PMRC COASTAL PLAIN CULTURE / DENSITY INTERACTION STUDY:

AGE 4 ANALYSIS

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SUMMARY

The coastal plain Intensive Culture / Density study was established in 1995/96 to examine the effects of intensive silviculture and current operational practices on the growth and yield of slash and loblolly pine across a wide range of densities. The study was installed across a range of CRIFF soil types so soil type interactions could be tested.

Seventeen installations were established in the coastal plain of Georgia and Florida. All of the installations contain loblolly pine and nine installations also include slash pine at three densities. Both the operational and intensive treatments consisted of chemical site preparation and bedding followed by a fall herbicide treatment applied in five-foot bands over the planted rows. At planting, 500 lbs. of 10-10-10 fertilizer was applied on all plots. The intensive cultural treatment plots received additional herbicide treatments to keep them as completely free of competing vegetation as possible throughout their rotation. These plots also received additional fertilization treatments and were sprayed for tip moths during the first two growing seasons. In the spring of the third growing season, the plots received 600 lbs/ac 10-10-10 plus micronutrients and 117 lbs/ac NH_4NO_3. An additional 117 lbs/ac NH_4NO_3 was added in the spring of the fourth growing season.

Within both the intensive and operational treatments, six loblolly pine subplots with densities of 300, 600, 900, 1200, 1500 and 1800 trees per acre (tpa) were randomly located and established. Slash pine subplots were established at densities of 300, 900 and 1500 tpa. The arrangement of soil groups, cultural treatments and planting densities results in a split-split plot design. The main plots are soil groups, subplots are cultural treatments and densities are the sub-subplots. The installations are considered as a random sample of all possible locations so the installation (replication) factor is considered random. Since the other factors are fixed, this results in a "mixed model" and was analyzed as such. The analysis was carried out for average DBH, average height, percent survival, percent cronartium infection, per-acre basal area and per-acre, outside bark total volume for each species.

For loblolly pine, the cultural treatment or management intensity factor and the density factor had significant effects on average DBH. There was also a significant soil type x management interaction and a density x management interaction for average DBH. Only the management intensity factor had a significant effect on loblolly pine average height. There were no significant differences in survival due to any of the factors or interactions. Cronartium infection levels increased with management intensity and with decreasing density. Both factors and their interaction were significant. The trends for per-acre basal area and per-acre total stem volume

were similar. The management intensity factor, the density factor and their interaction had significant effects on these per-acre values.

For slash pine, management intensity, density and their interaction significantly impacted average DBH. Only the management factor was significant for average slash pine height. There were no significant factors on survival. The management, density and soil factors significantly affected the cronartium infection rate. Slash pine plots on the B2 soil type had nearly double the infection rate than the soil type with the next highest rate. For per-acre basal area and total stem volume, management, density and their interaction had significant effects.

The average DBH, average height, survival, cronartium infection level, basal area and volume of loblolly and slash pine were compared graphically. Average DBH's within each treatment combination were nearly equal for slash and loblolly pine. Loblolly was 3-5 feet taller than slash pine on the intensive treatments and 1-3 feet taller on the operational plots. Both species had good survival, but loblolly had better overall survival by 2-4 percent. The intensively managed slash pine plots had the highest level of cronartium infection. This was mainly due to the high level of cronartium infection on the slash pine plots located on the B2 soil type. Per-acre basal areas for both species were nearly equal on the operational treatment plots. On the intensively managed plots, loblolly had more basal area on the lower density (300, 900 tpa) plots and slash pine had more basal area on the 1500 tpa plots. Slash pine had more total, per-acre stem volume than loblolly pine for all treatment combinations. This is due, in part, to the different volume equations used for the two species. For a tree of a given size, the slash pine individual tree volume equation predicts up to 1/3 more total stem volume than the loblolly pine equation.

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1 INTRODUCTION

Industrial forest landowners in the Southeastern U.S. have experienced increasing pressure to maximize volume production from slash and loblolly pine plantations. As the demand for forest products continues to increase, the amount of land on which pine plantation management is feasible or practical continues to decrease. These pressures have created significant interest in genetic improvement, control of competing vegetation and forest nutrition. Many studies carried out by the PMRC and other researchers have reported significant gains in yield due to tree improvement and more intensive management practices. When contemplating the regeneration of a slash or loblolly pine plantation, forest managers in the Southeastern U.S. still have unanswered questions regarding the relationships between management practices and establishment densities across a range of soil types. To address this issue, the PMRC established the Intensive Culture / Density Study in 1995/96. The objectives of this study are to:

- Quantify and contrast the effects of intensive silviculture and current operational practices on the growth and yield of loblolly and slash pine plantations across a wide range of densities.
- Investigate potential interactions between cultural intensity and stand density across broad soil categories, particularly in the areas of survival, merchantable green and dry weight production and product class distributions.
- Describe and compare the development of stand leaf area index (LAI) produced by the various combinations of cultural intensity and stand density.

2 METHODS

Seventeen installations were established in the coastal plain of Georgia and Florida. All of the installations contained loblolly pine and nine installations included a slash pine component. At least three loblolly pine installations were established on each of five CRIFF soil groups A, B1, B2, C and D. Slash pine was established on all but the A soil group. Table 1 shows a description of the CRIFF soil groups.

Table 1. CRIFF soil groups used in the Culture / Density Study.

CRIFF Soil Group	Drainage Class	Diagnostic Horizons
A	Very poor – somewhat poor	No spodic, argillic < 20”
B1	Very poor – somewhat poor	No spodic, argillic 20 – 40”
B2	Very poor – somewhat poor	No spodic, argillic > 40” or absent
C	Very poor – somewhat poor	Spodic with argillic
D	Poor – moderately well	Spodic without argillic

Site preparation and subsequent silvicultural treatments represent two levels of management intensity; operational and intensive culture. The operational treatment consisted of bedding in the spring followed by a fall herbicide treatment. The herbicide treatment consisted of 12 oz. Arsenal plus 1 qt. Garlon 4 per acre if competition was waxy-leafed species such as gallberry (*Ilex glabra*) or palmetto (*Serenoa repens*), or 12 oz. Arsenal plus 1 qt. Accord per acre if the competition consisted mainly of grass or upland hardwood species. Herbicide was applied in a 5-foot band over the rows. At planting, 500 lbs. of 10-10-10 fertilizer was applied.

The intensive cultural treatment consisted of bedding in the spring followed by a fall herbicide application. The herbicide treatment was a broadcast application of 16 oz. Arsenal, 2 qts. Garlon 4 and 2 qts. Accord per acre. At planting, 500 lbs. of 10-10-10 fertilizer was applied. In the spring of the third growing season, the plots received 600 lbs/ac 10-10-10 plus micronutrients and 117 lbs/ac NH_4NO_3. An additional 117 lbs/ac NH_4NO_3 was added in the spring of the fourth growing season. Beginning in the spring of the first growing season (1996), the plots were sprayed with 4 oz. Oust per acre along with directed sprays to keep the plots as completely free of competing vegetation as possible. Insecticides (usually Pounce) designed to control tip moths were applied as often as necessary to maintain tip moth control through the first two growing seasons.

Within each site preparation treatment, six loblolly pine subplots with densities of 300, 600, 900, 1200, 1500 and 1800 trees per acre (tpa) were planted. Slash pine subplots were established at densities of 300, 900 and 1500 tpa. Bed widths ranged from 6 feet for the 1200-1800 tpa treatments, 8 feet for the 600 and 900 tpa plots and 12 feet for the 300 tpa treatment. Table 2 shows the spacings and plot sizes for the density subplots.

Table 2. Spacing and plot sizes for the density subplots.

Density (tpa)	Spacing (ft. x ft.)	Trees per meas. plot	Meas. plot size (ac)	Gross plot size (ac)
1800	6 x 4	184	0.10	0.31
1500	6 x 4.8	160	0.11	0.32
1200	6 x 6	120	0.10	0.30
900	8 x 6	96	0.11	0.31
600	8 x 9	80	0.13	0.37
300	12 x 12	80	0.26	0.56

The arrangement of soil groups, cultural treatments and planting densities results in a split-split plot design. The main plots are soil groups, subplots are cultural treatments and densities are sub-subplots. Since the replications, or installations in this case, can be considered as a random sample of all possible locations, the replication factor must be considered as random. This results in a mixed model. In order to make proper inferences across all sites represented by the five soil groups, the presence of the random factor must be considered (Parrish and Ware, 1989; Littell et.al., 1991) The mixed model, split-split plot design with 17 installations results in the analysis of variance setup shown in Table 3.

Table 3. Analysis of variance table for the mixed model, split-split plot experiment.

Factor		df
SOIL		4
INST(SOIL)	[error (soil)]	12
MANAGEMENT		1
MANAGEMENT*SOIL		4
MANAGEMENT*INST(SOIL)	[error (a)]	12
DENSITY		5
DENSITY*SOIL		20
DENSITY*CULTURE		5
DENSITY*CULTURE*SOIL	} [error (b)]	20
DENSITY*INST(SOIL)	} [error (b)]	60
DENSITY*CULTURE*INST(SOIL)	} [error (b)]	60
	Corrected total	203

All factors containing installation are considered random and are listed in the RANDOM statement in SAS PROC MIXED (Littell et.al., 1996).

3 LOBLOLLY PINE RESULTS

After the fourth growing season, diameters of all trees and heights on every other tree were measured. Each tree was also inspected for cronartium infection and tip moth damage. Individual tree, outside bark cubic foot volumes were calculated using the following equation from Pienaar, et al. (1987):

$$VOB = 0.00145519\, DBH^{1.826051} HT^{1.221965}$$

Analysis of variance as described above was carried out for average DBH, average height, percent survival, percent cronartium infection, per-acre basal area and per-acre total volume. Table 4 shows the loblolly pine means by soil type, management intensity and initial density.

Table 4. Loblolly pine means by CRIFF soil group, management intensity and initial density at age four.

CRIFF Soil Type A

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.34	18.8	86.7	14.8	29.1	237
	600	4.19	20.2	94.2	16.6	55.5	469
	900	3.63	19.9	93.0	9.7	62.9	539
	1200	3.60	20.6	95.3	4.4	83.5	738
	1500	3.22	19.4	88.8	11.8	75.4	633
	1800	3.18	21.0	97.8	6.1	117.4	1027
Operational	300	2.28	13.5	86.7	4.0	9.0	60
	600	2.09	12.8	81.2	4.9	15.8	105
	900	2.50	15.3	94.4	8.5	30.8	210
	1200	2.30	14.4	94.4	7.2	35.7	230
	1500	2.04	13.4	88.5	3.6	33.5	209
	1800	2.10	14.1	86.6	4.3	41.6	274

CRIFF Soil Type B1

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.92	22.1	98.3	8.4	39.6	357
	600	4.26	22.4	98.3	7.2	59.8	575
	900	3.73	22.0	97.6	6.8	68.4	648
	1200	3.56	22.1	98.3	2.6	84.2	815
	1500	3.24	21.6	97.3	2.4	86.5	835
	1800	3.16	21.6	97.6	2.8	99.1	963
Operational	300	3.10	16.8	97.1	6.1	15.9	115
	600	2.80	16.2	91.7	6.8	24.9	177
	900	2.74	16.7	90.3	4.2	36.0	271
	1200	2.43	15.6	91.1	4.3	37.9	263
	1500	2.56	16.8	93.8	4.8	53.2	395
	1800	2.32	16.2	93.3	3.3	53.2	388

CRIFF Soil Type B2

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.09	19.2	93.3	15.9	26.3	206
	600	3.52	18.9	90.8	16.1	37.8	300
	900	3.27	18.8	87.8	7.6	48.4	395
	1200	3.17	19.2	92.8	8.6	63.5	528
	1500	3.04	19.4	88.5	5.2	70.2	606
	1800	2.75	18.6	92.2	3.5	72.2	598
Operational	300	2.42	14.4	93.3	9.6	9.8	63
	600	2.40	15.8	94.2	3.9	19.2	136
	900	2.61	16.8	94.4	2.2	33.0	243
	1200	2.13	15.1	87.5	4.0	27.8	190
	1500	2.33	16.7	93.8	2.1	43.9	330
	1800	2.18	15.9	94.2	5.8	46.2	327

CRIFF Soil Type C

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.23	19.4	96.0	8.7	29.2	235
	600	3.85	20.7	97.5	7.7	49.8	446
	900	3.41	20.1	96.4	4.1	58.3	523
	1200	3.12	19.5	97.5	2.4	67.0	601
	1500	2.92	19.2	97.5	6.0	73.4	652
	1800	2.69	18.6	97.7	4.1	75.5	656
Operational	300	2.70	16.4	95.8	5.8	12.5	93
	600	2.82	17.5	94.2	6.3	27.0	222
	900	2.63	17.6	98.8	5.1	36.5	299
	1200	2.26	15.9	99.0	4.2	36.9	282
	1500	2.31	17.0	97.5	2.3	45.5	355
	1800	2.25	17.8	97.9	3.2	52.9	433

CRIFF Soil Type D

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.20	19.2	95.4	3.0	28.9	232
	600	3.78	19.7	93.8	3.5	46.7	396
	900	3.51	20.2	86.4	4.1	57.3	523
	1200	3.36	21.0	91.7	2.2	69.8	634
	1500	3.17	20.1	93.4	1.4	80.0	710
	1800	2.95	20.1	93.8	2.9	83.5	751
Operational	300	2.42	14.6	91.7	3.7	9.8	66
	600	2.17	13.5	92.1	1.8	16.5	111
	900	2.23	14.7	90.3	2.8	23.3	153
	1200	1.84	13.3	93.3	3.3	24.0	160
	1500	1.82	13.6	96.0	1.1	28.8	189
	1800	1.78	13.8	88.8	1.5	32.7	233

3.1 Average DBH

Table 5 shows the results of the analysis of variance for average DBH for loblolly pine. The management intensity factor was significant at the " = 0.05 level but there was no significant soil type x management intensity interaction. The density factor, as well as the management intensity x density interaction and the soil type x density interaction all had significant affects on average DBH. Figure 1 shows the loblolly pine average DBH's by management intensity and initial density and Figure 2 shows average DBH's by soil type and density.

Table 5. Analysis of variance results for loblolly pine average DBH at age four.

Source	df	Type III F	Pr > F
Soil	4	0.73	0.5914
Management	1	156.06	0.0001*
Soil x Management	4	1.60	0.2373
Density	5	71.10	0.0001*
Soil x Density	20	1.65	0.0499*
Management x Density	5	22.34	0.0003*

*Significant at " = 0.05.

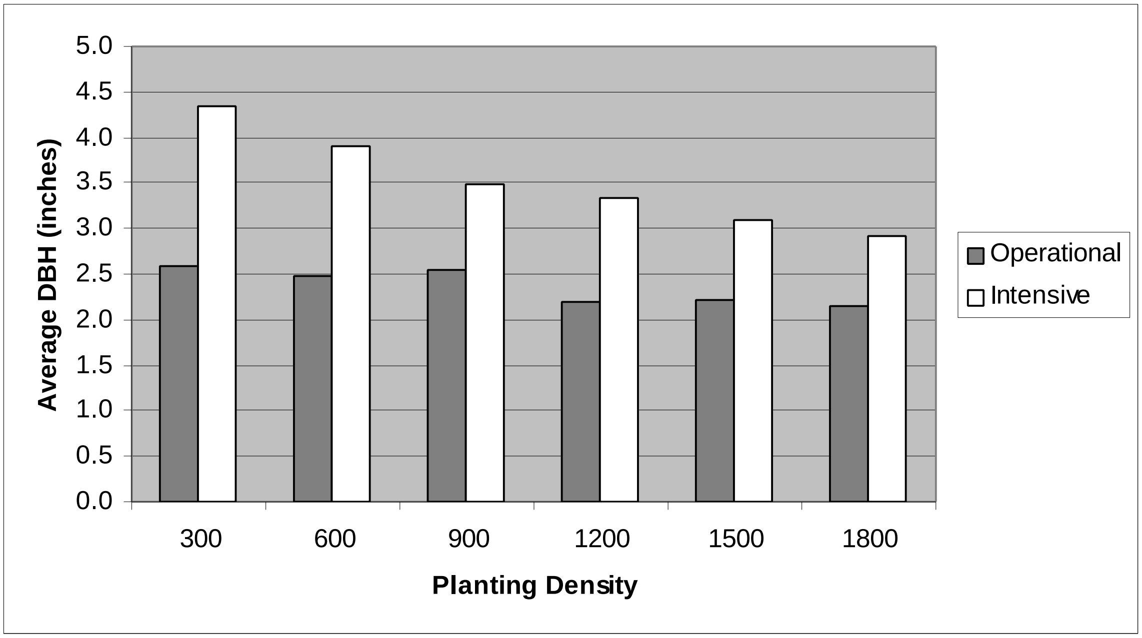

Figure 1. Average DBH by planting density and management intensity for loblolly pine at age four.

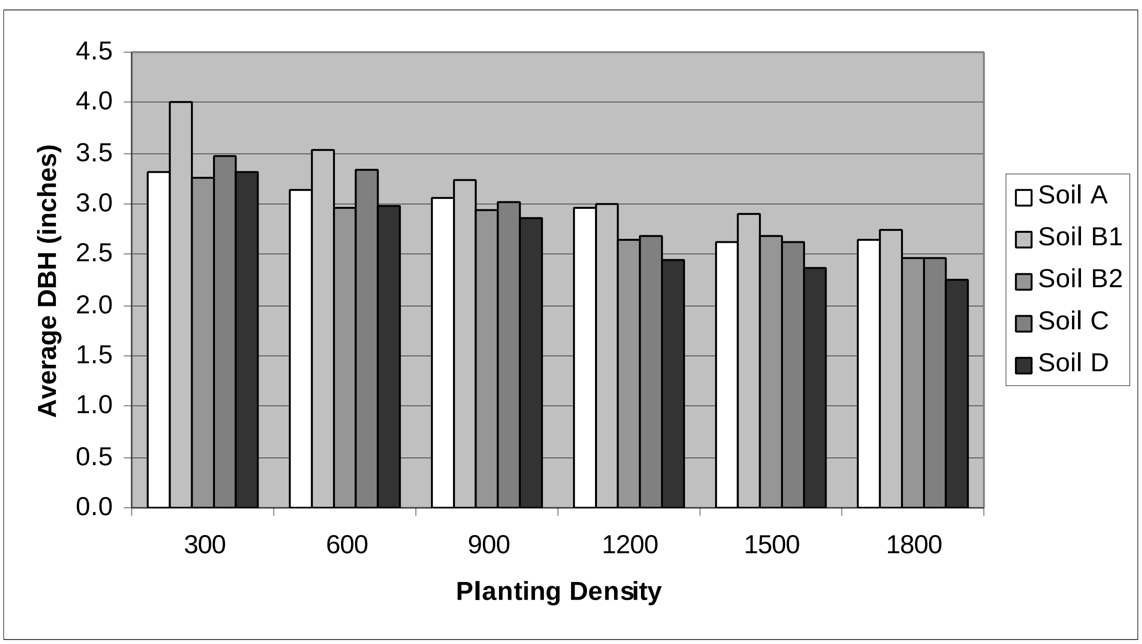

Figure 2. Average DBH by planting density and CRIFF soil type for loblolly pine at age four.

The analysis indicates that even as young as age four, the effects of more intensive management are significant and that there is a management intensity x density interaction. This interaction is probably caused by the increased level of stand development on the intensive culture plots. As a result, there is a marked effect on DBH as density increases. While the same trends are present on the operational plots, the differences are much smaller. This interaction will likely decrease in significance as the study ages. There was a significant soil x density interaction at age four, but the reason is difficult to rationalize (Figure 2).

3.2 Average Height

Table 6 shows the results of the analysis of variance for loblolly pine average height. The management intensity factor was significant at the " = 0.05 level with the intensive culture treatment heights averaging four to five feet taller across the different densities. The density factor had no significant effect on average height, and there was no management intensity x density interaction. Figure 3 shows the average heights by management intensity and initial density.

Table 6. Analysis of variance results for loblolly pine average height at age four.

Source	df	Type III F	Pr > F
Soil	4	0.78	0.5579
Management	1	90.26	0.0001*
Soil x Management	4	2.41	0.1065
Density	5	1.61	0.1607
Soil x Density	20	0.97	0.5057
Management x Density	5	1.98	0.0855

*Significant at " = 0.05.

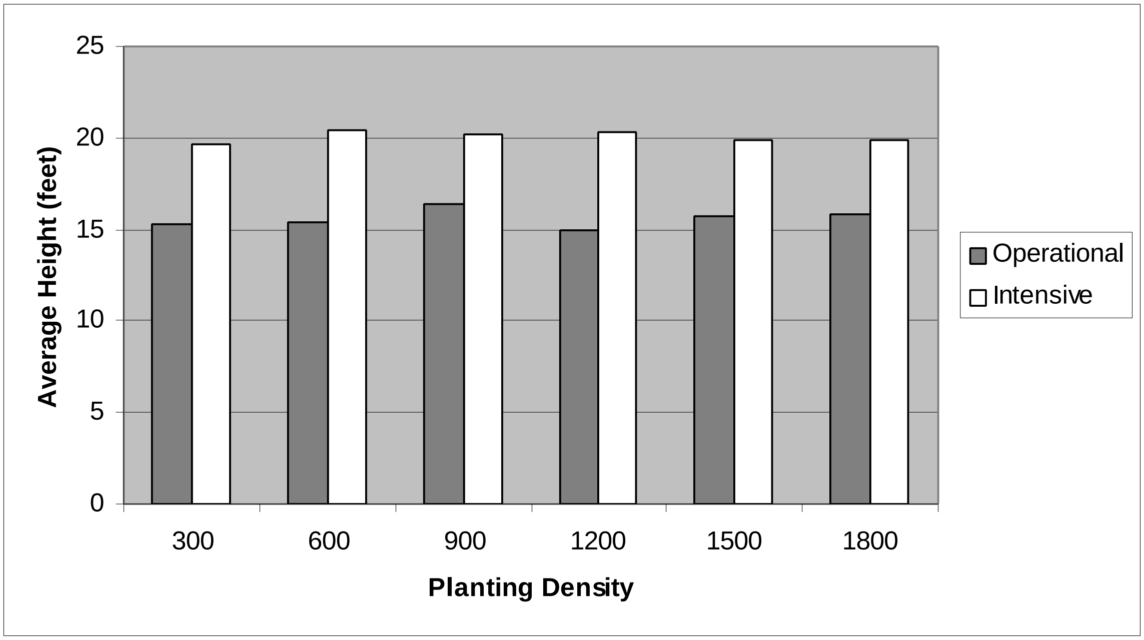

Figure 3. Average height by planting density and management intensity for loblolly pine at age four.

3.3 Percent Survival

Table 7 shows the results of the analysis of variance for average percent survival. Average survival by treatment was in excess of 92% for loblolly pine. There were no significant differences in survival rates due to any factor included in the analysis of variance. Figure 4 shows the average survival percentages by initial density and management intensity. Though the differences appear large in the histogram, each unit change on the y-axis is only 1% survival.

Table 7. Analysis of variance results for loblolly pine average percent survival at age four.

Source	df	Type III F	Pr > F
Soil	4	1.24	0.3472
Management	1	0.36	0.5622
Soil x Management	4	0.64	0.6431
Density	5	0.36	0.8725
Soil x Density	20	1.17	0.2860
Management x Density	5	1.60	0.1650

*Significant at " = 0.05.

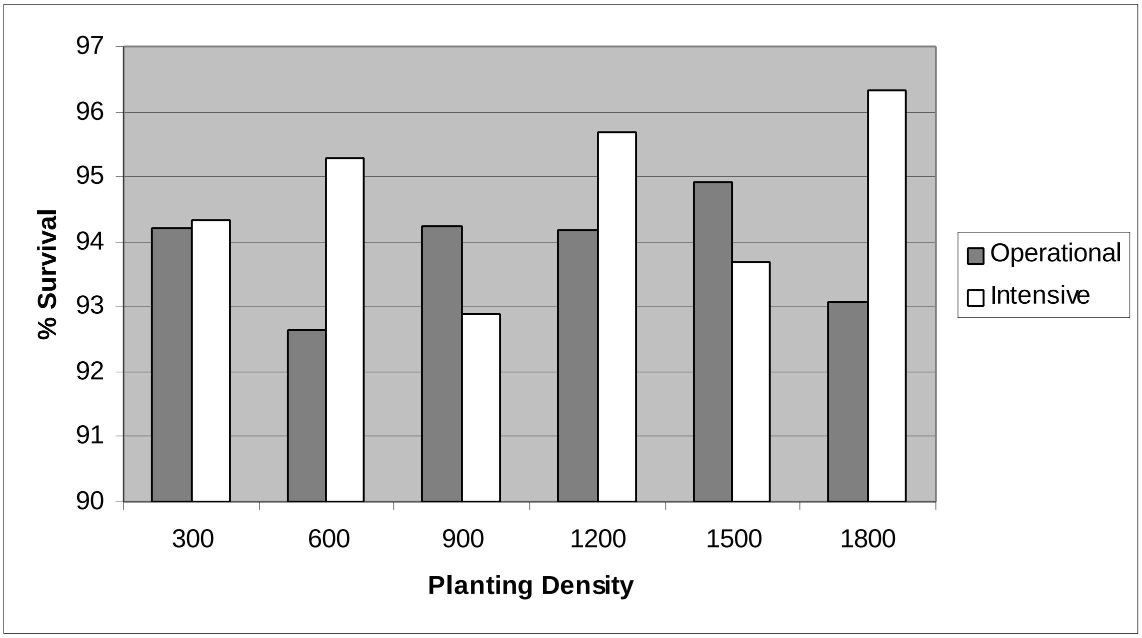

Figure 4. Percent survival by planting density and management intensity for loblolly pine at age four.

3.4 Percent Cronartium Infection

Table 8 shows the results of the analysis of variance for average percent cronartium infection. Average infection rates were very low, ranging from approximately 3 to 10% for all densities and management regimes. Management intensity, density and the management x density interaction significantly affected the cronartium infection rate. As shown in Figure 5, the intensive management treatment at initial densities of 300 and 600 trees/acre had the highest average infection rates. The differences between these two densities and the other four probably caused the density x management interaction to be significant.

Table 8. Analysis of variance results for loblolly pine average percent cronartium infection at age four.

Source	df	Type III F	Pr > F
Soil	4	1.15	0.3813
Management	1	10.94	0.0063*
Soil x Management	4	2.35	0.1133
Density	5	10.79	0.0001*
Soil x Density	20	1.22	0.2436
Management x Density	5	4.35	0.0010*

*Significant at " = 0.05.

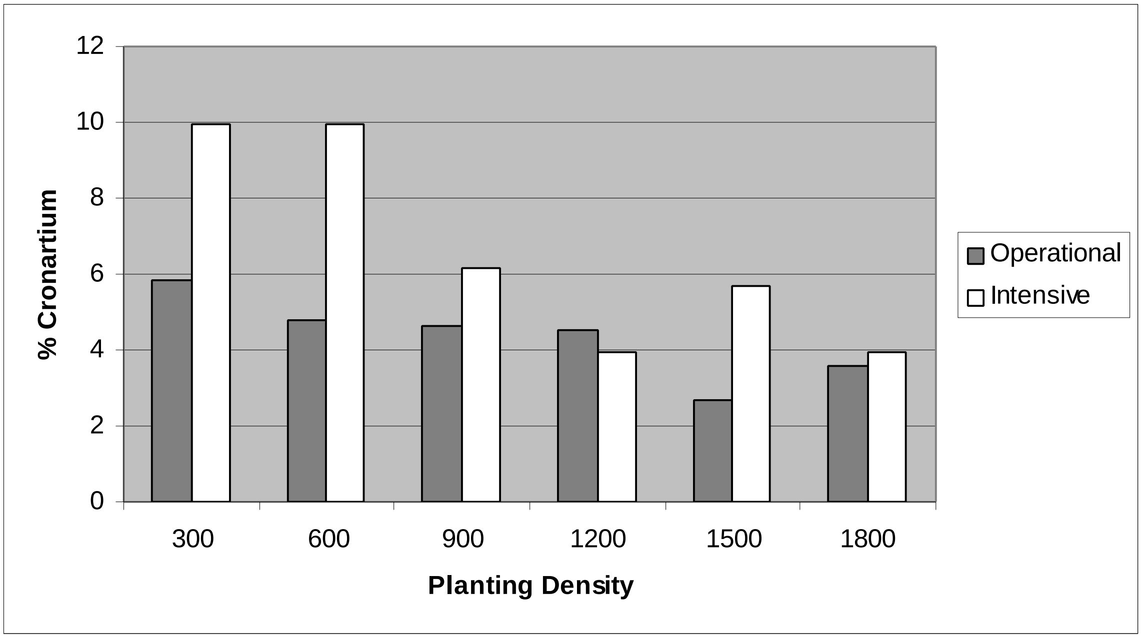

Figure 5. Average percent cronartium infection by planting density and management intensity for loblolly pine at age four.

3.5 Per-Acre Basal Area

Table 9 shows the results of the analysis of variance for per-acre basal area. Management intensity, density and their interaction were significant factors for per-acre basal area. Basal area increased with increasing density and at a much greater rate with the most intensive silvicultural regime at densities of 1200 trees/acre of more (Figure 6).

Table 9. Analysis of variance results for loblolly pine average per-acre basal area at age four.

Source	df	Type III F	Pr > F
Soil	4	0.90	0.4924
Management	1	146.43	0.0001*
Soil x Management	4	2.20	0.1301
Density	5	99.11	0.0001*
Soil x Density	20	1.20	0.2637
Management x Density	5	6.17	0.0001*

*Significant at " = 0.05.

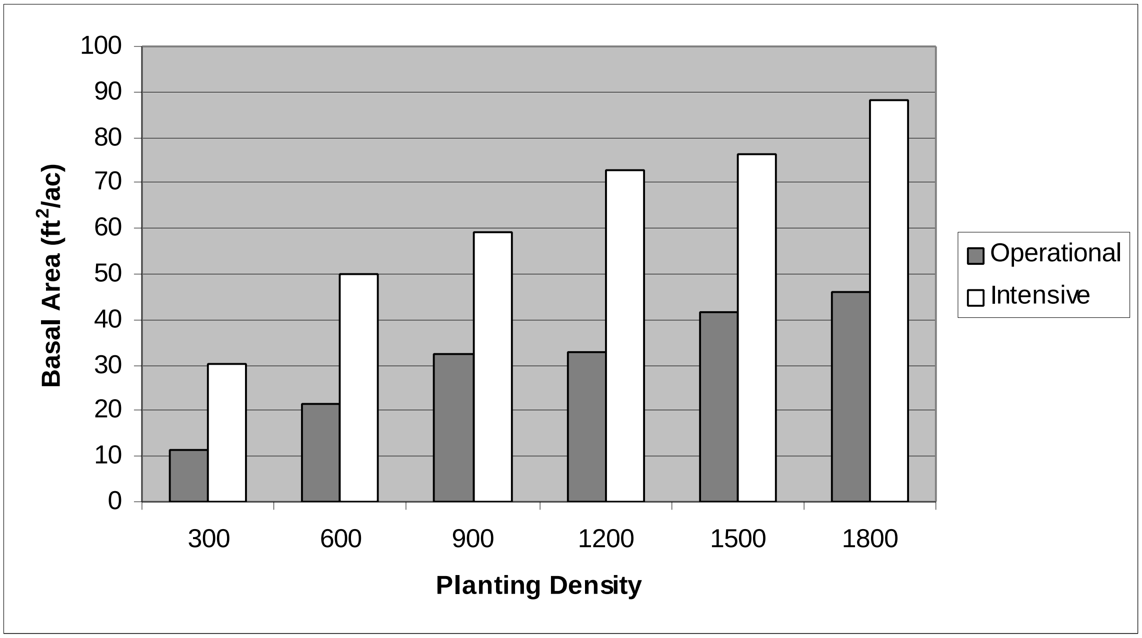

Figure 6. Average per-acre basal area by planting density and management intensity for loblolly pine at age four.

3.6 Per-Acre O.B. Volume

Table 10 shows the results of the analysis of variance for per-acre total stem volume. The results show nearly identical trends as seen for per-acre basal area. Management, density and their interaction significantly affected per-acre volume (Figure 7).

Table 10. Analysis of variance results for loblolly pine average per-acre, total volume at age four.

Source	df	Type III F	Pr > F
Soil	4	0.82	0.5359
Management	1	103.35	0.0001*
Soil x Management	4	1.91	0.1732
Density	5	70.03	0.0001*
Soil x Density	20	1.05	0.4119
Management x Density	5	8.69	0.0001*

*Significant at " = 0.05.

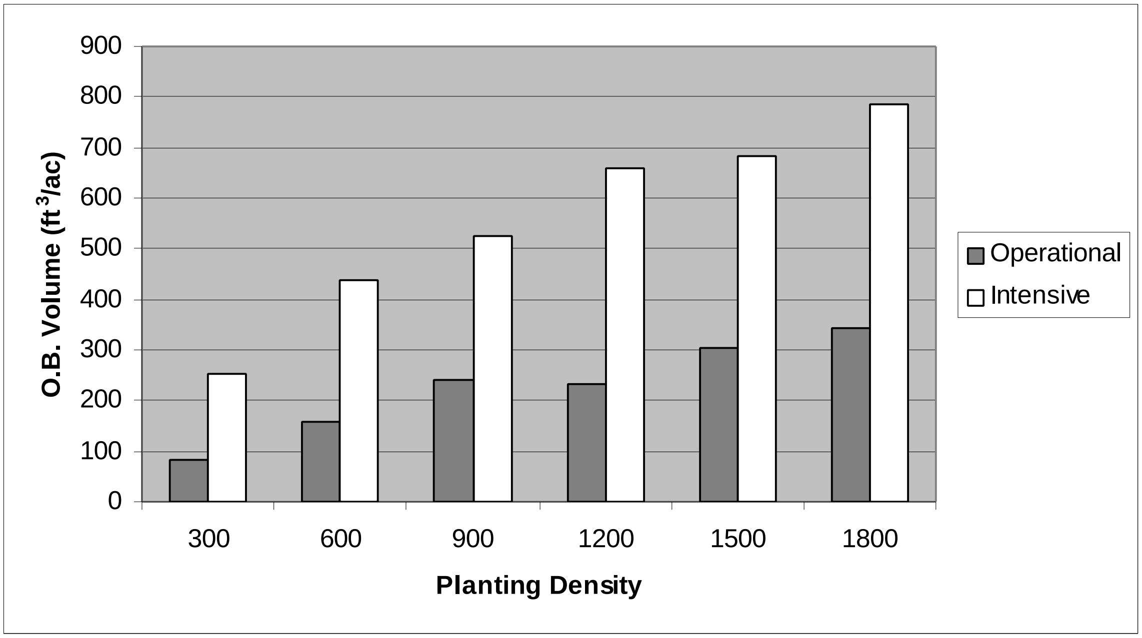

Figure 7. Average per-acre o.b. volume by planting density and management intensity for loblolly pine at age four.

4 SLASH PINE RESULTS

Individual tree, outside bark cubic foot volumes for slash pine were calculated using the following equation from Pienaar, et al. (1996):

$$VOB = 0.00456\,DBH^{2.0726}\,HT^{0.8114}$$

Analysis of variance as described above was carried out for average DBH, average height, percent survival, percent cronartium infection, per-acre basal area and per-acre total volume. Table 11 shows the slash pine means by soil type, management intensity and initial density.

Table 11. Slash pine means by CRIFF soil group, management intensity and initial density at age four.

CRIFF Soil Type B1

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.54	17.6	98.8	7.6	36.6	360
	900	3.87	18.0	92.7	16.3	70.4	696
	1500	3.33	16.8	96.7	5.2	90.7	845
Operational	300	3.12	14.5	89.2	7.3	14.5	118
	900	2.66	13.9	86.4	9.3	31.1	245
	1500	2.40	13.2	88.3	3.8	44.7	343

CRIFF Soil Type B2

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	3.8	15.1	73.8	26.4	18.6	164
	900	3.0	13.8	74.0	27.4	34.6	276
	1500	3.1	14.7	79.4	15.6	66.2	558
Operational	300	2.6	12.9	85.6	11.6	9.8	73
	900	2.6	13.8	90.6	12.9	30.8	238
	1500	2.2	12.9	89.7	10.3	38.2	296

CRIFF Soil Type C

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	3.77	15.2	90.0	10.7	21.6	186
	900	3.38	15.8	91.3	4.6	53.2	475
	1500	3.00	15.2	93.1	2.0	71.3	608
Operational	300	2.91	14.5	95.8	2.1	13.6	111
	900	2.62	14.5	92.7	3.7	32.5	264
	1500	2.54	14.9	95.6	0.6	52.5	436

CRIFF Soil Type D

Management	Plant Density	Avg. DBH	Avg. Height	% Survival	% Cronartium	Basal Area/ac	Total Volume/ac
Intensive	300	4.70	17.4	95.0	15.8	35.1	340
	900	3.79	20.7	95.8	12.0	69.1	757
	1500	3.35	17.4	94.4	9.9	89.7	856
Operational	300	3.32	15.4	92.5	12.2	16.8	144
	900	2.95	15.7	95.8	3.3	41.5	353
	1500	2.63	15.0	98.8	1.9	57.3	474

4.1 Average DBH

Table 12 shows the results of the analysis of variance for slash pine average DBH. Management intensity, density and their interaction significantly affected average DBH for slash pine. As shown in Figure 8, average DBH decreased with increasing density and the differences were more dramatic under the more intensive management scenario.

Table 12. Analysis of variance results for slash pine average DBH at age four.

Source	df	Type III F	Pr > F
Soil	3	1.73	0.2763
Management	1	92.42	0.0002*
Soil x Management	3	1.83	0.2585
Density	2	62.46	0.0001*
Soil x Density	6	1.85	0.1289
Management x Density	2	6.39	0.0055*

*Significant at " = 0.05.

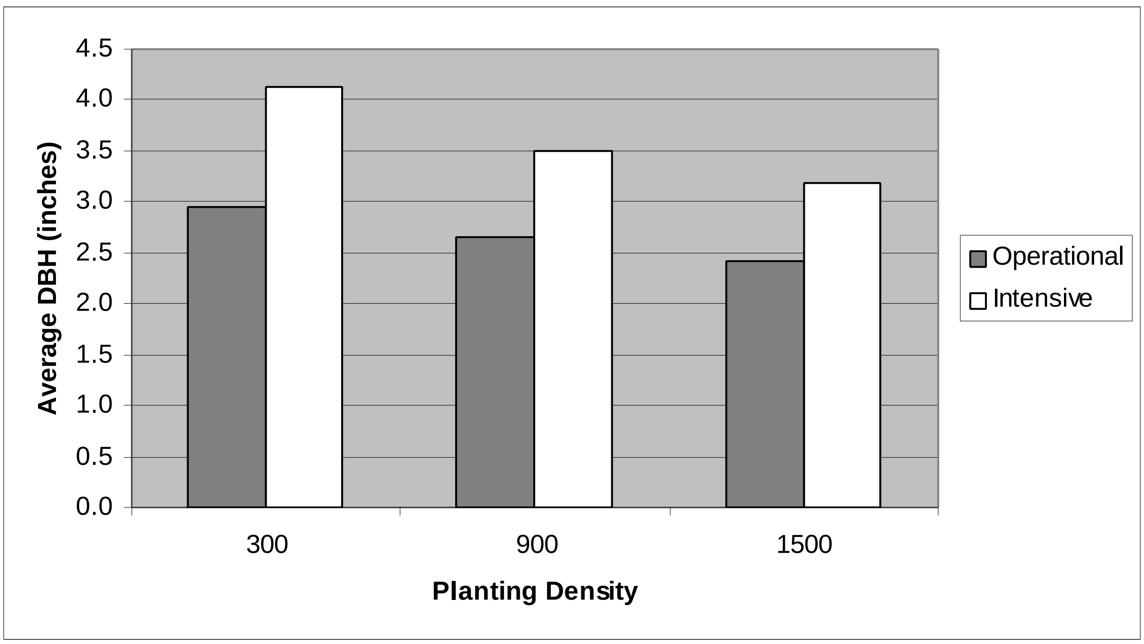

Figure 8. Average DBH by planting density and management intensity for slash pine at age four.

4.2 Average Height

Table 13 shows the results of the analysis of variance for slash pine average height. Management intensity was the only significant factor affecting average height. Figure 9 shows the average heights by initial density and management intensity.

Table 13. Analysis of variance results for slash pine average height at age four.

Source	df	Type III F	Pr > F
Soil	3	2.47	0.1764
Management	1	17.74	0.0084*
Soil x Management	3	2.40	0.1835
Density	2	2.93	0.0709
Soil x Density	6	1.31	0.2897
Management x Density	2	0.32	0.7303

*Significant at " = 0.05.

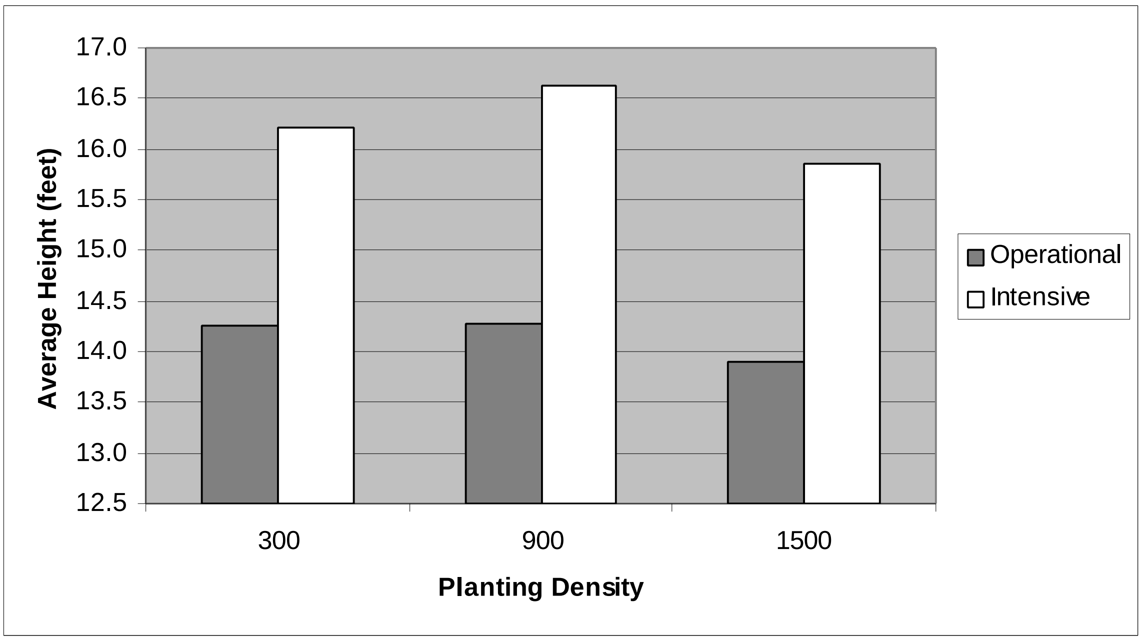

Figure 9. Average height by planting density and management intensity for slash pine at age four.

4.3 Percent Survival

Table 14 shows the results of the analysis of variance for slash pine average percent survival. The slash pine plots had good survival, averaging from 89% to 92% for all densities and management regimes. There were no significant differences in survival rates due to any factor included in the analysis of variance. Average survival rates by initial density and management intensity are shown in Figure 10.

Table 14. Analysis of variance results for slash pine average percent survival at age four.

Source	df	Type III F	Pr > F
Soil	3	4.50	0.0694
Management	1	0.70	0.4394
Soil x Management	3	3.29	0.1164
Density	2	0.89	0.4236
Soil x Density	6	0.63	0.7045
Management x Density	2	0.06	0.9447

*Significant at " = 0.05.

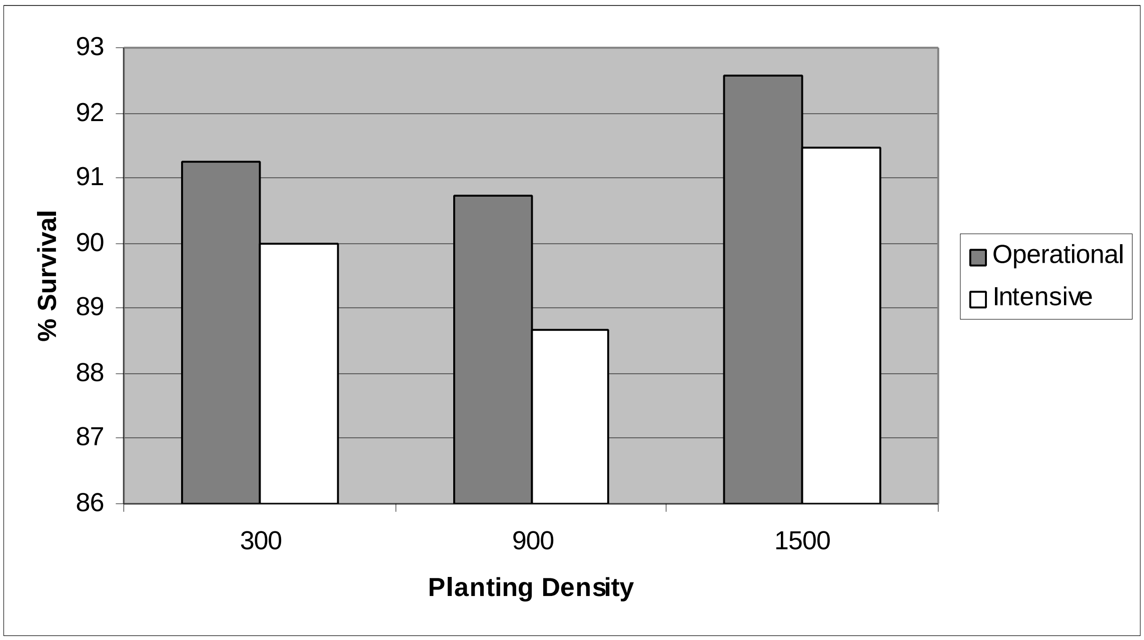

Figure 10. Average percent survival by planting density and management intensity for slash pine at age four.

4.4 Percent Cronartium Infection

Table 15 shows the results of the analysis of variance for slash pine average percent cronartium infection. All of the main factors, soil, management regime and density, significantly affected the cronartium infection rate for slash pine. Figure 11 shows that more intensive management increased the infection level and the rates were higher at the 300 and 900 tree/acre planting densities. Figure 12 shows that the cronartium infection rate was much greater on the B2 soil type.

Table 15. Analysis of variance results for slash pine average percent cronartium infection at age four.

Source	df	Type III F	Pr > F
Soil	3	8.33	0.0217*
Management	1	8.21	0.0352*
Soil x Management	3	1.03	0.4530
Density	2	4.17	0.0269*
Soil x Density	6	0.78	0.5915
Management x Density	2	0.64	0.5377

*Significant at " = 0.05.

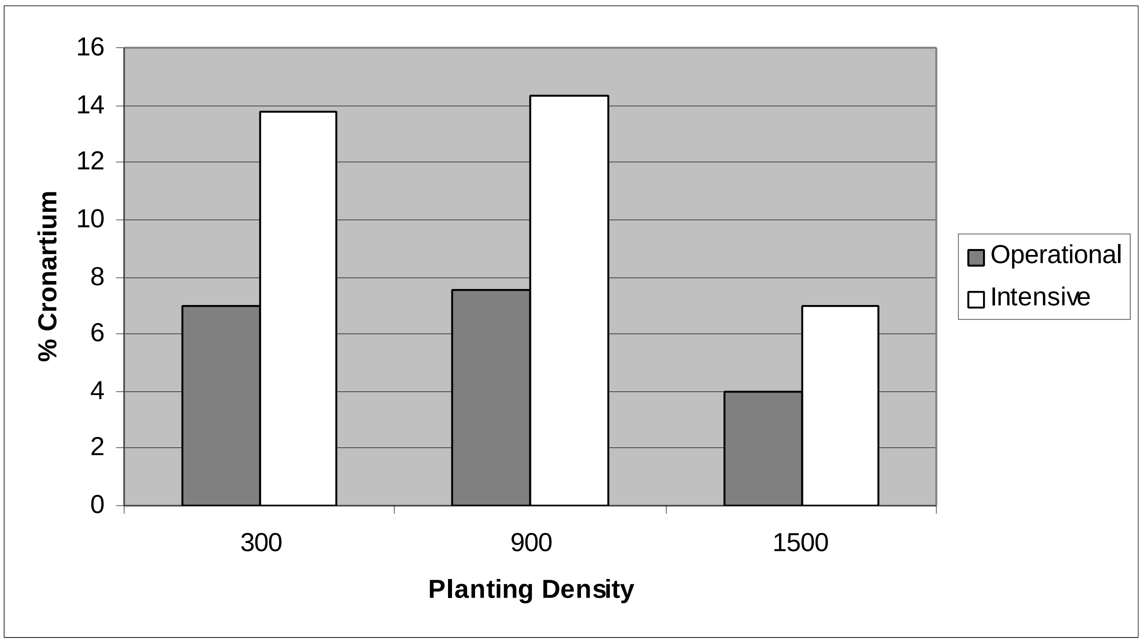

Figure 11. Average percent cronartium infection by planting density and management intensity for slash pine at age four.

4.5 Per-Acre Basal Area

Table 16 shows the results of the analysis of variance for slash pine per-acre basal area. Management intensity, density and their interaction significantly affected per-acre basal area. Basal area increased with increasing initial density and the differences were greater with the more intensive management regime. Figure 13 illustrates these trends.

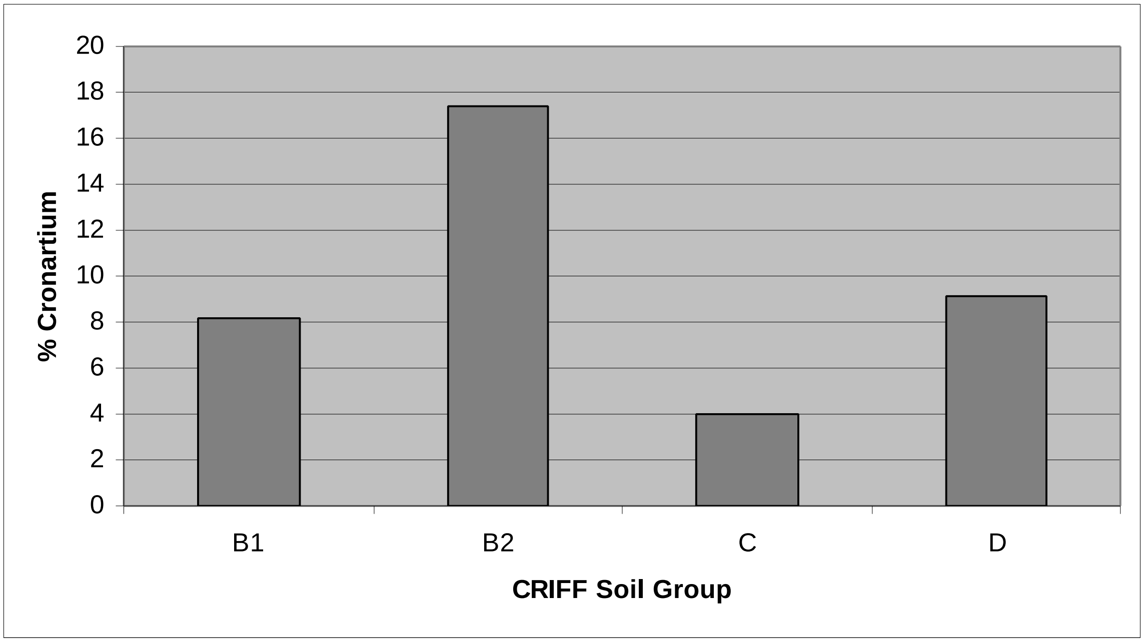

Figure 12. Average percent cronartium infection by CRIFF soil group for slash pine at age four.

Table 16. Analysis of variance results for slash pine average per-acre basal area at age four.

Source	df	Type III F	Pr > F
Soil	3	2.31	0.1983
Management	1	36.13	0.0018*
Soil x Management	3	2.63	0.1623
Density	2	114.57	0.0001*
Soil x Density	6	0.34	0.9094
Management x Density	2	5.71	0.0088*

*Significant at " = 0.05.

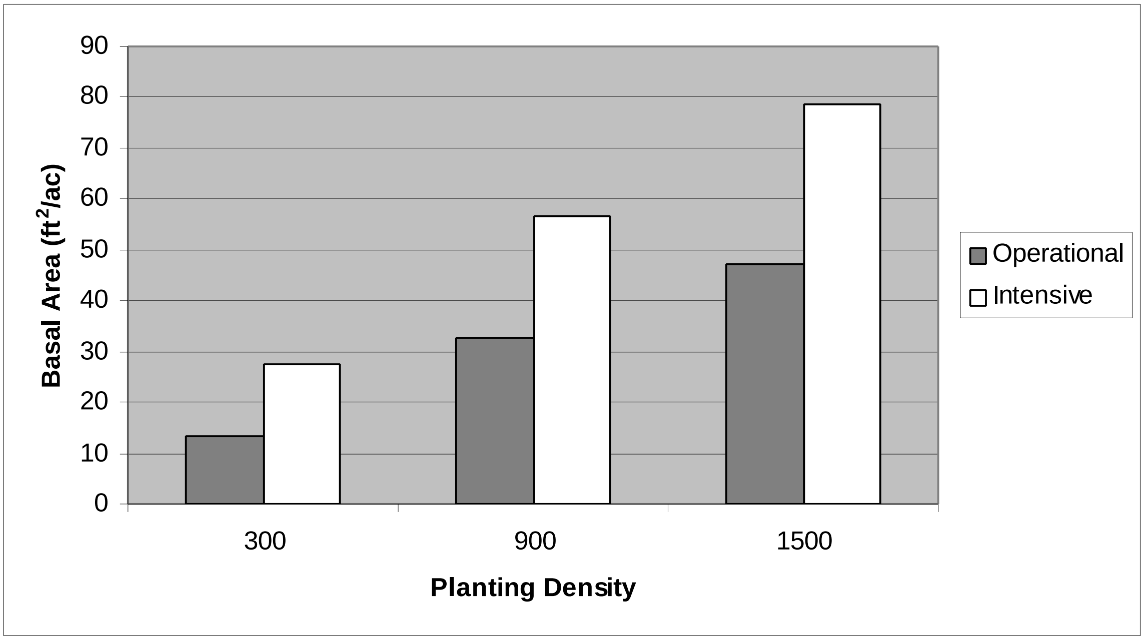

Figure 13. Average per-acre basal area by planting density and management intensity for slash pine at age four.

4.6 Per-Acre O.B. Volume

Table 17 shows the results of the analysis of variance for slash pine total volume. Management intensity, density and the management x density interaction had a significant effect on total, per-acre volume. Figure 14 shows a nearly identical trend for volume as for basal area.

Table 17. Analysis of variance results for slash pine average per-acre, total volume at age four.

Source	df	Type III F	Pr > F
Soil	3	2.49	0.1753
Management	1	31.21	0.0025*
Soil x Management	3	2.86	0.1434
Density	2	66.71	0.0001*
Soil x Density	6	0.53	0.7788
Management x Density	2	5.00	0.0145*

*Significant at " = 0.05.

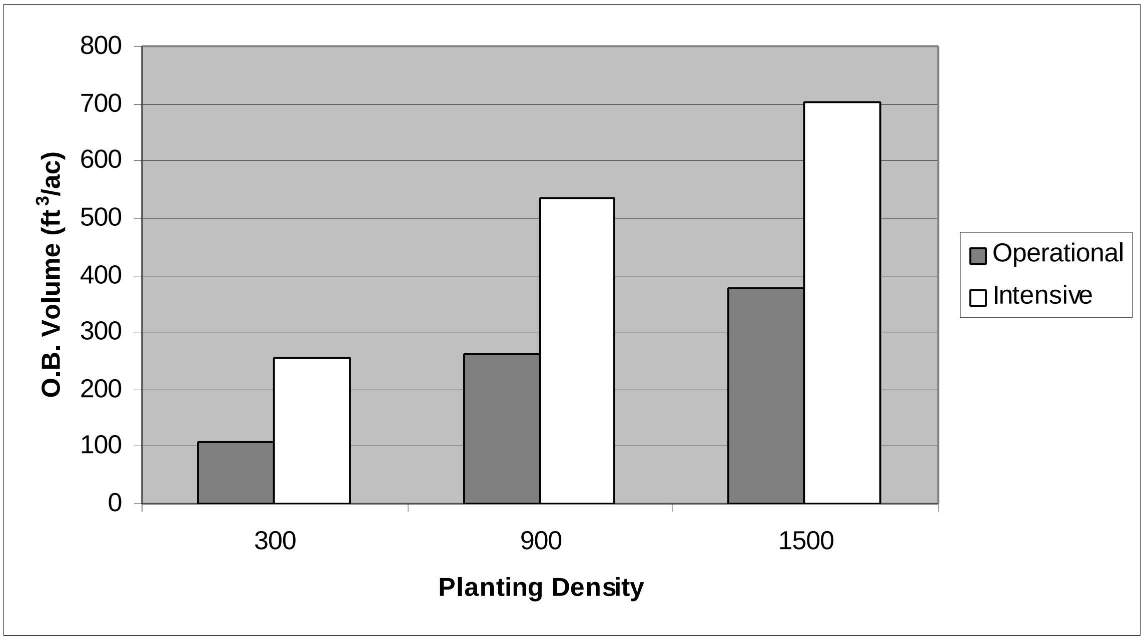

Figure 14. Average per-acre o.b. volume by planting density and management intensity for slash pine at age four.

5 SPECIES COMPARISON

A graphical comparison was carried out to assess differences in tree and stand characteristics of slash and loblolly pine. Figures 15-20 show the average DBH, height, survival percentage, cronartium infection percentage, per-acre basal area and per-acre total volume by species, initial density and management intensity level for all soil groups.

For operational treatments, slash pine had a greater average DBH than loblolly at all spacings. On the intensive treatments, slash pine had a smaller DBH at the 300 trees/acre density, nearly equal at the 900 density and had a greater DBH than loblolly at the 1500 trees/acre treatment (Figure 15).

The intensively managed loblolly pine plots had consistently greater average heights (4-5 feet) than any other treatments. The operational loblolly plots were nearly equal to slash intensive at all spacings. The intensive slash pine plots had average heights only 2-2.5 feet taller than the operational slash pine plots (Figure 16).

Except for loblolly pine planted at 300 trees/acre, operational treatment plots had better survival than the more intensively managed plots. Loblolly pine survived better than slash pine, in general, though the differences were minimal (Figure 17).

As has been reported in many previous studies, treatments that accelerated pine growth also tended to increase the cronartium infection rate. Slash pine had higher infection rates, overall (Figure 18).

For all treatments and species, per-acre basal area increased with increasing initial density. Within each treatment group, the basal areas for slash and loblolly pine were nearly equal for each spacing level (Figure 19). Slash pine had slightly higher basal areas than loblolly at the highest density.

The trends for per-acre, outside bark volume were nearly identical to those seen for per-acre basal area. Volume increased with increasing management intensity and initial density. Slash pine had slightly more volume at all spacings for the operational treatments. Slash and loblolly pine volumes were nearly equal on the intensive treatments at all spacings. This result seems peculiar in light of the fact that loblolly pine survived slightly better and was nearly five feet taller, on the average, than slash pine. Two points may provide some explanation. First, the equations used to calculate individual tree volumes were not developed from trees of this young age and relatively small size. Second, volumes computed using the slash pine equation are up to 1/3 more than the loblolly pine equation for the same sized tree. For example, a 3.5-inch DBH, 17-foot tall slash pine has 0.6095 ft^3 while the same sized loblolly pine has 0.4571 ft^3. Using the overall average dimensions for slash and loblolly pines, a 3.14-inch DBH, 15.2-foot tall slash pine has 0.4445 ft^3 of stem volume, while a 3.05-inch DBH, 17.8-foot tall loblolly pine has 0.3760 ft^3, an 18% advantage in favor of slash pine.

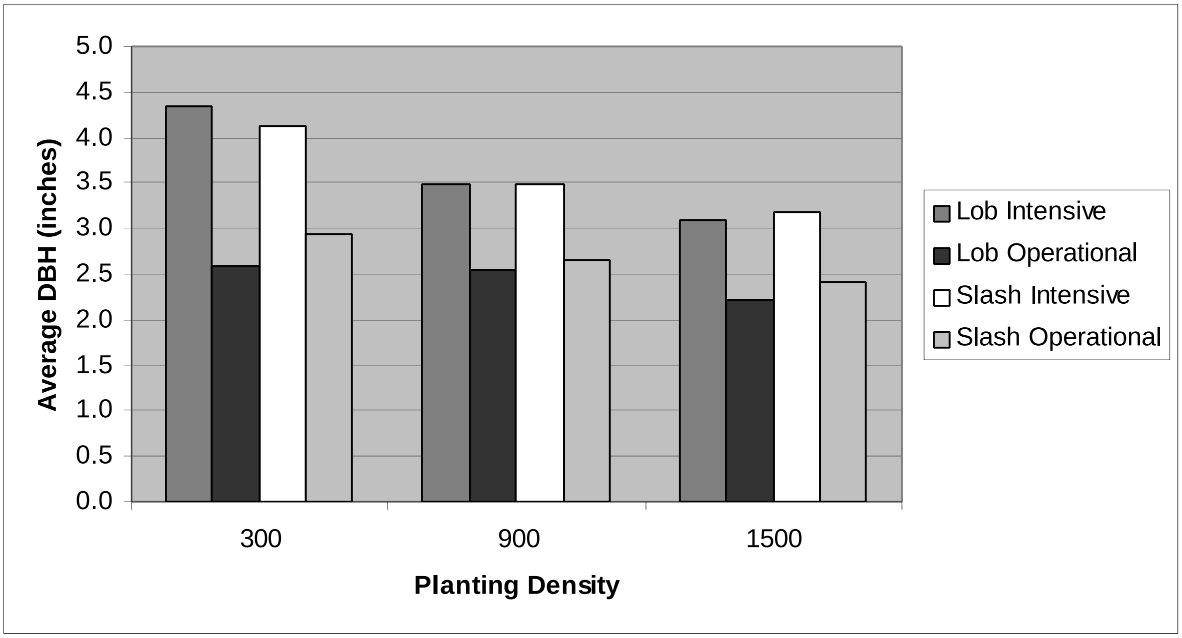

Figure 15. Average DBH by species, management intensity and density at age four.

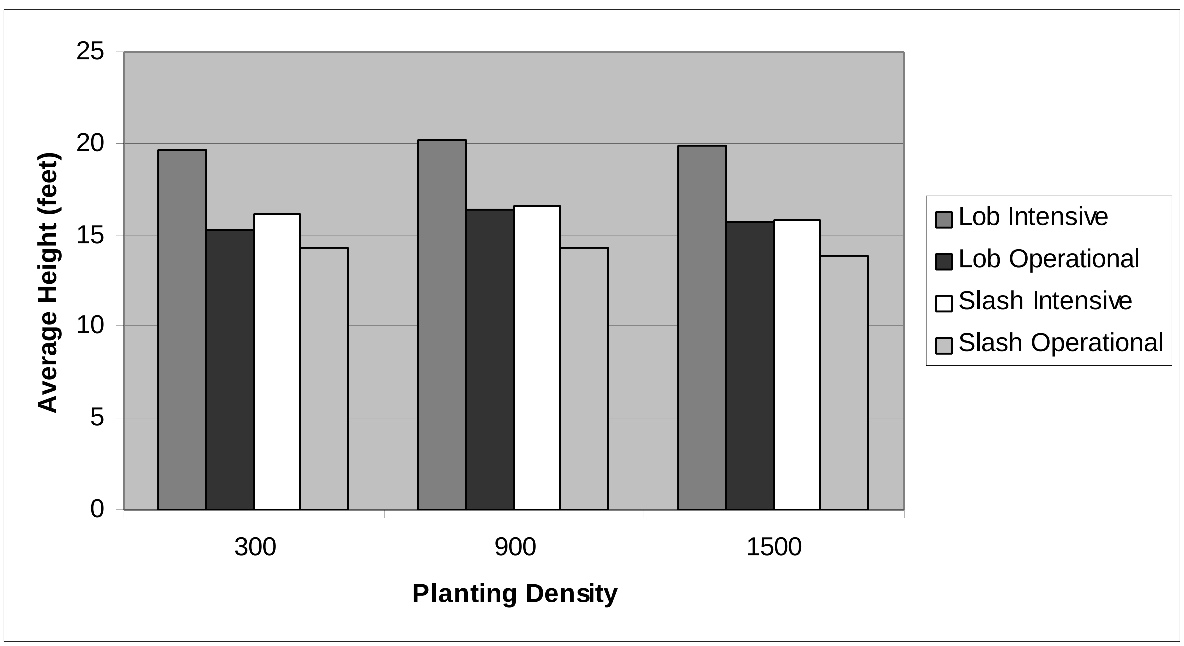

Figure 16. Average height by species, management intensity and density at age four.

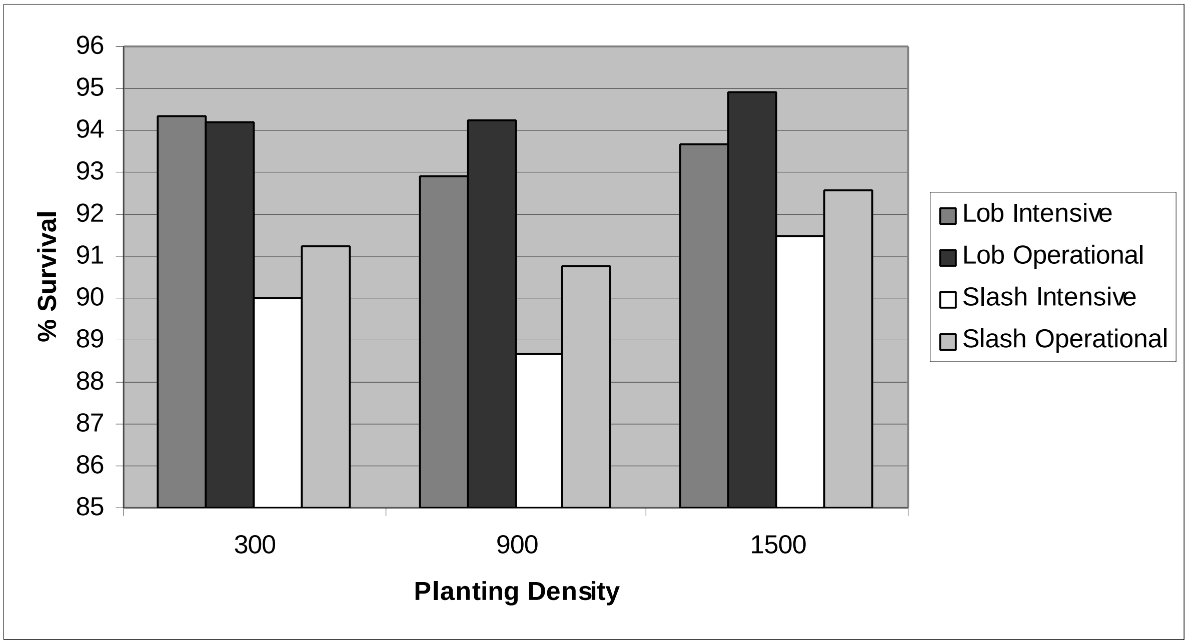

Figure 17. Average percent survival by species, management intensity and density at age four.

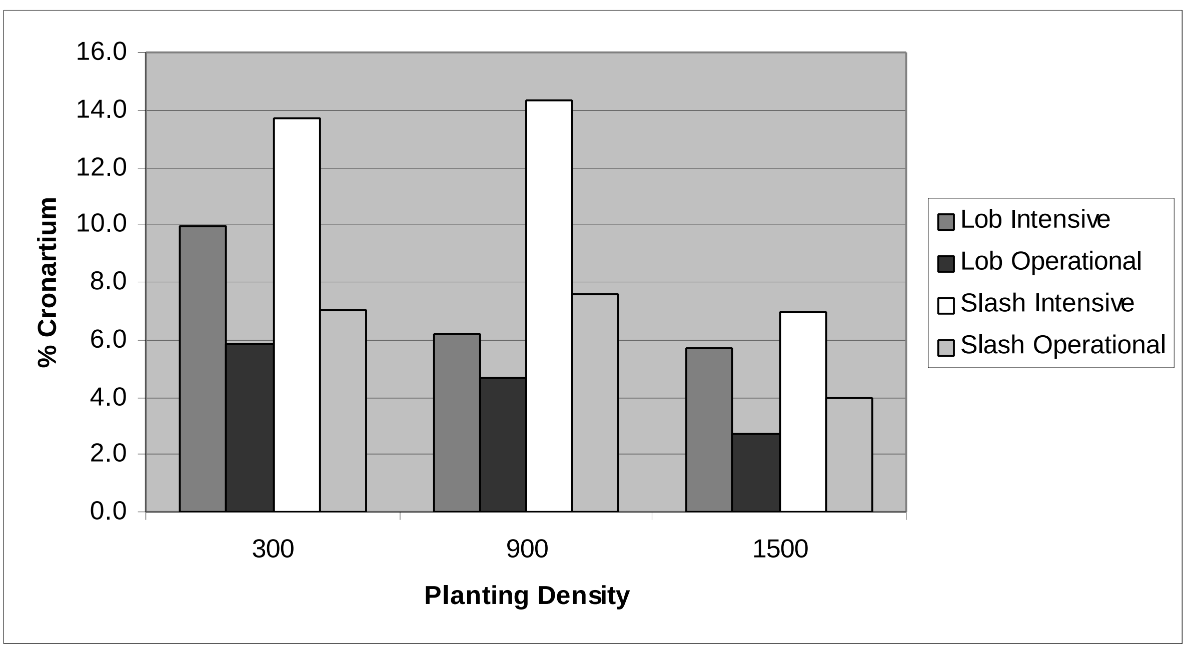

Figure 18. Average percent cronartium infection by species, management intensity and density at age four.

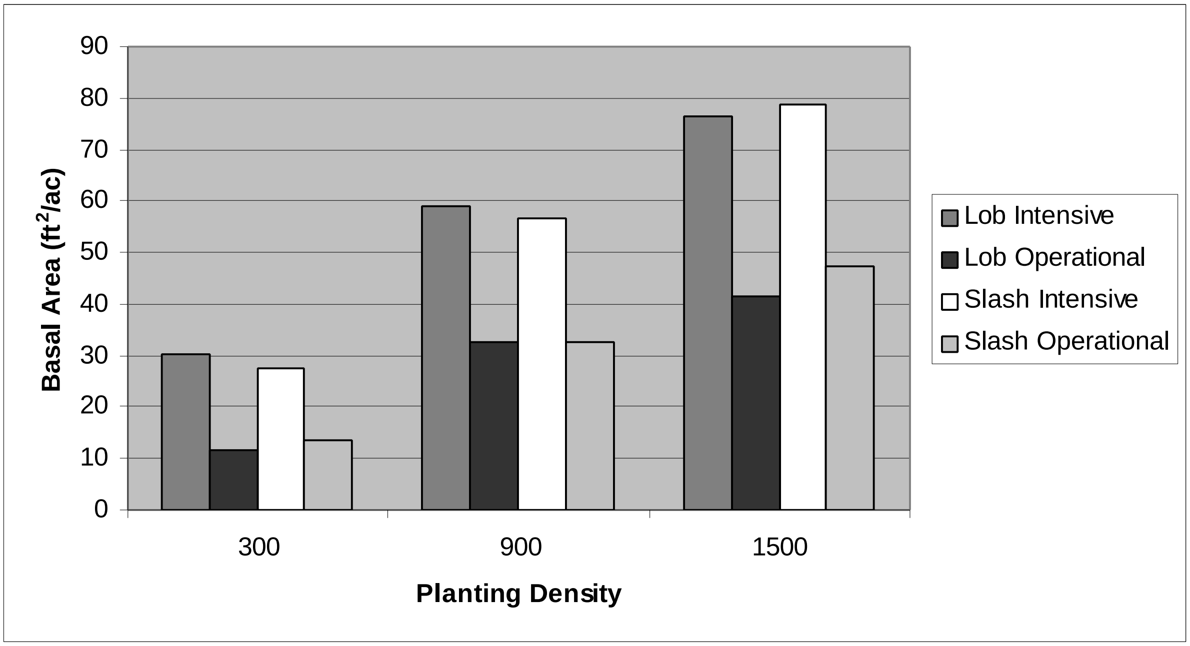

Figure 19. Average per-acre basal area by species, management intensity and density at age four.

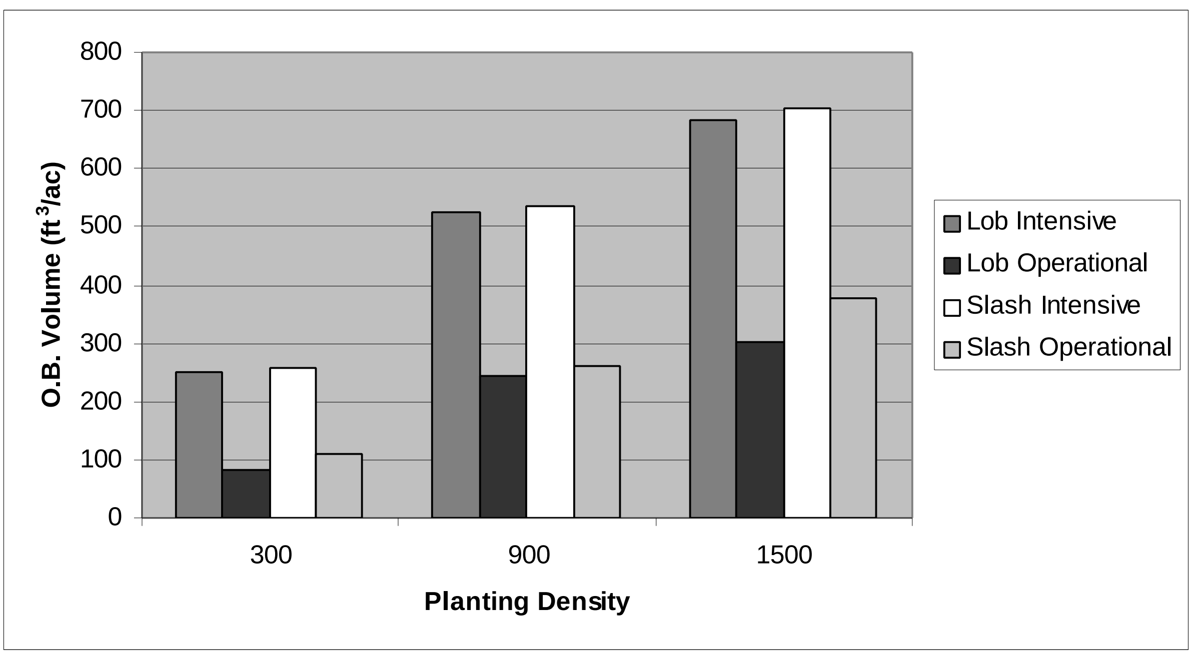

Figure 20. Average per-acre o.b. volume by species, management intensity and density at age four.

Differences between slash and loblolly pine tree and stand characteristics for the culture density study can be clarified, somewhat, by an analysis of the differences on a soil group basis. Figures 21-26 show the average DBH, average height, survival percentage, cronartium infection percentage, per-acre basal area and per-acre volume by CRIFF soil group, species, management treatment and initial density.

On all soil groups, the intensively managed slash pine plots had greater average DBH's than the intensive loblolly plots at the 1500 trees/acre initial density. On soil class D, slash pine had greater average DBH's than loblolly pine for both management schemes and all spacings (Figure 21).

Loblolly pine had consistently taller average heights than slash pine for most soil and treatment groups. On soil class D, slash pine was taller than loblolly on the intensive, 900 trees/acre plots and on the operational plots at all spacings (Figure 22).

There were no obvious trends in average survival. In general, the operational treatment plots survived somewhat better than the intensively managed plots and loblolly pine survived better than slash pine. Slash pine survival was particularly poor on the CRIFF B2 soil type (Figure 23).

With only a couple of exceptions, the intensive treatments had higher cronartium infection rates than the operational plots for both species. Slash pine had higher infection rates, overall. Slash pine infection rates were particularly high on the intensively managed plots found on the CRIFF B2 soil type (Figure 24).

Slash pine had more per-acre basal area in the intensive, higher density treatments on the B1 soil type. Slash pine had consistently more per-acre basal area for both management treatments on the D soil group. The species differences on soil group D increased with increasing initial density (Figure 25).

The trends for per-acre, outside bark total volume were similar to the trends for per-acre basal area. Loblolly pine had consistently more volume for all treatments on the B2 and C soil groups. On the B1 soil type, intensively managed slash pine plots had more volume than loblolly pine at the higher densities. Slash pine had consistently more total volume on the D soil group (Figure 26).

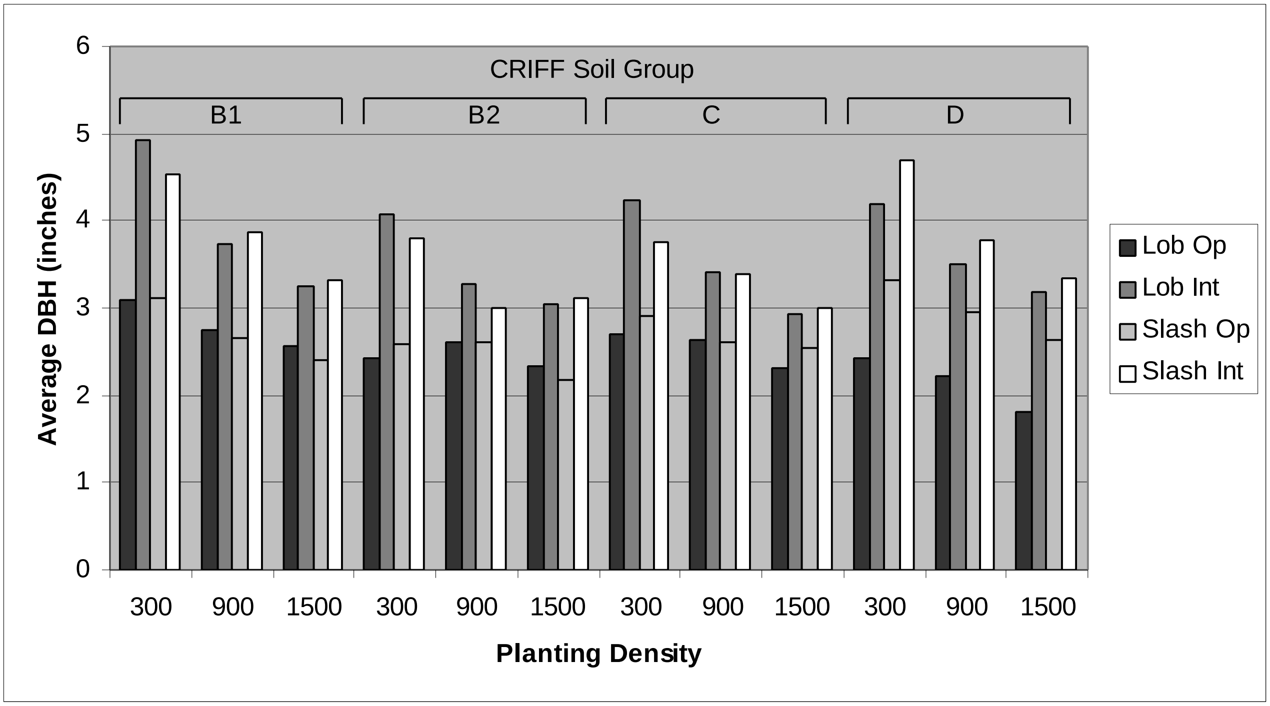

Figure 21. Average DBH by CRIFF soil group, species, management intensity and density at age four.

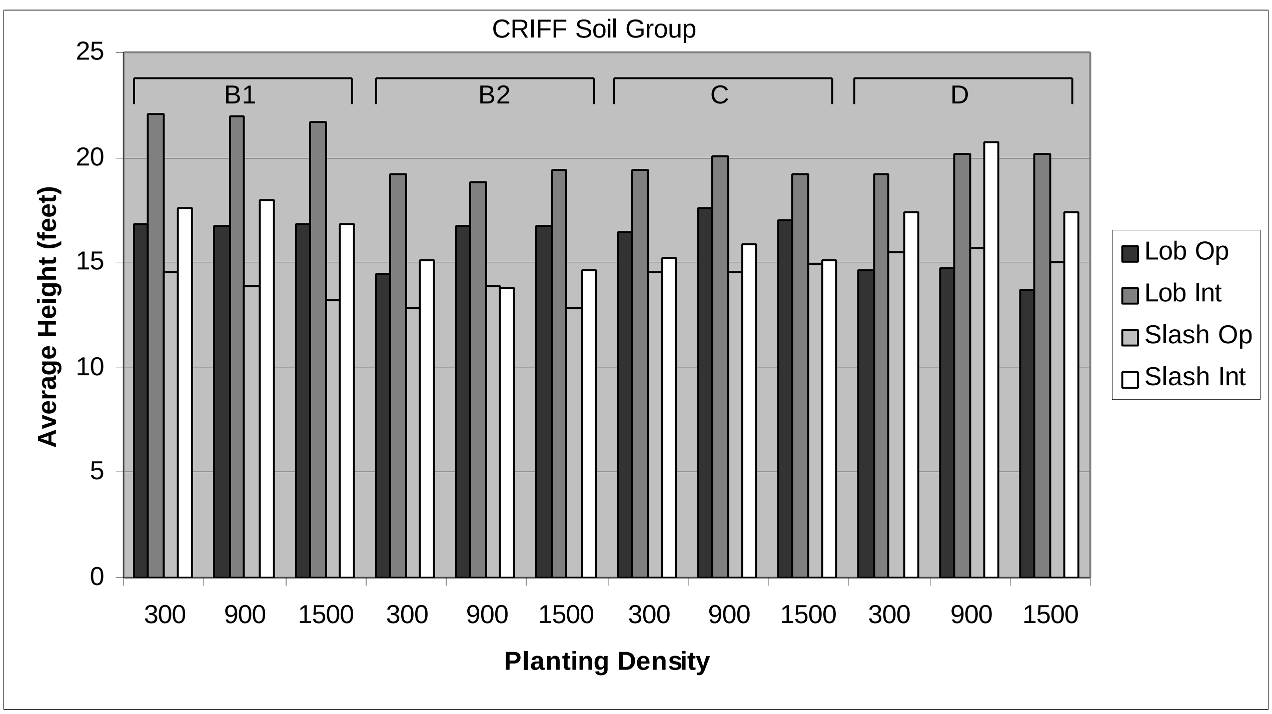

Figure 22. Average height by CRIFF soil group, species, management intensity and density at age four.

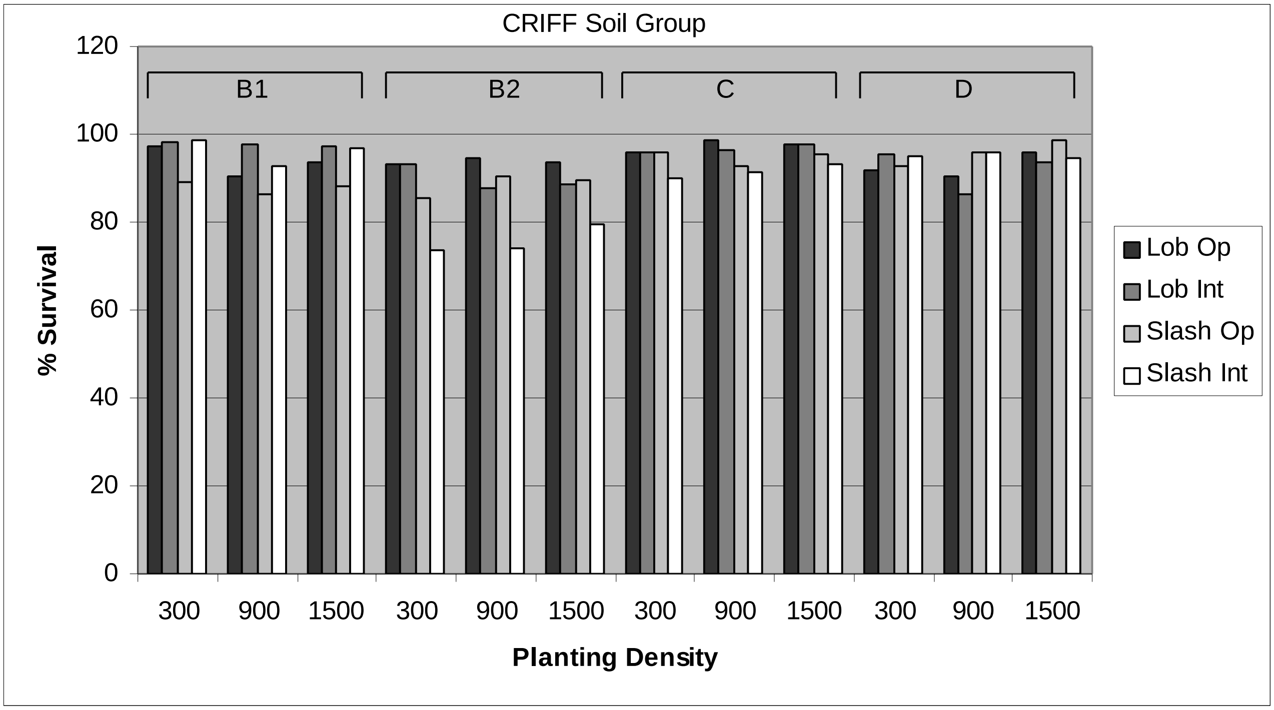

Figure 23. Average percent survival by CRIFF soil group, species, management intensity and density at age four.

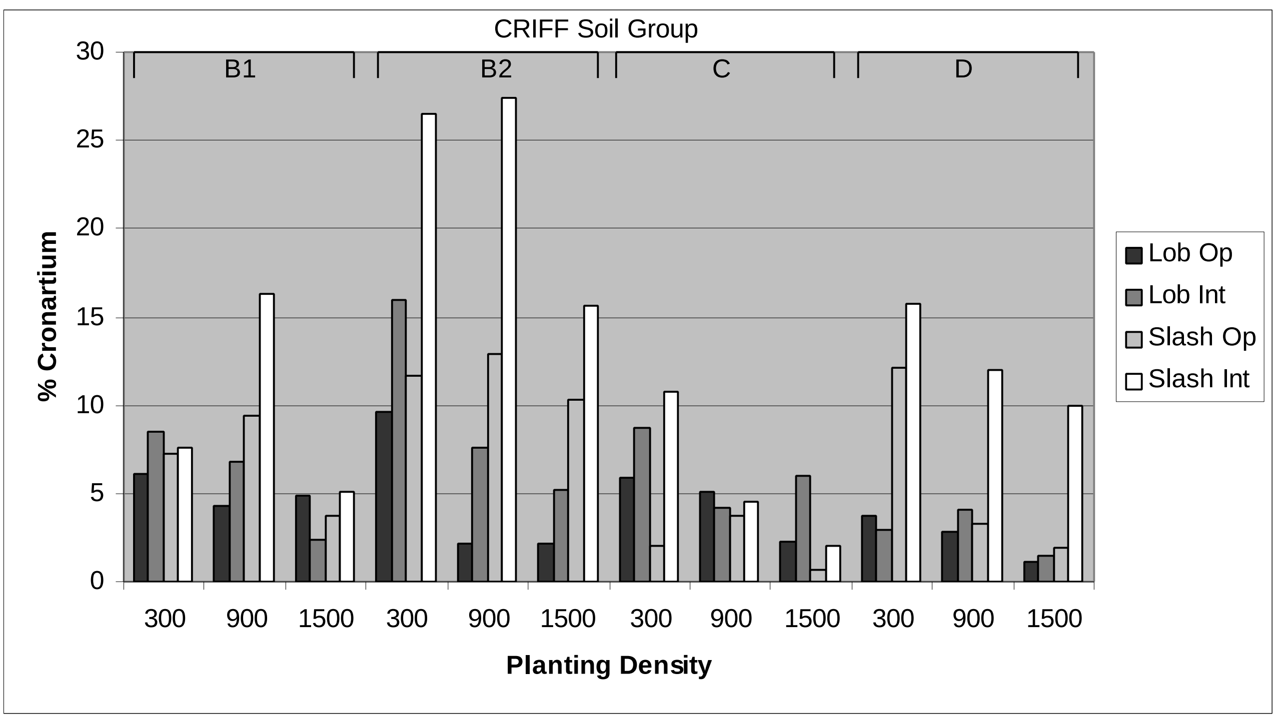

Figure 24. Average percent cronartium by CRIFF soil group, species, management intensity and density at age four.

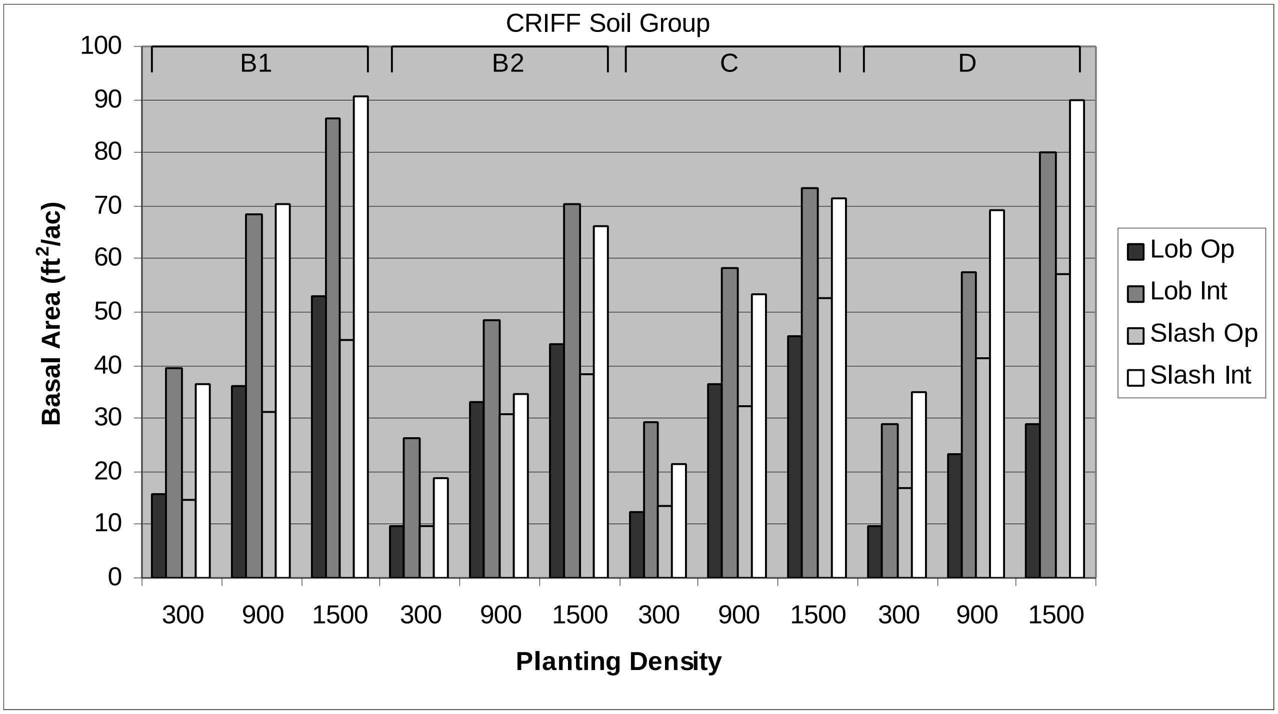

Figure 25. Per-acre basal area by CRIFF soil group, species, management intensity and density at age four.

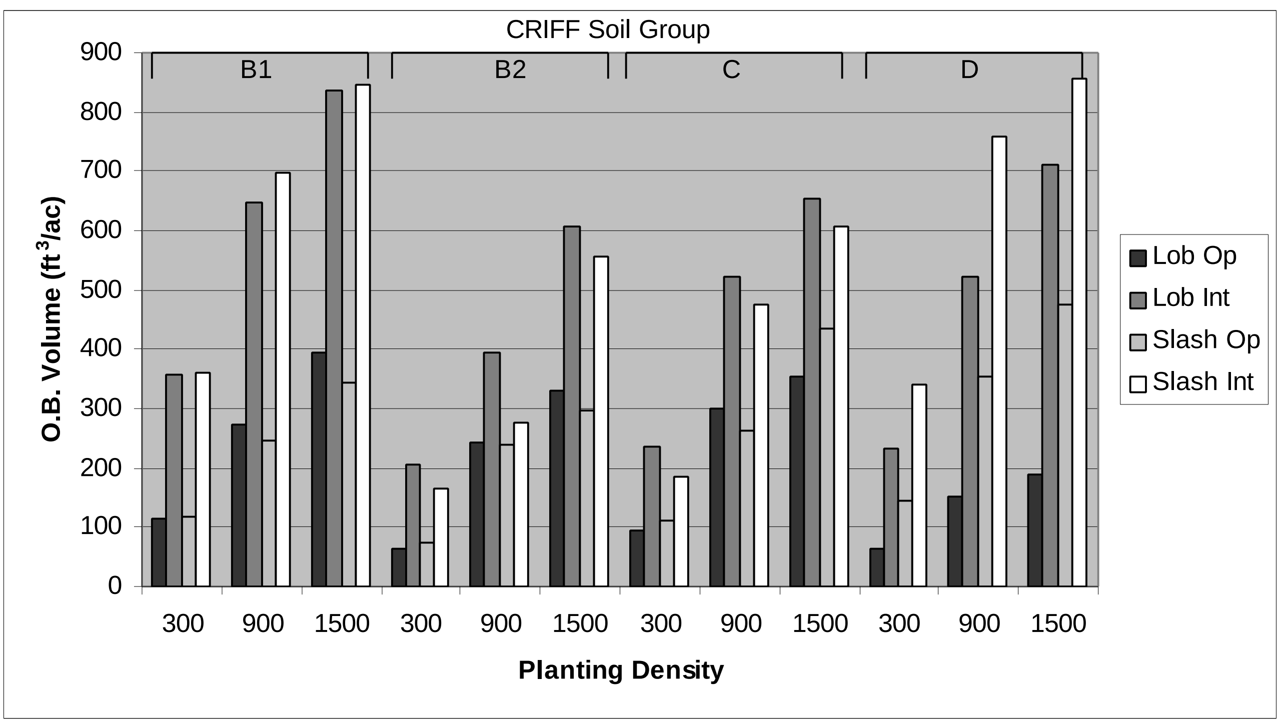

Figure 26. Per-acre o.b. volume by CRIFF soil group, species, management intensity and density at age four.

6 DISCUSSION

The data reported on here are from 4-year-old plantations. Accelerated growth for both the operational and more intensive treatments has allowed the calculation of realistic per-acre basal areas and total volumes. These stand characteristics account for tree dimension as well as stand density and provide interesting criteria to examine differences due to management treatment regime, planting density, species and soil group.

As with numerous studies reported in the literature, more intensive management has resulted in larger average DBH's for all spacing treatments and soil groups. An examination of the average DBH's for the different spacing treatments shows that the additional weed control and fertilization has accelerated the onset of inter-species competition on the intensive treatment plots. There is a hint of the relationship between average DBH and initial density on the operational treatment plots, but the relationship is already prominent under the more intensive regime.

More intensive management has significantly increased height growth at all spacing treatment levels. The differences in average height between the operational and more intensive treatments are much more pronounced in slash pine. There is no discernable relationship between initial density and average height for either species.

On the negative side, more intensive management has increased mortality and the cronartium infection rate over the operational treatment. Increased mortality may be due to overspray of herbicide onto pine trees or increased inter-species competition due to accelerated growth. The relationship between increased growth and increased cronartium infection has been well documented so does not come as a surprise in this study. What is surprising is that slash pine had higher infection rates, in general, than loblolly pine. Perhaps the gains in rust resistance due to tree improvement for loblolly pine have surpassed those of slash pine. The differences in cronartium infection rates for slash pine also seem to be soil related with infection rates much greater on the B2 soil group.

Trends for per-acre basal area and total volume were nearly identical for slash and loblolly pine. Both quantities increased with increasing initial density. The more intensive management regime produced between 76 and 234 percent more basal area per acre and between 105 and 354 percent more total volume than the operational treatment. Slash pine outgrew loblolly pine in terms of per-acre basal area and total volume on the higher initial densities. Also, slash pine grew better for all treatments on the D soil group.

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