14 Year Results of the PMRC Species Comparison Study

Plantation Management Research Cooperative

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Introduction

Intensive pine plantation management may have various objectives. These objectives include creation of a constant sustainable flow of raw materials for production facilities, and/or maximization of income from forested lands. There are many management techniques which can be used to reach these objectives. Current PMRC studies are examining the effects of site preparation and fertilization (Shiver et al., 1994a), genetically improved planting stock and vegetation control (Shiver et al., 1994b), as well as thinning and density control (Pienaar and Rheney, 1994). Another major factor affecting productivity is the site specific selection of species in the lower coastal plain. The purpose of this report is to present the 14 year results for the PMRC species comparison study.

Data

The original study plan called for 160 installations on eight soil drainage classes throughout the lower coastal plain of Florida and Georgia (Figure 1). Twenty installations were randomly located in each of the eight soil classes during the 1978/79 and 1979/80 planting seasons. At each installation two plots were laid out with care taken to select areas with uniform soil conditions across both plots. The individual plots were then planted with bulk lot improved seedlings. Loblolly pine *(Pinus taeda* L.) seedlings were planted on one plot and slash pine *(Pinus elliotii* Engelm.) seedlings were planted on the other. Each plot contained 64 trees with an approximate density of 720 trees/acre. The age 2 results were reported by Clutter (1983), age 5 results were reported by Borders and Brister (1986), and age 8 results were reported by Borders and Harrison (1989). Age 14 information was collected in 1994 and is now available for analysis.

Methods

At the end of 14 growing seasons there were 138 complete installations remaining, due to withdrawal of cooperators, fire, thinning, damage, etc. Originally the installations were evenly distributed over eight soil drainage classes. However, there was also interest in the reliable performance of slash and loblolly pine plantations on Cooperative Research in Forest Fertilization (CRIFF) soil groups, CRIFF groups were assigned to the existing plots in 1989 based on the soil descriptions made at study initiation. However there was some concern that the CRIFF groups assigned were not consistent with those assigned by the cooperators. In 1994 soils were reexamined by cooperators and CRIFF groups were modified where appropriate. Since some original plots were lost and installations were not originally balanced by CRIFF groups, The design was no longer balanced (Tables 1 & 2).

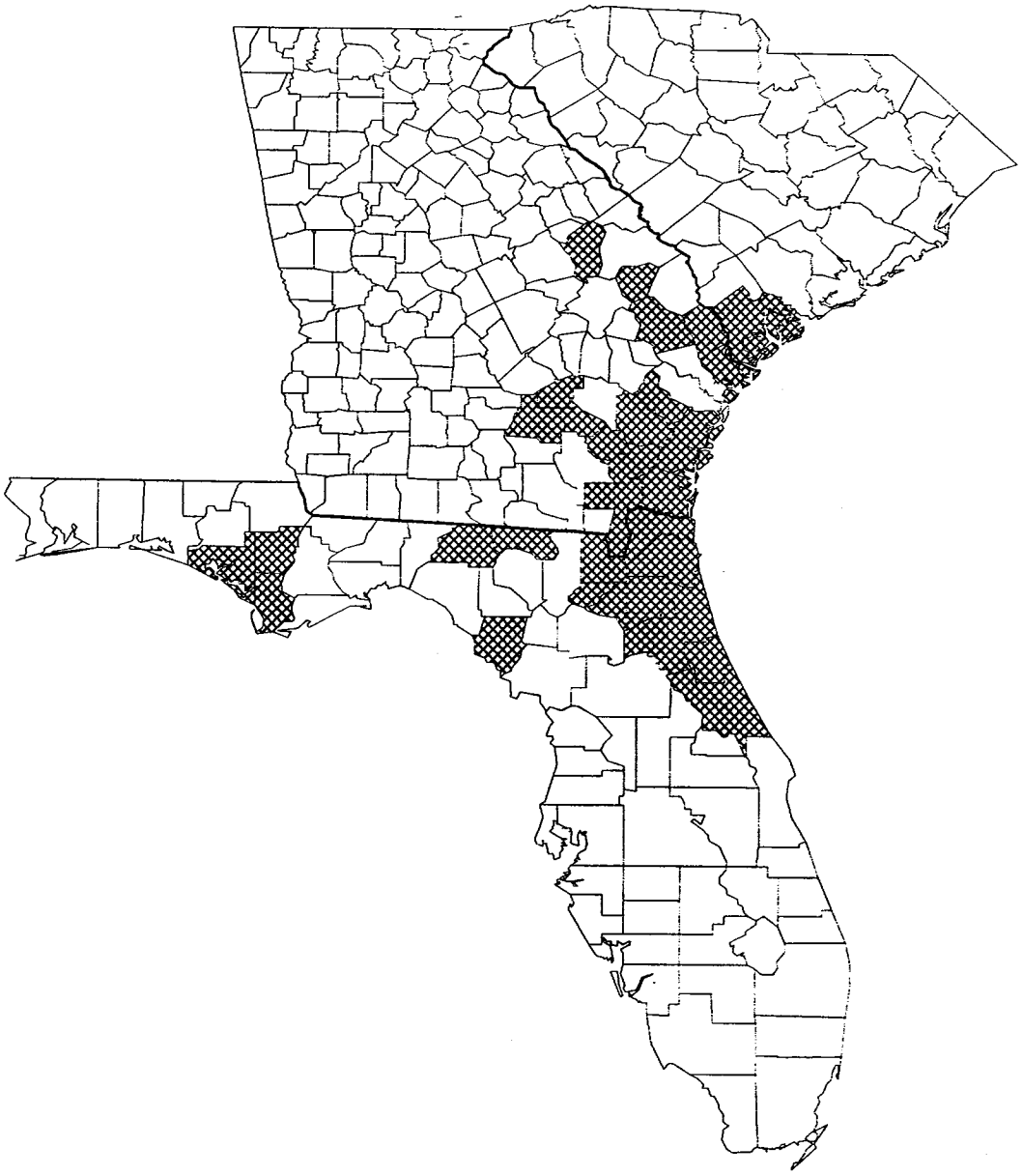

Figure 1. Geographic distribution of species comparison installations.

Each surviving tree at a location was measured for DBH in inches (.1"), presence of fusiform rust, (Cronartium *fusiforme* Hedge. and Hunt.), and total height. There were rare occurrences where a tree did not have a recorded height. In these cases the height was estimated using a height/DBH equation proposed by Curtis(1967):

$$\ln(\mathrm{Ht} - 4.5) = B_0 + \frac{B_1}{\mathrm{DBH}}$$

The equation was fit to each plot and heights were estimated using the stand specific regression coefficients. Total volumes and merchantable volumes to a 4 inch top, as well as total green weight and green weight to a 4 inch top were calculated for loblolly pine (Borders et al., 1990) and slash pine (Pienaar et al., 1988). Basal area per acre, trees per acre, and survival were also calculated.

Table 1. Description of CRIFF soil groups with number of installations in each group for the species comparison study.

CRIFF Soil Group	# of Installations	Drainage Class[1]	Diagnostic Horizons	Depth to Horizons
H	0	VP	Histic	surface
A	7	VP, P, SP	Argillic	< 20 inches
B	23	VP, P, SP	Argillic	> 20 inches
C	31	VP, P, SP	Spodic, Argillic	any
D	36	VP, P, SP	Spodic	any
E	0	MW, W	Argillic	< 20 inches
F	22	MW, W	Argillic	> 20 inches
G	19	SE,E	none or Argillic	deep
Total	138			

Table 2. Description of UGA soil groups with number of installations in each group for the species comparison study.

UGA Soil Group	# of installations	Drainage Class[1]	Description
1	17	P, VP	spodic with argillic horizon
2	14	P, VP	spodic without argillic horizon
3	17	P, VP	non-spodic soils
4	17	SP, MW	spodic with argillic horizon
5	19	SP, MW	spodic without argillic horizon
6	19	SP, MW	non-spodic soils
7	17	W	non-spodic soils
8	18	SE, E	non-spodic soils
Total	138		

Analyses were done by UGA soil class, CRIFF soil group, and across all soils. Analysis of variance was used to examine species*soil interactions as well as species and soil differences. The variation among installations within each

[1]VP=very poorly drained, Poorly drained, SP=somewhat poorly drained, MW=moderately well drained, W=well drained, SE=somewhat excessively drained, E=excessively drained

soil class was used to test species differences among soil classes. When species*soil interactions were not present, the analysis of species differences was done using a paired T-test.

Results

Age 14 Stand variables

Analysis of variance was performed on the 1994 stand data (Appendix A) Variables tested included, percent cronartium, survival, basal area per acre, trees per acre, total volume, merchantable volume (4" top), total green weight, and merchantable green weight. The analysis showed no significant (α=0.05) species*soil type interactions for the UGA soil groups. This means that one species does not perform better on one soil type, while the other species performs better on another soil type. In other words one species performs as well or better than the other species across all soil types. There was a significant (p=0.0355) species*soil type interaction for percent cronartium infection when the analysis was done using the CRIFF soil groups, but there were no significant (α=0.05) species*soil type interactions for the remaining stand variables. Since there were no important species'` soil group interactions, it is possible to examine the species differences using a paired T-test across all soil classes.

Paired T-tests were performed to examine differences due to species across all soil groups. Loblolly pine showed better survival carrying higher basal area per acre, total volumes, and green weights per acre than slash pine in spite of having a higher incidence of fusiform infection (Table 3). These results agree with those found at age 11 by Borders and Harrison (1989).

Table 3. Mean species differences across all soil types in the species comparison study.

Variable	# of installations	loblolly value	Slash value	P value for difference
cronartium	138	19.7	17.8	0.0219
survival	138	71.9	65.9	0.0006
basal area (ft2/ac.)	138	98.79	81.21	0.0001
trees/ac.	138	522.4	478.1	0.0006
Total Volume (ft3/ac.)	138	1878.16	1716.65	0.0286
Merch. Volume (ft3/ac.)	138	1512.37	1338.07	0.0099
Total Weight (tons/ac.)	138	53.12	46.35	0.0014
Merch. Weight (tons/ac.)	138	52.49	35.83	0.0001

An analysis was also performed to examine differences in productivity by soil group. When the ANOVA was performed with UGA soil groups, soil groups 6, 3, 1, and 4 were superior to soil group 8 (α=0.05) for basal area/acre,

trees/acre, total volume/acre, merchantable volume/acre to a 4" top, total outside bark O. B. green weight/acre, and merchantable O.B. green weight/acre to a 4" top (Table 4).

Table 4. Mean soil group values in the species comparison study (both species combined).[2]

	Soil Group							
Variable	1	2	3	4	5	6	7	8
% Cronartium	15:5 abc	12.2 c	18.7 abc	13.3 bc	16.1 abc	24.0 ab	26.7 a	21.8 abc
% Survival	73.0 a	68.0 ab	73.0 a	73.4 a	65.7 a	74.3 a	65.2 ab	59.1 b
Trees/ac.	530 a	494 ab	530 a	533 a	477 ab	540 a	473 ab	429 b
Basal Area (ft^3/ac.)	94.03 a	88.93 a	100.96 a	93.78 a	88.79 a	105.53 a	86.59 a	61.89 b
Total Volume (ft^3/ac.)	1940.6 a	1805.3 a	2087.0 a	1915.5 a	1641.2 ab	2225.6 a	1640.3 ab	1158.4 b
Merch. Volume (ft^3/ac.)	1510.88 a	1439.7 ab	1682.6 a	1503.7 a	1296.0 ab	1821.3 a	1297.5 ab	877.6 b
Total Weight (tons/ac.)	53.726 a	49.970 a	57.829 a	52.879 a	45.289 ab	61.827 a	45.225 ad	32.047 b
Merch. Weight (tons/ac.)	47.524 a	44.382 ab	51.821 a	46.372 a	40.255 ab	55.814 a	40.090 ab	27.709 b

The same analysis was performed using the CRIFF soil groups. Average basal area/ac. total volume/ac. merchantable volume/ac. total O.B. green weight/ac. and Merchantable O.B. green weight/ac. for soil group G was less than that for soil groups A, B, C, D, and F(α=0.05), despite the fact that survival was not significantly different for soil groups D, F, and G. Additionally, cronartium infection rates were lower on soil group G than for soils A and F (Table 5).

Growth Variables

Results of the analyses of variance for 3 year growth from age 11 to age 14 indicated that there were no species*soil interaction (α=0.05). The same analyses indicated that loblolly pine had superior growth characteristics when compared to slash pine for the 3 year period (Table 6).

The results of the ANOVA for 3 year growth of both loblolly and slash pine on UGA soil types indicate that soil group 8 had lower basal area/ac., total

[2]Means with the same letter are not significantly different (α=0.05).

volume/ac., merchantable volume/ac., total weight/ac., and merchantable weight/ac. growth than all other UGA soil classes (Table 7).

Table 5. Average stand values for the various CRIFF soil groups in the species comparison study.[3]

	Soil Group					
Variable	A	B	C	D	F	G
% Cronartium	29.7 a	16.8 b	14.7 b	15.0 b	29.9 a	18.8 b
Survival	71.4 ab	78.1 a	71.6 ab	67.6 abc	59.2 c	65.8 bc
Trees/ac.	519 ab	567 a	520 ab	491 abc	430 c	478 bc
Basal Area (ft^2/ac)	105.05 a	99.90 a	92.99 a	91.14 a	94.87 a	60.38 b
Total Volume (ft^3/ac)	2198.9 a	2062.9 a	1933.9 a	1754.0 a	1911.4 a	1081.1 b
Merch. Volume (ft^3/ac.)	1814.4 a	1630.6 a	1525.9 a	1391.3 a	1606.9 a	748.6 b
Total Weight (tons/ac.)	61.081 a	57.114 a	53.534 a	48.448 a	52.940 a	29.753 b
Merch. Weight (tons/ac.)	56.0108 a	50.289 a	47.322 a	43.151 a	48.642 a	24.342 b

Table 6. Average per acre growth differences for the species comparison study from age 11 to age 14.

Variable	Loblolly Pine	Slash Pine	P Value for difference
Mortality (trees/ac.)	1.1	14.9	0.0467
Basal Area Growth (ft^2/ac.)	30.83	23.32	0.0020
Total Volume Growth (ft^3/ac.)	864.26	736.93	0.0092
Merch. Volume Growth (ft^3/ac.)	825.29	720.85	0.0250
Total Weight Growth (tons/ac.)	24.634	20.571	0.0034
Merch. Weight Growth (tons/ac.)	23.650	19.844	0.0045

[3]Means with the same letter are not significantly different at the α=0.05 level.

Table 7. Average per acre growth for both species for all UGA soil groups in the species comparison study from age 11 to age 14.

Variable	Soil Group 1	2	3	4	5	6	7	8
Mortality (trees/ac.)	-1.3 a	8.6 a	16.4 a	-0.328 a	12.5 a	0.6 a	12.7 a	15.8 a
Basal Area Growth (ft^2/ac.)	31.26 a	26.57 a	29.77 a	29.515 a	28.82 a	29.61 a	26.76 a	14.22 b
Total Volume Growth (ft^3/ac.)	941.2 a	795.5 a	945.6 a	893.4 a	722.1 a	938.1 a	760.3 a	416.0 b
Merch. Volume Growth (ft^3/ac.)	896.4 a	776.8 a	923.6 a	849.6 a	705.6 a	903.4 a	743.0 a	395.5 b
Total Weight Growth (tons/ac.)	26.62 a	22.41 a	26.76 a	25.16 a	20.34 a	26.56 a	21.36 a	11.81 b
Merch. Weight Growth (tons/ac.)	26.33 a	22.13 a	26.54 a	24.68 a	20.21 a	26.27 a	20.96 a	7.20 b

The average stand growth variables were also analyzed by CRIFF soil groups and the results of this ANOVA indicate that there are no interactions between species and CRIFF soil types. Significant differences (α=0.05) were found for survival, basal area/ac., volume/ac., and green weight/ac. Soil Group G was inferior to all other soils for both loblolly and slash pine in terms of basal area growth, volume growth, and weight growth (Table 8).

Table 8. Average per acre growth for each CRIFF soil group in the species comparison study from age 11 to age 14.[4]

Variable	Soil Group A	B	C	D	F	G
Mortality (trees/ac.)	29.2 a	-1.5 a	9.4 a	1.1 a	14.4 a	15.8 a
Basal Area Growth (ft^2/ac.)	27.15 a	30.02 a	28.108 a	30.59 a	28.678 a	13.00 b
Total Volume Growth (ft^3/ac.)	924.5 a	903.9 a	891.98 a	816.6 a	861.4 a	375.3 b
Merch. Volume Growth (ft^3/ac.)	926.9 a	852.1 a	855.4 a	793.0 a	860.9 a	342.2 b
Total Weight Growth (tons/ac.)	26.251 a	25.529 a	25.205 a	22.996 a	24.277 a	10.642 b
Merch. Weight Growth (tons/ac.)	26.586 a	24.916 a	24.803 a	22.842 a	24.208 a	6.029 b

[4]Means with the same number are not significantly different at the α=0.05 level.

Discussion

The results of this analysis suggest that loblolly pine will exhibit equal or superior growth when compared to slash pine throughout the species comparison study region. In addition UGA soil group 8 and CRIFF soil type G appear to be inferior to the other soil types in this study. These soils comprise the somewhat excessive to excessively drained soils with no, or at least a very deep histic or argillic horizon. The droughty sand sites of the lower coastal plain would fit this description. There were no species*soil interactions, and therefore no need to analyze the species differences on a soil by soil basis. Because some readers will be curious as to the gains of loblolly pine on certain soil types and the information is available, this information is included (Tables 9 and 10). It is interesting to note that loblolly pine performed as well or better than slash pine in volume and weight across all soils despite the fact that cronartium levels were higher for loblolly pine. It is also apparent that loblolly pine is growing more basal area per acre than slash pine at ages 11- 14 (Figure 2).

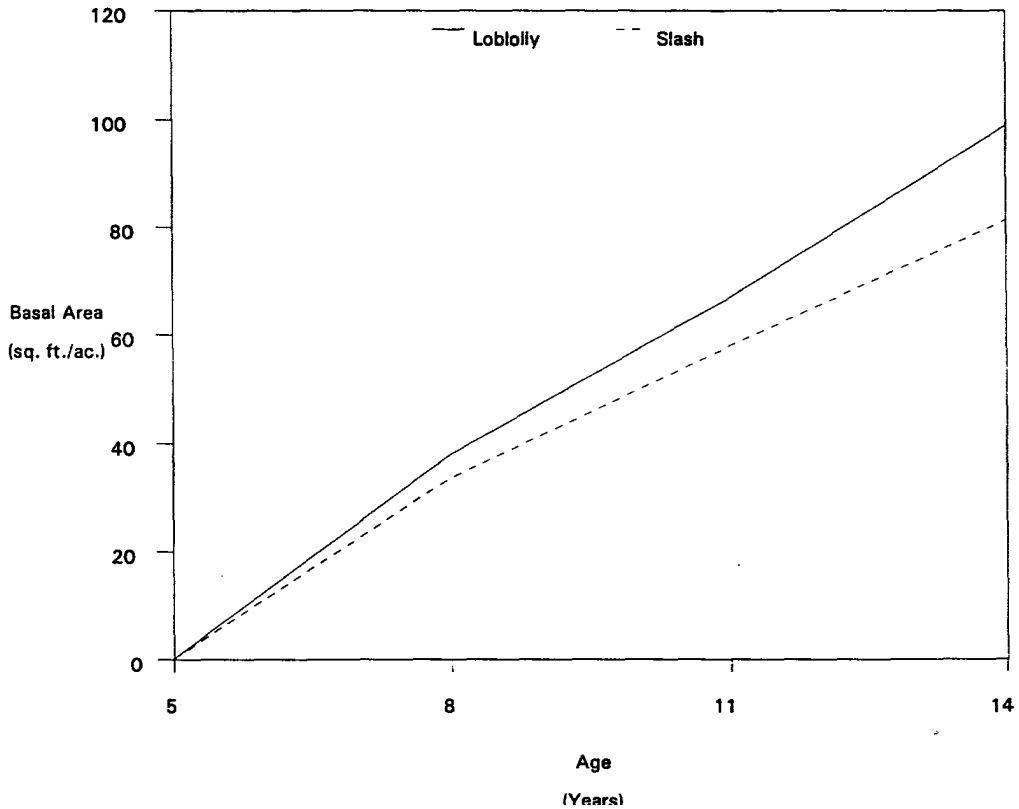

Figure 2. Basal area per acre vs age for loblolly and slash pine across all soil types in the species comparison study.

Another interesting trend is the fact that though there was no early advantage in terms of total volume, loblolly pine has attained more total volume

as of age 14. The data from this study suggests that this has occurred since age 11 (Figure 3).

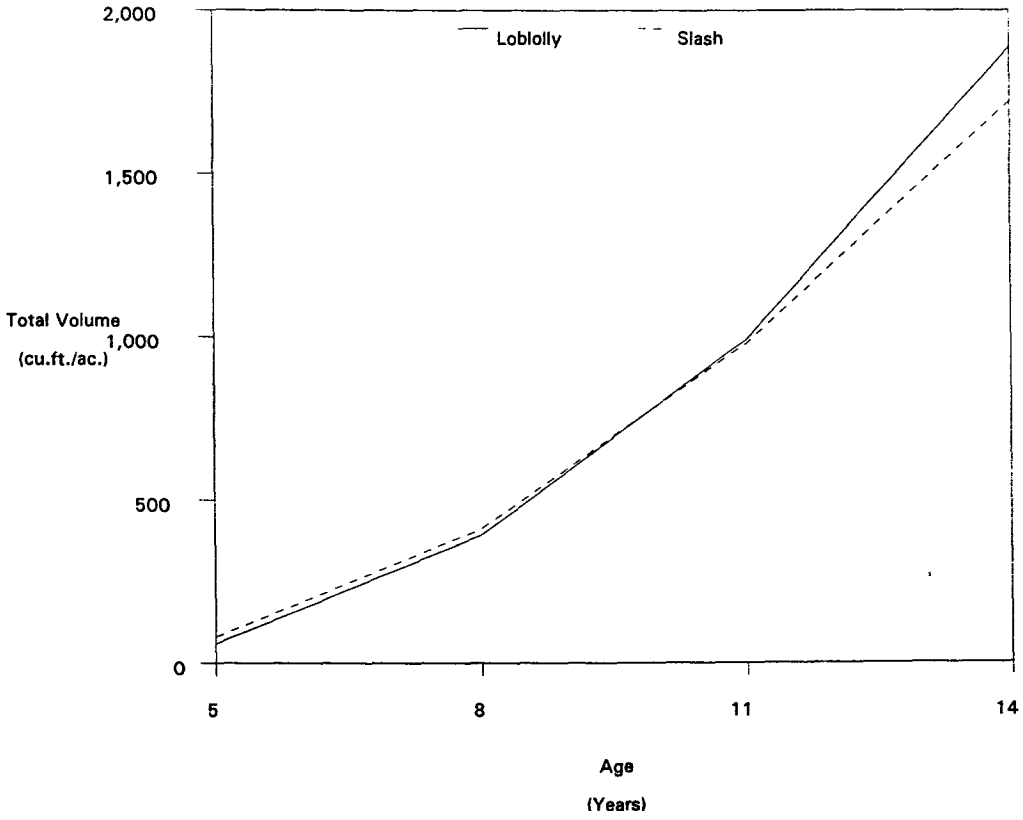

Figure 3. Stand average total volume vs. age for loblolly and slash pine across all soil types in the species comparison study.

Table 9. Mean species differences by UGA soil group for all installations in the species comparison study.

Variable		Soil Group 1	2	3	4	5	6	7	8
% Cronartium	Loblolly	16.8	12.3	18.3	17.8	16.6	25.5	26.4	22.8
	Slash	14.2	11.8	19.2	10.2	15.7	22.4	26.9	20.7
	P Value	0.1041	0.8555	0.7683	0.0016	0.6558	0.2356	0.8574	0.3660
Survival	Loblolly	77.6	67.9	76.7	76.6	70.7	78.9	67.3	59.4
	Slash	68.4	67.2	69.3	70.4	60.6	69.8	63.1	58.8
	P Value	0.2080	0.8963	0.0410	0.1467	0.0278	0.0927	0.2994	0.9199
Basal Area/ac.	Loblolly	98.27	92.99	110.00	96.97	100.53	120.13	96.70	72.53
	Slash	89.79	82.96	91.92	90.70	77.04	90.94	76.49	51.25
	P Value	0.4041	0.4582	0.0495	0.5689	0.0658	0.0042	0.0004	0.0190
Trees/ac.	Loblolly	563.18	492.64	557.2	555.8	513.4	572.6	488.4	431.1
	Slash	496.46	487.78	503.1	511.1	440.0	506.9	458.4	426.7
	P Value	0.2076	0.8955	0.0407	0.1468	0.0275	0.0926	0.2990	0.9197
Total Volume (ft^3/ac.)	Loblolly	1900.80	1818.34	2189.26	1890.09	1682.51	2473.39	1731.98	1314.52
	Slash	1980.31	1735.57	1984.67	1932.57	1599.92	1977.78	1548.54	1002.25
	P Value	0.7190	0.7695	0.3761	0.8752	0.6076	0.0310	0.0912	0.1005
March. Vol. (ft^3/ac.)	Loblolly	1459.52	1488.69	1786.45	1483.58	1331.41	2073.94	1400.36	1053.11
	Slash	1562.11	1342.09	1578.69	1515.66	1260.48	1568.73	1194.72	702.15
	P Value	0.5628	0.5734	0.3266	0.8958	0.6252	0.0189	0.0501	0.0599
Total Green Weight (tons/ac.)	Loblolly	53.72	51.44	61.95	53.45	47.49	70.08	48.89	37.22
	Slash	53.73	46.80	53.71	52.21	43.09	53.57	41.56	26.87
	P Value	0.9981	0.5608	0.2129	0.8708	0.3354	0.0148	0.0245	0.0618
Merch. Green Weight (tons/ac.)	Loblolly	53.00	50.86	61.31	52.67	46.87	69.43	48.41	36.69
	Slash	42.05	35.86	42.34	40.58	33.64	43.19	31.77	18.73
	P Value	0.0812	0.0718	0.0081	0.1001	0.0083	0.0002	0.0001	0.0038
# of Observations		17	14	17	17	19	19	17	18

Table 10. Mean species differences for each CRIFF soil group for all installations in the species comparison study.

Variable		Soil Group A	B	C	D	F	G
% Cronartium	Loblolly	25.8	18.8	16.2	16.0	30.2	19.9
	Slash	33.4	14.8	12.6	13.8	30.3	17.5
	P value	0.1704	0.0750	0.0160	0.1724	0.9582	0.2326
Survival	Loblolly	81.7	77.9	75.8	72.2	63.9	63.7
	Slash	61.2	76.6	69.4	63.7	54.1	66.4
	P value	0.0026	0.7622	0.0247	0.0461	0.0102	0.5994
Basal Area/ac.	Loblolly	124.63	100.09	98.49	102.4	110.12	68.22
	Slash	85.47	91.95	90.70	81.4	81.16	50.93
	P value	0.0370	0.3226	0.2557	0.0211	0.0001	0.0328
Trees/ac.	Loblolly	593.1	565.7	550.0	524.3	464.1	462.7
	Slash	444.0	555.8	503.9	462.6	392.9	482.4
	P value	0.0026	0.7596	0.0247	0.0460	0.0102	0.5998
Total Volume (ft^3/ac.)	Loblolly	2573.46	1947.77	1963.13	1834.85	2130.76	1188.68
	Slash	1824.37	1965.59	1985.74	1697.87	1727.74	959.33
	P value	0.1233	0.9201	0.8970	0.3730	0.0015	0.1889
Merch. Vol. (ft^3/ac.)	Loblolly	2144.24	1558.21	1550.30	1465.92	1818.48	895.79
	Slash	1484.64	1504.70	1563.50	1336.51	1436.54	603.47
	P value	0.1444	0.7278	0.9351	0.3474	0.0013	0.0942
Total Green Weight (tons/ac.)	Loblolly	72.90	55.09	55.55	51.83	60.27	33.62
	Slash	49.26	53.18	53.83	45.75	46.60	25.65
	P value	0.0913	0.7050	0.7302	0.1644	0.0003	0.1171
Merch. Green Weight (tons/ac.)	Loblolly	72.31	54.32	54.80	51.24	59.91	33.00
	Slash	39.71	40.40	42.05	35.68	38.37	16.07
	P value	0.0281	0.0019	0.0106	0.0009	0.0001	0.0035
# of Observations		7	23	31	36	22	19

Conclusions

Information from this study is still being gathered, and rotation age information is still several years down the road. However midrotation results indicate that loblolly pine is capable of maintaining higher basal areas, more total and merchantable volume, and producing more green weight of wood on all sites within the study region. This gain in production exists despite the increased incidence of cronartium infection. In fact it is possible that the increased

cronartium rates are a direct result of the increased growth exhibited by loblolly pine (Zutter et al., 1987). Another explanation is that loblolly pine is better capable of surviving cronartium infection. Therefore infected stems remain in the stand and contribute to stand volume, basal area, and weight. This corresponds to the superior survival of loblolly pine across all soil types observed in this study (Table 3). This study indicates that loblolly pine is capable of establishing more volume than slash pine at age 11, and increasing the gains in volume at least to age 14. The results collected at this time indicate that loblolly pine, with higher volumes, superior survival, and decreased risk of ice damage when compared to slash pine, would be the logical species choice on the soils and sites covered by this study.

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Appendix A

Analysis of variance (ANOVA) table for the loblolly-slash pine species comparison study.

Source of Variation	UGA Soil Groups DF	CRIFF Soil Groups DF
Soil	7	5
Error A[1]	133	135
Species	1	1
Soil*Species	7	5
Error B[2]	130	132
Total	278	278

[1] Error A is the variation of installations within a soil drainage class and is used to test for differences among soil drainage classes.

[2] Error B is used to test for differences between species and for soil*species interaction.