GENETIC VARIATION IN SURVIVAL OF LONGLEAF PINE

R. E. Goddard and Richard Bryant [1/]

Abstract.--Open pollinated progenies of approximately 300 longleaf pines were established in 8 tests across Florida, Georgia and Alabama. Family heritability of survival one year after establishment was 0.35 for bare-root planted seedlings. Phenotypic variance included a large environmental component from the various nurseries, planting crews, and site factors affecting survival.

Heritability of survival of tubelings was lower (0.24). For families planted both as bare-root seedlings and as tubelings, the GxE interaction was low but random error was high. Somewhat different genetic and environmental factors may affect survival of the two seedling types.

Additional keywords: Pinus palustris, genotype x environment interaction.

Although longleaf pine was the dominant species in much of the virgin forestland of the South, it has played a relatively insignificant role in managed forests. Longleaf pine was greatly reduced in second growth forests due to the low frequency of good cone crops, fire protection, and wide use of open range for hogs. Longleaf pine is found even less frequently in the wide scale forest plantation system that has been developed since World War II. Poor survival of planted longleaf was frequently experienced, much more so than with the widely used alternatives, slash and loblolly pines. Additionally, longleaf pine has the "grass stage" habit. Initiation of height growth can be delayed two or three or up to more than 20 years. These two features are certainly not viable for plantation forestry.

The almost uniformly excellent bole form, good growth rate once height growth has started, and, especially, relatively high resistance to fusiform rust have caused renewed interest in longleaf pine. Members of the University of Florida Cooperative Program greatly expanded longleaf pine improvement activities with initial focus on juvenile traits. Testing is underway to determine the extent of genetic variation in planting survival, duration of the grass stage, and rate of early height growth. To the extent that potential for genetic improvement of these traits is indicated, selection will follow.

Earlier studies showed the importance of survival in assessment of families. Snyder (1973) determined that survival was the most critical factor determining 15 year plot volume. Rockwood and Kok (1977) estimated family heritability of initial survival as 0.73.

Certainly, planting survival is subject to many environmental influences. It has long been known that longleaf survival is improved by reduction of nursery

---

[1/] Professor, Forest Genetics, University of Florida, and Project Leader, Tree Improvement, International Paper Company, respectively.

bed density (Derr, 1955; Scarbrough and Allen, 1954; Shipman, 1960). Lifting, handling, storage, and planting procedures, as well as site factors and weather conditions at time of planting and during following months all influence survival.

The report concerns survival of longleaf pine progenies subjected to a variety of nursery, planting and site factors.

MATERIALS AND METHODS

In the fall of 1977, open-pollinated cones were collected from approximately 300 longleaf pines. These were mostly trees in natural stands but collections from a few seed orchard clones were included. After extraction, seed were divided among 12 cooperators, each receiving seed of up to 200 trees.

Seed were sown in April, 1978, at a spacing of 4" x 4", providing a maximum bed density of 9 per square foot. Beds were undercut once or twice during late summer and fall. There was heavy loss of seed to birds at two locations, but at all other nurseries large, vigorous longleaf pine seedlings were produced. Minor variation in germination percents did not appear to greatly affect seedling size due to the original low density of sowing.

For the planting by International Paper Company in Decatur County, Georgia, containerized seedlings for 150 families were grown in a greenhouse. Ray Leach tubes were filled with a 1:1 mixture of peat and vermiculite to which Osmocote was added. Seed were sown in tubes on October 17, 1978, about six months later than nursery sowing.

Nursery grown seedlings were lifted in January-February, 1979, and, in most cases, planted within one to three days. Tubelings, farily small but actively growing, were outplanted during the last half of March, 1979. Four-tree family plots were randomized within 8-10 blocks per location. In two plantings, seedlings were obtained from three or four different nurseries. In these cases, seedlings from different nurseries (including tubelings) were planted in different blocks.

Survival in all plots was determined as of January, 1980. Plot survival data were subjected to analysis of variance for each planting individually. To determine family x environmental interactions, selected data from 5 locations were analyzed together. Only families common to all five locations and having no missing plots were included. Nursery sources varied but only one nursery source was used per location. Comparable analyses were run for the International Paper Company test (No. 105). In this location, seedlings planted were produced in different nurseries and in containers.

Family heritability for survival was calculated from the analysis of variance tables for individual tests and from the combined tests. For the combined analyses which include GxE interactions, heritability was estimated as:

$$h_f^2 = \frac{\sigma_f^2}{\frac{\sigma_e^2}{BS} + \frac{\sigma_{fxs}^2}{S} + \sigma_f^2}$$

where σ_f^2 = variance among family means

σ_{fxs}^2 = interaction variance of family x site or nursery source

σ_e^2 = residual error variance

B and S = number of blocks or sites, respectively.

RESULTS

Plantings at three locations on very well drained soils suffered drought during the spring after planting. Survival was so poor that these plantings were dropped from further consideration. Excellent initial survival was obtained at a fourth location, but very heavy animal predation of the seedlings destroyed the plantation. The eight plantings retained ranged in survival from 47 to 87 percent (Table 1).

Table 1.--Longleaf pine progeny plantings, including locations, nursery sources of seedlings, survival, and family heritability of survival.

Test No.	Location (County)	Nursery[1]	No. Families	Survival Mean (%)	Survival Range (%)	Family Heritability
104	Escambia, Ala.	3	87	44	9-81	0.57
		7	105	53	8-83	0.42
		10	106	53	6-88	0.30
105	Decatur, Ga.	3	110	47	0-94	0.77
		4	200	76	25-100	0.26
		9	42	70	25-100	0.64
		11	147	87	56-100	0.24
106	Escambia, Ala.	10	177	74	25-97	0.42
109	Marion, Fla.	7	183	78	47-100	0.58
110	Lafayette, Fla.	8	174	62	20-90	0.65
111	Leon, Fla.	9	196	86	38-100	0.63
112	Hamilton, Fla.	9	188	78	38-100	0,68
113	Nassau, Fla.	5	65	72	40-95	0,70

[1] Nursery code: 3 - Archer, Fla.; 4 - Bainbridge, Ga.; 5 - Glenville, Ga.; 7 - Chief land, Fla.; 8 - Day, Fla.; 9 - Capps, Fla.; 10 - Atmore, Ala.; 11 - Tubelings - Bainbridge, Ga.

Family means varied significantly at each planting location. Regardless of mean survival, standard deviations for the individual locations and for nursery sources within locations ranged from 20 to 30 percent. Family heriabilities from the various individual analyses (Table 1) varied considerably but there was no consistent relationship between mean survival and heritability.

For indication of the extent of genetic control of survival with operational planting, an estimate of heritability over a range of environments may be more pertinent than that observed for any single planting. In the analysis of 49 progenies established in five locations, the major effect on survival was due to "locations." This is a complex variable and includes effects on each family of different nurseries, lifting procedures, and planting crews as well as planting sites and local weather. The geographical range was from Escambia County, Alabama, to Marion County, Florida. Family heritability under this very substantial range of environments was 0.35. This is a conservative estimate as the 49 families had a range of survival means about 2/3 as great as the range of all families planted at each location. Family survival was fairly consistent over locations (Table 2) except that occasional families had much higher or lower survival in one test than in the other four. It might be suspected that aberrant low survival of a family at a single location could be due to some unique nursery or handling circumstance.

Test 105 provided comparison of nursery effects on survival at a single location. Analyses utilized data from bare-root seedlings produced in two nurseries and grown in containers (nursery source 11). The combined analysis of 62 families from all three sources indicated significantly higher survival of tubelings than bare-root seedlings. Heritability was much lower than was the estimate from the analysis of families planted in five locations (Table 3). Analysis of survival of bare-root seedlings from two nurseries in Test 105 also indicated significant nursery effects, but heritability was similar to that indicated in the five locations analysis. Finally, data from 119 families in Test 105 produced in nursery 4 and as tubelings were analysed. Methods of seedling production were not significantly different, and there was no significant interaction between family and seedling source. However, error variance was greatly increased with the consequence that heritability was reduced.

DISCUSSION

Survival after planting is obviously subject to many environmental influences. These include those imposed by nursery practices such as spacing, fertilization and watering regimes, etc., seedling handling and storage from lifting through planting, and site and weather conditions at the planting location. However, assuming avoidance of extremes of environmental stress, there appears to be genetic variation in survival.

Because longleaf pine survival is particularly sensitive to nursery and planting treatment, there is possibility of imposing within family common environmental effects. Unique treatments imposed on one or a few families due to

Table 2.--Mean survival of longleaf pine progenies at five locations, ranked by mean survival over sites.

Rank	Family	Survival Test 106	109	110	111	112	Mean
		BEST 10 FAMILIES					
1	6378	84	82	80	88	100	87
2	75378	88	96	80	94	75	86
3	6770	91	89	58	88	100	85
4	36278	81	80	83	84	94	84
5	8067	78	80	73	94	97	84
6	1078	69	89	88	91	91	84
7	6165	69	87	80	84	91	82
8	12978	81	80	63	88	91	80
9	6178	56	93	68	91	91	80
10	51278	66	80	78	97	78	80
		POOREST 10 FAMILIES					
40	10978	88	69	58	81	50	69
41	31278	78	58	63	78	66	68
42	30678	78	56	53	81	72	68
43	45778	78	69	43	88	57	67
44	45578	69	64	43	88	69	66
45	72078	72	60	50	69	75	65
46	5170	75	53	28	81	78	63
47	31078	66	47	50	86	66	63
48	31678	59	58	53	91	53	63
49	31578	56	60	60	84	50	62
	mean	75	76	59	85	77	74

non-uniformity in nursery or handling procedures are confounded with genetic effects and lead to exaggerated estimates of heritability. The wide range of heritability estimates from the various individual tests reported here may be, in part, due to such accidentally imposed bias. However, as seedlings for each test were independently grown and planted, the possibility of common environmental effects on a family was eliminated in the combined analyses and differences among families shown would reflect real genetic differences.

Survival is a complex characteristic and may be composed of more discrete traits such as avoidance of excessive dessication during the planting process, ability to rapidly regenerate new roots, or rapid rate of root extension. Whatever the elements of survival, tubelings appear to be responding to somewhat different environmental constraints than nursery grown seedlings. Even with

Table 3.--Proportions of phenotypic variance of longleaf pine survival attributable to family genotypes and genotype x environmental interaction.

Analyses	Major Environmental Effect	No. of Families	Total Phenotypic Variance: Family	Family x Environment	Random
Analysis 1 Tests 106, 109, 110, 111, 112	Locations[1/]	49	35*	32*	33
Analysis 2 Tests 105, Sources 3, 4, 11	Nurseries[2/]	62	21*	22*	57
Analysis 3 Test 105, Sources 3, 4	Nurseries	69	37*	14	49
Analysis 4 Test 105, Sources 4, 11	Nurseries[2/]	119	22*	7	72

*Significant variance at the .01 level of probablity.

1/ Includes different nurseries and planting crews as well as site and weather differences.

2/ Includes bare-root and tubeling seedlings (source 11).

great care, many very fine roots are lost in the lifting, transport, and planting of bare-root seedlings. This loss is avoided in planting tubelings and redevelopment of fine roots is not a factor in their survival. There are no doubt other differences between the seedling types as well as factors that affect them similarly. The interaction of families to microenvironmental differences in blocks within sides led to reduced estimates of heritability that included tubelings.

Goodwin (1976) reported that tubelings survived and grew better than bare-root planted longleaf seedlings in North Carolina. In Test 105, the superior survival of tubelings was confirmed, but, probably due to their superior size, nursery grown seedlings appear to be coming out of the grass much more rapidly than the tubelings.

Family heritability reported here is appropriate for estimation of genetic gain from selection of parent trees or selection of families. Individual tree heritability is not applicable. There can be no direct within-family selection for survival as all surviving trees are of equal value in this respect.

Using the heritability estimate of 0.35 for nursery grown seedlings, selection of one-half of the families with best survival should yield a genetic improvement of 6.5 percentage points. If 70 percent of the families were selected for survival, allowing selection for other traits, genetic gain for survival would be about 4 percentage points. This modest genetic improvement in survival, coupled with proper attention to environmental factors, should provide satisfactory longleaf pine survival under most site conditions.

LITERATURE CITED

Derr, H. J. 1955. Seedbed density affects longleaf pine survival and growth. U.S.D.A. Forest Serv. Tree Planters' Notes 20:28-29.

Goodwin, 0. C. 1976. Summer-planted loblolly and longleaf pine tubelings outgrow 1-0 nursery seedlings in North Carolina. Jour. Forestry 74:515-516.

Rockwood, D. L. and H. R. Kok. 1977. Development and potential of a longleaf pine seedling seed orchard. Proc. 14th South. For. Tree Imp. Conf. p. 78-86.

Scarbrough, N. M., and R. M. Allen. 1954. Better longleaf seedlings from low-density nursery beds. U.S.D.A. Forest Serv. Tree Planters' Notes 18:29-32.

Shipman, R. D. 1960. Survival and growth of graded longleaf pine nursery stock. J. Forest 58:38-39, 42.

Snyder, E. B. 1973. Fifteen year gains from parental and early family selection in longleaf pine. Proc. 12th South. For. Tree Imp. Conf. p. 46-49.