SUPERIOR PINES REVISITED: A PLUS-TREE PROGENY TEST ON THE CROSSETT EXPERIMENTAL FOREST AT A HALF-CENTURY

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Abstract—Between 1966 and 1969, Forest Service Plant Geneticist Hoy Grigsby installed the last of his tree improvement studies on the Crossett Experimental Forest (CEF). This research, a series of plus-tree progeny tests of full- and half-sib loblolly pine (*Pinus taeda*), was installed to compare the survival, form, vigor, fusiform rust resistance, and height growth of these families (and CEF "woods-run" sources). Due to a variety of reasons, this study was discontinued in the 1970s. Recently, we have started to investigate the remaining trees in this now 48- to 51-year-old superior pine progeny test. This initial report summarizes what is known about the 1969 outplanting and considers what may be possible for future research. Although past thinnings mean this research can no longer document survivorship or fusiform response, valuable information on growth and yield can still be extracted. For example, comparisons of "winners" and "losers" based on 3-year height outcomes are not consistent with those noted on a more limited sample after 48 years of growth.

INTRODUCTION

Recent reviews have explored the dramatic successes—and some notable failures—of forest genetics and tree improvement programs in loblolly pine (*Pinus taeda*) across the Southern United States (for example, Allen and others 2005, Borders and Bailey 2001). From humble beginnings with "common garden" experiments using field-collected pine seed (Wakeley and Bercaw 1965) to outplantings of mass-controlled pollinations and cloned seedlings, plantations of improved loblolly pine have become the commercial foundation of the most productive timber region in the world (Allen and others 2005). As these programs matured, industry has pursued a research and development trajectory focusing on the selection of loblolly pine for rapid growth, crown ideotypes, and disease resistance using a relatively limited number of genetically improved families.

Over the years, progeny tests have proved invaluable in this process. However, few published results on southern pine progeny/provenance tests older than 30 years can be found in the literature. Examples of longer-term studies include Wakeley and Bercaw (1965), who reported on 35-year results of a common garden study of four geographic sources of loblolly pine planted in southern Louisiana; Wells and Rink (1984), who described loblolly performance in a different provenance test in southern Illinois after 35 years; and Rink and Wells (1988), who compared loblolly pine seed sources with shortleaf pine (*P. echinata*) in southern Illinois 37 years after planting. Loblolly pine in the Southwide Pine Seed Source Study (SPSSS) (Wells and Wakeley 1966) was measured to age 25 years (Wells 1983). By the late 1980s, very few of the original SPSSS locations remained (Buford 1989), although Schmidtling and Froehlich (1993) did report on 37-year results for the Maryland location.

Given that intensively managed loblolly pine stands are rarely grown more than 25 years, knowing the long-term (30+ year) outcomes of progeny tests has not been a priority—especially given the likelihood of new and even more improved families becoming available during that time span. Today, loblolly pine families are usually evaluated using short-term assessments of performance (for example, Farjat and others 2016). Research has shown that the growth performance of different families can be effectively evaluated within the first few years after planting, with early success being maintained through at least mid-rotation (Bridgwater and McKeand 1997, McKeand 1988). However, there are valid questions that cannot be addressed with short-term experiments. For instance, what are the long-term consequences of culling poor early-performing families that may actually be good performers ("Type A" of Bridgwater and McKeand 1997)? What happens if indirect selection results in the choosing of families that ultimately prove unsuccessful under longer rotations (Martin and others 2001)? Could landowners interested in the long-term performance of improved loblolly pine for certain forest products (such as poles or pilings, or high specific gravity wood) or

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non-commodity ecosystem services (such as carbon sequestration) desire families not selected for rapid, early-volume growth?

Since many of the aforementioned longer-term studies yielded interesting and sometimes unexpected results decades after their establishment, it is worth revisiting old progeny tests. Hence, the objective of this limited study is to evaluate the potential of a half-century-old loblolly pine progeny test on the Crossett Experimental Forest (CEF) in southern Arkansas to inform silvicultural researchers about the long-term performance of second-generation, improved loblolly pine from locally derived, superior pines.

METHODS

From 1951 until 1975, a number of tree improvement and forest genetics studies were conducted by staff from the CEF in southern Arkansas (Bragg and others 2016). Between 1966 and 1969, Forest Service Plant Geneticist Hoy Grigsby installed part of a superior pine progeny test in the eastern half of Compartment 3 on the CEF (fig 1). Grigsby chose this approximately 20-acre site because it was relatively level, without any significant drainages, and was dominated by soils common to this portion of the Upper West Gulf Coastal Plain (Bude and Providence silt loams, with a nominal loblolly pine site index of 85 to 90 feet at 50 years; Gill and others 1979). When installed, the existing pine-dominated timber was cleared and the site prepared prior to the first outplantings in February of 1966.

The full- and half-sib seeds came from superior pines identified by trained foresters on the lands of Georgia-Pacific in Ashley and Drew Counties in Arkansas and Morehouse Parish in Louisiana during the preceding decade; open-pollinated seeds (“woods-run”) were collected from the general population of loblolly pines on the CEF (Grigsby 1967–1969). Pine seeds were germinated and raised to 1-year-old seedlings before being planted (bare-root) on 8-foot by 8-foot spacing in a series of replicated blocks (Grigsby 1967–1969). Most seedlings were pure loblolly pine crosses—the few loblolly x shortleaf hybrids included in the 1967 outplantings are not included in this analysis. The Compartment 3 outplantings were established to determine the influence of family on a number of traits, including survival, vigor, growth, form, wood specific gravity, and fusiform rust (*Cronartium quercuum* f. sp. *fusiforme*) susceptibility. The retirement of Project Leader Russ Reynolds in 1969 led to Forest Service’s closing of the CEF, and Grigsby was reassigned to the genetics unit in Saucier, MS (Bragg and others 2016). After Grigsby’s retirement a few years later, Forest Service Plant Geneticist Warren Nance assumed responsibilities for the remaining CEF genetics projects. Shortly thereafter, Nance decided there was insufficient value in continuing the CEF tree improvement studies and formally closed the projects (Nance 1978). In the decades since, the progeny tests in Compartment 3 have been operationally thinned and salvaged several times but remain largely intact.

This paper focuses on the last outplanting of 28 families (22 full-sibs + 6 half-sibs) produced by crossing superior pines and CEF woods-run pines (table 1). This outplanting (shaded area on fig. 1) was installed in February 1969 using five blocks, each of which contained twenty-nine 48-foot by 48-foot plots with 36 planting points, for a grand total of 5,220 pine seedlings (Grigsby 1967–1969). The original data used for this paper were adapted from a spreadsheet of block-level plot means for the 1969 outplantings assembled by family contained in the study file (dated February 16, 1972). Block-level plot means were treated as replicates; since there were 5 blocks, n = 5 for each family for survival percentage, total height (in feet), and fusiform rust occurrence (percent of seedlings showing signs of fusiform). No statistical analysis had been done in 1972, so I conducted an evaluation for some initial perspective. Because these data were not normally distributed and two of the variables of interest were measured in terms of percentages, a Kruskal-Wallis test was conducted to determine if significant ($\alpha = 0.05$) differences among family rankings were present. Post-hoc nonparametric multiple comparisons were also performed to determine which families performed the best (Zar 2010). For his brief unpublished closing report, Nance (1978, his figures 26–28) made a limited statistical assessment when the 1969 outplanted pines were 5 years old.

In January of 2017, a 36-plot subset of the 1969 outplanting was remeasured (Figure 1). This subsection contained at least one block of all families and each live pine in each plot was measured for its diameter at breast height (d.b.h.; to the nearest 0.1 inch) using a diameter tape and total tree height (to the nearest 0.5 foot) using the sine method of height determination (Bragg and others 2011) and a TruPulse 200X laser hypsometer. In addition, merchantable inside-bark volume (*V*, in cubic feet) was calculated using a local CEF volume equation (Farrar and others 1984):

$$V_{CEF} = -1.41726 - 0.02484\ d.b.h. + 0.09948\ d.b.h.^2 + 0.00748\ d.b.h.^3 - +0.00017\ d.b.h.^4 \qquad [1]$$

and a regional volume equation (Van Deusen and others 1981):

$$V_{VD} = -0.00296 + 0.00193881\ d.b.h.^2\ HT \times R \qquad [2]$$

where

HT = total tree height
R = a top-diameter conversion ratio.

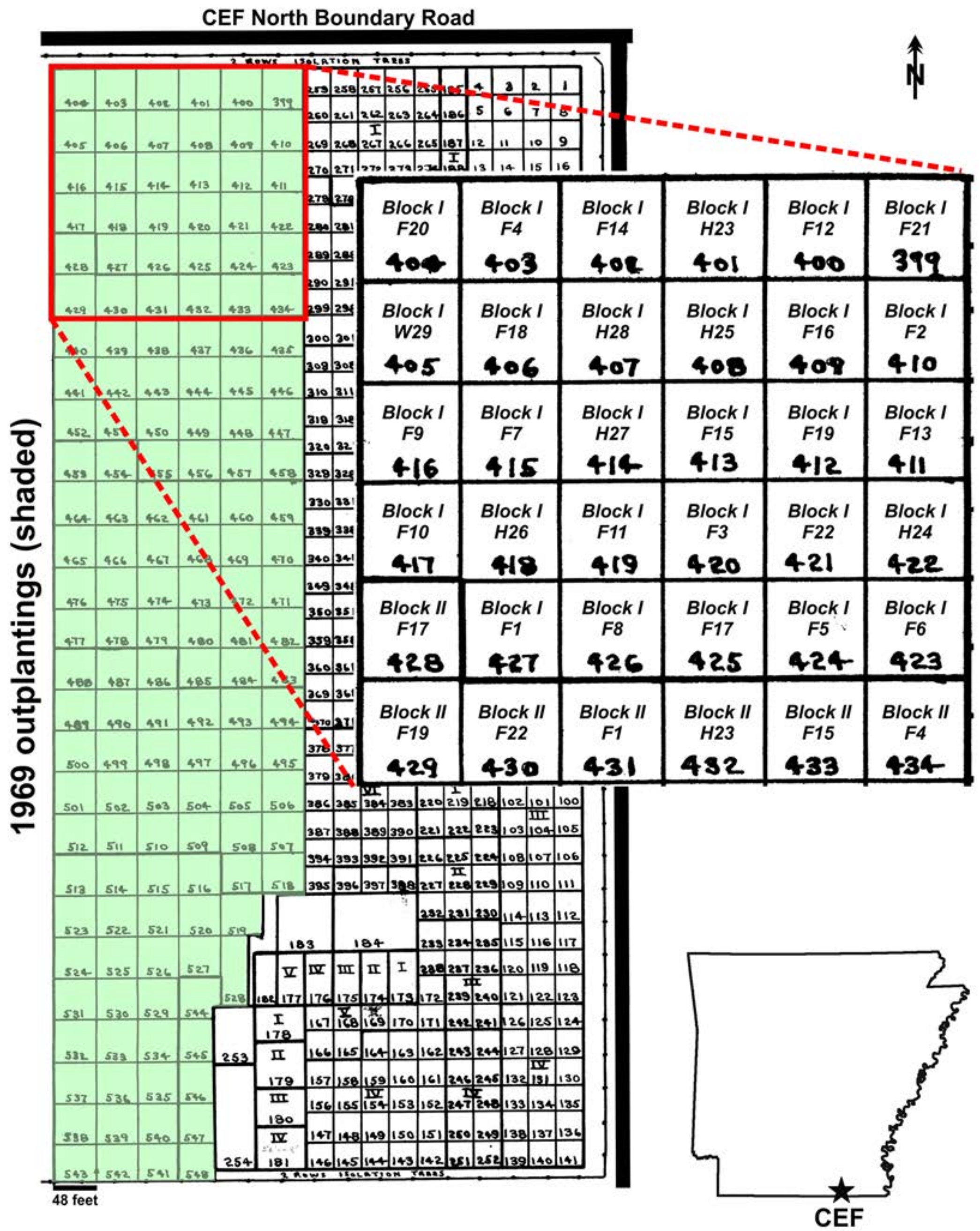

Figure 1—Map of the 20-acre superior pine progeny test outplantings in the eastern half of Compartment 3 on the Crossett Experimental Forest (CEF), southern Arkansas; the outplantings were established between 1966 and 1969 by Hoy Grigsby. The shaded area on the west side is the 1969 outplanting; inset shows the layout of the 36-plot subsample of the 1969 outplanting sampled in January 2017 (48 years post-planting), with planting block and family code (see table 1) indicated [for example, the Crossett woods-run pines (W29) in Block I were located in Plot 405].

Table 1—Family labels by Georgia-Pacific district codes[a] and superior pine number for the families tested in the 1969 outplanting in Compartment 3 of the Crossett Experimental Forest

Full-sibs (F)				Half-sibs (H)		Open-pollinated (W)	
Family	Parent x Parent	Family	Parent x Parent	Family	Parent x wind	Family	wind x wind
F1	BE-12 x YA-01	F12	BE-11 x BE-12	H23	BE-12 x wind	W29	CEF woods-run
F2	BE-12 x CR-04	F13	BE-11 x YA-01	H24	YA-01 x wind		
F3	BE-12 x EA-21	F14	BE-11 x CR-04	H25	CR-04 x wind		
F4	BE-12 x BL-05	F15	BL-05 x YA-01	H26	BL-05 x wind		
F5	CR-14 x BE-12	F16	YA-01 x BE-12	H27	CR-14 x wind		
F6	CR-14 x YA-01	F17	YA-01 x CR-04	H28	BE-11 x wind		
F7	CR-14 x EA-22	F18	YA-01 x BL-05				
F8	CR-14 x BL-42	F19	CR-04 x BE-11				
F9	CR-14 x CR-04	F20	CR-04 x BE-12				
F10	BE-11 x BL-05	F21	CR-04 x CR-14				
F11	BE-11 x EA-21	F22	CR-04 x YA-01				

[a] Georgia-Pacific district codes: BE = Berea; BL = Berlin; CR = Crossett; EA = East; YA = Yale Camp.

D.b.h., total tree height, and merchantable volume were then compared between the Crossett woods-run seedlings (Family 29; hereafter, W29) and all other families using one-way ANOVA; Tukey's HSD test for unequal sample sizes ($\alpha = 0.05$) was used to separate means.

RESULTS

1970s Data Reanalysis

Unpublished long-term records from the CEF showed a wet year in 1968 (just over 76 inches of precipitation; the CEF averages about 55.5 inches annually) and slightly drier than average years in 1969 (49.0 inches) and 1970 (53.0 inches), followed by a major drought in 1971 (38.9 inches) and an average year in 1972 (55.8 inches). Not surprisingly, mortality following 3 years post-planting was low, with only two families (H25 and F8) experiencing significantly lower—less than 85 percent—survival (table 2). All but three full-sib families had at least 92 percent survival; all of the half-sib families had between 83 and 89 percent survival, and W29 had an average survival of 92.8 percent. Five-year survivorship reported in Nance (1978) was virtually unchanged for all families.

The considerable variation in height within families resulted in many of them being statistically indistinguishable from each other after 3 years (table 2). On average, the tallest family was F15 at 6.6 feet; families F2 and F6 also averaged at least 6.0 feet tall. Most families had good (5.0 to 5.9 feet) to fair (4.0 to 4.9 feet) height performance after 3 years, and only two (F11 and F12) proved poor (less than 4.0 feet) (tables 2 and 3). At 5.2 feet, W29 was on the lower end of good, but only one family (F15) was significantly taller than W29 after 3 years, and only F11 (at 3.8 feet) was shorter (table 2). Nance (1978, his table 27) reported similar findings; his analysis of height performance at 5 years post-planting noted only five families had exceeded W29 by 5 percent or more and some families averaged more than 25 percent shorter than W29.

In 1972, fusiform rust occurrence was universally low, with only a handful of individual plots at about 6 percent infection, and only a single family (F8) averaging more than 2 percent infected (table 2). It is likely that the higher fusiform infection rate in F8 contributed to this family having the lowest survival rate (54.4 percent) after three growing seasons. Along with 16 other families, W29 showed no evidence of fusiform infection when checked in February of 1972. While it remained relatively modest, the rate of fusiform rust infection increased in all families when evaluated by Nance (1978). Because of this still low rate, Nance (1978) paid little attention to family-based differences; however, his Figure 26 indicated most families had a somewhat more fusiform than W29.

In summary, a reanalysis of the 1972 plot-level data (table 3) show that most tested families had good to excellent survivorship, fair to good height growth, and low to very low fusiform infection rates at 3 years. W29 seedlings performed well after 3 years in the field. Compared to the other 28 families, W29 seedlings had slightly above average survivorship, total height, and lack of fusiform occurrence. Using the performance categories given in table 3, only one family (F6) fell into the excellent category in all three measures of success (survivorship, total height, and fusiform rate). Families F15 and F2 were found in two of three categories,

Table 2—Statistics for the 1969 outplantings in Compartment 3 of the Crossett Experimental Forest, measured in 1972 and summarized by family (using blocks as replicates)

	Survival				Total height				Fusiform rust occurrence			
Family	Min.	Max.	Avg.[a]	SD	Min.	Max.	Avg.[a]	SD	Min.	Max.	Avg.[a]	SD
	%				*feet*				%			
F1	94.4	100.0	98.9 a	2.5	5.2	6.8	5.9 ab	0.6	0.0	0.0	0.0 a	0.0
F2	94.4	100.0	96.7 a	2.3	5.1	7.3	6.0 ab	0.9	0.0	5.9	1.7 a	2.6
F3	88.9	100.0	96.7 a	4.6	5.4	5.9	5.6 abcd	0.2	0.0	2.9	0.6 a	1.3
F4	91.7	100.0	96.7 a	3.6	4.5	6.4	5.3 abcd	0.7	0.0	2.8	0.6 a	1.2
F5	94.4	100.0	97.2 a	2.0	5.0	6.6	5.8 abc	0.6	0.0	2.9	0.6 a	1.3
F6	94.4	100.0	97.2 a	2.8	5.1	7.2	6.0 ab	0.9	0.0	0.0	0.0 a	0.0
F7	61.1	100.0	88.3 a	16.2	4.3	5.5	4.9 bcdef	0.5	0.0	0.0	0.0 a	0.0
F8	25.0	100.0	54.4 b	28.1	4.0	5.9	5.2 bcde	0.8	0.0	6.3	2.2 a	3.1
F9	83.3	100.0	94.4 a	6.5	3.5	5.6	4.8 bcdef	0.8	0.0	0.0	0.0 a	0.0
F10	94.4	100.0	98.3 a	2.5	4.6	5.7	5.2 bcd	0.5	0.0	0.0	0.0 a	0.0
F11	80.6	97.2	87.2 a	7.2	3.3	4.3	3.8 f	0.4	0.0	0.0	0.0 a	0.0
F12	88.9	97.2	93.9 a	3.6	3.3	4.7	3.9 ef	0.6	0.0	0.0	0.0 a	0.0
F13	91.7	100.0	96.7 a	4.6	3.8	4.9	4.5 cdef	0.4	0.0	3.0	1.2 a	1.6
F14	91.7	100.0	96.7 a	3.6	3.8	5.0	4.5 cdef	0.5	0.0	0.0	0.0 a	0.0
F15	88.9	100.0	96.1 a	4.2	5.9	7.2	6.6 a	0.5	0.0	3.1	0.6 a	1.4
F16	94.4	100.0	97.2 a	2.0	5.2	6.6	5.7 abc	0.6	0.0	2.9	1.1 a	1.5
F17	80.6	100.0	94.4 a	7.9	4.4	5.4	5.0 bcdef	0.4	0.0	2.9	0.6 a	1.3
F18	91.7	100.0	94.4 a	3.4	4.4	5.6	4.8 bcdef	0.5	0.0	0.0	0.0 a	0.0
F19	86.1	100.0	92.8 a	5.8	3.7	5.1	4.3 def	0.5	0.0	5.7	1.1 a	2.6
F20	91.7	97.2	93.3 a	2.5	4.4	5.5	4.8 bcdef	0.4	0.0	0.0	0.0 a	0.0
F21	94.4	97.2	96.7 a	1.2	4.0	5.5	4.6 cdef	0.6	0.0	0.0	0.0 a	0.0
F22	91.7	100.0	97.2 a	3.4	4.6	5.7	5.1 bcdef	0.4	0.0	0.0	0.0 a	0.0
H23	80.6	94.4	87.8 a	5.0	3.9	5.2	4.6 cdef	0.5	0.0	0.0	0.0 a	0.0
H24	75.0	97.2	88.3 a	8.2	3.8	4.9	4.3 def	0.4	0.0	0.0	0.0 a	0.0
H25	80.6	88.9	83.9 b	3.0	4.4	5.0	4.7 bcdef	0.2	0.0	0.0	0.0 a	0.0
H26	75.0	97.2	88.9 a	9.4	4.1	5.4	4.6 cdef	0.5	0.0	0.0	0.0 a	0.0
H27	80.6	94.4	88.3 a	6.0	4.5	5.7	5.0 bcdef	0.5	0.0	3.2	0.6 a	1.4
H28	83.3	94.4	88.9 a	4.4	4.5	5.3	4.9 bcdef	0.3	0.0	3.3	1.3 a	1.7
W29	88.9	97.2	92.8 a	4.2	4.8	5.8	5.2 bcde	0.4	0.0	0.0	0.0 a	0.0

[a] Averages with the same letters are not significantly different at $\alpha = 0.05$ (Kruskal-Wallis test; non-parametric multiple comparison).

Table 3—Relative ranking of family performance in 1972 using arbitrary categories (the Crossett woods-run family W29 is highlighted in bold)

Performance category	Survivorship (%)		Total height (feet)		Fusiform (%)	
	Range	Families	Range	Families	Range	Families
Excellent	≥95%	F1, F10, F22, F5, F6, F16, F13, F3, F4, F14, F21, F2, F15	≥ 6.0	F15, F2, F6	0.0	F1, F6, F7, F9, F10, F11, F12, F14, F18, F20, F21, F22, H23, H24, H25, H26, **W29**
Good	90–95%	F18, F17, F9, F12, F20, F19, **W29**	5.0–6.0	F1, F5, F16, F3, F4, F10, F8, **W29**, F22, H27, F17	0.0–0.7	F4, F3, F5, F17, F15, H27
Fair	85–90%	H28, H26, H27, H24, F7, H23, F11	4.0–5.0	H28, F7, F18, F20, F9, H25, F21, H23, H26, F14, F13, F19, H24	0.7–1.4	F16, F19, F13, H28
Poor	<85%	H25, F8	<4.0	F12, F11	>1.4	F2, F8

and most families (including W29) were in at least one excellent category and usually multiple good ratings (table 3). Indeed, in 1972, only F8 seemed to be poorly suited for the CEF location, receiving two poor ratings and one good rating.

Intervening Thinnings and Their Consequences

Although the CEF records are unclear about details, Compartment 3 (including all or part of the progeny tests) were thinned in 1985, 1996, and 2002. The first thinnings in the 1966–1968 plots were implemented in a prearranged pattern; however, it does not appear that the 1969 outplanting was cut in such a fashion, and later thinnings of all outplantings were conducted operationally to improve growth performance. In addition, over the last 40 years, sporadic salvage following other mortality events (for example, lightning, wind, ice, insects, fire) removed some of the planted pines. The thinnings and salvage removals greatly limit any modern-day interpretations of survivorship and fusiform occurrence because they purposefully removed smaller, damaged, and/or diseased individuals.

2017 Data Analysis

Of the 1,296 pines originally planted in this 36-plot subset, 154 remained in January of 2017 (table 4). Although the sample is limited and should be interpreted cautiously, measurements taken in 2017 show changes in performance of the families over time. After 48 years of growth, only one family (H26, averaging 87.9 feet tall) proved significantly shorter than the four tallest families (F3, F6, F11, F16; these tallest families all averaged at least 96.8 feet) (table 4). While the shortest specimen in H26 had a badly ice-mangled crown (after storms in the 1990s), other less damaged individuals in this half-sib family were not particularly tall, either. By 2017, the Crossett woods-run stock (W29) was on the lower end of height performance, averaging 91.5 feet in total height (table 4), or just about a half-log shorter than the tallest family (F6, at 99.1 feet tall on average). The family with the largest average d.b.h. (F20, at 20.6 inches) was significantly larger than several other families, especially the smallest (F13, 14.2 inches). At 17.2 inches in average d.b.h., W29 remained in the middle of the pack, and was not significantly larger or smaller than any other family (table 4).

Because of the models used to calculate this measure, total inside bark merchantable volume patterns mirrored the trends in d.b.h. According to the CEF (equation [1]) and Van Deusen and others (equation [2]) models, the largest merchantable volumes corresponded most closely with the trees of largest girth (not height). Hence, F20 produced the greatest estimated average merchantable tree volume (over 75 cubic feet), and F13 produced the smallest (less than 36 cubic feet). W29 again fell in the middle, with an average total inside bark merchantable volume of about 51 to 52 cubic feet, and was not significantly different than the other families. Note that for W29, equations [1] and [2] differed only

Table 4—Performance statistics 48 years after planting (January 2017) for the 36-plot subsample of the 1969 outplanting in Compartment 3 of the Crossett Experimental Forest by family

		--- Diameter at breast height ---				------------- Total height -------------				Total inside bark merchantable volume	
Family	n	Min.	Max.	Average[a]	Std. dev.	Min.	Max.	Average[a]	Std. dev.	V_{CEF} [a, b]	V_{VD} [a, b]
		inches				*feet*				*cubic feet*	
F1	9	14.1	19.0	16.9 abcd	1.8	85.5	99.0	95.4 ab	4.6	48.9 abcd	52.2 abcd
F2	5	17.4	20.1	19.0 abc	1.1	89.0	101.5	96.3 ab	4.6	63.8 abc	67.4 abc
F3	5	17.3	20.0	19.1 abc	1.1	94.0	101.0	97.0 a	2.5	64.0 abc	68.1 abc
F4	8	15.0	21.6	17.7 abc	2.1	90.0	104.0	95.4 ab	4.8	54.2 abcd	57.3 abcd
F5	5	16.0	18.7	17.2 abcd	1.1	86.5	99.0	94.2 ab	6.2	50.9 abcd	53.6 abcd
F6	4	13.8	17.1	16.0 bcd	1.6	93.5	104.0	99.1 a	5.4	43.6 bcd	49.0 bcd
F7	5	16.1	19.7	17.5 abcd	1.4	88.5	99.5	94.2 ab	4.0	53.2 abcd	55.7 abcd
F8	3	17.3	20.0	18.6 abcd	1.4	95.0	97.0	95.7 ab	1.2	60.8 abcd	64.0 abcd
F9	4	17.8	22.2	19.9 ab	2.1	94.0	96.0	95.3 ab	1.0	69.8 ab	72.6 ab
F10	4	17.6	20.8	19.2 abc	1.5	88.0	93.5	91.8 ab	2.6	64.7 abc	65.1 abc
F11	5	15.0	16.8	16.1 bcd	0.8	93.0	101.0	96.8 a	3.6	44.2 bcd	48.5 bcd
F12	5	12.9	18.7	16.9 abcd	2.4	88.0	96.0	91.2 ab	3.1	49.3 abcd	50.1 abcd
F13	6	12.6	16.8	14.2 d	1.7	85.0	100.0	93.3 ab	5.2	32.5 d	35.7 d
F14	4	15.7	18.6	16.9 abcd	1.3	94.0	97.0	95.5 ab	1.3	48.8 abcd	52.3 abcd
F15	8	14.4	18.1	16.8 abcd	1.4	94.0	98.5	96.8 ab	1.5	48.3 bcd	52.4 abcd
F16	5	14.1	20.0	16.8 abcd	2.2	96.0	100.0	97.4 a	1.9	48.5 abcd	52.9 abcd
F17	9	15.1	19.4	16.9 abcd	1.3	91.0	102.0	96.2 ab	3.0	49.3 abcd	53.1 abcd
F18	4	17.2	18.9	18.0 abcd	0.9	94.0	100.0	95.8 ab	2.8	56.7 abcd	60.1 abcd
F19	10	14.2	19.9	16.8 abcd	1.9	87.0	97.0	92.2 ab	3.1	48.3 bcd	49.9 bcd
F20	4	19.3	21.1	20.6 a	0.9	93.5	96.0	94.5 ab	1.1	75.6 a	77.8 a
F21	5	14.9	18.0	16.3 bcd	1.3	89.5	95.5	92.1 ab	2.2	45.6 bcd	47.4 bcd
F22	9	14.5	18.6	16.5 abcd	1.3	92.0	98.0	95.6 ab	2.1	46.9 bcd	50.4 abcd
H23	4	18.9	21.0	19.7 ab	1.0	93.0	98.0	95.4 ab	2.1	68.9 ab	71.8 ab
H24	5	14.1	16.7	15.5 cd	1.1	92.0	99.0	96.6 ab	2.8	40.2 cd	44.6 cd
H25	3	16.9	20.2	18.2 abcd	1.8	95.5	97.5	96.2 ab	1.2	57.7 abcd	61.3 abcd
H26	4	13.9	18.6	16.5 bcd	2.0	81.0 [c]	91.0	87.9 b	4.6	46.7 bcd	46.2 bcd
H27	3	17.0	19.9	18.4 abcd	1.5	94.0	95.5	94.5 ab	0.9	59.1 abcd	61.6 abcd
H28	5	15.5	17.0	16.3 bcd	0.7	91.0	97.0	94.5 ab	2.5	45.4 bcd	48.6 bcd
W29	4	15.6	19.6	17.2 abcd	1.8	90.5	93.0	91.5 ab	1.2	51.1 abcd	52.2 abcd
ALL:[d]	154	12.6	22.2	17.2	1.9	81.0	104.0	94.8	3.7	51.7	55.3

[a] Average d.b.h., total heights, and total inside bark merchantable volumes with the same letters are not significantly different at α = 0.05 (ANOVA; Tukey's HSD for unequal n).

[b] Total inside bark merchantable (to 4-inch top) volumes determined with a local equation (Farrar and others 1984; V_{CEF} uses d.b.h. only) and Van Deusen and others (1981) (V_{VD}; uses d.b.h. and total height).

[c] This specimen's crown was severely damaged by an ice storm in the 1990s and never fully recovered apical dominance, as had most other similarly injured trees in this stand.

[d] ALL: n = total number of pines sampled for all families; all other variables determined using individual tree measurements, not family-level averages.

slightly from each other in their predictions (51.1 versus 52.2 cubic feet, respectively)—the local model appears well-tuned to the more regional model. However, as is often the case when using a locally derived volume model for trees from outside the calibration source, the addition of height as a variable added several cubic feet to the merchantable volume estimates for the non-local families (table 4).

DISCUSSION AND CONCLUSIONS

Even though one of the original goals of this outplanting was to determine relative susceptibility to fusiform rust, the intervening thinnings mean that we still do not have a good sense of its frequency as a function of family in the Crossett area. Regionally, loblolly pine from the Upper West Gulf Coastal Plain (especially southeastern Arkansas) tend to have a relatively low incidence (less than 10 percent infected), although this also depends on the family being considered (Grigsby 1975a, 1975b; Grigsby 1977; Randolph and others 2015). Short-term differences in fusiform rate were hard to glean from the 1969 outplanting on the CEF, but other longer-duration local progeny tests suggested family-based differences in survival. For example, when planted in other regions and exposed to a wider range of environmental conditions, woods-run loblolly pine from the CEF (and vicinity) had good survivorship and low (less than 20 percent) fusiform infection rates after the first decade, although in some locations survivorship was low and fusiform infection reached 50 percent (Grigsby 1975b). Other studies of fusiform infection indicated that the progeny of superior pines may fare somewhat better than those of conventional woods-run sources (for example, Grigsby 1975a).

From this limited assessment of the tested families, growth performance—as suggested by height—was not consistent between 3 and 48 years post-planting (tables 2 and 4). For example, the family that had the lowest height at 3 years (F11, averaging 3.8 feet) was amongst the tallest at 48 years (averaging 96.8 feet). The Crossett woods-run family (W29) was about average (5.2 feet) at 3 years, but is amongst the shortest today, and other families varied in their eventual outcomes as well (table 4). However, a larger sample of the 1969 outplanting will be required as the height data from 36 plots may be too limited to distinguish between fine-scale site and stand density effects and the influence of family on height performance.

Because bole volume was not determined in 1972, a comparison between short- and long-term patterns in wood accumulation cannot be made. However, the volumes given in table 4 support two other conclusions. First, local volume equations that do not incorporate differences in tree height (and most do not) are inappropriate for comparing volumes between families selected from the local population and those chosen from more distant seed sources. Local volume equations based solely on d.b.h. (or height, or some other single variable) will probably fail to capture significant differences in allometry and lead to inaccuracies in volumetric predictions that could meaningfully impact predictions (for example, Avery and Burkhart 1983). Second, although this limited sample failed to produce statistically significant volume differences between most families tested, it is clear that the noticeably bigger full- and half-sib families would have yielded more fiber than the woods-run stock, assuming the same number of trees had been planted (and survived) on the same site.

Though the early evaluation of progeny tests has become the standard, this preliminary study suggests this may not be advisable for planted pines to be retained much longer than conventional silvicultural rotations (currently, between 20 and 30 years in the Upper West Gulf Coastal Plain). While further analysis and a larger data set are required, the change in rank order of the most and least "successful" families after 48 years could mean that certain objectives (such as carbon sequestered under long-term contracts) may be better served by a more measured evaluation of growth performance.

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