Fifth-Year Results From a Test of Longleaf Pine Seed Sources on the Francis Marion National Forest and in Central Georgia

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Longleaf pine seedlings from 8 sources ranging from eastern North Carolina to southern Mississippi were planted in tests at 3 locations on the Francis Marion National Forest in South Carolina and 1 location in central Georgia. Seedlings were started in the greenhouse in January and field-planted in May 1991. At age 5 years from seed, survival was high and few seedlings were still in the grass stage. Variation among seed sources was significant for survival in 1 location, for height in 2, and for within-plot coefficient of variation in height in 1. In combined analyses, neither survival nor CV in height varied significantly among seed sources averaged over plantations, but height did. Differences among plantation averages were significant for height and CV in height. Height growth was best and least variable in the Georgia plantation. Tree Planters' Notes 47:6-10; 1996.

Hurricane Hugo in 1989 destroyed much of the timber on the USDA Forest Service's Francis Marion National Forest (FMNF) in South Carolina. Forest managers plan to plant longleaf pine on suitable sites in the storm-damaged area. However, the local longleaf pine seed orchard was also destroyed. Until the seed orchard is re-established and producing, using seeds from other sources will be necessary. Some of these seed sources may not be genetically well-adapted to conditions on the FMNF whereas others may do better than the local source. In 1991, a study was installed on the FMNF to evaluate relative performance of 8 prospective seed sources. Data from the study will provide a basis for deciding whether to use natural methods, such as shelterwood, to reproduce stands established from nonlocal sources, and whether some sources perform well enough on the FMNF to be used even after local seeds are available.

Background

Early European settlers found most of the land in what is now the southeastern United States covered by park-like stands of old-growth longleaf pine. The range of the species extended from southeastern Virginia to eastern Texas and from south-central Florida to north-central Alabama and Georgia (figure 1). Over this range, it originally occupied about 60 million acres. Longleaf pine stands have now been reduced to about 4 million acres by land clearing for agriculture or harvesting without provision for reproduction (Croker 1987).

Longleaf pine is prized for its resistance to fire, insects, and disease; deep root system; and rapid growth through middle age. Its demanding planting requirements, however, have caused planting failures in the past that discouraged management of the species. Mature stands can be regenerated with shelterwood techniques that include prescribed burning, and directseeding has had some success (Croker 1987, Derr and Mann 1971).

Successful planting techniques have recently been developed, greatly increasing interest in managing longleaf pine (Croker 1987). These techniques include producing large seedlings, handling and storing them carefully (including refrigeration), planting at the correct depth, and controlling competition and brown-spot needle blight (caused by *Mycosphaerella dearnsii* Barr) (Brissette and others 1990, Croker 1987, Hatchell and Muse 1990, Sirmon 1990, Snow and others 1990, Wakeley 1954).

With artificial regeneration, nonlocal seed can be used, but forest managers first need to know the geographic limits within which seed can be moved safely. The Southwide Pine Seed Source Study has provided information on the broad pattern of genetic variation in longleaf pine. Significant variation in survival, growth, and resistance to brown-spot needle blight occurred among the widely spaced seed sources in the study (Henry and Wells 1967, Schmidtling and White 1990, Wells and Wakeley 1970). Results indicate that variation patterns permit wide movement of seeds with low risk of failure within certain specified climatic limits. Other studies indicate that local variation is greater than that associated with broad geographic patterns (Kraus and Sluder 1990, Snyder and Derr 1972).

A breeding program to improve the genetic quality of planting stock would increase benefits from use of artificial regeneration in managing longleaf pine. Longleaf pine areas in the national forests of the Southern Region (region 8) have been divided into breeding populations;

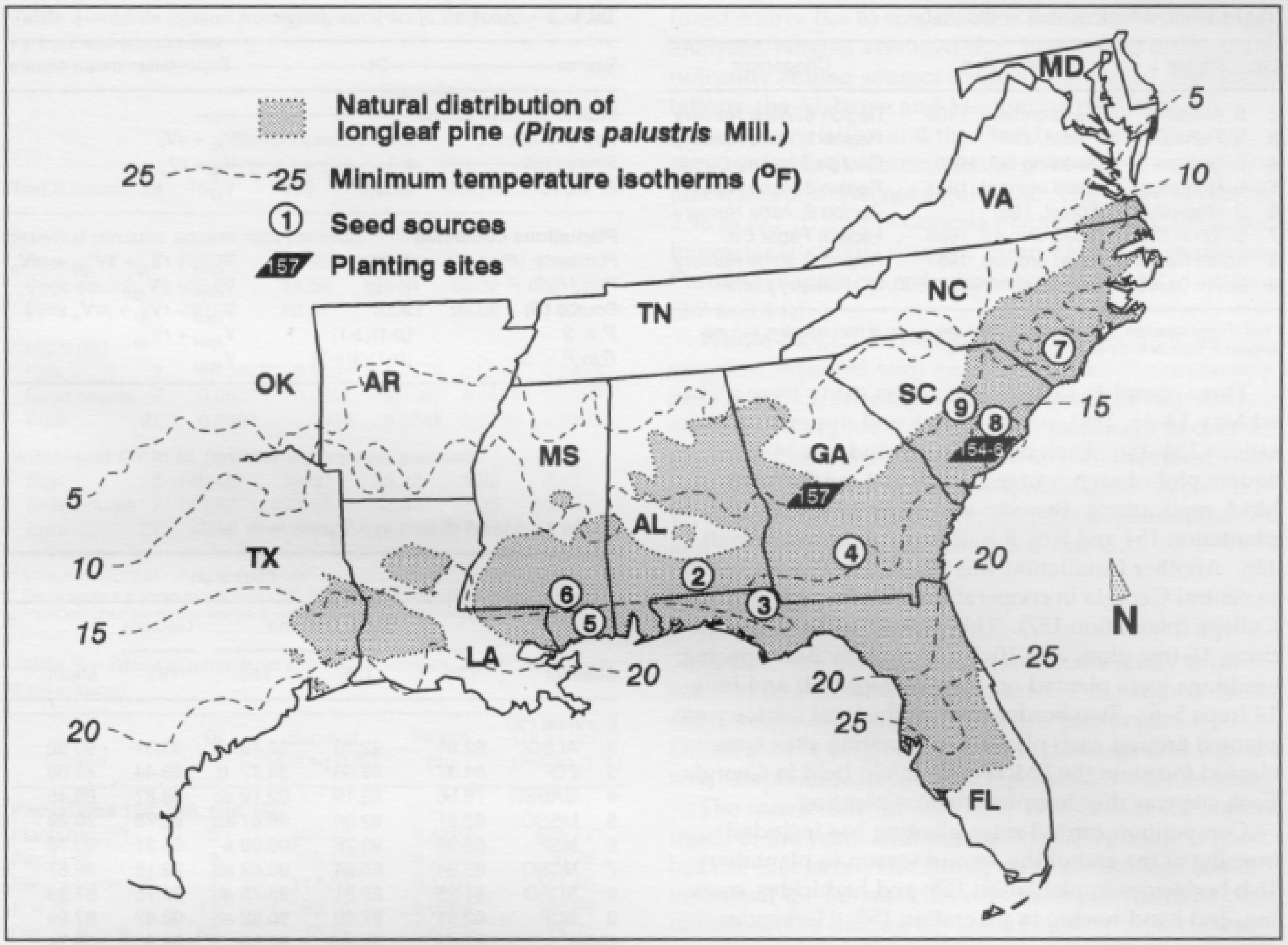

Figure 1—*Natural distribution of longleaf pine and minimum temperature isotherms in southeastern United States, seed sources, and planting sites.*

phenotypically superior trees have been selected; and clonal seed orchards and progeny tests have been established (Schmidtling and White 1990, Wells and McConnell 1984).

Tests that determine the limits within which planting stock from the region 8 seed orchards could safely be moved are needed. Only then will forest managers be able to meet possible future emergency planting needs caused by disasters such as that inflicted by Hurricane Hugo on the FMNF. This paper describes a test designed to fill this need.

Methods

Longleaf pine seeds from 8 geographic sources (4 from clonal seed orchards, 3 from forest collections, and 1 from a seedling seed orchard) were included in this study (table 1). The sources, located in 6 states, were distributed within or near a zone with average minimum temperatures of 10 to 15 °F (-12.2 to -9.5 °C). This zone includes the Francis Marion National Forest (figure 1). Seeds from cooperators were obtained in 1990 (table 1). Seeds collected before 1990 were stored at subfreezing temperatures.

Seeds were planted in the greenhouse in January 1991, in 10-in^3 (164-cm^3) plastic tubes filled with a medium of peat, perlite, and vermiculite to which a slow-release fertilizer had been added. When the seedlings became crowded, tubes were rearranged to occupy alternate spaces within the racks. In April, seedlings were moved from the greenhouse to a shadehouse, then a week later to full sun. A benomyl (Benlate®) drench was used periodically to control fungal infection.

Table 1—*Seed sources used in the study*

Lot	Source	Description	Cooperator
2	S. Alabama	Seed orchard, 1988*	Region 8, Ashe Nursery
3	N. Florida	Forest, 1987	Region 8, Ashe Nursery
4	S. Georgia	Seedling SO, 1990	Georgia Forestry Comm.
5	S. Mississippi	Seed orchard, 1987	Region 8, Ashe Nursery
6	S. Mississippi	Forest, 1987	Region 8, Ashe Nursery
7	E. North Car.	Seed orchard, 1988	Federal Paper Co.
8	South Carolina	Seed orchard, 1987	Region 8, Ashe Nursery
9	South Carolina	Forest (sandhills), 1990	SC Forestry Comm.

*Year of seed collection. Lot 1 differed from lot 2 only in year of seed collection; lot 1 was dropped to facilitate field layout. SO= seed orchard.

Three complete installations of the study were planted May 14-16, 1991, on the FMNF and designated plantations 154-156. Each plantation included a 16-tree square plot of each source in each of 4 randomized-block replications. Spacing was 10 by 10 ft (3 by 3 m) in plantation 154 and 8 by 8 ft (2.4 by 2.4 m) in 155 and 156. Another installation was planted in Peach County in central Georgia in cooperation with Fort Valley State College (plantation 157). This plantation has 6 replications, 16-tree plots, and 10- by 10-ft (3- by 3-m) spacing; seedlings were planted on May 24 (reps 1-4) and June 14 (reps 5-6). Two border rows of the local source were planted around each plantation. Planting sites were cleared forest on the FMNF and an old field in Georgia. Each site was disc-harrowed before planting.

Competition control since planting has included burning at the end of the second season in plantation 154; herbicides in plantation 155; and herbicides, mowing, and hand-hoeing in plantation 157. Herbicides caused some mortality in plantation 157 and excess water caused some in plantation 155 during the first growing season. The vacant spots were replanted with tubelings from the same sources. The tubelings had been transferred to larger containers and kept to replace dead trees.

The study was assessed at the end of the 1995 growing season, the end of the seedlings' fifth year from seed. Survival was recorded and heights measured to the nearest centimeter. Data were analyzed for survival, plot mean height, and within-plot coefficient of variation (CV) in height. Percentage data (survival and CV) were transformed to the arcsines of their square roots for analysis. Data were analyzed by plantation and with plantations combined (table 2).

Results

Survival was high and varied significantly among seed sources in only 1 plantation (tables 3 and 4). Plantation mean survival ranged from 83% in plantation 154 to 94% in plantation 157. Table 5 shows that sur-

Table 4— *Mean squares from analyses of variance of 5th-year data, by trait and plantationa*

		Plantation				
		South Carolina			Georgia†	
Trait & source	Df	154	155	156	157(4)	157(6)
Survival (arcsine square root percent)						
Rep	3	176.77	307.99*	130.74	32.84	43.46
Seed source	7	22.09	56.58	199.21*	65.32	36.13
Error	21	90.50	80.51	63.43	98.02	91.32
Height (m)						
Rep	3	0.3362***	0.3594***	0.0678	0.0246	0.0413
Seed source	7	0.0823	0.0801	0.1087*	0.0977*	0.1707**
Error	21	0.0397	0.0435	0.0348	0.0392	0.0495
Within-plot CV in ht. (arcsine square root percent)						
Rep	3	140.46*	38.50	33.27	1.90	6.40
Seed source	7	115.48*	175.98	61.67	17.35	35.63
Error	21	34.93	140.80	48.38	17.01	17.59

* 0.05> P >0.01; **0.01> P >0.001; *** P<0.001.
† Two analyses are shown for plantation 157, for 4 and 6 reps; the 4-rep analysis is for comparison with ohter plantations and the 6-rep analysis for complete information.

Table 5— *Mean squares from combined analyses, age 5 years, 3 or 4 plantations*

Source	Df	Survival (Arc sq rt %)	Height (m)	CV in height (Arc sq rt %)
Plantations 154, 155, and 156				
Plantation (*P*)	2	907.73	0.4223	695.77*
Rep in *P*	9	205.17*	0.2545***	70.75
Seed source (*S*)	7	117.50	0.1704*	111.40
P × *S*	14	80.18	0.0503	120.86
Rep in *P* × *S*	63	78.15	0.0393	74.70
Plantations 154, 155, 156, and 157†				
Plantation (*P*)	3	1166.74	33.6066***	3290.74***
Rep in *P*	12	453.77	0.1970***	53.54
Seed source (*S*)	7	96.20	0.22.62**	69.00
P × *S*	21	82.33	0.0475	100.49
Rep in *P* × *S*	84	83.12	0.0393	60.28

* 0.05> P >0.01; ** 0.01>P >0.001; *** P<0.001.
†Only reps 1-4 from plantation 157 were used in these analyses.

vival rates among plantations did not differ significantly, with or without the Georgia plantation. No plantation-by-seed-source interaction in survival was evident.

According to standard analysis of variance (table 4), mean heights varied significantly among sources (P<0.05) in plantations 156 and 157. However, Bonferroni's somewhat conservative method of multiple comparisons among means (table 3) showed significance among mean heights only in plantation 156. In 156, the SC seed orchard source (lot 8) was tallest and the Florida source (lot 3) was shortest. In 157, the Alabama source (lot 2) was tallest and the Mississippi forest source (lot 6) was shortest (table 3). In combined analyses, heights averaged over plantations differed significantly among sources (table 5). Averaged over plantations, the Alabama and Mississippi seed orchard sources were tallest and the Florida forest source was shortest (table 3). Interaction of seed source with plantation location was not significant. The mean height of 2.96 m (9.7 ft) for the Georgia plantation was significantly greater (P<0.001) than the mean heights in the South Carolina plantations, which ranged from 0.81 to 1.04 m (2.7 to 3.4 ft).

Within-plot CV in height was generally high, as might be expected with longleaf pine seedlings recently emerged from the grass stage. Variation among seed sources in this trait, however, was significant in only 1 plantation (tables 3 and 4). In combined analyses, variation was significant only among plantations (table 5). Within-plot CV in height was greatest in plantations 155 and 156 and least in plantation 157 (table 3).

Discussion

To date, the most striking result in the study is the contrast in mean height and mean CV in height between the Georgia and the South Carolina plantings. Differences between the 2 areas in drainage and vegetative competition are largely responsible for the contrast.

The water table on the FMNF is at or near the surface much of the year. Drainage on the Georgia site is good but not excessive. The strong effect of drainage could be seen at the microsite level in the South Carolina plantations, where discing left some planting spots noticeably lower than others. After rains, seedlings in low spots stayed under water longer, had higher mortality, and grew less than those in better drained spots.

Vegetative competition built up slowly in the South Carolina plantations and has not been well controlled. Competition on the Georgia site was almost immediate and would have been severe without intensive control measures. Because vegetation was controlled and drainage was good on the Georgia site, a majority of the seedlings began height growth during the second growing season, and many were more than 4 m (13 to 15 ft) tall by the end of the fifth season.

The brown-spot needle blight disease has been no problem in this study. A few seedlings were noticeably infected during the second year in the Georgia plantation, but little infection was evident at the end of the third, fourth, and fifth seasons.

The plantings are well established, and the next assessment will occur at age 10 years. By that age, the effects of the grass stage and early competition on height variation should be relatively small, and managers should be able to base decisions on reliable variation patterns. The study has already shown that sources of longleaf pine from a wide east-west and relatively narrow north-south band of similar climate will perform similarly on the FMNF. The performance of the west Florida source may reflect local variation in the genetic quality of the stand from which the seed was collected rather than a deviation from a broad pattern of variation associated with climate. The high survival rate of seedlings used in this study is due in part to the use of container planting stock. High survival with bareroot stock can be difficult to achieve. In a study comparing performance of bareroot and container planting stock, with the best combination of treatments, survival was 66% for bareroot and 97% for container seedlings (Boyer 1988).

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Literature Cited

Boyer WD. 1988. Effects of site preparation and release on the survival and growth of planted bare-root and container-grown longlealf pine. For. Res. Pap. 76. Macon: Georgia Forestry Commission. 7 p.

Brissette JC, Elliott M, Barnett JP 1990. Producing container longleaf pine seedlings. In: Farrar RM Jr, ed. Proceedings, Symposium on the Management of Longleaf Pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO-75. New Orleans: USDA Forest Service, Southern Forest Experiment Station: 52-78.

Croker TC Jr. 1987. Longleaf pine: a history of man and a forest. Forestry Rep. R8-FR7. Atlanta: USDA Forest Service. 37n

Derr HJ, Mann WF Jr. 1971 Direct-seeding pines in the South. Agric. Handbk. 391. Washington, DC: USDA Forest Service. 68 p.

Hatchell GE, Muse HD. 1990. Nursery cultural practices and morphological attributes of longleaf pine bare-root stock as indicators of early field performance. Res. Pap. SE-277. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 34 p.

Henry BW, Wells 00. 1967. Variation in brown-spot infection of longleaf pine from several geographic sources. Res. Note SO-52. New Orleans: USDA Forest Service, Southern Forest Experiment Station. 4p.

Kraus JF, Sluder ER. 1990. Genecology of longleaf pine in Georgia and Florida. Res. Pap. SE-278. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 31 p.

Miller RG Jr. 1981. Simultaneous statistical inference. 2nd ed. New York: Springer-Verlag Inc. 301 p.

Schmidtling RC, White TL. 1990. Genetics and improvement of longleaf pine. In: Farrar RM Jr, ed. Proceedings, Symposium on the Management of Longleaf Pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO-75. New Orleans: USDA Forest Service, Southern Forest Experiment Station: 114-127.

Sirmon GA. 1990. A prescription for successful management of longleaf pine. In: Farrar RM Jr, ed. Proceedings, Symposium on the Management of Longleaf Pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO-75. New Orleans: USDA Forest Service, Southern Forest Experiment Station: 247-257.

Snow GA, Hoffard WH, Cordell CE, Kais AG. 1990. Pest management in longleaf pine stands. In: Farrar RM Jr, ed. Proceedings, Symposium on the Management of Longleaf Pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO75. New Orleans: USDA Forest Service, Southern Forest Experiment Station: 128-134.

Snyder EB, Derr HJ. 1972. Breeding longleaf pines for resistance to brown spot needle blight. Phytopathology 62(3):325-329.

Wakeley PC. 1954. Planting the southern pines. Agric. Monogr. 18. Washington, DC: USDA Forest Service. 233 p.

Wells OO, McConnell JL. 1984. Breeding populations in the R-8 tree improvement programs. In: Miller D, ed. Progeny testing. Proceedings, Servicewide Genetics Workshop; 1983 December 5-9; Charleston, SC. Washington, DC: USDA Forest Service: 61-67.

Wells OO, Wakeley PC. 1970. Variation in longleaf pine from several geographic sources. Forest Science 16(1):28-42.