TEN-YEAR RESULTS OF AN OPEN-POLLINATED PROGENY TEST OF LONGLEAF PINE IN SOUTH CAROLINA

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ABSTRACT. In March 1966, 1-0 seedlings from 50 open-pollinated mother trees of longleaf pine were planted in Aiken County, South Carolina. The site was a sandy barren with typical sandhill vegetation of scrub oak and longleaf pine which was mechanically removed prior to planting. The design was a 10-tree row plot, randomized complete block with 5 replications. In November 1974 all trees were tallied for survival and measured for height. Significant differences were found among the progenies for both traits. Heights averaged 6.6 meters (21.6 ft.) for the best progeny and 4.4 meters (14.3 ft.) for the poorest. Survival ranged from 4 to 76 percent among the different progenies. There was no correlation between survival and height. The results indicate that selection for either good growth or high survival would achieve satisfactory results but that combining the two characteristics would best be accomplished by screening a large number of progenies.

Additional keywords: Height growth, survival, grass-stage, brown-spot, *Pinus palustris, Scirrhia acicola.*

In southeastern United States, longleaf pine (*Pinus palustris* Mill.) has not received as much attention from forest tree breeders as the more widely-planted loblolly (P. *taeda* L.) and slash (P. *elliottii* Engelm.) pines. This means that there is little information on The amount of variation in survival, disease resistance, and height growth of progeny lines (families) derived from individual mother trees. This study reports on the 10-year performance of 50 unselected longleaf pine progenies of South Carolina provenance, planted on a typical longleaf site in Aiken County, South Carolina. The results should be of interest to tree breeders, silviculturists, and forest managers contemplating the use of this species in plantations on similar sites.

METHODS

In October 1964 seed was collected from 192 longleaf pine trees in 33 counties of South Carolina. This seed was sown in beds of the South Carolina State Forestry Commission's Ridge nursery in November. The seedlings were

1/ This study was supported jointly by funds provided under AEC Contract No. AT (38-1)-228 between Clemson University and the Atomic Energy Commission; and under the McIntire-Stennis Program administered by the Cooperative State Research Service (CSRS).

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lifted as 1-0 stock in March 1966. Because of spotty germination and low survival in many seed lots, only 50 lots yielded enough seedlings to plant a 5 replicate, 10-tree row plot in a randomized complete block design. The site was a sandy barren from which the native vegetation, consisting mainly of scrub oak (*Quercus* spp.) and longleaf pine was mechanically removed prior to planting. The plantations were examined 7 times in the ensuing 9 years. The latest examination was made in December 1974 when the trees were 10 years old. Examination parameters included survival, number of trees in a "grass stage" (not showing height growth), number of trees severely attacked by the brownspot disease organism (*Scirrhia acicola* (Dearn.) Siggers), and height (Table 1). Analyses of variance, using the RCB(random model)(Steele and Torrie, 1960), were performed to determine whether differences in the measured traits could be accounted for by individual progenies.

Table 1. History of examinations of a longleaf pine progeny test in Aiken County, South Carolina

Information	Date: Mo./Yr.	Age of Trees[a]	Examination Parameters
Seed Collected	10/64	0	-
Seed Sown	11/64	0	-
Seedlings lifted	3/66	1	-
Seedlings planted	3/66	1	-
1st examination	1/67	2	Survival
2nd examination	12/67	3	Survival, Grass Stage, Brownspot, Height
3rd examination	3/69	4	Survival, Grass Stage, Brownspot, Height
4th examination	4/70	5	Survival, Grass Stage, Brownspot, Height
5th examination	5/71	6	Survival, Grass Stage, Brownspot, Height
6th examination	5/72	7	Survival, Grass Stage, Brownspot, Height
7th examination	12/74	10	Survival, Height

a/ Counted in terms of growing seasons completed since seeds were sown.

RESULTS

Survival

Longleaf pine characteristically has low initial survival when compared with other southern pines (Wakeley, 1954). This proved true in the present study in which the average survival at age 2 was only 53.6 percent (Table 2). After 10 years there was a further decline to 41.7 percent. There were, however, significant differences among progenies for this trait (Table 6), suggesting that genetic factors may be at least partially responsible. Environmental factors that may have affected the results, and were not controlled, included seedbed location and seedbed density in the nursery. The trees were planted over a two-day period by an experienced planting crew.

Table 2. Survival by frequency classes of 50 longleaf pine progenies at selected ages in an Aiken County, South Carolina plantation

Survival Frequency Class (Percent)	No. of Progenies at Stated Ages 2	4	6	10
91-100	0	0	0	0
81-90	4	1	0	0
71-80	6	4	3	1
61-70	9	6	5	5
51-60	8	9	11	8
41-50	9	11	9	11
31-40	7	9	12	12
21-30	4	7	6	9
11-20	2	1	2	2
0-10	1	2	2	2
Mean Survival Percent	53.6	47.2	44.7	41.7

Grass Stage

Longleaf pine does not begin height growth at once, but remains in a stemless condition known as the "grass stage" for 2 to 5 years or more, during which the taproot enlarges and elongates, and the terminal bud thickens (USFS, 1965). The progression out of the "grass" for the 50 progenies is shown in Table 3. Most differences among the progenies occurred at ages 3 and 4, when they were spread over 7 frequency classes. At the end of the sixth year, virtually all seedlings had started height growth. Ability to begin early height growth is undoubtedly influenced by several genetic and environmental factors. Among these are root size and length, terminal bud diameter, and physiological condition of the seedling, some of which may be inherent and some of which may be affected by seedbed density, soil fertility, etc. External factors affecting grass stage persistence could include disease (especially brownspot needle blight), and competition from sprouts and non-woody plants at the planting site.

Severe Brownspot Infection

Brownspot needle disease (*Scirrhia acicola*) is the major pathogen of longleaf pine seedlings and can either kill young trees outright or prolong the grass stage indefinitely. Data were first taken on brownspot infection in the third year. Although initially all trees had some disease-infected needles, severe infection (needle surface 50 percent brown as estimated by eye) was much less. The data showed that brownspot infection increased through age 5, then rapidly declined (Table 4). At age 5, the progenies affected by severe brownspot were spread over 8 frequency classes. Actual mortality caused by this disease was not tallied, but it undoubtedly played a role in the declining survival from the third through the sixth year. Significant differences (Table 6) in severity of infection among the 50 progenies suggests strongly that genetic factors were responsible for some of these results.

Table 3. Frequency of trees in the grass stage of 50 progenies of longleaf pine at selected ages in an Aiken County, South Carolina plantation

Grass Stage - Frequency Class (Percent)	No. of Progenies at Stated Ages 2	3	4	5	6
91-100	50	4	0	0	0
81-90	0	7	0	0	0
71-80	0	11	1	0	0
61-70	0	15	0	0	0
51-60	0	7	2	1	0
41-50	0	5	4	2	0
31-40	0	1	10	2	0
21-30	0	0	12	9	0
11-20	0	0	13	15	0
0-10	0	0	8	21	50
Mean Percent of Trees in Grass Stage	100	65.7	24.4	14.4	0.1

Table 4. Frequency of trees with severe brownspot infection of 50 longleaf pine progenies at selected ages in an Aiken County, South Carolina plantation

Severe Brownspot - Frequency Class (Percent)	No. of Progenies at Stated Ages 3	4	5	6	7
91-100	0	1	0	0	0
81-90	0	0	0	0	0
71-80	0	0	1	0	0
61-70	0	1	1	0	0
51-60	0	2	2	1	0
41-50	0	5	8	0	0
31-40	0	7	12	1	0
21-30	3	12	14	1	1
11-20	20	15	8	10	1
0-10	27	7	4	37	48
Mean severe brownspot infection	9.4	24.9	31.5	6.6	3.2

Height

Height growth of longleaf pine is strongly influenced by time in the "grass." In the measurements shown, only seedlings actively showing height growth at the time of the various measurements were included. Seedlings showing height growth averaged 2.0 feet at age 4, 8.5 feet at age 7, and 18.7 feet at age 10 (Table 5). The spread among progenies at age 10 ranged over 6 frequency classes, and significant differences (Table 6) were shown. Although influenced both by length of time in the grass stage and severity of brownspot infection, it is reasonable to conclude that some of the differences in height shown among the progenies are inherent.

Table 5. Frequency of heights in feet of 50 longleaf pine progenies at selected ages in an Aiken County, South Carolina plantation

Mean Height Frequency Class (Feet)	No. of Progenies at Stated Ages 4	7	10
0- 2.0	23	0	0
2.1- 4.0	27	1	0
4.1- 6.0	0	8	0
6.1- 8.0	0	21	0
8.1-10.0	0	14	0
10.1-12.0	0	5	0
12.1-14.0	0	1	2
14.1-16.0	0	0	6
16.1-18.0	0	0	15
18.1-20.0	0	0	15
20.1-22.0	0	0	9
22.1-24.0	0	0	3
Mean Height (Feet)	2.0	8.5	18.7

Correlations

Correlation coefficient matrices were obtained for the 6 sets of data involving the 4 measured traits (Table 7). Survival was not significantly correlated with height at any age. Third year brownspot infection was negatively correlated with survival only at ages 7 and 10. Survival/grass stage correlations were mostly weak and non-significant. The height/grass stage correlations were negative with these two traits showing complementarity. Progenies remaining in the grass stage were poor growers, and good growers were those that overcame the grass stage at an early age. Correlations between brownspot infection and grass stage were positive. Thus, a high incidence of brownspot infection was correlated with a high proportion of trees in the grass stage and this effect generally held for several years. Brownspot infection class was negatively correlated with height growth, i.e., progenies having high brownspot infection rates were also slower growing. This effect lasted as long as 4 years for those progenies that were attacked by the disease organism at an early age.

Table 6. Analyses of variance for percent survival, grass stage, severe brownspot infection, and total heights at selected ages of 50 longleaf pine progenies in an Aiken County, South Carolina plantation[a/]
(RCB - Random Model)

----Mean Squares ----

Percent Survival

Source	df	Age 2	Age 6	Age 10
Block	4	164 ns	185 ns	111 ns
Progeny	49	1936 **	1445 **	1251 **
Error	196	287	271	276

Grass Stage

Source	df	Age 3	Age 4	Age 5
Block	4	2968 **	690 ns	558 ns
Progeny	49	1156 **	991 ns	568 ns
Error	186	729	720	509

Severe Brownspot

Source	df	Age 3	Age 5	Age 7
Block	4	178 ns	729 ns	61 ns
Progeny	49	245 ns	920 *	275 **
Error	186	248	579	106

Mean Plot Heights

Source	df	Age 4	Age 7	Age 10
Block	4	.047 ns	33.5 ns	52.1 ns
Progeny	49	.042 **	36.6 **	60.4 **
Error	188	.022	17.4	34.9

a/ ** = Significant at 1% level
   * = Significant at 5% level
  ns = Non-significant

Table 2. Correlation coefficient matrices at selected ages for six sets of data among four traits of 50 longleaf pine progenies in an Aiken County, South Carolina plantation [a]

Survival (Age)	Height (Age) 3	4	5	6	7	10
2	.22	.23	.10	.08	.04	.21
3	.21	.21	.09	.07	.03	.18
4	.23	.18	.06	.04	.01	.10
5	.25	.24	.10	.08	.04	.11
6	.23	.23	.09	.06	.02	.11
7	.24	.25	.12	.10	.06	.11
10	.23	.26	.14	.15	.13	.12

All correlations are non-significant

Survival (Age)	Brownspot Infection (Age) 3	4	5	6	7
2	-.10	.06	.18	.05	.21
3	-.11	.06	.16	.03	.19
4	-.18	.03	.15	-.02	.16
5	-.22	-.01	.14	-.03	.14
6	-.22	-.01	.17	-.02	.11
7	-.28*	-.05	.13	-.10	.07
10	-.31*	-.09	.09	-.15	.03

33 of 35 correlations are non-significant

Grass Stage (Age)	Height (Age) 3	4	5	6	7	10
3	-.99*	-.65*	-.58*	-.51*	-.44*	-.28*
4	-.55*	-.84*	-.70*	-.69*	-.63*	-.40*
5	-.35*	-.40*	-.62*	-.51*	-.51*	-.29*
6	-.27	-.36*	-.45*	-.48*	-.50*	-.16
7	.17	.07	-.13	-.18	-.31*	.10

Significant negative correlations are shown for 23 of 30 comparisons

Grass Stage (Age)	Brownspot Infection (Age) 3	4	5	6	7
3	.25	.11	.22	.24	-.15
4	.39*	.34*	.10	.29*	.02
5	.29*	.14	.34*	.58*	.15
6	.38*	.33*	.42*	.56*	.11
7	.31*	.39*	.18	.38*	.83*

Significant correlations are shown for 14 of 25 comparisons

Survival (Age)	Grass Stage (Age) 3	4	5	6	7
2	-.21	-.22	.15	.15	.11
3	-.21	-.21	.12	.12	.09
4	-.23	-.20	.13	.11	.08
5	-.25	-.26	.11	.12	.05
6	-.23	-.26	.12	.13	.04
7	-.24	-.28*	.07	.06	-.01
10	-.23	-.27	.06	.04	-.10

34 of 35 correlations are non-significant

Height (Age)	Brownspot Infection (Age) 3	4	5	6	7
3	-.25	-.11	-.22	-.25	.15
4	-.41*	-.46*	-.22	-.26	-.04
5	-.40*	-.40*	-.35*	-.37*	-.08
6	-.41*	-.41*	-.41*	-.45*	-.13
7	-.40*	-.40*	-.42*	-.48*	-.23
10	-.16	.12	-.10	-.20	.18

Significant negative correlations are shown for 14 of 30 comparisons

[a] * Significant at the 5% level

DISCUSSIONS AND CONCLUSIONS

In longleaf pine, progeny differences up to age 10 are clearly shown for survival, height growth, time in the grass stage, and severity of brownspot infection. The data suggest that inherent differences among progenies exist for these traits although, because of several uncontrolled environmental factors, the degree of genetic control could not be estimated.

The correlation values can be useful in assessing early results of a breeding program in longleaf pine. The lack of correlation between height growth and survival indicates that the traits may be independent. Thus, to obtain good growth and high survival, twice as many parents should be tested as would he necessary if the two traits were highly correlated. Conversely, selecting parents whose progenies showed early height growth indicates not only that their length of time in the grass stage would be reduced but also that severity of brownspot infection would be lessened.

Longleaf pine breeding might well begin by the selection of large numbers of parents of above average quality, growing open-pollinated progenies, and roguing those parents whose progenies show (1) low first-year survival, (2) have high brownspot infection rates, and (3) remain in the grass stage beyond the third year. The remaining progenies would be carried for 10 years or longer to show outstanding growers. Given complete independence with 50 percent roguing, 500 parents could be evaluated and reduced to 62 at the end of the fourth year, and to 31 at the end of the tenth year. However, it is very likely that complete independence will not occur; and the degree of roguing required may be less than 50 percent. A clonal seed orchard could be delayed until after the fourth year when most inferior parental types would be identified and discarded. It would be further rogued at the tenth year when poor growers among the progenies would be identified.

In longleaf pine, several planned breeding programs are currently underway. On the basis of this limited study, there is evidence that such programs can be successful in developing a superior strain of this valuable species.

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