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ABSTRACT. *The performance of young (less than 10 yr) loblolly (*Pinus taeda *L.) and slash (*Pinus elliottii *Engelm.) pine trees was compared on planted sites in southeast Texas. Performance was compared for: total tree height; tree diameter; height to live tree crown; tree volume index,; incidence of fusiform rust (*Cronartium quercuum *[Berk.] Miyabe ex Shirai f. sp. fusiforme); crookedness of stems ; and survival rates. For these young trees, slash pine tended to perform better in southeast Texas than loblolly pine in total tree height, tree diameter, stem size, height to first live branch and stem straightness. However, loblolly pine was less susceptible to fusiform rust than slash pine, and its mortality rate was lower than slash pine. However, based on the performance of these young plantations, a recommendation on the preferred pine species to plant in southeast Texas might be premature. South. J. Appl. For. 17(1): 26–31.*

Approximately 25% of the 11 million ac of forestland in East Texas have been planted to loblolly (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.). Of these plantations, an estimated 15–20% are slash pine, and almost all the planted slash pine are located in southeast Texas (McWilliams and Lord 1988). However, slash pine planted anywhere in East Texas is an exotic well west of its natural range. Loblolly pine is native to East Texas, and natural and planted stands of this species occur throughout the region.

Comparisons of the performance of loblolly and slash pine plantations within their natural ranges in South Carolina, Georgia, and Florida have shown that, in general, on most sites, loblolly performs as well as or better than slash pine (Cole 1975, Van Lear et al. 1977, Haines and Gooding 1983, Outcalt 1984, Borders and Harrison 1989). Exceptions include a droughty site in South Carolina on which slash pine performed better than loblolly pine (Van Lear et al. 1977). In Florida, slash pine performance exceeded that of loblolly pine on disked sites (Outcalt 1984). On intensively prepared sandhill sites in Florida, slash pine outperformed loblolly pine, but on sandhill sites in South Carolina, loblolly and slash pine performed in a similar manner (Burns 1973). In Georgia, slash pine and loblolly pine performed similarly on two soil groups characterized by poor drainage (Borders and Harrison 1989).

A comparison of slash and loblolly plantations in northwest Louisiana (outside the natural range of slash pine) indicated comparable growth and yield values (Clason and Cao 1982). A performance comparison in western Louisiana (outside natural range of slash pine), southeastern Louisiana, and southern Mississippi showed that both species in general grew equally well (Shoulders 1976).

A comparison of the performance of these two species in southeast Texas at relatively young ages (3–15 yr) might assist in the management of existing southeast Texas pine plantations, as well as deciding which species to replant after final harvest of the current plantations. The goal of this study was to answer the research question: How do the performances of the two species compare at early ages, when planted in southeast Texas?

Plantation Measurements

Information from the East Texas Pine Plantation Research Project (ETPPRP) was utilized in this study. The ETPPRP is a long-term, comprehensive research endeavor initiated by the School of Forestry, Stephen F. Austin State University, in 1982 with support from East Texas forest industries.[1] To provide data to drive analyses, the ETPPRP has installed 246 permanent research plots in loblolly and slash pine plantations on industrial land throughout East Texas. Loblolly plots are located in plantations from the Gulf Coast to the Red River, while slash plots are only located in plantations in Southeast Texas. Plots were established and first measured during 1982–1884. Remeasurements are conducted on a 3-yr cycle with three cycles completed to date. Fusiform rust (*Cronartium quercuum* [Berk.] Miyabe ex Shirai f. sp. *fusiforme*) resistant planting stocks were not used in plantations sampled by the ETPPRP.

During plot establishment, a goal was to achieve a wide distribution of samples across site factors such as: geographic

[1] Support from participating companies—Champion International Corporation, International Paper Company,Louisiana-Pacific Corp. and Temple-Inland Inc.—is appreciated.

location, landform, edaphic conditions, site index, planted trees per acre and plantation age. The intent was to obtain an appropriate sample space for regression analyses. Subsequent measurements, various studies, and the passage of time indicate success in accumulating wide-ranging data suitable for regression analyses.

Each of the 246 plots is situated in a different plantation and consists of two adjacent subplots separated by a 60-ft–wide buffer zone. Data from one subplot are used for model development, and data from the other subplot are used for model evaluation. A subplot is 100 × 100 ft in size, and all planted pines within a subplot are tagged and numbered for measurement. Model development subplot data were used in this study.

From these available field observations, seven measures of performance were used to compare the two species:

1. H—average per tree total height in feet.
2. D—average per tree dbh in inches.
3. DSQH—average per stem size index (calculated as D × D × H).
4. HLC—average per tree height to live crown in feet.
5. STEM%—average per acre percent stems with fusiform rust galls.
6. CRK%—average per acre percent stems that are crooked.[2]
7. SUR%—average per acre percent stems surviving over preceding 3 yr.

After initial measurement and two subsequent measurements, a total of 810 observations (558 from loblolly plots and 252 from slash plots) were available for consideration. Due to young plantations, all seven performance measures are not available for all 810 observations.

The Grouping Process

It was a challenge to use these data to answer the research question "How do the performances of young planted loblolly and slash pine compare in southeast Texas?" A typical tree species comparison study is usually a balanced, well-designed, side-by-side experiment with research plots installed on a small number of sites. At none of our 246 sites did we have adjacent research plots of the same species, much less different species. The ETPPRP was not designed to test sample means in a species performance comparison. In an attempt to resolve this problem and be able to use ETPPRP data to answer the research question, our approach was to group the observations from the three complete measurement cycles into classes representing fairly narrow site/stand clusters.

The goal of the grouping process was to obtain matches of ETPPRP loblolly and slash pine plots with similar stand/site attributes. However, the plots are not geographically situated side-by-side. In order to calculate species sample means and test the means for significant difference with some degree of reliability, each grouping should have two or more observations for each species.

The first grouping process was to limit the ETPPRP observations to southeast Texas. Loblolly pine plantations were sampled throughout East Texas, but no slash pine plantations north of a Nacogdoches County to Sabine County line were sampled in the ETPPRP. This removed the possible comparison of the performance of a loblolly pine plantation along the Red River in North Texas with a slash pine plantation near the Texas Upper Gulf Coast. In addition, plantation observations less than 3 yr old were deleted. As a result, 291 of the 810 observations were eliminated, leaving 519 observations (304 from loblolly and 215 from slash) available for analysis.

The next process was to form age (A), surviving trees per acre (T) and site index-base age 25 years (S) groups. After considering silvicultural aspects of planted loblolly and slash pine plantations in southeast Texas, group break values for A, T, and S were selected. The number of observations by species by groups are listed in Table 1. The total number of possible matches is 7 (number of age groups) times 4 (number of trees per acre groups) times 5 (number of site index groups) for a product of 140. Of these 140 potential matches, 34 matches had 2 or more observations for each species, and 18 matches had 3 or more observations for each species. A representative example of a match within an A, T, and S group is shown in Table 2.

The last stage in the grouping process was to consider site categories. By including a site factor, the matching of loblolly and slash pine plots for performance comparison might be more definitive. Three site characteristics available from ETPPRP data were (1) landform position, (2) surface soil texture, and (3) depth to mottling. Using site-preparation techniques as a site category was considered, but then abandoned when it was determined that over 75% of the ETPPRP plots had been sheared and piled. Table 3 presents the observations grouped into each of the three site category classes. Initial investigations indicated that only one of the site catego-

Table 1. Number of observations by species for age, trees per acre, and site index groups in southeast Texas.

	Obs. by species	
Age groups (yr)	Loblolly	Slash
3–4	51	26
5–6	59	43
7–8	65	47
9–10	47	32
11–12	20	30
13–14	25	17
≥15	37	20
Totals	304	215
Trees per acre groups (no.)		
100–250	6	40
251–450	126	99
451–650	138	53
≥651	34	23
Totals	304	215
Site index groups (ft)		
≤55	22	24
56–65	49	64
66–75	85	59
76–85	64	48
≥86	84	20
Totals	304	23

[2]During ETPPRP plot measurement, a tree was classified by the field crew as crooked, if it exhibited a distinct sweep, bend or twist.

Table 2. Performance values for a match of loblolly and slash observations occurring when age group = 7–8 yr, trees per acre group = 300–400, and site index group = 60 ft.

Species	Performance values							County
	H (ft)	D (in.)	HLC (ft)	DSQH	STEM%	CRK%	SUR%	
Loblolly	28	4.4	5	491	1	70	95	Polk
Loblolly	24	3.6	3	278	3	86	100	Trinity
Loblolly	18	2.1	4	69	0	93	100	Angelina
Loblolly	20	3.1	2	167	8	81	93	San Augustine
Slash	22	2.7	5	139	48	83	96	Jasper
Slash	22	3.7	na	254	75	16	na	Tyler
Slash	24	3.6	6	276	28	63	82	Polk
Slash	22	2.9	4	162	19	94	100	Jasper
Slash	20	2.9	na	147	42	5	na	Tyler

ries can be used as a grouping component at a time. If two or three site categories are used concurrently in an attempt to obtain more precise grouping, no matches of two observations or more occurred.

An example of the reduction in number of observations by considering one of the three site categories can be illustrated for the four loblolly and five slash observations in Table 2. It is not noted in Table 2, but of the four loblolly pine observations, three have depth to mottling of 2 ft or less, while two of the five slash pine observations have depth to mottling of 2 ft or less. This still qualifies as a match but with 25% less loblolly observations and 60% less slash observations. All the remaining observations have depth to mottling of 2–4 ft but do not qualify as a match (must have two observations or more per species).

By classifying each of the 519 observations by the A, T, and S groups and one of the site factor groups, the sample means of the performance variables might reflect differences in growth characteristics of each species and not the influence of stand/site factors.

Table 3. Number of observations[a] by species for landform, soil texture and depth to mottling categories in southeast Texas.

	Obs. by species	
Landform position groups	Loblolly	Slash
Flood plain-lower slope	94	106
Side slope	113	49
Upper slope-ridge	96	60
Totals	303	215
Soil texture groups		
Sandy	22	39
Loamy	127	117
Fine	105	54
Totals	254	210
Depth to mottling groups (ft)		
<2	146	79
2–4	86	87
>4	66	45
Totals	298	211

[a] The totals vary because some plots have incomplete site factor determinations.

Performance Comparison

In an attempt to provide informative performance comparisons, 1 of the 3 possible site categories had to be selected In the 3 landform groups, 10 matches occurred in the first group, and 2 each in groups 2 and 3 for a total of 14 matches. A total of 14 matches also occurred for soil texture—none in the first group, 10 in the second, and 4 in the third. However, for the depth to mottling category, a total of 20 matches occurred—10 in the first group,8 in the second, and 2 in the third. Note that each of these 3 totals are from 420 possible matches (140 from the A-T-S grouping × 3 groups of the site category). Depth to mottling was chosen as the site category, because it had more total matches, better match representation across the 3 groups, and represents a site factor which can influence tree performance. A list characterizing the 20 matches is presented in Table 4. As a result, tree performance was analyzed in plantations with relatively young (<10 yr) trees, generally less than 600 trees/ac, and a fairly wide range of site index and depth to mottling values.

The next step was to calculate an average value by species for each performance measure in each match. As mentioned earlier, in some matches, not all performance measures were available because of observations from relatively young plantations. The mean values were available for statistical and graphical analyses.

Figures 1–7 were developed to compare graphically the species performance trends across the 20 matches for each of the 7 measures of performance. Each figure represents 1 of the 7 measures. The vertical axis depicts the performance of planted slash pine, and the horizontal axis shows the performance of planted loblolly pine. The diagonal line represents equal performance. If a match is above the diagonal, slash pine outperformed loblolly pine in that match. If a match is below the diagonal, then loblolly pine outperformed slash pine.

After consideration of mean performance values and Figures 1–7, results of the seven comparisons of performance follow.

Height

Along the height scale of about 5–50 ft and across the array of 20 matches, the total height of slash pine exceeds the total height of loblolly in 75% of the matches (Figure 1). When loblolly height is greater than slash, it is only by a foot or two However, when slash height is greater than loblolly, the

Table 4. A listing of the group characteristics and number of observations for the 20 performance matches with depth to mottling as the site category.

Match	Age (yr)	Trees/ acre (no.)	Site index[a] (ft)	Depth to mottling (ft)	Observations	
					Loblolly	Slash
01	3–4	500–600	60	<2	4	2
02	3–4	≥700	90	<2	3	3
03	3–4	300–400	50	2–4	2	2
04	3–4	500–600	90	2–4	3	3
05	5–6	300–400	50	<2	2	2
06	5–6	500–600	70	<2	2	2
07	5–6	500–600	80	<2	6	2
08	5–6	≥700	90	<2	3	2
09	5–6	300–400	70	2–4	2	3
10	5–6	500–600	70	2–4	2	2
11	5–6	500–600	80	2–4	2	3
12	7–8	300–400	60	<2	3	2
13	7–8	300–400	70	<2	2	3
14	7–8	500–600	80	<2	2	2
15	7–8	300–400	80	2–4	2	2
16	7–8	500–600	70	2–4	4	3
17	7–8	300–400	80	>4	4	2
18	9–10	500–600	60	<2	3	2
19	9–10	500–600	80	2–4	4	2
20	≥15	500–600	60	>4	2	2

[a] Base age = 25 yr.

differences are higher ranging up to 6 ft. In three of 20 matches, t-tests indicated that slash pine total tree height was significantly higher at a 5% probability level.

Diameter

A visual inspection of Figure 2 indicates that along the 1–6 in. diameter range, slash pine diameter tends to be larger than loblolly. When the mean tree diameter is less than 4 in. in diameter, slash pine outperforms loblolly, while above 4 in. in diameter, loblolly tends to exceed slash. In only 1 of 20 matches was slash mean diameter significantly larger than loblolly at the 5% level.

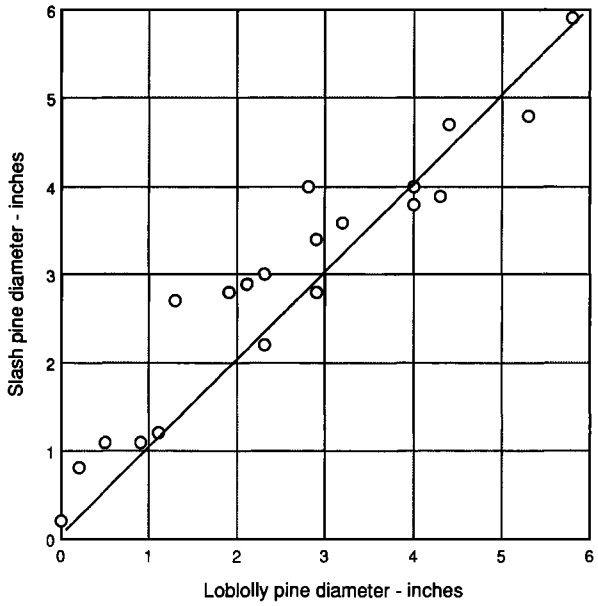

Figure 2. A comparison of the tree diameter performance of planted slash and loblolly pine trees.

Stem Size Index

Based on this indicator of observed stem size, stem dimensions of slash appear to be inclined to surpass the stem size of loblolly pine (Figure 3). However, due perhaps to the magnitude of the numbers, a general trend is difficult to define. Results of t-tests indicated no significantly different means.

Height to Live Crown

Due to young plantations and resulting lack of height to live crown field measurements, only 10 matches were available for comparison (Figure 4). Two matches had identical values. The distance from the ground to the first live branch appears

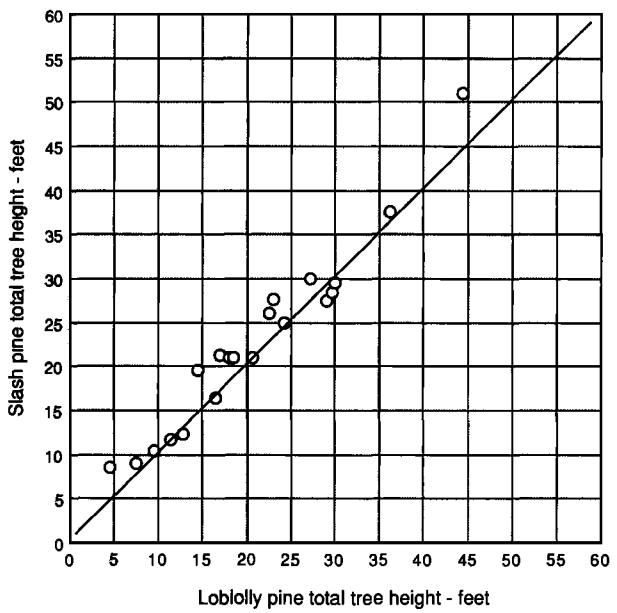

Figure 1. A comparison of the total tree height performance of planted slash and loblolly pine trees.

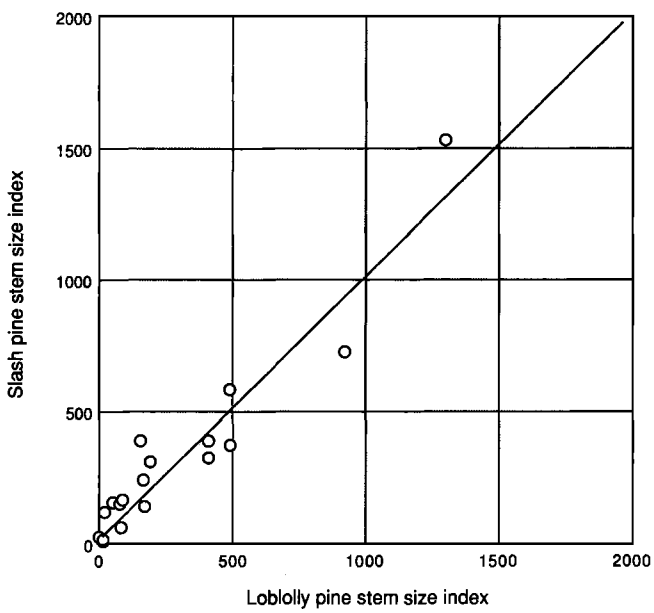

Figure 3. A comparison of the tree size index of planted slash and loblolly pine trees.

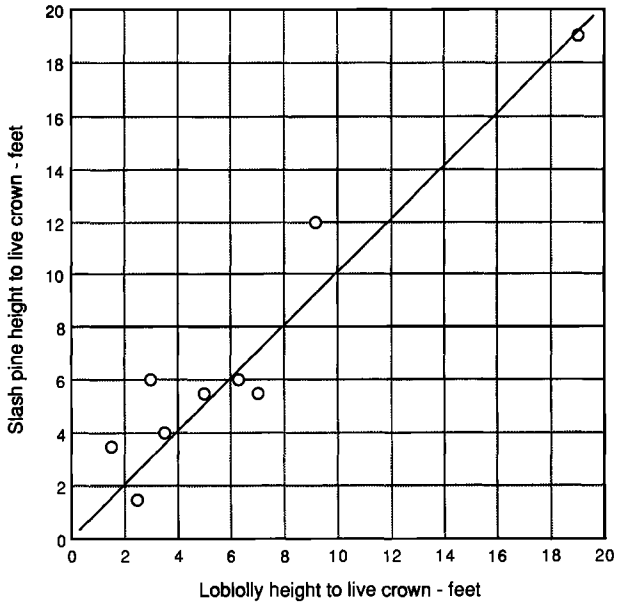

Figure 4. A comparison of the height to live crown of planted slash and loblolly pine trees.

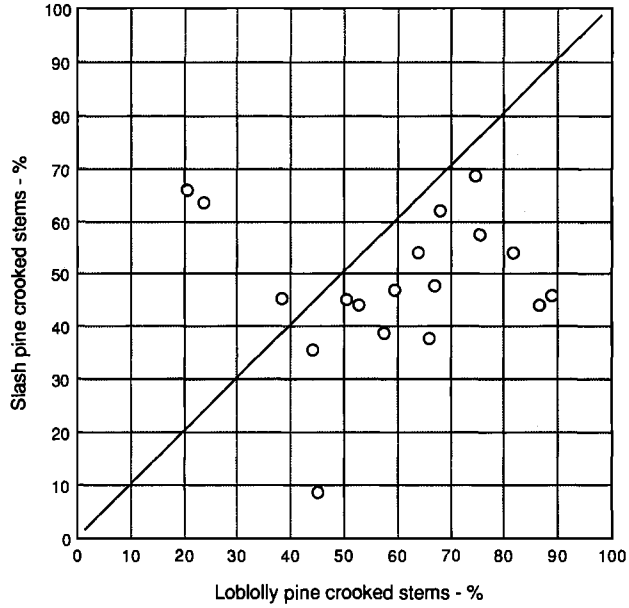

Figure 6. A comparison of the percentage of crooked stems of planted slash and loblolly pine trees.

to be usually greater for slash pine than for loblolly pine. Slash pine tends to have more clear stem than loblolly pine in these relatively young plantations. In only one match, slash clear stem length exceeded loblolly in a significant manner at the 5% level.

Percentage of Stems with Fusiform Rust Cankers

The stems of planted slash pines in southeast Texas are much more infected with fusiform rust than loblolly (Figure 5). Of the 16 matches, t-tests indicated that in 9 matches the percentage of slash pine with stem galls was significantly different at the 5% level. In this region, with non-rust-resistant planting stock, slash pine is much more likely to be heavily infected with stem galls than loblolly pine.

Percentage of Crooked Stems

In these young plantations, the tendency is for loblolly pine trees to be more crooked than slash pine (Figure 6). Except for three matches, slash pine outperformed loblolly on the ability to produce straight stems. This is an interesting result due to the high occurrence of fusiform rust galls on slash pine stems. Apparently in these young plantations, the stem gall may not cause a definitive crook in the stem. Statistically, in only two matches was there a significant difference at the 5% level in average percentage of crooked stems.

Survival Percentage

Due to limited observations, only eight matches were available (Figure 7). In these eight matches, planted loblolly

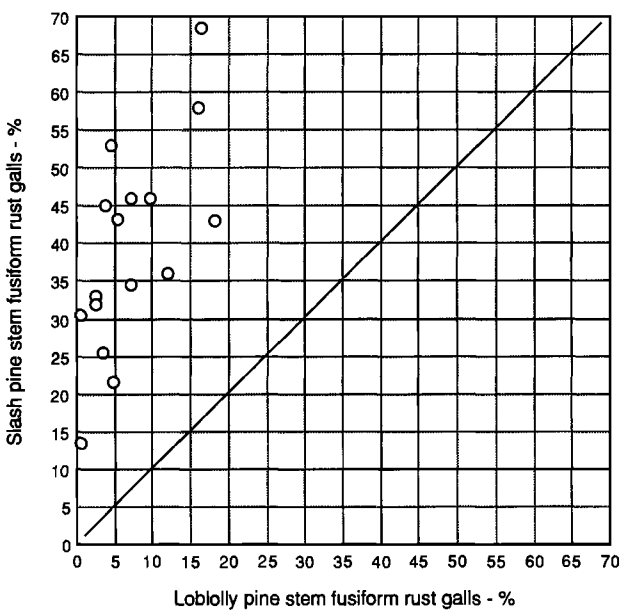

Figure 5. A comparison of the percentage of fusiform rust infected stems of planted slash and loblolly pine trees.

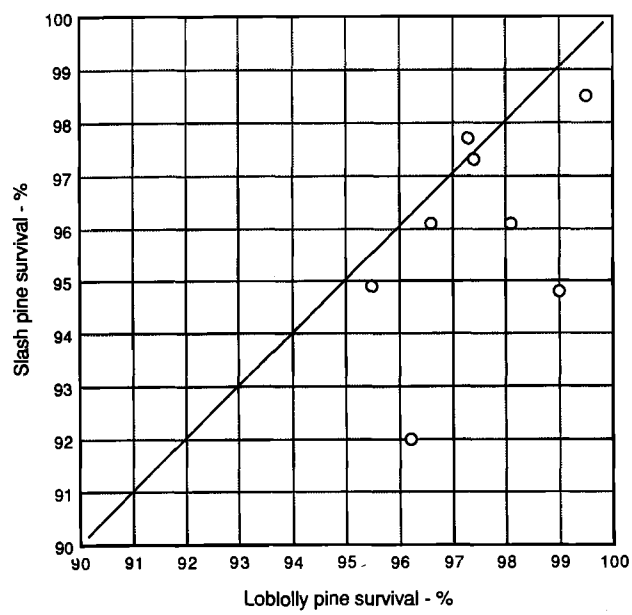

Figure 7. A comparison of the survival of planted slash and loblolly pine trees.

survives better than slash pine. Survival rates are relatively high because they represent the changes in number of trees per acre over a 3-yr period. They do not represent survival since plantation establishment. Slash pine survival may be affected by relatively high fusiform rust infections. In one match, loblolly survival was statistically higher at the 5% level than slash survival.

Discussion and Conclusion

Analysis of observations from permanent sample plots located within young (less than 10 yr) loblolly and slash pine plantations in southeast Texas indicated that slash pine usually outperformed loblolly pine in several attributes. Typically, the slash pine trees are taller, have larger diameters, have a greater stem size index, have more clear bole before the first live branch, and have straighter stems. However, loblolly pine tended to outperform slash pine in terms of lower incidence of fusiform rust and better survival rates. It appears that in these young plantations slash pine may be a better producer of wood than loblolly pine.

A conclusion that slash pine is the preferred species to plant in southeast Texas is difficult to reach for several reasons. Slash pine is an exotic in southeast Texas. It is several hundred miles west of its natural range and has several management problems. The high occurrence of fusiform rust in slash pine in southeast Texas is an important aspect of pine plantation management (Mason and Griffin 1970, Texas Forest Service 1982, Lenhart et al. 1988, Arabatzis et al. 1991). On average, about 50% of the slash pines in East Texas have a rust gall on the stem, while only about 10–15% of the planted loblolly pines in East Texas have stem galls. The tree stem area in and around a gall may not be suitable for utilization for high value products. A tree with a stem gall may be more susceptible to wind breakage with an associated higher mortality risk. The typical location of stem galls on trees in young slash pine plantations in southeast Texas is within 1–2 ft of the ground. If a slash pine stem breaks at a low-level gall, usually minimal material can be salvaged.

Another factor affecting the development and survival of slash pine trees in southeast Texas is ice damage. Even though ice storms are infrequent occurrences in southeast Texas, damage due to ice loads can be severe in slash pine plantations located in this area. As a result of weakened condition due to fusiform rust and/or icing, slash pine trees may be more susceptible to attack by bark beetles.

Based on the results of this study of the performance of loblolly and slash pine trees during the first 10 years of their life, there is probably no advantage to converting existing loblolly pine plantations in southeast Texas to slash pine. However, the management of existing slash pine plantations needs to be carefully considered. In some slash pine plantations it might be advisable to harvest and replant with loblolly pine stock, as soon as possible. Appropriate slash pine management strategies are described by Powers and Brender (1977) and Belcher et al. (1977).

Since early growth characteristics may not be indicative of future tree size and quality, we are curious if slash pine will continue to outperform loblolly pine in the five areas listed above, as the trees approach intermediate or final harvest. By the year 2000, we will have a large amount of additional data from ETPPRP permanent plots. We hope that these future plot measurements will provide data in the 15–20 yr age classes suitable for performing more definitive performance comparisons.

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