LONGLEAF PINE TREE IMPROVEMENT IN THE WESTERN GULF REGION

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Abstract.--Longleaf pine collected from North Louisiana, Southeast Texas, South Louisiana and South Mississippi were outplanted in seven locations in the Western Gulf area. Family heritabilities across locations were 0.56 for second year survival, 0.54 for grass stage emergence and 0.72 for brown-spot needle blight resistance. Coefficients of genetic prediction indicated a positive relationship between survival and grass stage emergence but not between these traits and brown-spot resistance. Tentative conclusions based on one year's plantings indicate that North Louisiana, Southeast Texas, South Louisiana and South Mississippi can be considered one breeding zone for improving survival. Southeast Texas, South Louisiana and South Mississippi can be considered one breeding zone for improving emergence from the grass stage and brown-spot resistance.

Additional keywords: Pinus palustris, Scirrhia acicola, genotype by environment interaction, survival, grass stage emergence.

In recent years, increased interest has been shown in using longleaf pine (Pinus palustris Mill.) in artificial regeneration programs in the Western Gulf Region. This stems from 1) the increasing value of poles, pilings and other solid wood products, 2) the increasing losses to fusiform rust (Cronartium quercuum [Berk.] Miybe ex Shirai f. sp. fusiforme) on slash pine (Pinus elliottii Engelm. var elliottii), 3) an increasing emphasis on planting the proper species on appropriate sites, and 4) longleaf's suitability for planting in high fire hazard areas.

Many of the problems traditionally associated with the establishment and early growth of longleaf pine are manageable by improved nursery techniques, seedling care and silvicultural practices (Shipman 1960, Smith and Schmidtling 1970). Traits related to establishment are also under genetic control. Family heritabilities for early survival were estimated as 0.73 at one location (Rockwood and Kok 1977) and 0.35 across a wide range of environments (Goddard and Bryant 1981). Goddard and Bryant calculated that selecting the top one-half of the families in their study resulted in a 6.5 percent gain in survival. Family heritabilities for height initiation at two years of age across several environments ranged from 0.47 to 0.68 (Layton and Goddard 1982).

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Snyder and others (1977) reported heritabilities for height initiation of 0.48 and 0.52 at three years of age. They also reported family heritabilities for brown-spot needle blight (*Scirrhia acicola* [Dearn.] Sigg.) resistance of 0.30 and 0.57.

Goddard and others (1973), and Snyder (1969) noted that selection of phenotypically superior plus trees was not particularly effective in improving juvenile traits and recommended a two step testing program. The Western Gulf Forest Tree Improvement Longleaf Pine Program is similar to the two step selection procedure developed by the Florida Cooperative Forest Genetics Program (Goddard and others 1973, Goddard and Rockwood 1978).

Western Gulf Longleaf Pine Program

Approximately 100 low intensity selections will be made from each of four provenances - Southeast Texas, South Louisiana, North Louisiana, and South Mississippi. The 400 selections will be included in short duration tests (three years) to evaluate juvenile traits. Families that exhibit acceptable performance will be established in long term, good growth and form progeny tests. Both stages of the testing program are designed to determine the effects of different provenances, the relative amount of family variation, and the presence of genotype by environment interactions.

Provisions have been made to meet seed needs with the establishment of seedling seed orchards concurrently with the establishment of the short term tests, in conjunction with the long term tests or by establishing clonal orchards based on the long term test results.

This paper presents the second year data from the first plantings of the short-term tests. The objectives are to estimate heritabilities and examine genotype by environment interactions for survival, grass stage emergence and brown-spot resistance.

Materials and Methods

In the spring of 1982, 100 families plus four bulk checklots were sown in three nurseries for outplanting at seven locations (Figure 1). Seedlings were sown at an initial density of nine per square foot and grown according to standard nursery procedures for longleaf pine. The two North Louisiana plantings were grown at one nursery, the two South Mississippi plantings were grown at a second nursery and the two Southeast Texas plantings and the South Louisiana planting were grown at a third. Sixty-four of the 100 families were common to all seven locations and ninety-three families were in at least five of the seven plantings. Field design consisted of eight replications at each location with four or five trees per row plot depending on the planting. Spacing was two by 10 feet at four locations, three by nine feet at two locations, and two by eight feet at a single location. Sites ranged from dry sand ridges to poorly drained flatwoods.

At the end of the second growing season survival, percent of living trees initiating height growth, and percent of foliage infected by brown-spot needle blight were scored. Brown-spot infection was scored on a 0 to five scale with 0 representing a brown-spot free individual. Higher scores represented the amount of foliage infected in 20 percent increments.

Figure 1. County/parish locations of the short-term longleaf pine plantings.

All percent data was transformed by the arc sine of the square root and each location was analyzed separately. The 64 families common to all seven locations were combined in one analysis across locations to examine the relative amount of genotype by environment interaction. Variance components were calculated for family within provenance and provenance effects to determine the relative importance of geographic variability in selection. Family heritabilities for survival, percent height initiation, and brown-spot severity were calculated at each of the locations with significant family effects as well as for the combined analysis according to the following formulas:

One location

$$h^2 = \frac{\sigma^2_F}{\sigma^2_F + \sigma^2_{E/r}}$$

Multiple locations

$$h^2 = \frac{\sigma^2_F}{\sigma^2_F + \sigma^2_{F(P)*L/l} + \sigma^2_{E/lr}}$$

Where

σ^2_F = variance among family means within provenances

$\sigma^2_{F(P)*L}$ = variance among families within provenance by planting location means
σ^2_E = error variance
l = number of locations
r = number of replications

The coefficients of genetic prediction (CGP) were used to examine the relationship between traits (Baradat 1976). They were also calculated for the same trait across locations to examine the amount and direction of genotype by environment interaction.

RESULTS AND DISCUSSIONS

Single Locations

Second year planting survival ranged from 26 to 95 percent (Table 1). There were differences between families within provenances in six of the seven locations. Family heritability for survival varied from 0.21 to 0.55. Low heritability estimates at the Tyler and Hardin County, Texas, tests are primarily caused by lack of variation due to uniformly good survival.

Table 1. Locations, averages, family heritability estimates, and standard errors for survival, grass stage emergence and brown-spot severity at seven plantings of two-year-old longleaf pine in the Western Gulf region.

Location County/Parish State	Survival			Grass Stage Emergence			Brown-spot Severity Code		
	%	$h^2 \pm$	SE	%	$h^2 \pm$	SE	$\bar{x}$	h^2	SE
Stone, MS	78	.47±	.16	58	.37±	.16	1.34	.70±	.15
Pearl River, MS	32	.55±	.17	45	.23±	.18	0.67	.49±	.18
Tyler, TX	95	.21±	.16	44	.40±	.16	2.88	.69±	.15
Hardin, TX	95	.29±	.16	93	---		.09	.23±	.16
Vernon, LA	72	---		27	.22±	.16	.65	.32±	.16
Bienville, LA	26	.34±	.16	64	---		.23	---	
LaSalle, LA	75	.28±	.16	82	---		.40	---	
Combined location		.56±	.18		.54±	.18		.72±	.18

The percent of living trees emerging from the grass stage ranged from 27 to 93 percent. The Hardin County, Texas, test showed the benefit of intensive competition control with both very high survival and a high percentage of living trees initiating height growth. There were differences between families within provenances for grass stage emergence in four of the seven locations. Family heritabilities ranged from 0.22 to 0.40.

Percent of trees infected with brown-spot needle blight varied from only 5 percent at the Hardin County, Texas, test to 96 percent at the Tyler County, Texas, test. In this planting, the average tree had almost 50 percent of its foliage infected. Brown-spot severity score was used for analysis because it was more heritable than the percent of trees infected. The average planting severity code ranged from a low of 0.09 to a high of 2.88. There were differences between families within provenances in five of the seven tests. Family heritabilities varied from 0.23 to 0.70. The low heritability estimate for the Hardin County test was primarily caused by the lack of infection. Brown-spot resistance was the most heritable of the three traits scored.

Combined Locations

When the 64 families common to all plantings were analyzed, there were differences between families within provenances for all three traits. There were also differences attributable to provenances for survival and grass stage emergence. The North Louisiana and Southeast Texas sources had slightly higher survival and grass stage emergence (Table 2). There was no provenance by planting location interaction for either trait. While there was no provenance effect for brown-spot infection, there was evidence of a provenance by planting location interaction (Figure 2). This interaction was statistically significant but not operationally meaningful. Although there were some changes in ranks at the Louisiana plantings, where the differences among provenances were small, the interaction resulted primarily from changes in magnitude. North Louisiana sources tended to be more susceptible while South Mississippi sources were affected least.

Table 2. Provenance means for survival and grass stage emergence for two-year-old longleaf pine planted in the Western Gulf region.

Provenance	Survival (Percent)	Growth Initiation (Percent)
North Louisiana	70.8	62.0
Southeast Texas	70.4	62.7
South Louisiana	68.1	59.6
South Mississippi	65.0	55.6

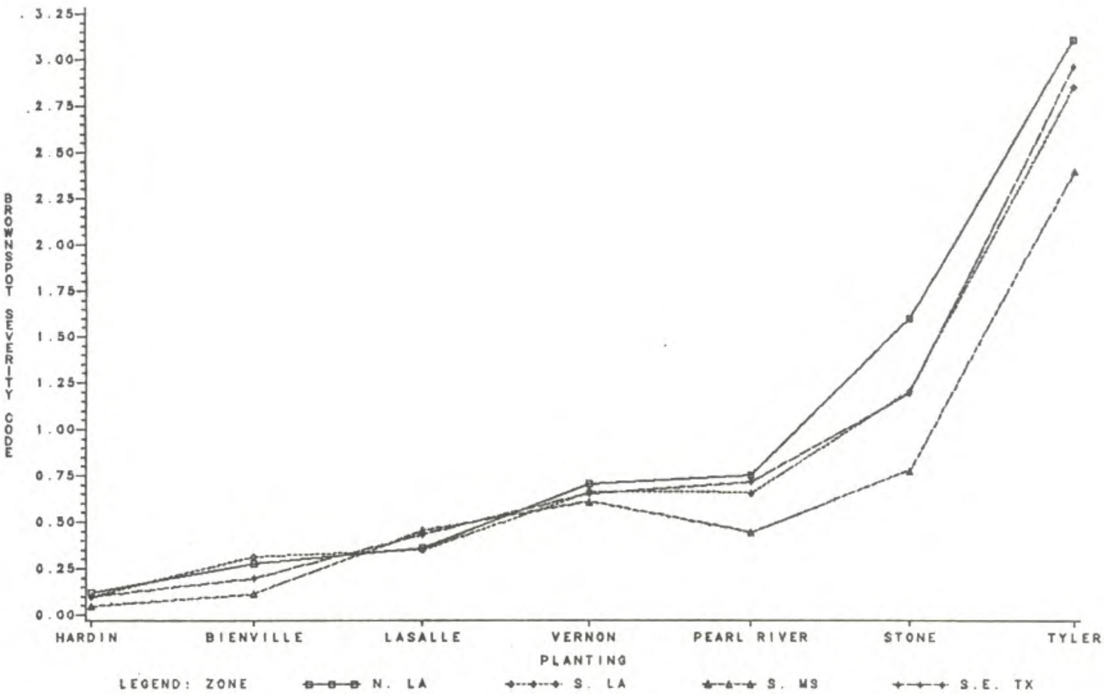

Figure 2. Provenance (zone) by planting averages for brown-spot severity in two-year-old longleaf pine.

There was a family within provenance by planting location interaction for all three traits. This interaction accounted for approximately 10 percent of the total phenotypic variation and was considered unimportant because of the large amount of family variation. Family heritability across all locations was 0.56 for survival, 0.54 for grass stage emergence and 0.72 for brown-spot resistance (Table 3). These moderate to strong heritabilities and the distribution of variation between the provenance effect and family within provenance effect (Table 4) indicate that emphasis should be placed on selecting the best individuals regardless of seed collection zone.

Table 3. Heritabilities and coefficients of genetic predition from the combined locations analysis for seven plantings of two-year-old longleaf pine in the Western Gulf region.

Trait	Survival	Grass Stage Emergence	Brown-Spot Severity Score
Survival	0.56	0.18	0.07
Grass Stage Emergence		0.54	0.05
Brown-Spot Severity Score			0.72

Table 4. Distribution of variation in percent between provenances and families within provenances for two-year-old longleaf pine planted in the Western Gulf region.

Type of Variation	Survival	Grass Stage Emergence	Brown-spot Severity Code
Provenance	28	35	10
Family (Provenance)	72	65	90

The coefficient of genetic prediction indicates that survival and the percent of trees initiating height growth are positively related (Table 3). Selection resulting in a one standard deviation increase in the phenotypic value for percent survival would be accompanied by an 0.18 standard deviation gain in breeding value for grass stage emergence. Brown-spot resistance at this age does not appear to be related to either survival or percent of trees initiating growth. This pathogen causes fatality by repeated defoliation and at least one of the mechanisms for escaping brown-spot needle blight is early height initiation. It may be that the relationship between these traits has not had sufficient time to develop in this study.

By considering the **same** variable across locations as different traits the coefficients of genetic prediction can be calculated across environments. This is a good device for examining genotype by environment interactions as suggested by Burdon (1977) for genetic correlations and demonstrated by Yeiser and others (1981). It is also useful in formulating seed movement recommendations and delineating breeding zones. The danger, when examining longleaf pine in this manner, is that most of the juvenile traits are strongly affected by nursery treatment. In this study, plantings in each zone were grown at the same nursery and can be expected to have similarities related to common nursery culture. Planting locations for which family variation was statistically insignificant, indicating no detectable additive genetic variance, were dropped from the CGP matrix.

CGP's for survival across locations are shown in Table 5. Because of the high overall survival at the Hardin and Tyler County, Texas, plantings, CGP's with these tests are very low. If these tests are ignored, it becomes apparent that survival at all of the other locations is positively correlated. For example, families selected for a one phenotypic standard deviation increase in survival at Stone County would have an increased breeding value of 0.46 standard deviations if planted at Pearl River County. In this example, it is impossible to separate the planting location effects from those contributed by a common nursery. Comparisons to the heritabilities along the diagonal indicate the relative efficiency of indirect selection.

Table 5. Coefficients of genetic prediction for survival in two-year-old longleaf pine across different test locations in the Western Gulf area.

Test	Stone MS	Pearl River MS	Tyler TX	Hardin TX	Bienville LA	LaSalle LA
Stone, MS	0.47	0.46	0.01	0.22	0.24	0.26
Pearl River, MS		0.55	-0.12	0.16	0.21	0.34
Tyler, TX			0.21	0.00	0.00	-0.05
Hardin, TX				0.29	-0.03	0.11
Bienville, LA					0.34	0.25
LaSalle, LA						0.28

Table 6 contains the CGP's for grass stage emergence. There appears to be a positive relationship between all test locations. This implies no special breeding zones are needed for east-west seed movement in the Western Gulf region. Seed movement recommendations for North Louisiana could not be made because the CGP's for these tests could not be calculated.

Table 6. Coefficients of genetic prediction for grass stage emergence in two-year-old longleaf pine across different test locations in the Western Gulf region.

Test	Stone MS	Pearl River MS	Tyler TX	Vernon LA
Stone, MS	0.37	0.51	0.48	0.34
Pearl River, MS		0.23	0.25	0.14
Tyler, TX			0.40	0.37
Vernon, LA				0.22

The coefficients for genetic prediction for brown-spot severity are listed in Table 7. CGP's for brown-spot are very similar to those for percent height initiation. There is a strong positive relationship between all test locations with possible exceptions of the North Louisiana tests for which CGP's could not be calculated. Again, positive gains in brown-spot resistance at any of the five southern tests would result in positive gains at any of the other southern tests.

Table 7. Coefficients of genetic prediction for brown-spot severity in two-year-old longelaf pine across different test locations in the Western Gulf region.

Test	Stone MS	Pearl River MS	Tyler TX	Hardin TX	Vernon LA
Stone, MS	0.70	0.41	0.68	0.35	0.45
Pearl River, MS		0.49	0.36	0.20	0.26
Tyler, TX			0.69	0.23	0.52
Hardin, TX				0.23	0.59
Vernon, LA					0.32

CONCLUSIONS

1. Good gains can be made in longleaf pine through selection for survival, grass stage emergence, and brown-spot resistance.

2. Family selection will result in twice as much gain as provenance selection.

3. Survival and grass stage emergence are positively related while brown-spot resistance is independent of either trait at this early age.

4. The same selection criteria will improve survival for all areas within the Western Gulf region.

5. Southeast Texas, South Louisiana and South Mississippi can also be considered one zone when selecting families for grass stage emergence and brown-spot resistance.

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