected at random from seed in storage at North Carolina State University. Relative quality was ignored in choosing seed lots.

A split-plot design was used with three replications. Two soils with acidities of pH 4.5 and pH 6.5 were the main plots, seed sources were sub-plots, and the half-sib families were nested within sources. Families in the main plots were represented by 10 seedlings. A base soil media of pH 4.5 was developed using equal parts of river sand, peat moss, and coarse vermiculite. Calcium carbonate was used to adjust the soil acidity to pH 6.5. The seedlings grew for 16 weeks in cylindrical containers of cc volume. The temperature settings in the greenhouse were 26°C days and 22°C nights.

Poor germination caused the deletion of 3 families of the Atlantic Coastal Plain and 1 family of the Gulf Coast source. Seedlings were given optimum conditions for growth, other than soil acidity, which proved to be fairly easy to regulate. Approximately two whole pH units were maintained between the main plot treatments over the course of the study, although they varied from the target pH levels of 4.5 and 6.5.

At the end of the growth phase, the growth variables looked at were seedling height, root collar caliper, and stem dry weight. An analysis of variance was done on plot means for each trait.

RESULTS

Seedling Height

Seed weight accounted for only a small part of the variability associated with seedling height (r= -0.19) and was not significant. The analysis showed a significant acidity effect. Seedlings on the low pH soil averaged 27.77 cm, 13% taller than seedlings on the high pH soil (Table 1). There were marked differences in appearance as well. Seedlings looked healthy and vigorous at the, lower pH level while those growing under the acidity level of pH 6.5 looked distressed and were less bushy with needles that were a paler shade of green.

Source rankings were exactly the same under both acidity regimes, with no significant interaction of acidity and sources (Table 1). This suggests that none of the sources tested are especially adapted genetically to either high or low soil acidity. The fact that Marion County was tallest and Gulf Hammock was second is in agreement with previous seed source studies (Draper, 1975 and Labrach, 1980) and is encouraging evidence that the Florida sources respond similarly to soil acidity.

Table 1.--Seedling height for all four seed sources, by pH level and combined over pH levels.

Seed Source	Seedling Height		
	pH 4.5	pH 6.5	overall
	- - - - - - Centimeters - - - - - -		
Marion County	28.76	25.44	27.10 b [a/]
Gulf Hammock	28.26	24.93	26.60 b
Atlantic Coastal Plain	27.97	24.87	26.42 b
Gulf Coastal Plain	26.08	22.95	24.51 c
Means	27.77	24.55	26.16

[a/] Means within a soil pH level no sharing the same superscript are significantly different at the 1% level.

The source effect was highly significant in the analysis. A multiple comparison procedure using Waller-Duncan's Bayesian K-ratio t-test revealed that the Gulf Coast source was significantly different at the K=100 level (approximately equal to the 0.05 level). This result was surprising since the GCP source had the heaviest seed and was ranked first in height at age ten weeks. This apparent genetic difference in height growth would be a considerable handicap if it persisted well into the rotation.

There was a large and highly significant family within source effect. The large amount of variation within sources indicates that mass selection would be effective in a breeding program.

While there was no significant family X acidity interaction, a closer look at the two Florida sources revealed interesting family rank changes. Using Spearman's Coefficient of Rank Correlation (Steel and Torrie, 1980), families of the MC source exhibited a high degree of stability over acidity regimes ($r_s = 0.85$). The rank of GH families over acidity regimes was very poorly correlated ($r_s = 0.08$), indicating a lack of stability to soil acidity extremes. These results are supported by linear correlation r values of 0.90 for MC and 0.36 for GH.

Some GH clones apparently are genetically adapted to either low or high soil pH values. For instance, clone 23-341/ ranked second under pH 4.5 but dropped to last in pH 6.5, while clones 22-33, 22-32, 22-23, and 22-4 performed well on the high pH soil.

Root Collar Caliper

Root collar caliper is more sensitive than seedling height to stocking density (McGilvary and Barnett, 1981). It has limited value as a measure of growth because of the high seedling sensity in the study (527 seedlings per square meter) and the small amount of variation detectable with the measuring

[1-7-] Clone number assigned by the North Carolina State University - Industry Cooperative Tree Improvement Program.

instruments on small stems. Also, stem dry weight accounted for 76% of the variability associated with root collar caliper.

Diameter growth was significantly better on the low pH value soil where the mean caliper was 8.5% greater. The analysis found no interaction between soil acidity and sources or families within sources, although there was some rank change amoung the sources between pH levels (Table 2). The Gulf Coastal Plain source had the largest caliper on both pH levels, with no clear second place. The fact that seed weight accounted for 39% of the variation in caliper (r = 0.63) and that the Gulf Coastal Plain had the heaviest seed may explain the good showing of this source material.

Table 2.--Root collar caliper for all four sources by pH levels and combined over pH levels.

Seed Source	Root Collar Caliper		
	pH 4.5	pH 6.5	overall
	- - - - - Millimeters - - - - -		
Gulf Coastal Plain	2.85	2.65	2.75 b [a/]
Marion County	2.82	2.58	2.70 b
Atlantic Coastal Plain	2.84	2.56	2.70 b
Gulf Hammock	2.78	2.60	2.69 b
Means	2.82	2.60	2.71

[a/] Means within a soil pH level sharing the same superscript are not significantly different at the 0.05 level.

For this trait, sources were basically equal, with no significant differences. However, once again there were important family within source differences, indicating enough potential variation to make mass selection worthwhile. Variability among families ranged from a high of 3.00 mm for family 24-1 (GCP source) to 2.45 mm for family 22-22 (MC source), a difference of 22% in root collar caliper and 150% in cross sectional area.

As the data in Table 2 shows, the GH source had slightly larger caliper (2.60 mm vs. 2.58 mm) than MC on the pH 6.5 soil. When the GCP and ACP sources were dropped from the analysis, the Florida sources exhibit a significant interaction with acidity levels at the 0.05 level. The Gulf Hammock source may be better adapted to high pH levels; some families did show the ability to grow well on the adverse soil of pH 6.5. Families 22-32 and 22-33 had larger root collar caliper on the high pH value soil than on the low pH value soil, and family 22-23 was nearly the same on both soil acidities. These three Gulf Hammock clones were also top performers for seedling height. This suggests that these clones are tolerant of soil acidity in the range of pH 6.5. At the same time, they are adaptable enough to show good growth on soil with acidity more typical of loblolly pine sites.

Each Florida source had good correlation of family ranks between acidity extremes when using Spearman's Coefficient of Rank Correlation (r_s values were

0.53 and 0.86 for GH and MC). A linear correlation check revealed a lower correlation of r = .46 for GH versus r = .84 for MC. Only one Marion County clone grew reasonably well on the soil with pH value of 6.5.

Stem Dry Weight

Seed weight or common environment effect contributed 40% of the variation in stem dry weight at age 16 weeks (r = 0.63). Similar results have been reported at age 24 weeks when the correlation coefficient was 0.57 (Waxier and van Buijtenen, 1981).

The analysis showed that stem dry weight was strongly affected by soil acidity levels. Overall, seedlings grown on the low pH soil were 33% heavier (Table 3). Fluctuations in the target acidity levels indicated that growth was severely restricted when the soil acidity rose to approximately pH 7; the ability of the seedlings to absorb nutrients, even if abundantly supplied, and function well physiologically was impared at pH 6.5 and above.

Table 3:--Stem dry weight for all from sources by pH levels and combined over pH levels.

Seed Source	Stem Dry Weight		
	pH 4.5	pH 6.5	overall
	- - - - - - - - grams- - - - - - - -		
Gulf Coastal Plain	1.454	1.139	1.297 b [a/]
Marion County	1.467	1.062	1.265 b
Atlantic Coastal	1.422	1.028	1.225 b
Gulf Hammock	1.299	1.009	1.154 b
Means	1.411	1.060	1.235

[a/] Means within a soil pH level sharing the same superscript are not significantly different at the 0.05 level.

As in the other two traits measured, there was a significant family response. Dry weights for families, averaged over pH levels, ranged from 0.925 grams to 1.569 grams, a difference of 70%. There obviously is sufficient genetic variation to make good gains with selection in a breeding program.

Sources were not found to be significantly different in their dry weights, at least at the 0.05 level. The Gulf Coastal Plain and Marion County sources were nearly equal, with a slight edge to the GCP material (Table 3). The Gulf Hammock source was consistently last in dry weight, despite the fact with GH material exhibited good height growth and average diameter growth. Seedlings of this source apparently contained more water in the above ground biomass. The reason for this is not known.

Neither sources nor families within sources were found to vary in performance with respect to soil acidity; no statistically significant evidence of ecotypic adaptation was found. Both of the Florida sources gave high rank

correlations when Spearman's procedure was used to compare family ranks on the high and low pH value soils, (rs was 0.64 for GH and 0.68 for MC). Again, clones 22-32, 22-33, and 22-23 of GH source grew very well on the less acidic soil. These clones appear to be well adapted to a wide range of soil acidity levels.

CONCLUSIONS

The most reliable growth trait examined, seedling height, gave strong evidence that the two Florida seed sources, Gulf Hammock and Marion County, are genetically similar in their response to soil acidity. Combining the Florida sources into one breeding program seems to be justified. Additionally, there is evidence for including selections from adjacent geographical sources in an expanded breeding population for Florida loblolly pine, particularly selections from the Atlantic Coastal Plain of Georgia and possibly South Carolina. Use of selections from the Gulf Coastal Plain should be avoided until more reliable data is available. These results must be considered tentative until field trails either confirm or dispute the findings.

Fortunately, field trials using the same open-pollinated seed lots for each source have been established in a join project between the N. C. State University - Industry Cooperative Tree Improvement Program and University of Florida Cooperative Forest Genetics Program. The tests are located at nine sites chosen to sample the environment within the provenances and provide information on the extent of genotype X environmental interaction.

While no sources exhibited edaphic adaptation to either high or low soil acidity, there was evidence of intra-source G X E within the Gulf Hammock material. Several GH families consistently grew very well on the pH 6.5 soil and could represent physiological ecotypes. As proposed by Bridgwater and Stonecypher (1978), the real opportunity here is for realized genetic gains, made possible by assigning half-sib families to sites to which they are specifically adapted.

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