ASSESSING THE ESTABLISHMENT, GROWTH, AND SURVIVAL OF WEST GULF COAST SOUTHERN PINES IN EAST TEXAS

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Abstract—West Gulf Coast provenance loblolly *(Pinus taeda* L.), longleaf (*P. palustris* Mill.), shortleaf (*P. echinata* Mill.), and slash pines (*P. elliottii* Engelm.) were planted in east Texas to compare initial growth and survival across various soil types. Containerized seedlings were planted in December 2015 on three sites in Shelby, Houston, and Cherokee counties using a randomized complete block design. Seedlings were measured initially January-February 2016 and again January-February of 2017, 2018, and 2019. Three years after planting, survival was greatest (76.4 percent) on the study site with fine sandy loam textured soils that were well drained to somewhat poorly drained and was lowest (26.4 percent) at the study site with high Texas leafcutter ant (*Atta texana*) activity. Tree heights and diameters were greater for loblolly and slash pine than shortleaf and longleaf pine.

INTRODUCTION

Pine plantations are an important economic resource in east Texas. Pines are grown for timber production across diverse landscapes and soil types by private landowners and large timber management organizations. Because these plantations can take up to 35 years to maximize financial returns, it is important for landowners to invest in the species that will best meet desired objectives. Each of the four commonly planted southern yellow pine species in this region (loblolly pine (*Pinus taeda* L.), longleaf pine *(P. palustris* Mill.), shortleaf pine (*P. echinata* Mill.), and slash pine (*P. elliottii* Engelm.)) requires specific site conditions to achieve maximum timber growth rates. Capitalizing on these differences in yield may provide the landowner with improved profit. Because of their resistance to fusiform rust and drought injury, West Gulf Coast provenance southern pines are gaining interest as viable options in this sub-region, and comparisons between these species may provide landowners with a better understanding of which will maximize wood production on their site in the early years of rotation. Similar studies have been conducted on southern pine growth comparisons but were further east and predated tree improvement programs (Coile and Schumacher 1953).

MATERIALS AND METHODS

Site Locations and Descriptions

The study took place on three sites in Houston, Cherokee, and Shelby counties located within the east Texas Upper Gulf Coastal Plain. All study sites were located in recently clearcut areas that were adjacent to loblolly pine plantations but varied greatly in dominant soil type and drainage classifications (table 1). The Houston County site was located 11.3 km east of Crockett, TX (31°18’45.7”N 95°18’05.1”). Study plots were predominantly on fine-loamy, fine silty loam, and loamy soils. Soil drainage was classified as somewhat poorly drained to well drained with slopes ranging from 1 to 5 percent. A mix of herbicides including 1.4 L of Chopper, 3.7 L of Accord, and 0.1 L of Oust was applied at 30 L per hectare by ground application in fall of 2015. The Cherokee County tract was located 9.6 km west of Rusk, TX (31°46’32.3”N 95°13’46.2”W) on fine-loamy to loamy textured soils with drainage classifications of well drained to somewhat excessively well drained. The study plots were on a small ridge where commercial plantings of loblolly pine had repeatedly failed due to poor survival. This site was mowed prior to planting. The Shelby County site was located 6.4 km southeast of Tenaha, TX (31°54’48.8”N 94°12’43.9”W). The soil textures were

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very fine sandy loam, and fine loamy sand with drainage ranging from moderately well drained to well drained. Study plots were laid out on the property edge on either side of a logging road. A mix of herbicides including 1.4 L of Chopper, 3.7 L of Accord, and 0.1 L of Oust was also applied at 30 L per hectare by ground application in fall 2015.

Experimental Design

Plots were arranged in a randomized complete block design with three replicates per site for each of the four species. Research plots were 36.5 m by 36.5 m, with trees planted at a 2.4-m by 2.7-m spacing (1,500 trees per hectare). In Houston and Shelby counties, all blocks were directly adjacent to the others, but plots were more dispersed in Cherokee County in non-stocked openings within a 14-year-old loblolly pine commercial planting already on site.

Planting

Trees were planted in December 2015. Loblolly, slash, and shortleaf pines were machine planted as containerized seedlings, but longleaf pine containerized seedlings were hand planted to reduce the deep planting of a machine planter. All seedlings were planted in furrows created by the machine planter. Seedlings were provided by International Forest Company and all were of West Gulf Coast provenance (table 2).

Data Collection

To eliminate edge effects, the outer rows of each plot were reserved as buffer rows where no data were collected. Groundline diameter (GLD) was measured on each seedling where the main stem of the seedling intercepted the soil and was recorded to the nearest millimeter. Seedling height was measured to the nearest 0.5 cm from the intercept of the main stem with the soil

Table 1—Soil series characteristics found at sites in Cherokee, Houston, and Shelby counties in east Texas

Site Soil series	Soil texture	Drainage class	Slope
			%
Cherokee County			
Bowie	fine sandy loam	well drained	3-8
Darco	loamy fine sand	somewhat excessively drained	1-3
Lilbert	loamy fine sand	well drained	3-8
Houston County			
Fuller	fine sandy loam	somewhat poorly drained	1-3
Lovelady	loamy sand	well drained	1-5
Pophers	silt loam	somewhat poorly drained	0-1
Shelby County			
Eastwood	very fine sandy loam	well drained	5-15
Latex	fine sandy loam	moderately well drained	1-3
Metcalf-Sawtown	complex	somewhat poorly drained	0-2

Source: USDA NRCS (2016).

Table 2—Genetic information and origin of pines planted at Houston, Shelby, and Cherokee counties, December 2015

Pine species	Genetics	Origin
Loblolly	Improved, second generation, superior growth and form	Cherokee County, Texas
Longleaf	Natural stand mix	Newton County, Texas
Shortleaf	Improved, orchard mix	Southern Arkansas
Slash	Improved, second generation, superior growth, form, and rust resistance	Northern Louisiana

to the top of the terminal bud. GLD, height, and survival data were recorded each January-February from 2016 to 2019.

Data Analysis

A mixed model analysis of variance was used to test the effects of site and species on seedling height and diameter using the model:

$$Y_{ijkl} = \mu + Site_i + Species_j + Block_{k(i)} + Site_i{*}Species_j + \varepsilon_{ijkl} \quad (1)$$

where site and species were considered fixed variables and block was considered a random variable.

Binary survival data were analyzed using a logistic model to calculate the odds ratio estimates and probability of survival for each species at each site for each individual year. The effect of site, species, and block on survivability were analyzed using the model:

$$Y_{ijkl} = \mu + Site_i + Species_j + Block_{k(i)} + Site_i{*}Species_j + \varepsilon_{ijkl} \quad (2)$$

Assumptions of normality were checked by plotting residual values of heights and diameters by species for all three measurement years. For both models a significance threshold of $\alpha=0.05$ was used.

RESULTS

Establishment

One month after planting, mean initial heights and diameters varied significantly at the species level ($p < 0.0001$). Loblolly and slash pine mean heights were greater than shortleaf pine heights, which was also greater than longleaf pine. Mean basal diameters were significantly different at the species ($p < 0.0001$) and site ($p = 0.0090$) levels. Cherokee site diameters were greater than both Shelby and Houston site diameters. Longleaf diameters were greater than loblolly and slash pine diameters, and slash diameters were greater than shortleaf diameters. Four months after planting (April 2016), survival was not significantly different among species ($p = 0.9688$) or sites ($p = 0.0720$).

Year 1

Heights among the four southern pines varied with site, as suggested by a significant site*species interaction ($p = 0.0298$). Differences in mean height among sites were only significant for loblolly pine ($p = 0.0325$). Loblolly pines at the Shelby site were significantly taller than those at the Cherokee site. Survival was significantly different at the site ($p = 0.0010$) and species ($p = 0.0015$) levels. Tree survival at both the Houston and Shelby sites was greater than at the Cherokee site. Loblolly, shortleaf, and slash pine survival rates were greater than longleaf pine across all study sites.

Year 2

Similar to first-year height, mean height at year 2 varied with site and pine species, as suggested by the significant species*site interaction ($p = 0.0022$). Loblolly pines differed significantly ($p = 0.0281$) in height among sites with greater mean heights at the Shelby and Houston sites than at the Cherokee site. Slash pine also differed significantly ($p = 0.0354$) among sites and similarly performed better at the Shelby site than at the Cherokee site.

Species differences in second-year diameter also varied with site ($p = 0.0004$ for the interaction between site*species). Loblolly pine diameters differed significantly ($p = 0.0286$) among sites. Loblolly pine trees at the Shelby site had the largest diameters, followed by trees at the Houston and Cherokee sites.

Two years after planting, survival rates varied significantly at the site ($p = 0.0015$) and species ($p = 0.0002$) levels. The survival rates at the Houston and Shelby sites were greater than survival rates at the Cherokee site. Loblolly, shortleaf, and slash pine survival rates were greater than longleaf survival rate across all sites.

Year 3

Pine species mean height varied with site (site*species interaction for mean height $p = 0.0028$) (fig. 1). Mean height differed across sites for loblolly ($p = 0.0167$) and slash pine ($p = 0.0243$); these species had similar trends with pines on the Shelby site being tallest and those in the Cherokee site the shortest.

Mean diameter results were similar to those of tree height (fig. 2). Loblolly ($p = 0.0160$) and slash pine ($p = 0.0190$) diameters differed among the sites, with trees from Shelby and Houston sites being significantly larger in diameter than trees from the Cherokee site.

The interaction between site and species for third-year survival was significant ($p = 0.0140$) (fig. 3). Survival in Houston and Shelby sites was greater ($p < 0.05$) than survival at the Cherokee site for all pine species.

DISCUSSION

Growth

Greater growth in loblolly pine could have been due to their improved genetics (McCrady and Jokela 1998), and the observed faster growth rates of loblolly pine compared to the other southern pines (Gibson and others 1986, Smith and Schmidtling 1970). Soils in

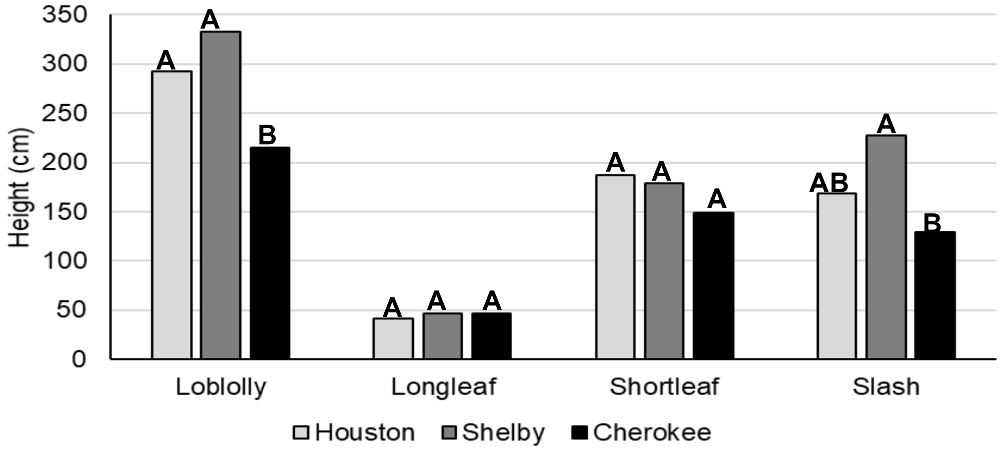

Figure 1—Mean height 3 years after planting of loblolly, longleaf, shortleaf, and slash pines at each study site. Tukey analysis conducted within species, columns headed by different letters are significantly different at $p < 0.05$.

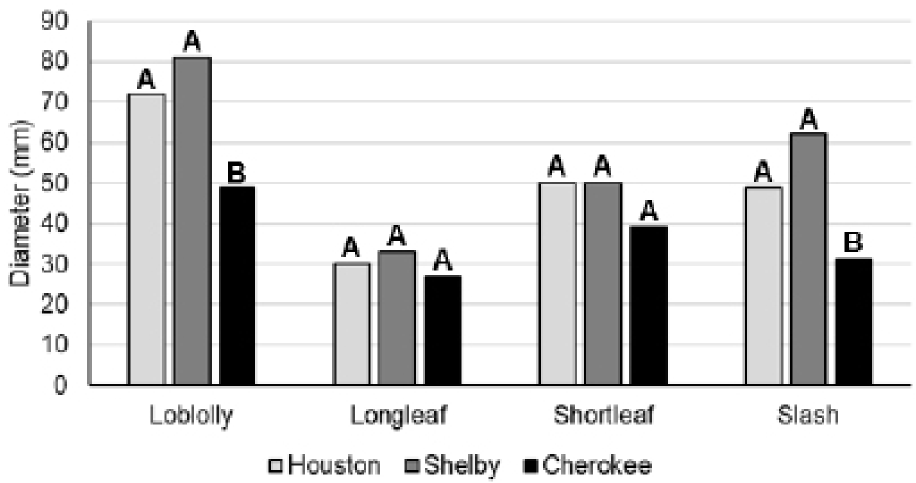

Figure 2—Mean diameter 3 years after planting of loblolly, longleaf, shortleaf, and slash pines at each study site. Tukey analysis conducted within species, columns headed by different letters are significantly different at $p < 0.05$.

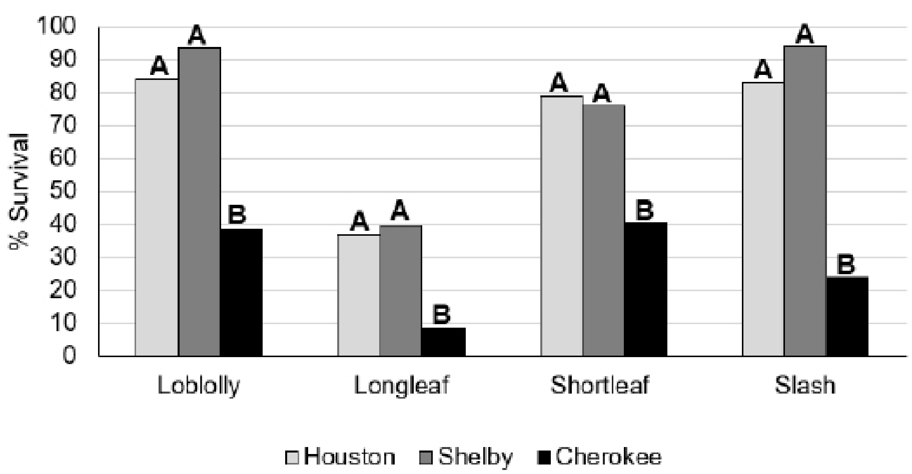

Figure 3—Percent survival of loblolly, longleaf, shortleaf, and slash pines at each study site 3 years after planting. Tukey analyses conducted within species, columns headed by different letters are significantly different at $p < 0.05$.

Houston and Shelby counties were representative of soils (moist, loamy textured, with adequate drainage) where loblolly pine typically outperforms the other southern pines (Baker and Langdon 1990, Haywood and others 1990, McKee and Shoulders 1970, Shoulders 1976, Tiarks and Shoulders 1982). In similar comparison studies, loblolly pine produced a much higher yield than other southern pines on soils with adequate nutrient and moisture availability (Haines and Gooding 1981, Haywood and others 1990, Faust and others 1999, Jokela and others 2000, Kramer 1943).

Slash pine was genetically superior to shortleaf pine in terms of growth, form, and rust resistance; however, east Texas is farther west than the native range of slash pine and receives less average annual rainfall which could potentially reduce its performance. When planted in poorly drained and nutrient deficient soils, which made up a small area of the Houston County site, slash pine began to outperform loblolly pine (Fisher 1983, Shoulders 1976, Shoulders and Parham 1983). However, slash pine does not put on substantial growth on soils with a nutrient availability that satisfies the higher relative demands of loblolly pine (Jokela and others 2000) and is quickly outcompeted. Shortleaf seedling genetics and naturally slower growth rate (Guldin 1986, Lawson 1990) than loblolly and slash pine resulted in lower yearly growth rates.

The majority of longleaf seedlings produced almost no aboveground stem biomass 3 years after planting. The length of the grass stage in longleaf pine was affected by competition of herbaceous plants (Barnett 1989, Boyer 1993, Brockway and Outcalt 1998, Nelson and others 1985, Ramsey and others 2003, Scott and Burger 2014). Those few longleaf that grew out of the grass stage within the first 3 years had the potential to meet the productivity of the other southern pine species in future growing seasons (Croker 1990, Landers and others 1995).

Survival

The higher-than-expected survival rates of loblolly, shortleaf, and slash pines may have been a result of higher than average rainfall received in east Texas between 2016 and 2019 (total rainfall 2016 = 1440 mm, total rainfall 2017 = 1235 mm, total rainfall 2018 = 1490 mm, total average annual rainfall in east Texas = 1185 mm). The greatest causes of mortality among loblolly, shortleaf, and slash pine were damage to seedlings by feral hog activity. Similar to other studies, feral hogs uprooting pine seedlings leaves roots without suitable soil contact and exposed to high temperatures and sunlight, preventing them from recovering (Pessin 1939). Feral hog damage to seedlings was the main cause of mortality in Shelby County and Houston County. During the first and second years of growth, feral hog activity at these sites was high, and uprooting of seedlings caused them to be exposed to wind, low moisture, and hot temperatures. Another factor affecting seedling mortality immediately after planting was inundated conditions of several plots for several weeks after establishment.

Much of the longleaf mortality in the first year may have been due to inadequate planting conditions (planting temperatures of 26 °C were higher than recommended (Lantz and others 1996)). Terminal buds and root collars of the longleaf pine seedlings remained underwater in inundated plots for several weeks, preventing the absorption of sunlight and oxygen for root allocation. Several containerized seedlings also floated out of planting holes, exposing the roots to winds and direct sunlight. Sediment washed over top of the terminal buds once waters subsided, and buried the root collars of longleaf pine, resulting in high mortality within the first 4 months (Hainds 2003, Larson 2002).

During summer months and months with low precipitation, soils in Cherokee County did not provide adequate soil moisture. Defoliation by Texas leafcutter ants (*Atta texana*) were the leading cause of mortality for all species at Cherokee County. Leafcutter ant damage was observed as early as 1 month after planting and continued through the third year. Survival on plots affected by leafcutter ants ranged from a high of 20 percent to a low of 1 percent. Cherokee County longleaf pine plots were also subject to feral hog damage and deer herbivory over the course of the study. Herbivory mortality was caused by the removal of the terminal bud and root collar and the exposure of root systems (Pessin 1939). Herbaceous plant competition for nutrient and water resources may have also impacted the survival and lower growth rates of pines (Metcalfe 1985).

CONCLUSIONS

Growth of the four species in this study varied greatly, potentially driven by differing nutrient demands, response to moisture stress, and site-based environmental factors. The highest yield of all four species after the third growing season was observed on the moist, sandy loam, high-nutrient-available soils in Shelby County. The least amount of aboveground growth was on the well-drained, deep sands in Cherokee County. Seedling survival was greatest in Shelby and Houston counties, which could have been due to the lack of environmental factors affecting survival (Texas leafcutter ants and feral hog damage) in Cherokee County. Lower survival rates of longleaf pine could potentially be attributed to the lack of herbaceous weed control and planting error.

For landowners who wish to obtain the highest growth, we recommend loblolly pine be planted on sites where soil nutrient availability and soil moisture are adequate to support its faster growth rates. Loblolly has high adaptability and can outcompete the other pine species when soil water and nutrients are readily available. Slash pine is recommended as the species of choice on poorly drained soils where nutrients become limiting to loblolly pine. Shortleaf pine should be considered on soils that are excessively drained, where nutrients are very limiting, or on sites where prescribed fire may be frequently applied. Longleaf pine should be considered on sites that are most prone to drought, as its ability to retain high needle moisture and surface area during extended periods of low precipitation allows it to outcompete loblolly and slash pines on extremely dry soils (Sayer and others 2005). Prescribed fire, active forest management, and herbaceous competition control should also be implemented to increase longleaf pine success. If properly managed, longleaf pine growth is comparable to the other southern pines after growing out of the grass stage. (Schmidtling 1987, Outcalt 1993).

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