PMRC CULTURE / DENSITY STUDY:

AGE 2 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 that 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 include slash pine. 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 free of competing vegetation. These plots also received additional fertilization treatments and were sprayed for tip moths during 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 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 and percent cornartium infection for each species.

For loblolly pine, the management intensity factor had a significant effect on average DBH and average height. There was also a significant soil type X management interaction for both variables. The density factor had no significant effect on DBH but there was a management X density interaction. Neither density nor any density interactions had a significant effect on average height. There were no significant differences in cronartium infection level due to any of the factors or interactions.

For slash pine, no significant differences were found in average DBH, average height or percent cronartium infection. The more intensive management treatment tended to boost DBH and height growth on the B1 soil group but had very little effect, otherwise.

The average DBH and average height of loblolly and slash pine were compared graphically. In most cases, the intensively managed loblolly was the top performer. On the operational treatment plots, the loblolly outgrew the slash on non spodosols but the slash prevailed on the spodosols.

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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 or 12 oz. Arsenal plus 1 qt. Accord per acre if the competition consisted mainly of grass. 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. Fertilizer treatments, including the addition of micro nutrients, will be repeated at least every three years. 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 free of competing vegetation. Insecticides 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 following setup for the analysis of variance:

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		20
DENSITY*INST(SOIL)	[error (b)]	60
DENSITY*CULTURE*INST(SOIL)		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 second 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. Analysis of variance as described above was carried out for average DBH, average height and percent cornartium infection.

3.1 Average DBH

Table 3 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 and there was a significant soil type x management intensity interaction. The density factor had no significant effect on average DBH, but there was a management intensity x density interaction. Figure 1 shows the loblolly pine average DBH's by soil group and management intensity. Figures 2-6 show average DBH's by management intensity and density for each soil group.

Table 3. Analysis of variance results for loblolly pine average DBH.

Source	df	Type III F	Pr > F
Soil	4	2.36	0.1120
Management	1	59.72	0.0001*
Soil x Management	4	4.52	0.0186*
Density	5	2.09	0.0700
Soil x Density	20	1.40	0.1332
Management x Density	5	4.97	0.0003*

*Significant at ∀ = 0.05.

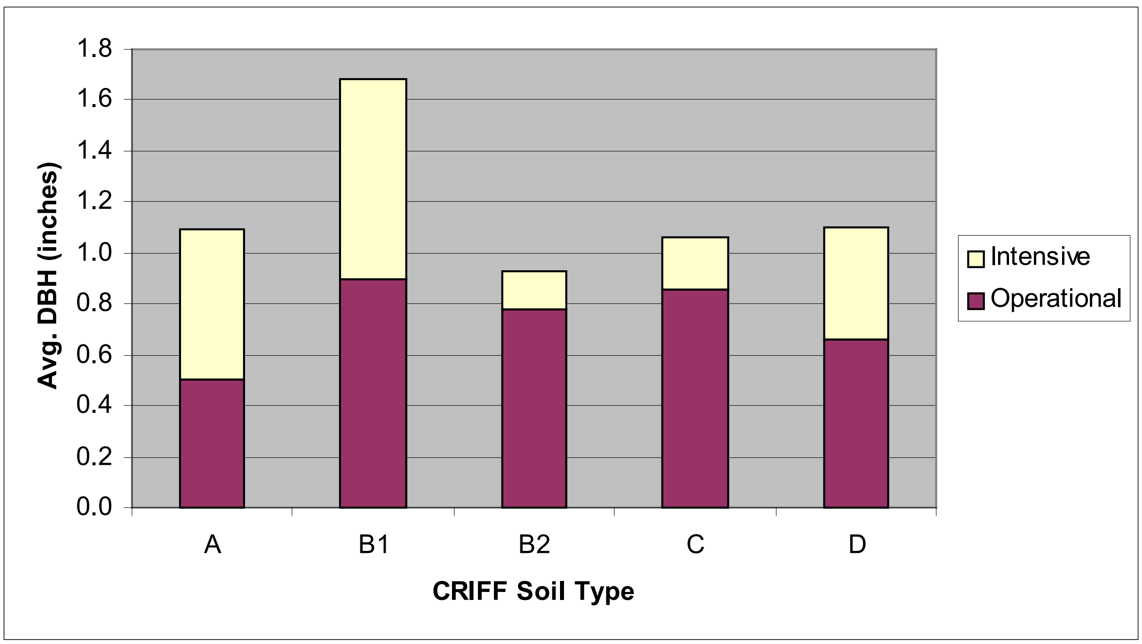

Figure 1. Average DBH by CRIFF soil type and management intensity for loblolly pine.

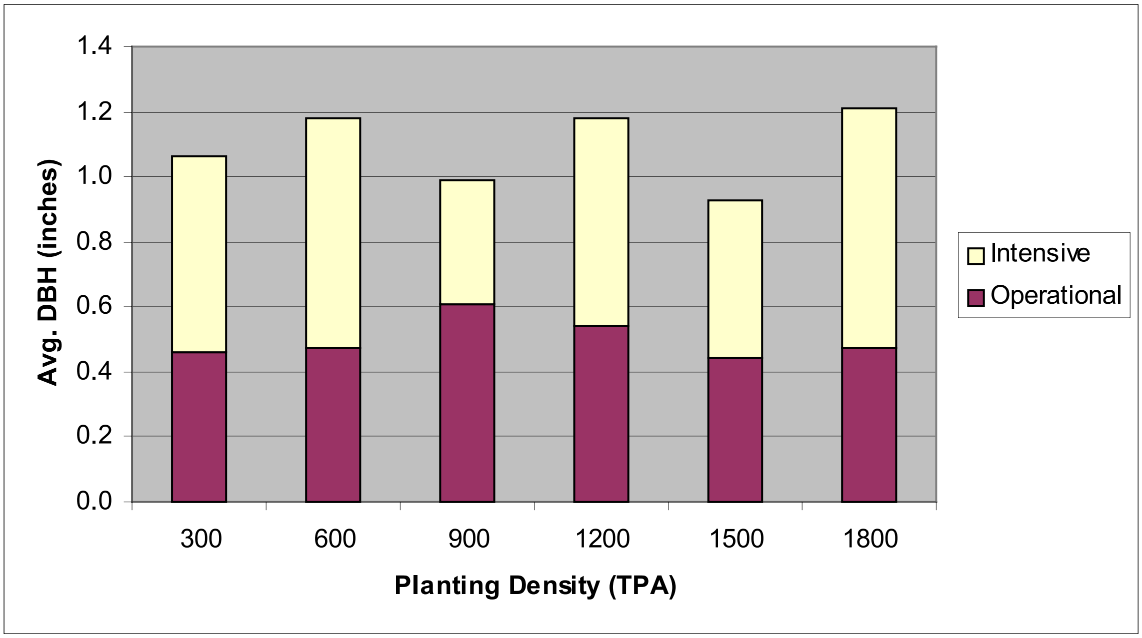

Figure 2. Average DBH by management intensity and density for CRIFF soil type A for loblolly pine.

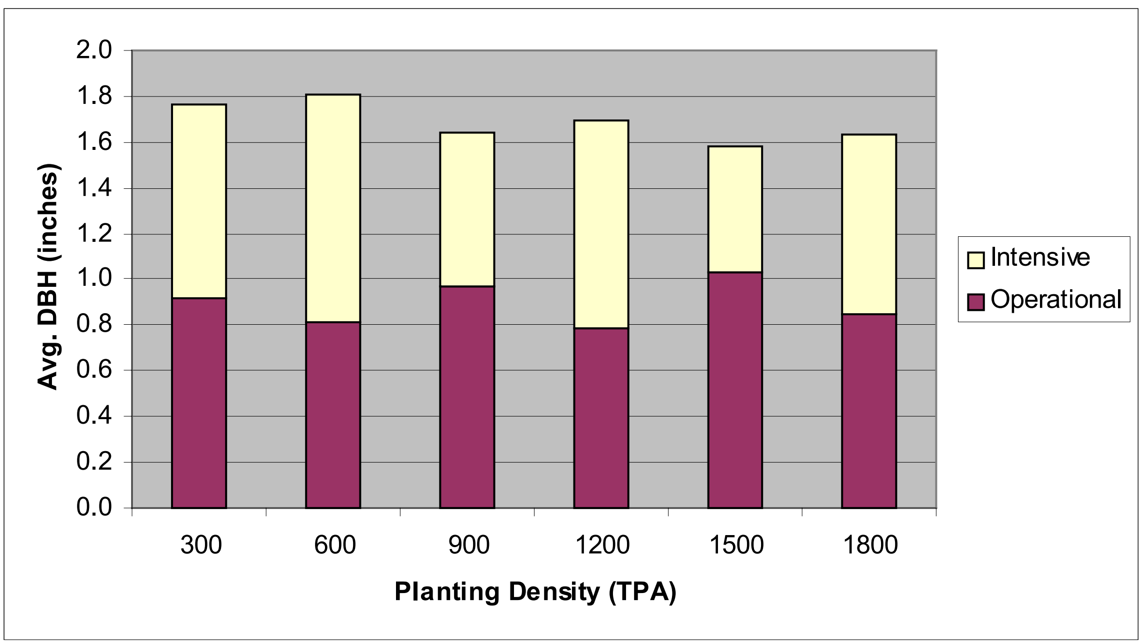

Figure 3. Average DBH by management intensity and density for CRIFF soil type B1 for loblolly pine.

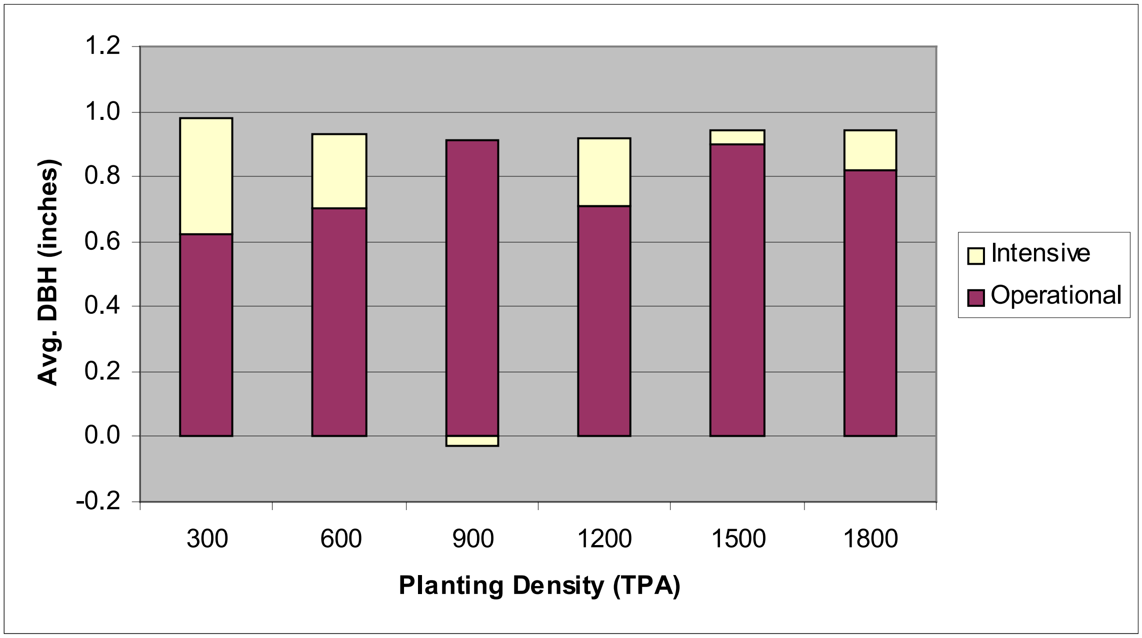

Figure 4. Average DBH by management intensity and density for CRIFF soil type B2 for loblolly pine.

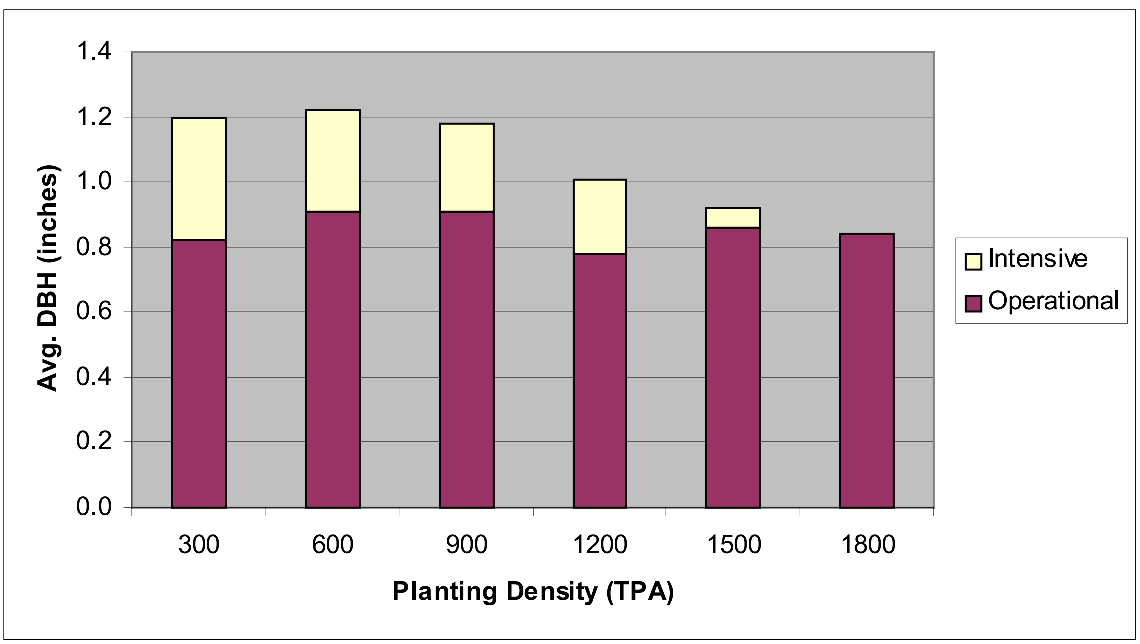

Figure 5. Average DBH by management intensity and density for CRIFF soil type C for loblolly pine.

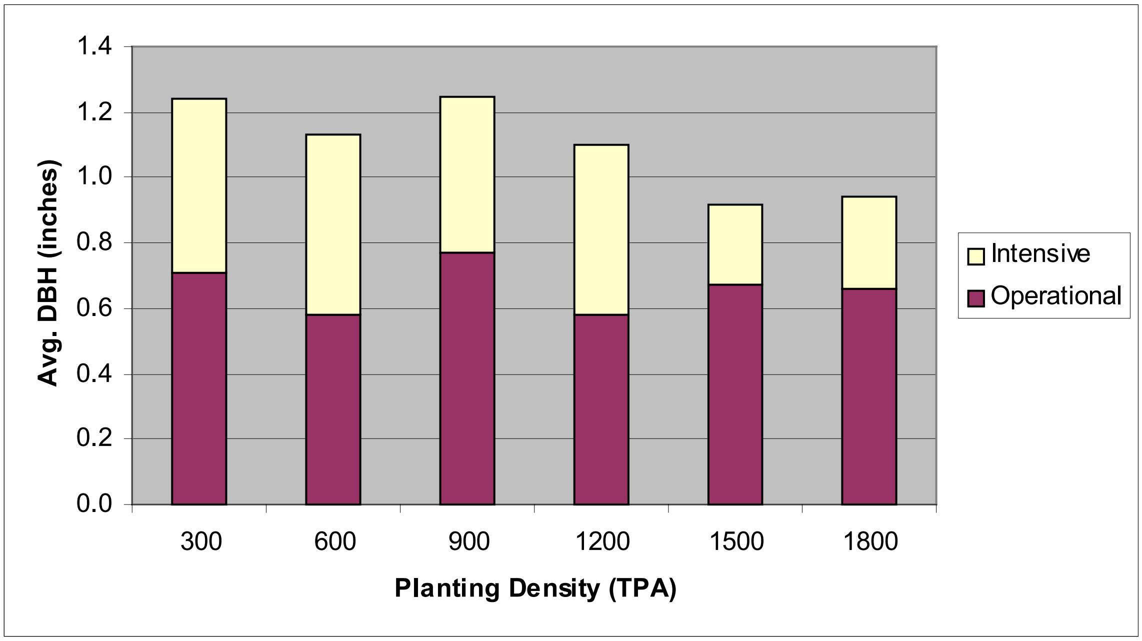

Figure 6. Average DBH by management intensity and density for CRIFF soil type D for loblolly pine.

3.2 Average Height

Table 4 shows the results of the analysis of variance for loblolly pine average height. The management intensity factor was significant at the ∀ = 0.05 level and there was a significant soil type x management intensity interaction. The density factor had no significant effect on average height, and there was no management intensity x density interaction. Figure 7 shows the average heights by soil group and management intensity. Figures 8-12 show average heights by management intensity and density for each soil group.

Table 4. Analysis of variance results for loblolly pine average height.

Source	df	Type III F	Pr > F
Soil	4	1.94	0.1688
Management	1	43.44	0.0001*
Soil x Management	4	4.46	0.0194*
Density	5	1.80	0.1173
Soil x Density	20	1.26	0.2169
Management x Density	5	1.68	0.1423

*Significant at ∀ = 0.05.

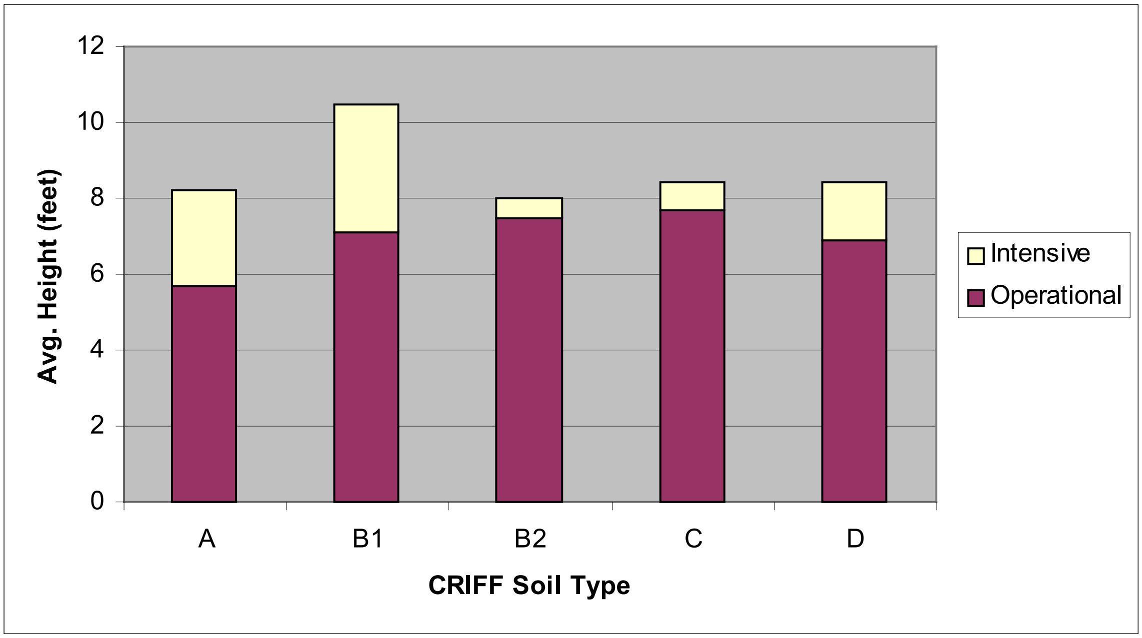

Figure 7. Average height by CRIFF soil type and management intensity for loblolly pine.

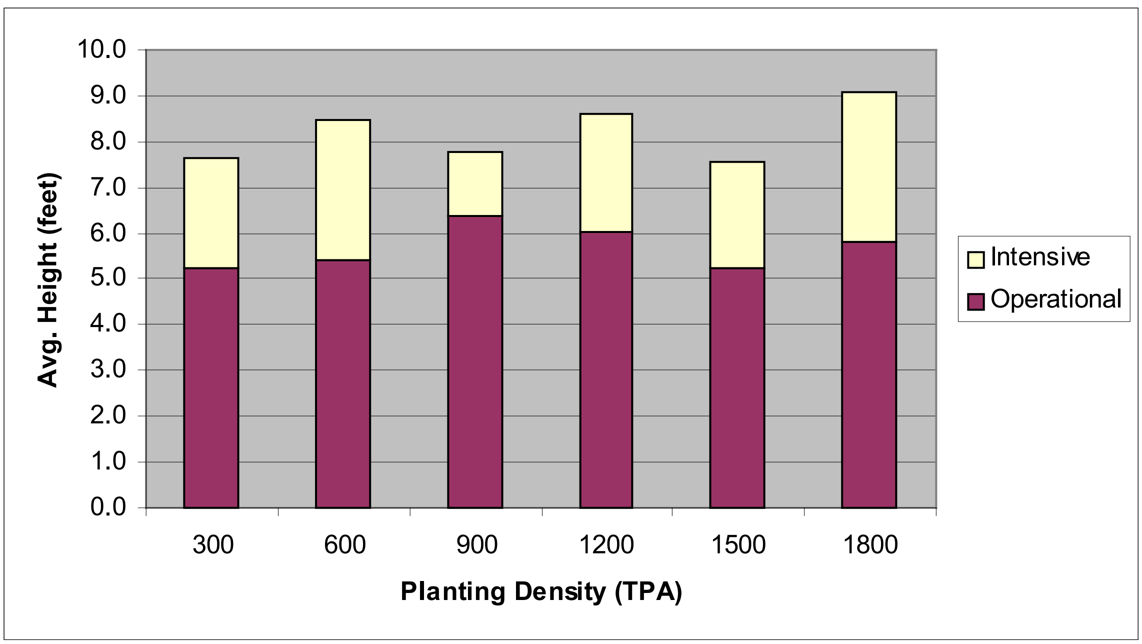

Figure 8. Average height by management intensity and density for CRIFF soil type A for loblolly pine.

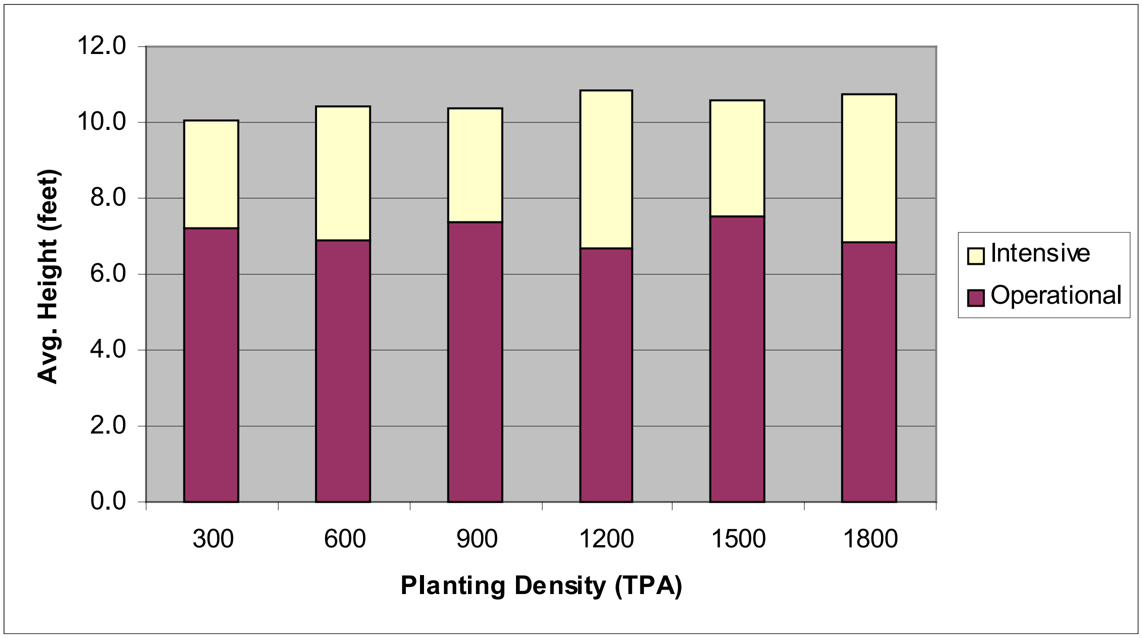

Figure 9. Average height by management intensity and density for CRIFF soil type B1 for loblolly pine.

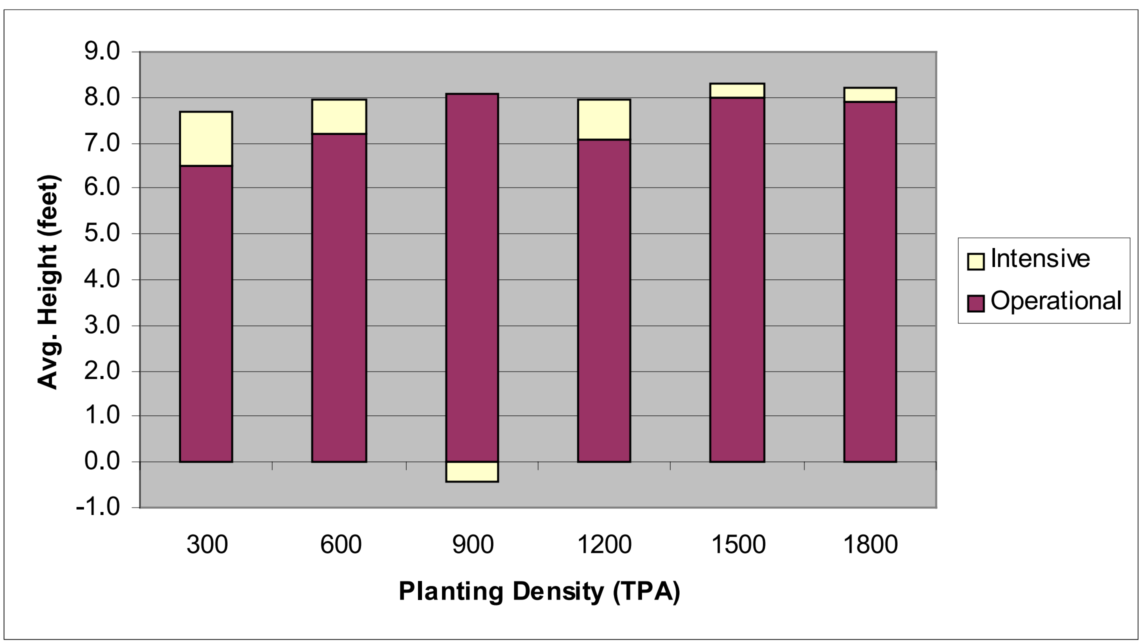

Figure 10. Average height by management intensity and density for CRIFF soil type B2 for loblolly pine.

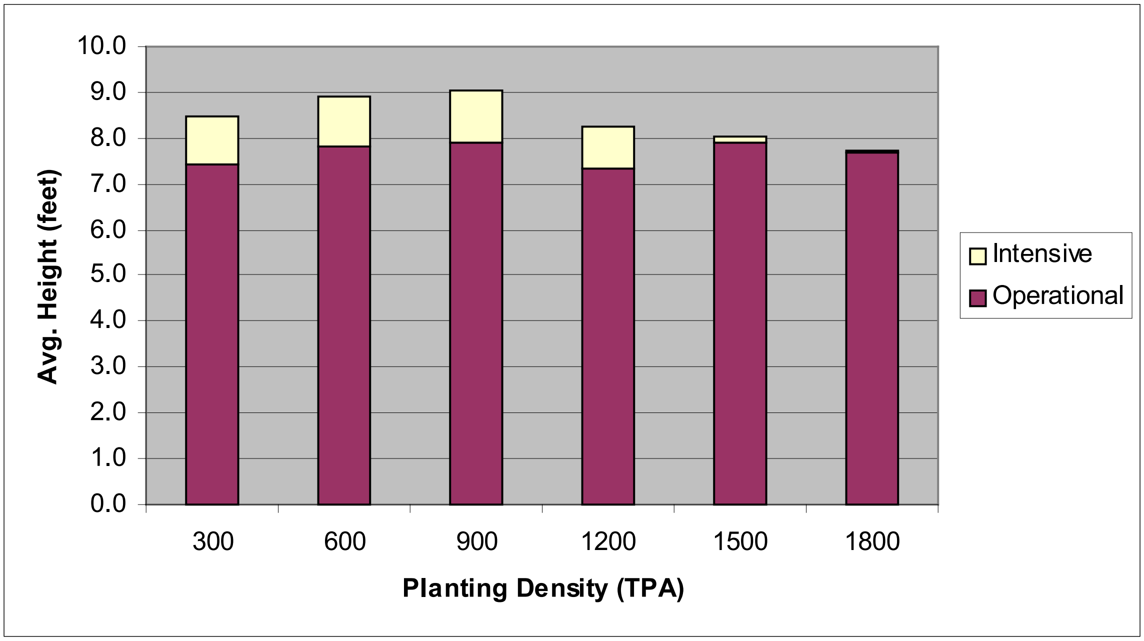

Figure 11. Average height by management intensity and density for CRIFF soil type C for loblolly pine.

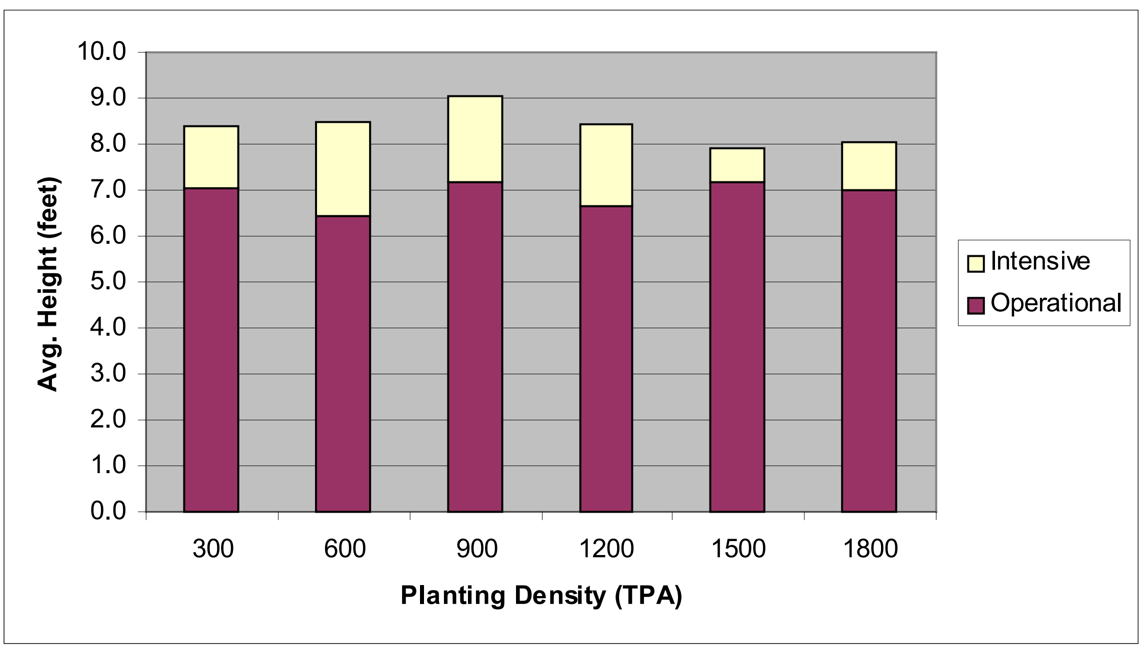

Figure 12. Average height by management intensity and density for CRIFF soil type D for loblolly pine.

3.3 Percent Cronartium Infection

Table 5 shows the results of the analysis of variance for average percent cronartium infection. Infection rates were very low, ranging from 0 to 6.6%. There were no significant differences in cronartium infection rates due to any factor included in the analysis of variance.

Table 5. Analysis of variance results for loblolly pine average percent cronartium infection.

Source	df	Type III F	Pr > F
Soil	4	1.68	0.2194
Management	1	0.53	0.4803
Soil x Management	4	1.49	0.2670
Density	5	1.76	0.1255
Soil x Density	20	1.00	0.4639
Management x Density	5	0.29	0.9157

*Significant at ∀ = 0.05.

4 SLASH PINE RESULTS

4.1 Average DBH

Table 6 shows the results of the analysis of variance for slash pine average DBH. None of the factors had a significant effect on average DBH. Figure 13 shows the slash pine average DBH's by soil group and management intensity. Figures 14-17 show average DBH's by management intensity and density for each soil group.

Table 6. Analysis of variance results for slash pine average DBH.

Source	df	Type III F	Pr > F
Soil	3	3.00	0.1341
Management	1	1.32	0.3027
Soil x Management	3	2.13	0.2153
Density	2	1.24	0.3059
Soil x Density	6	0.44	0.8464
Management x Density	2	0.05	0.9479

*Significant at ∀ = 0.05.

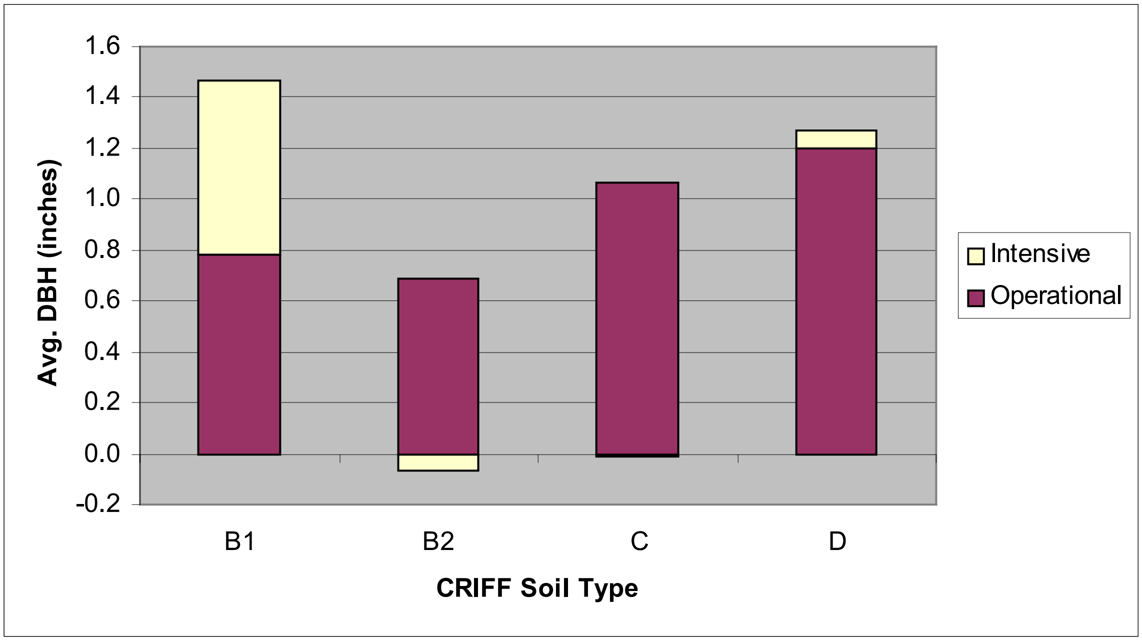

Figure 13. Average DBH by CRIFF soil type and management intensity for slash pine.

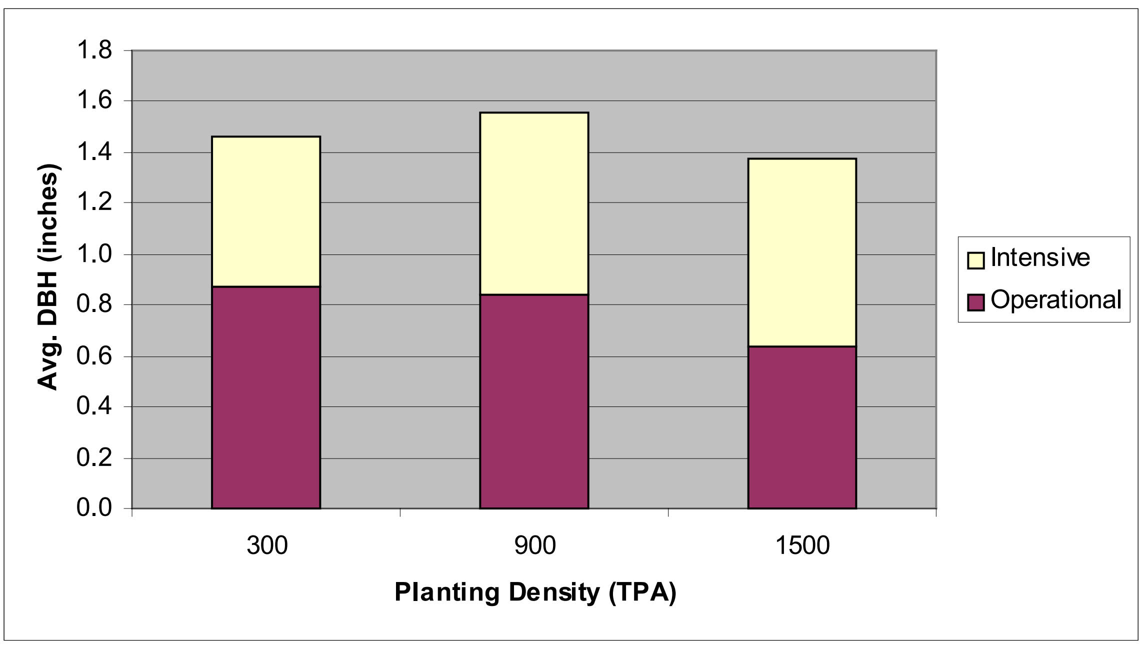

Figure 14. Average DBH by management intensity and density for CRIFF soil type B1 for slash pine.

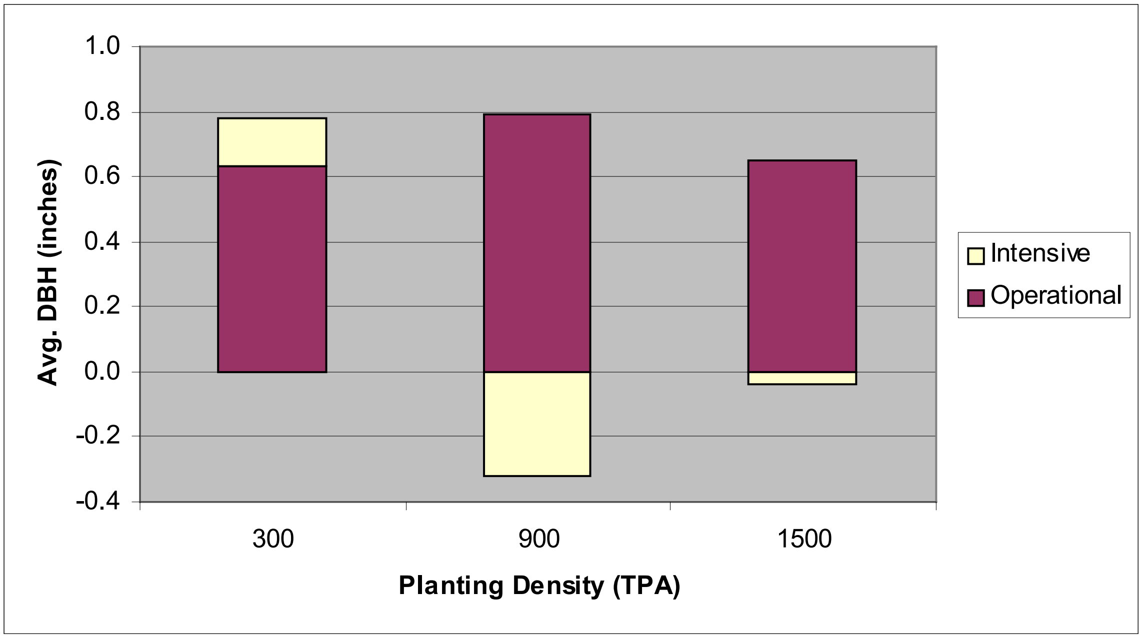

Figure 15. Average DBH by management intensity and density for CRIFF soil type B2 for slash pine.

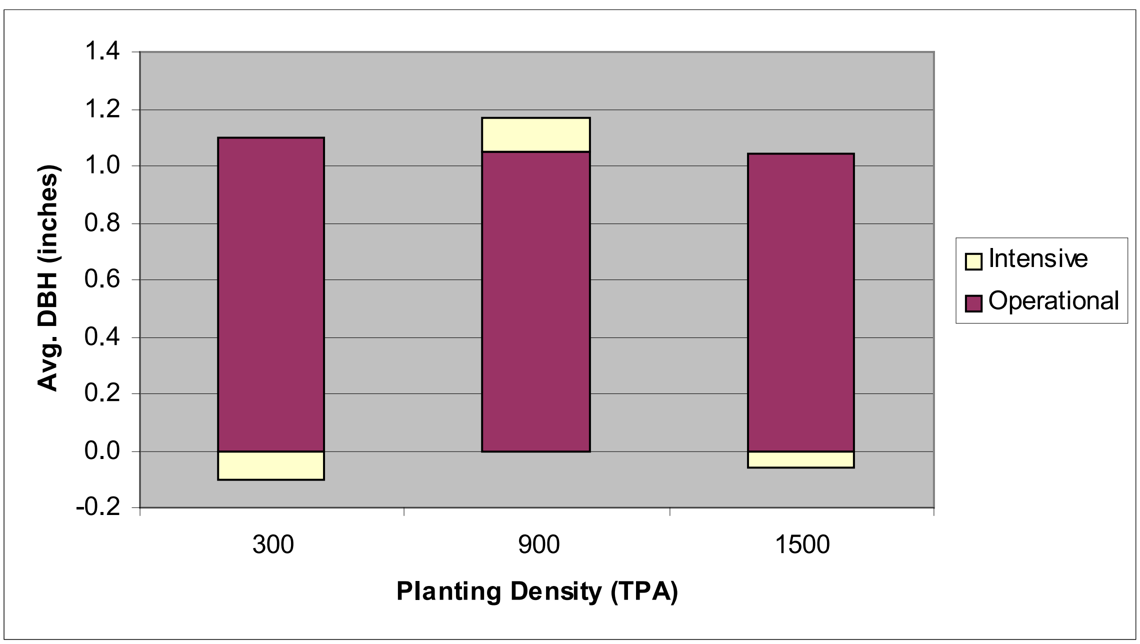

Figure 16. Average DBH by management intensity and density for CRIFF soil type C for slash pine.

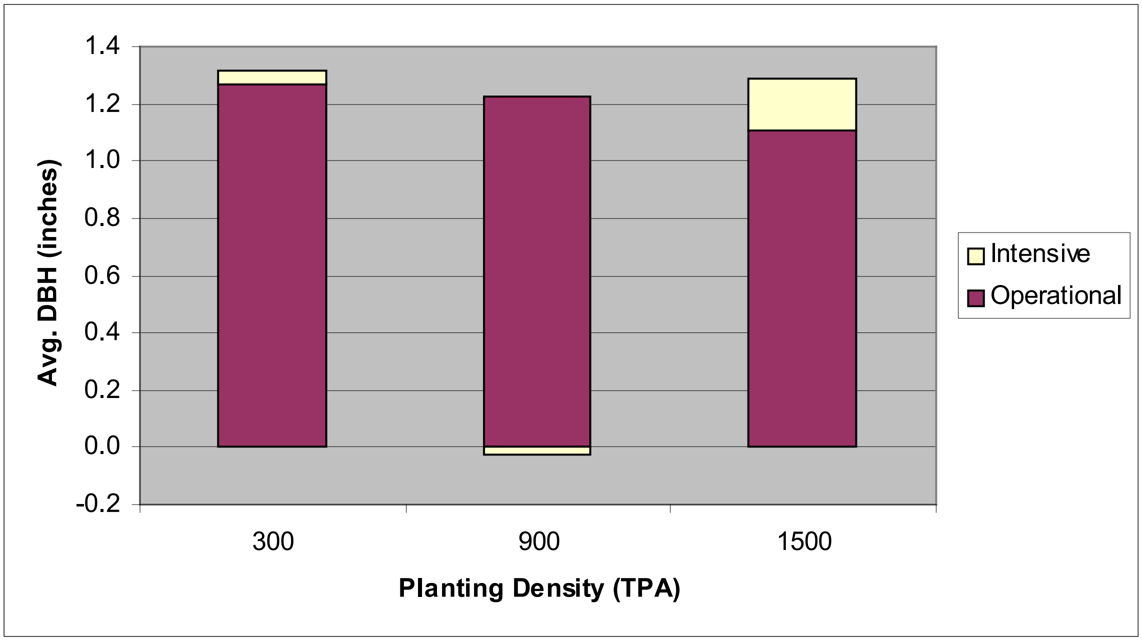

Figure 17. Average DBH by management intensity and density for CRIFF soil type D for slash pine.

4.2 Average Height

Table 7 shows the results of the analysis of variance for slash pine average height. There were no significant differences in average height due to any of the main factors or interactions. Figure 18 shows the average heights by soil group and management intensity. Figures 19-22 show average heights by management intensity and density for each soil group.

Table 7. Analysis of variance results for slash pine average height.

Source	df	Type III F	Pr > F
Soil	3	2.19	0.2078
Management	1	0.11	0.7545
Soil x Management	3	2.74	0.1529
Density	2	0.29	0.7479
Soil x Density	6	0.55	0.7626
Management x Density	2	0.05	0.9485

*Significant at ∀ = 0.05.

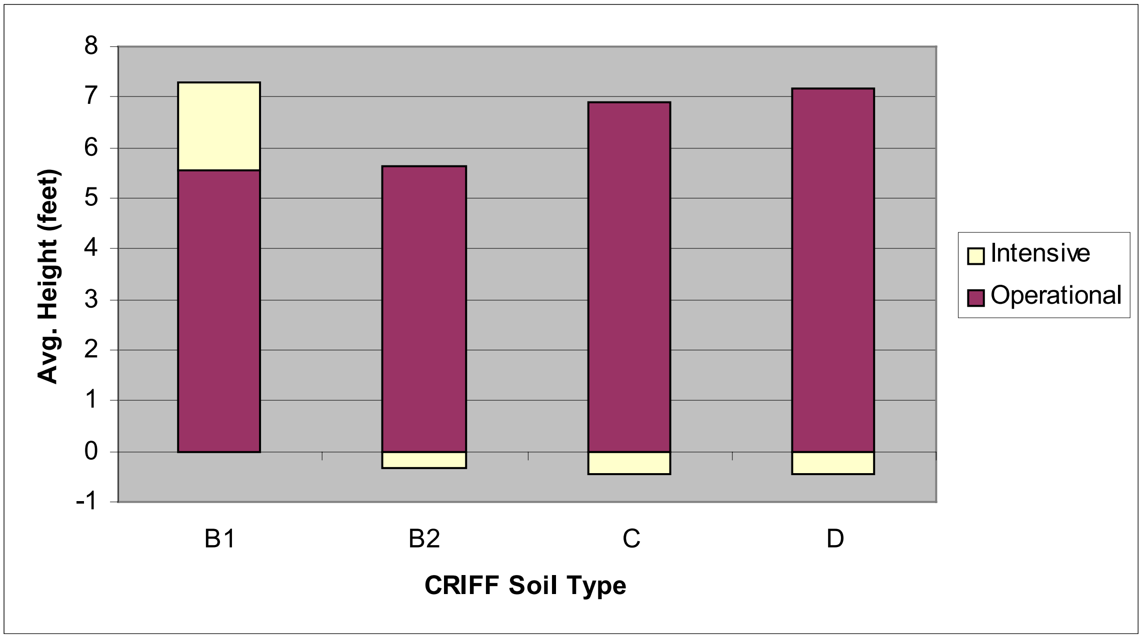

Figure 18. Average height by CRIFF soil type and management intensity for slash pine.

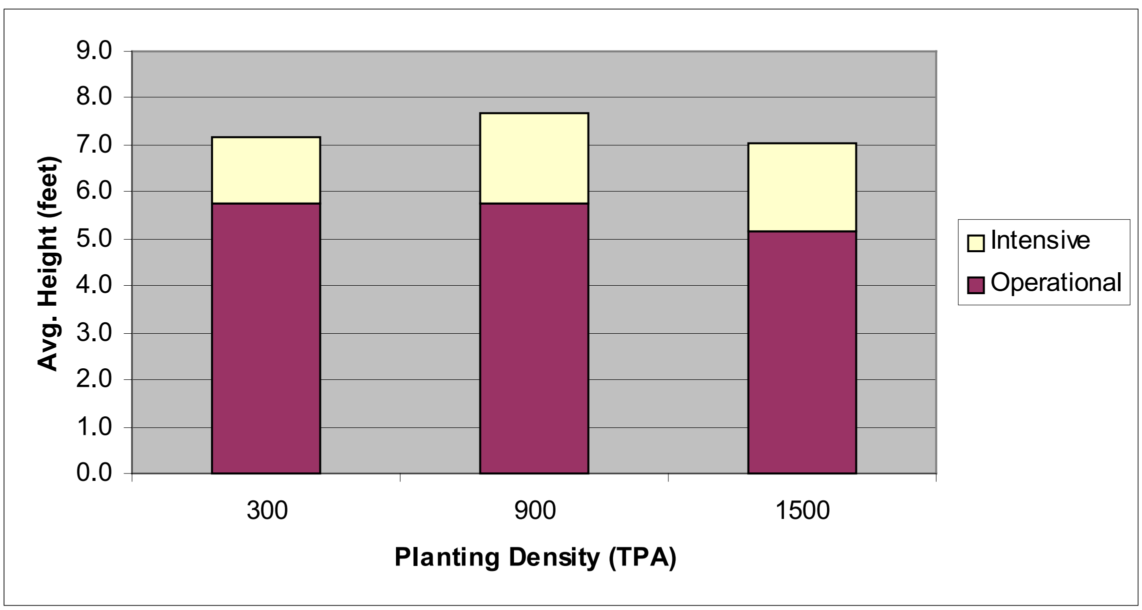

Figure 19. Average height by management intensity and density for CRIFF soil type B1 for slash pine.

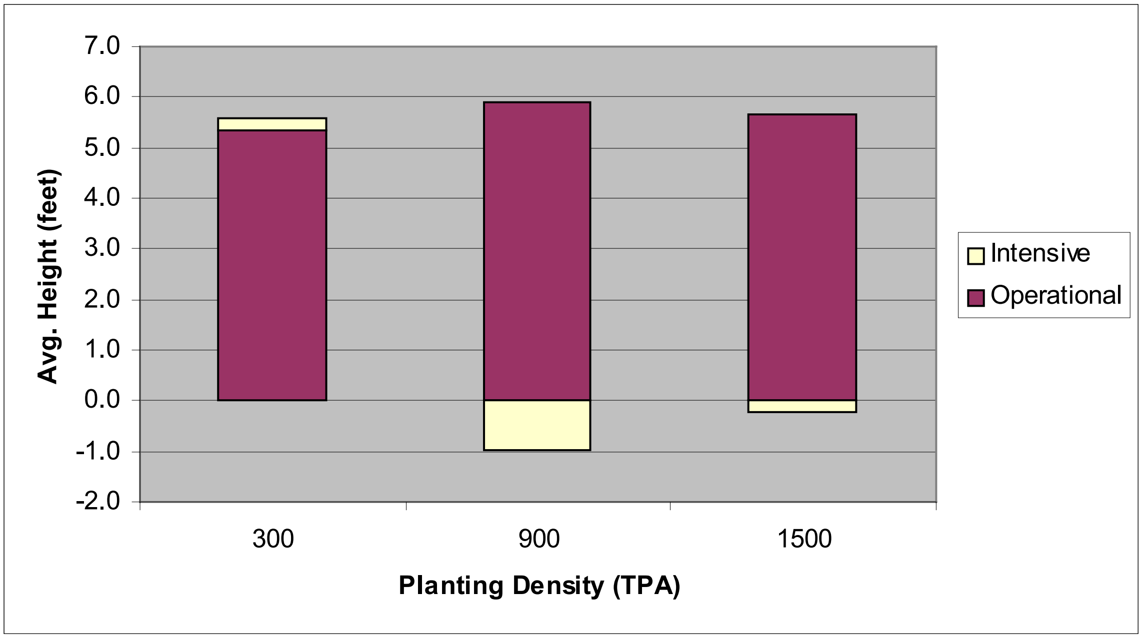

Figure 20. Average height by management intensity and density for CRIFF soil type B2 for slash pine.

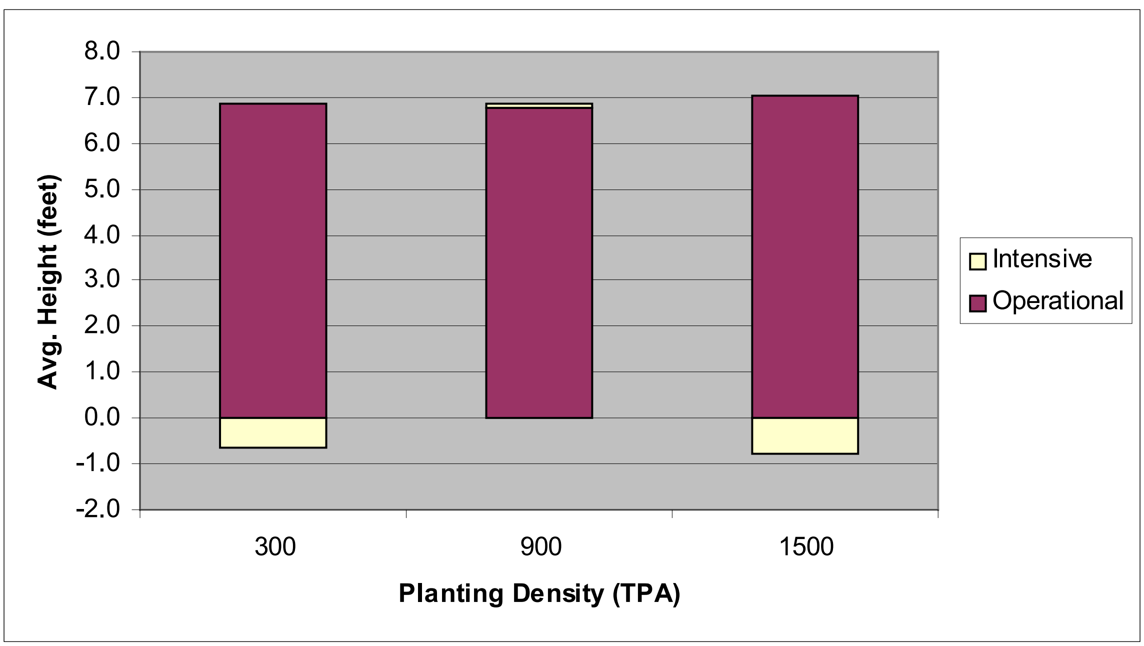

Figure 21. Average height by management intensity and density for CRIFF soil type C for slash pine.

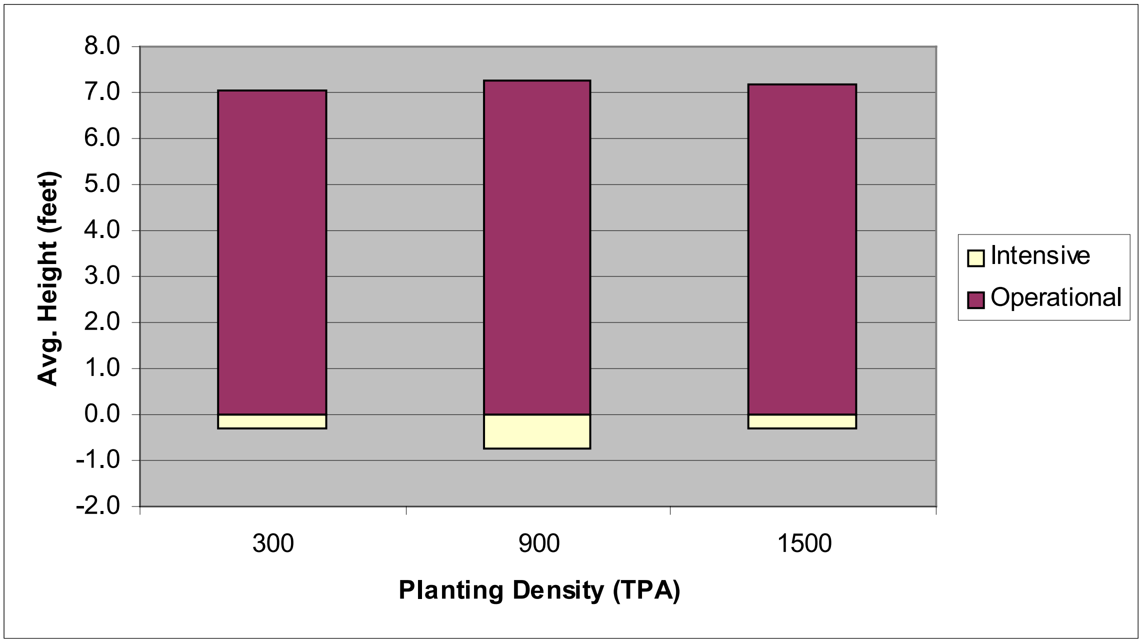

Figure 22. Average height by management intensity and density for CRIFF soil type D for slash pine.

4.3 Percent Cronartium Infection

Table 8 shows the results of the analysis of variance for slash pine average percent cronartium infection. The majority of slash pine plots had no cronartium infection and all but two plots had an infection rate less than 4.5%. The two exceptions had infection rates of 11% and 30%. There were no significant differences in cronartium infection rates due to any factor included in the analysis of variance.

Table 8. Analysis of variance results for slash pine average percent cronartium infection.

Source	df	Type III F	Pr > F
Soil	3	0.90	0.5041
Management	1	1.48	0.2779
Soil x Management	3	1.02	0.4577
Density	2	1.57	0.2275
Soil x Density	6	0.96	0.4715
Management x Density	2	1.50	0.2408

*Significant at ∀ = 0.05.

5 SPECIES COMPARISON

A graphical comparison was carried out to assess differences in height and DBH growth of slash and loblolly pine. Figures 23-26 show the average DBH's by species, density and treatment level for each soil group. Figures 27-30 show the average heights.

On the B1 soils, the loblolly had a slightly larger average DBH on the operational treatment plots. This difference increased with increasing planting density. On the more intensive treatment plots, the loblolly had a slightly higher average DBH than the slash.

The results on B2 soils were similar to the B1 soils. The loblolly pines had the same or slightly larger average DBH than the slash. The main difference on the B2 soils was that as density increased, the difference in average DBH between the operational and more intensive treatments decreased for both species.

On the C soils, the operational slash pine plots had a higher average DBH than the loblolly for all densities. For the more intensive treatments, the loblolly was larger at 300 tpa, both species had the same average DBH at 900 tpa, and the slash was slightly larger at 1500 tpa.

On D soils, the operational slash plots were 1.5 to 2 times larger than the loblolly in terms of DBH. On the more intensive plots, the slash and loblolly DBH's were about the same at 300 and 900 tpa. At 1500 tpa, the slash had a larger average DBH than the loblolly.

In terms of average height, the loblolly pine was consistently taller than the slash across densities and treatments for soil types B1, B2 and C. On the D soils, slash and loblolly had about the same average height on the operational treatment plots. The loblolly pines were slightly taller than the slash on the more intensive treatment plots.

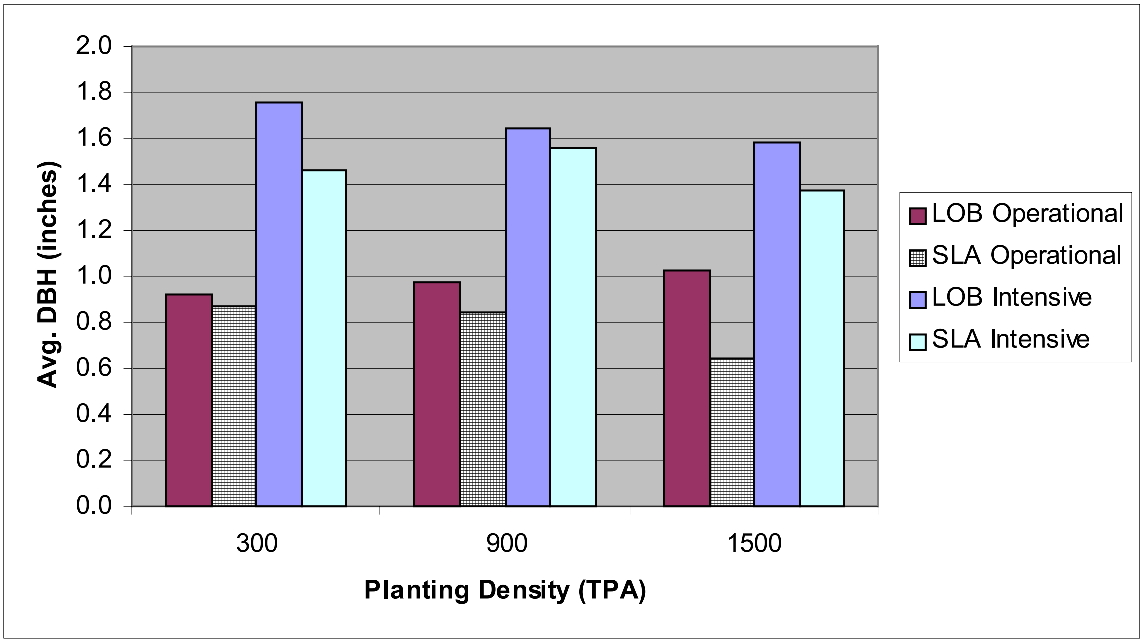

Figure 23. Average DBH by species, management intensity and density for CRIFF soil type B1.

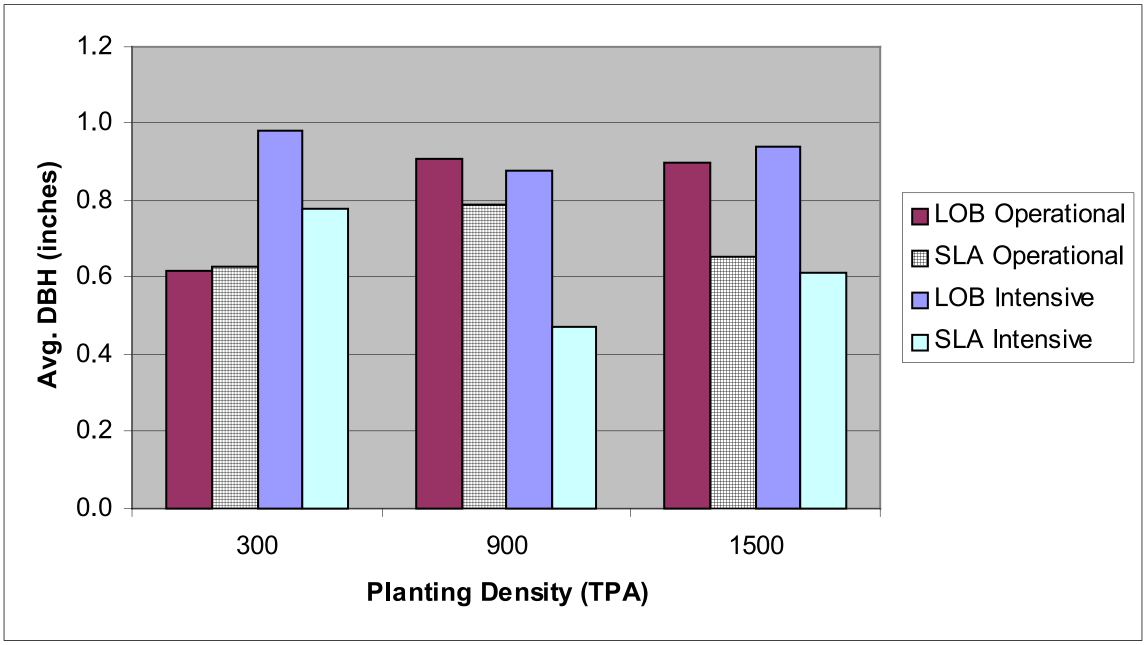

Figure 24. Average DBH by species, management intensity and density for CRIFF soil type B2.

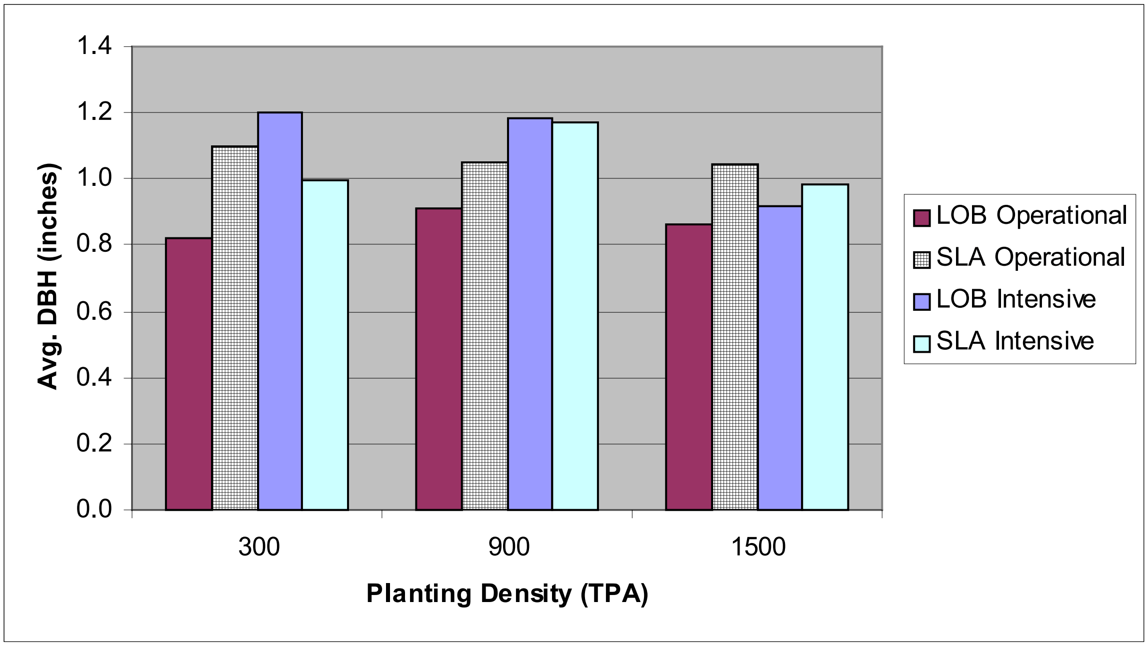

Figure 25. Average DBH by species, management intensity and density for CRIFF soil type C.

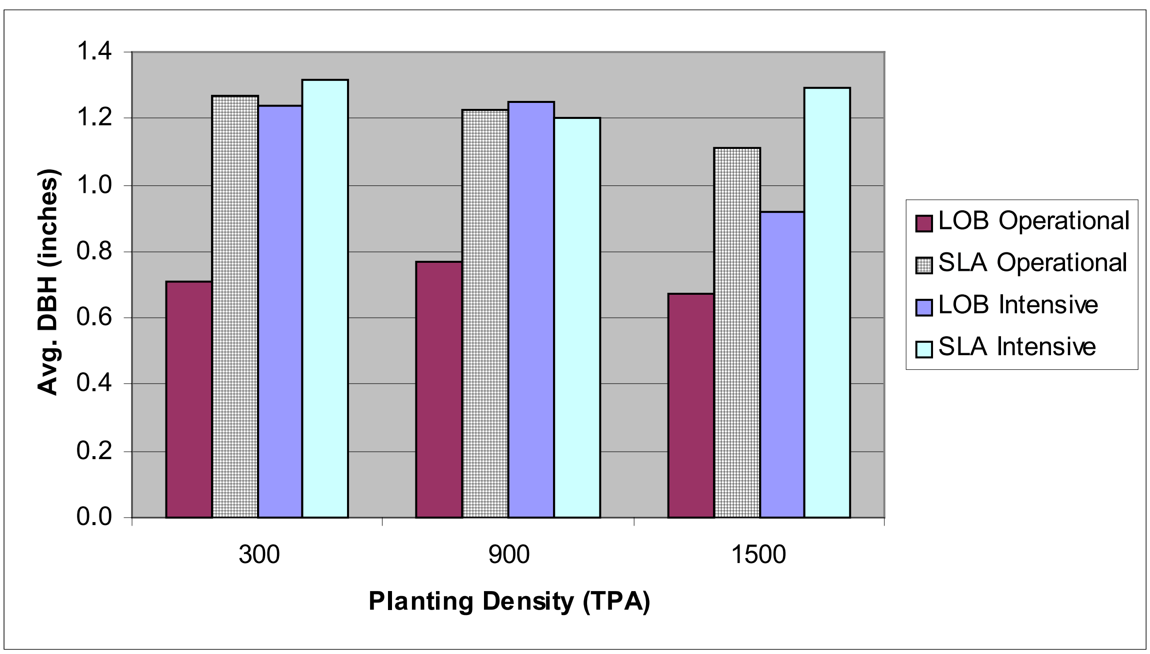

Figure 26. Average DBH by species, management intensity and density for CRIFF soil type D.

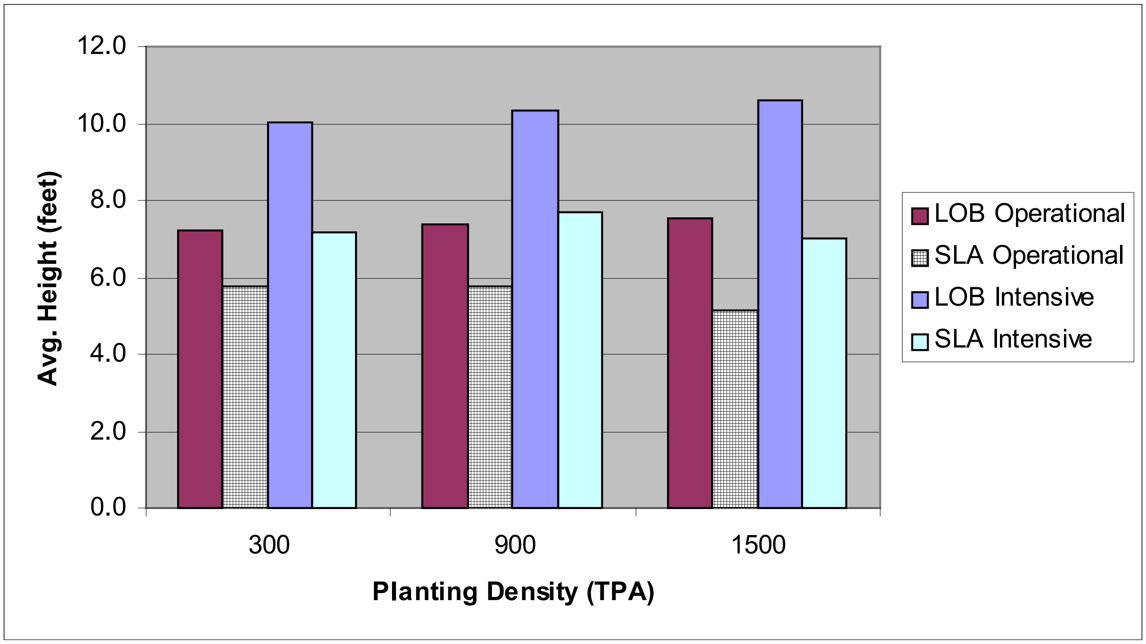

Figure 27. Average height by species, management intensity and density for CRIFF soil type B1.

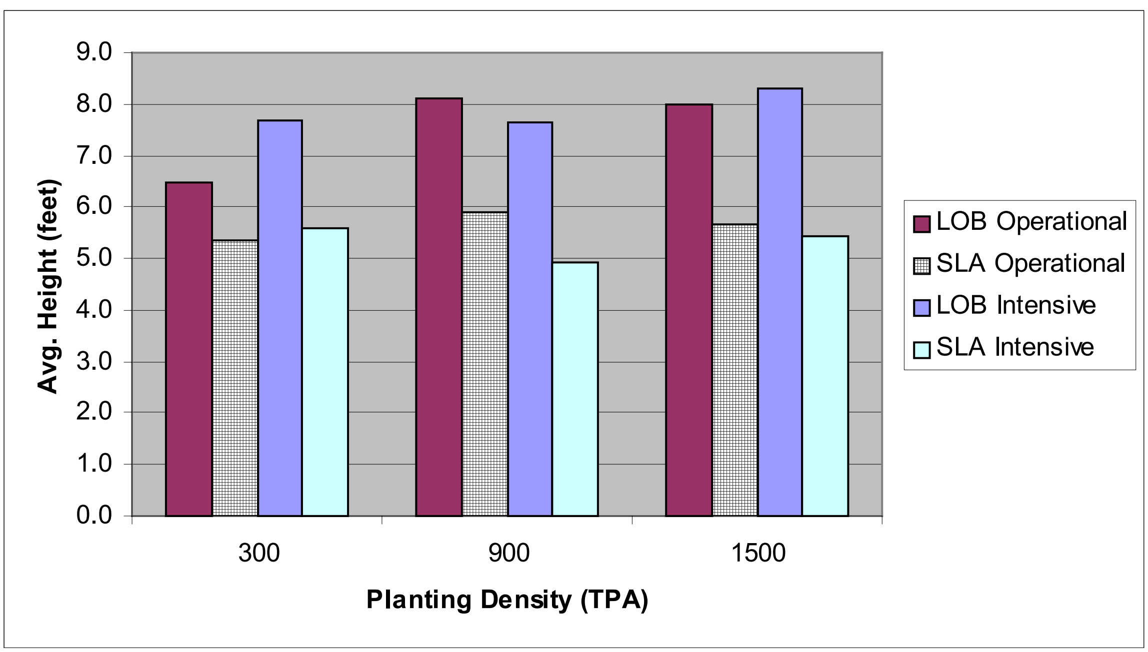

Figure 28. Average height by species, management intensity and density for CRIFF soil type B2.

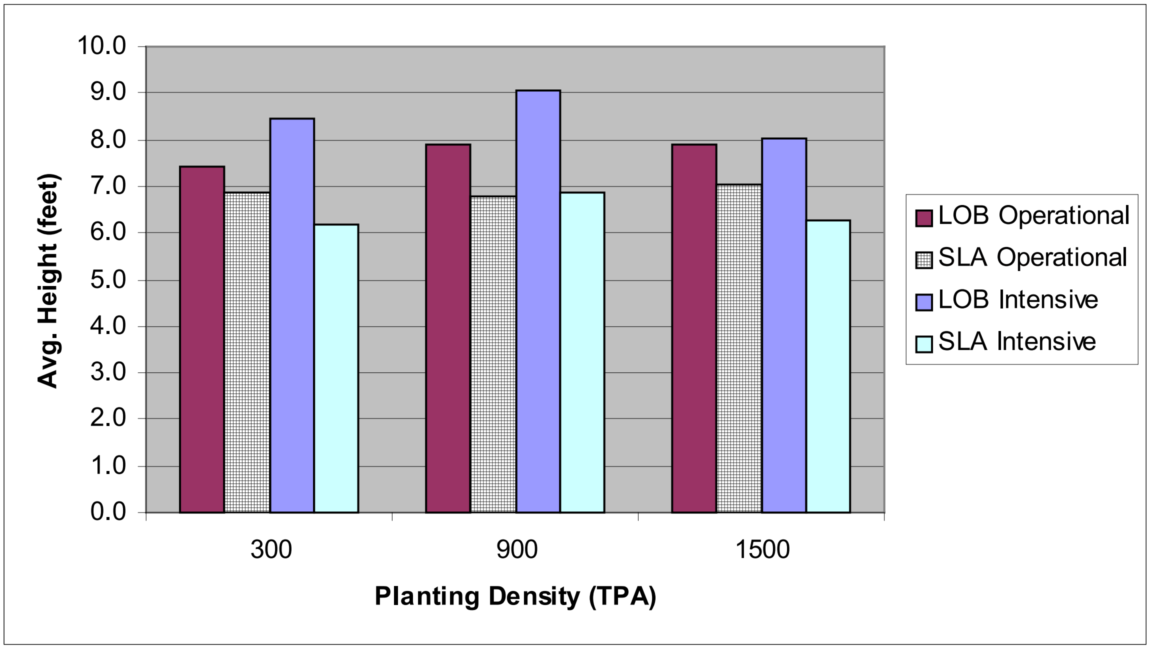

Figure 29. Average height by species, management intensity and density for CRIFF soil type C.

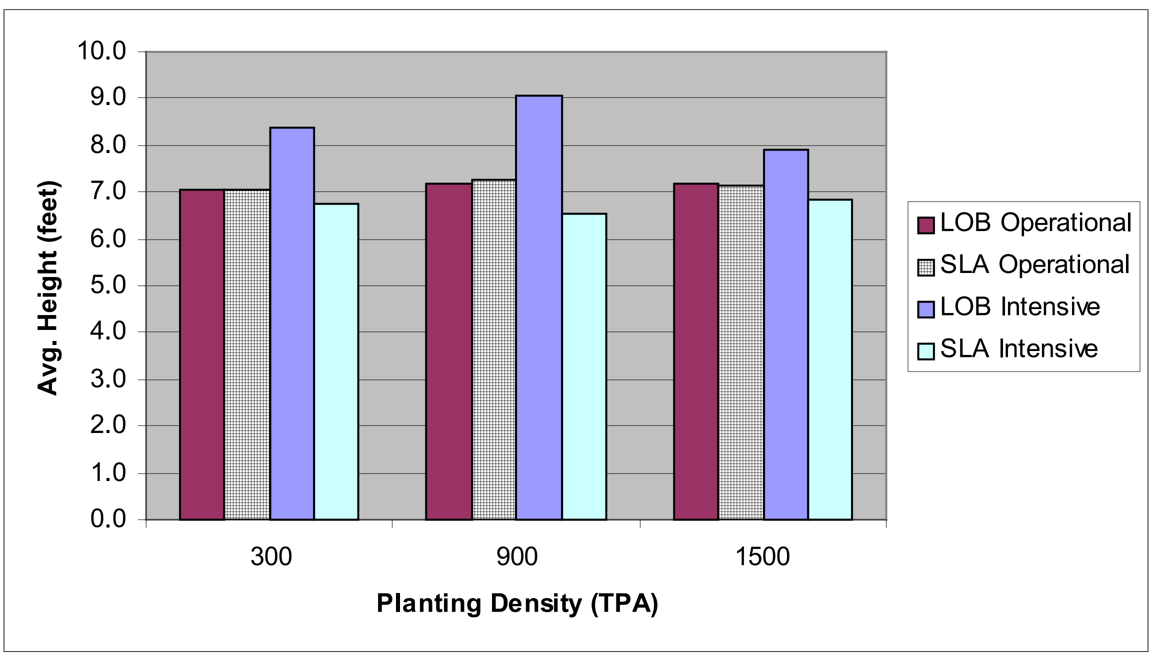

Figure 30. Average height by species, management intensity and density for CRIFF soil type D.

6 DISCUSSION

The data reported on here are from 2-year-old plantations so the results can only be considered preliminary. For both slash and loblolly pine, there was no significant density effect on average DBH, indicating that the onset of intra-specific competition has not yet occurred, even at densities of 1500 and 1800 trees per acre with accelerated growth. On the other hand, some potentially interesting trends are already emerging. Soil groups had no significant effect on average tree DBH or height, but for loblolly pine, management intensity did have an effect and there was a significant soil group x management intensity interaction for both variables. There was also a significant interaction between management intensity and density on average DBH.

Some interesting observations can also be made with regard to species . On spodosol sites (C and D soils), slash pine has either kept up with or surpassed loblolly pine through two growing seasons. Loblolly pine grew better than slash on the nonspodosols, and the differences generally increased with planting density. If these trends continue, the presence of significant interactions will allow forest managers to make better, site-specific decisions regarding species selection, silvicultural practices and planting densities.

7 LITERATURE CITED

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