SLASH PINE
IMPROVED PLANTING STOCK-
VEGETATION CONTROL STUDY-
AGE 12 RESULTS

Plantation Management Research Cooperative

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EXECUTIVE SUMMARY

A designed experimental study was established at 19 locations in the Coastal Plain region of Georgia and northern Florida with the objective of evaluating the impacts of first generation genetic improvement, and of combining genetic improvement and vegetation control on yields of slash pine. A mixed model approach was used to analyze the age 12 measurements for this study and the 3-year periodic growth from ages 6 to 9, and 9 to 12 years. Installation and all installation interactions were treated as random factors and competition control and genetics were treated as fixed factors. The two levels of competition control were either none other than that provided by the operational site preparation or complete control. Genetic improvement was either unimproved, bulk lot first generation improved stock or single family.

Competition control significantly increased average tree characteristics and basal area per acre. Average dominant height and basal area per acre were significantly increased by improved genetics. Total volume was significantly increased by both improved genetics and competition control. In terms of total volume, increases of approximately 50% can be obtained from using complete vegetation control. Improved genetic stock can increase total volume an average of 12% to 13%. For both total and merchantable volume the effects of competition control and improved genetics were additive. This additive nature of the effects indicates that managers should obtain the full benefit of these treatments. In the Coastal Plain region, neither competition control nor genetics significantly affected surviving trees per acre. Improved genetics significantly reduced the percent fusiform infection while the increased growth due to the competition control treatment led to an increase in the rust infection rate. No significant differences were detected between bulk lot and single family plantings across all dependent variables.

The results of the 3-year periodic growth analysis indicated no differences in mean dbh growth due to vegetation control or genetics. In terms of mean dominant height, improved genetic stock continued to outgrow the unimproved stock. During the 3-year period between 9 and 12 years there were no significant differences in dominant height growth between the two levels of competition control. Improved genetics and complete competition control continued to significantly increase volume growth during both periods. In terms of total volume per acre, the effects of the two treatments have been essentially additive throughout the life of the study.

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1 INTRODUCTON

PMRC studies have shown that control of competing vegetation can increase productivity in pine plantations by as much as 100 percent (Pienaar and Rheney, 1995). Another widely used regeneration practice is planting genetically improved seedlings. Results from slash pine first generation progeny tests indicate that volume gains from 7% to 19% (Talbert et al. 1985) are possible. Progeny tests, however, were typically planted as single row plots and often received better cultural treatments, such as mowing and fertilization, than operational plantations. It is likely that these cultural treatments could confound and possibly exaggerate results from progeny tests. Data from these row plots are not useful for developing growth and yield systems that provide breakdowns of stand structure in addition to total yield. Consequently, it is difficult for forest planners to estimate potential gains from using these genetically improved seedlings.

The PMRC designed and installed a study in 1986-87 with the following objectives:

(1) to compare the stand structure and yields of improved and unimproved plantations, with and without competing vegetation,

(2) to examine any interaction effects of genetic improvement and competition control,

(3) to evaluate single family genetically improved plantations versus bulk lot genetically improved plantations, and

(4) to identify and model different mortality patterns and rust infection levels of improved and unimproved plantations, with and with vegetation control.

This paper summarizes the results of the age 12 measurement analysis of slash pine for this study. Also included are the results of the analysis of the 3-year growth between ages 6 to 9 and 9 to 12 years.

2 STUDY DESIGN

A designed experimental study was established at 19 locations in the Coastal Plain region of Georgia and northern Florida. Two of these locations were planted during the 1986 planting season and 17 locations were planted in 1987. Genetically improved seed were obtained by polling the PMRC membership to determine the top ten families for each company. The six top-ranked families were tentatively scheduled for inclusion in the study. The families were then checked by personnel at the University of Florida Tree Improvement Program. They compared the family rankings with those provided by the PMRC cooperators and paid particular attention to disease resistance. Once the families were approved, seeds were obtained from rogued first generation open-pollinated seed orchards owned by PMRC cooperators. North Carolina State cooperative identification numbers identify the families chosen for the study in Table 1.

Table 1. Family identification numbers for the slash pine Improved Planting Stock-Vegetation Control Study.

Coastal Plain Slash
106-56
6-56
35-60
56-56
261-56
187-57

Unimproved seed was obtained from International Forest Seed Company. This unimproved seed was obtained in the same region encompassed by the study and from areas other than seed orchards or seed production areas.

Bulk lot improved stock was obtained by mixing equal amounts of seed from the six selected families for a particular region. The seedlings were grown at the Union Camp Corporation nursery at Belleville, Ga. Some seed from each family was kept separate and grown in separate nursery beds for the single family plantings.

Eight 0.4 ac treatment plots were included at each study installation:

(1) Unimproved stock, no vegetation control (UNC),
(2) Unimproved stock, complete vegetation control (UCC),
(3) Bulk lot improved stock, no vegetation control (BNC),
(4) Bulk lot improved stock, complete vegetation control (BCC),
(5) Replicate plot of one of the first four treatments,
(6) Single family improved stock, no vegetation control (SNC),
(7) Single family improved stock, complete control (SCC), and
(8) Replicate plot of one of the single family treatments.

Plots were randomly assigned to each of the six 2x3 factorial treatment combinations. In addition, one of treatments 1-4 and one of treatments 5-6 were randomly assigned to the remaining two plots at each installation. Only one single family was assigned to an installation and the assignments were made at random. Therefore, each family was planted on two to three installations on average. Most locations had some mechanical site preparation as the operational treatment. In the Lower Coastal Plain, the operational site preparation treatment was primarily bedding, while in the Upper Coastal Plain site preparation treatments ranged from chop and burn to shear, rake and disc. Each plot was 0.4 acre in size with a centrally located 0.2 acre measurement plot. The two levels of vegetation control were either none, other than that provided by the operational site preparation treatment applied by the cooperator prior to planting, or complete control of all competing vegetation. Complete control was achieved and maintained by killing woody vegetation prior to planting with prescribed herbicides, by spraying sulfometuron methyl in early spring of each of the first three growing seasons, and by directed sprays of glyphosate and triclopyr as needed during the growing season.

Seedlings were hand-lifted and planted at a density of 700-750 trees per acre. After the third growing season, every third pine tree on the measurement plot was measured for total height (ft). After the sixth, ninth and twelfth growing seasons, each tree was measured for dbh to the nearest 0.1 inch and checked for stem cankers caused by fusiform rust (*Cronartium quercum* f. sp. *fusiforme*). Tagged trees on each plot were measured for height to the nearest foot. The tree height data were used to develop height-diameter regression equations for each plot to estimate the heights of the unmeasured trees. The following height-diameter relationship was fit to each plot at each measurement age:

$$LH = b_0 + b_1 D^{-1}$$

where LH=natural log of height (ft), D=diameter (0.1 in.), and b_0 and b_1= parameter estimates from sample data.

Total (outside bark) and merchantable (4-in. min. diameter and 3-in. top ob) tree volumes were estimated using total and merchantable volume equations developed by Pienaar *et al*. (1987).

3 AGE 12 ANALYSIS AND RESULTS

Installations and all installation interactions were treated as random factors of the experiment, since region-wide recommendations were the objectives of the study. The replication within an installation represented an attempt to quantify the within-location error. We used a mixed model approach for the analysis because it allows for the mixed effects and unbalanced nature of this design. Competition control and genetics were treated as fixed factors. The two levels of competition control were either none other than that provided by the operational site preparation or complete control. Genetic improvement was either unimproved, bulk lot or single family. Analyses were completed separately on the following dependent variables: average dbh, average dominant height, surviving trees per acre, basal area per acre, total and merchantable stem volume per acre and percent fusiform rust infection. Effects of genetic improvement were calculated by averaging across both vegetation control treatments, and effects of vegetation control were determined by averaging across both unimproved and improved genetic treatments. Tukey's studentized range test was used to conduct pairwise comparisons of least square means to detect differences between individual treatment level means. All statistical tests were conducted at the overall significance level (experimentwise error rate) of a=0.05. To obtain the correct degrees of freedom for this analysis the Satterthwaite option in SAS®'s PROC MIXED (Littell et al. 1996) procedure was used. Unlike traditional analyses, the degrees of freedom may vary between dependent variables. In the discussion of the results, gains due to differences were calculated as differences in least squares means. Least square means are the estimated marginal means over a balanced population.

3.1 Average DBH

Table 2 gives the results of the tests of fixed effects for average dbh for slash pine. Competition control significantly increased average dbh by an average of 0.75 inches across all levels of genetic stock. There were no significant effects of genetics on average dbh. Table 3 and Figure 1 summarize the least square means for average dbh by treatment.

Table 2. Test of fixed effects for average dbh (inches) for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	106	1.25	0.2916
Competition Control	1	17.3	95.69	0.0001
Genetics* Competition Control	2	105	0.05	0.9524

Table 3. Summary of least squares means for average dbh (inches) for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	4.56	5.32	4.94
Bulk Lot	4.66	5.39	5.03
Single Family	4.65	5.41	5.03
Average	4.62	5.37	5.00

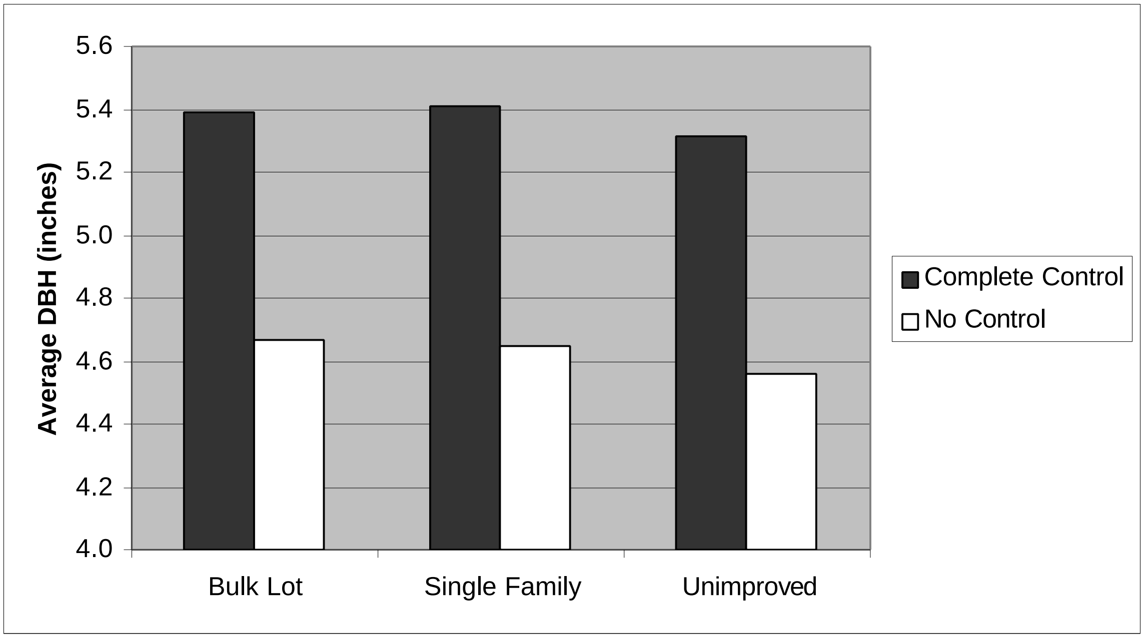

Figure 1. Mean dbh by treatment for 12-yr-old slash pine.

3.2 Range and Skewness of the DBH Distribution

There were no significant differences between the mean range of the dbh distributions for each treatment combination due to genetics. Genetics significantly affected the skewness of the distribution. While there were no differences between single family and bulk lot, both decreased the skewness statistic by 0.2 over unimproved stock indicating that improved genetics skewed the dbh distribution to the left. This means that the dbh distribution has fewer trees in smaller dbh classes and more trees in larger dbh classes.

3.3 Average Dominant Height

Table 4 gives the results of the tests of fixed effects for average dominant height. Competition control significantly increased average dominant height by an average of 4.2 feet at age 12 across all levels of genetic stock. Genetic stock also significantly increased average dominant height. While there was no significant difference between single family and bulk lot, dominant height increased by 2.3 feet and 2.4 feet, respectively, over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 5 and Figure 3 summarize the least square means for average dominant height by treatment.

Table 4. Test of fixed effects for average dominant height (ft) for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	35	9.08	0.0007
Competition Control	1	17.1	51.85	0.0001
Genetics* Competition Control	2	32.7	0.26	0.7715

Table 5. Summary of least squares means for average dominant height (ft) for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	34.4	38.4	36.4
Bulk Lot	36.9	40.8	38.8
Single Family	36.4	41.0	38.7
Average	35.9	40.1	38.0

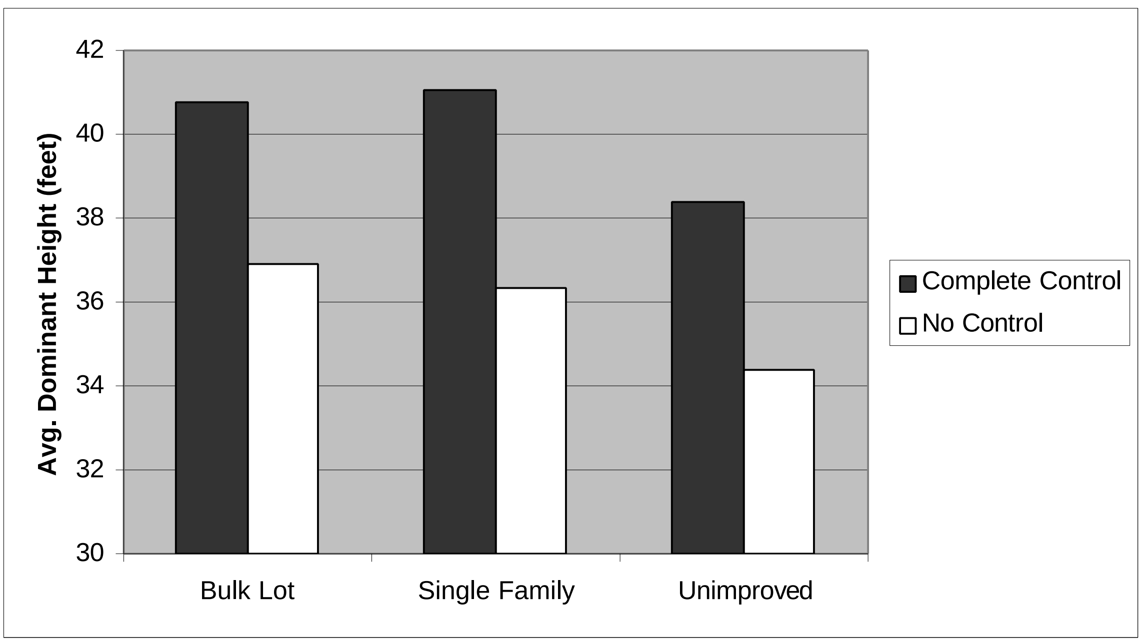

Figure 2. Mean dominant height by treatment for 12-yr-old slash pine**.**

3.4 Basal Area per Acre

Vegetation control significantly affected basal area per acre for slash pine (Table 6). Competition control significantly increased basal area an average of 24.5 ft^2/ac across all levels of genetic stock. Genetic stock did not have a significant effect on basal area per acre. While there was no significant difference between single family and bulk lot, or between bulk lot and unimproved, single family increased basal area by 5.4 ft^2/ac over unimproved stock. The interaction between competition control and genetic stock was not significant indicating the effects are additive in nature (Figure 3). Table 7 summarizes the least square means for basal area per acre.

Table 6. Test of fixed effects for basal area (ft^2/ac) for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	63.4	3.01	0.0565
Competition Control	1	17.2	80.92	0.0001
Genetics* Competition Control	2	65.3	0.73	0.4876

Table 7. Summary of least squares means for basal area (ft^2/ac) for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	80.2	100.9	90.5
Bulk Lot	83.4	109.9	96.6
Single Family	82.8	108.9	95.9
Average	82.1	106.6	94.4

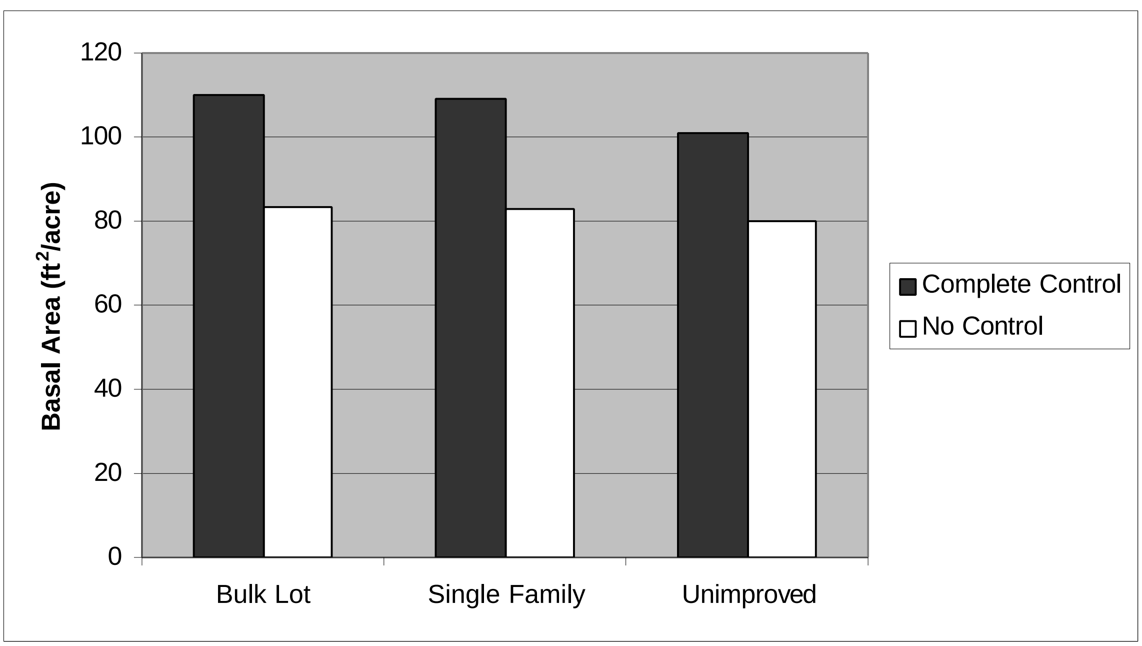

Figure 3. Basal area per acre by treatment for 12-yr-old slash pine.

3.5 Total Volume per Acre

Table 8 gives the results of the tests of fixed effects for total outside bark volume per acre. Competition control significantly increased slash pine yield by an average of 612 ft^3/ac across all levels of genetic stock. Genetic stock also significantly increased total volume per acre. While there was no significant difference between single family and bulk lot, they increased yield by 204 ft^3/ac and 220 ft^3/ac, respectively, over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 9 and Figure 4 summarize the least square means for total volume per acre by treatment.

Table 8. Test of fixed effects for total volume (ft^3/ac) for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	62.3	6.84	0.0021
Competition Control	1	17.2	79.39	0.0001
Genetics* Competition Control	2	64.2	0.86	0.4282

Table 9. Summary of least squares means for total volume (ft^3/ac) for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	1395.7	1907.6	1651.6
Bulk Lot	1537.2	2205.6	1871.4
Single Family	1527.3	2183.4	1855.3
Average	1486.7	2098.8	1792.8

3.6 Merchantable Volume per Acre

Results for merchantable volume were essentially the same as for total volume. Competition control significantly increased merchantable volume (3-in. top) an average of 675 ft^3/ac. across all levels of genetic stock (Table 10). A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased merchantable yield 217 ft^3/ac and single family 203 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 11 and Figure 5 summarize the least square means for merchantable volume by treatment.

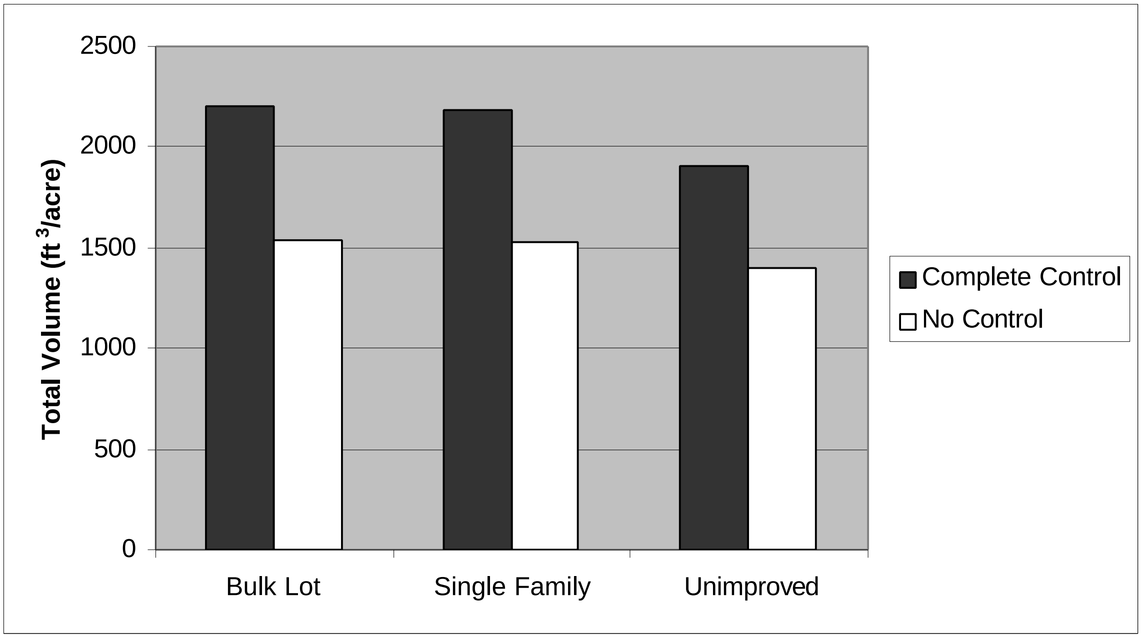

Figure 4. Total Volume per acre by treatment for 12-yr-old slash pine.

Table 10. Test of fixed effects for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	59.9	6.76	0.0022
Competition Control	1	17.1	86.19	0.0001
Genetics* Competition Control	2	61.9	0.68	0.5120

Table 11. Summary of least squares means for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	1107.7	1693.9	1400.8
Bulk Lot	1255.2	1979.6	1617.4
Single Family	1246.8	1960.9	1603.8
Average	1203.2	1878.1	1540.7

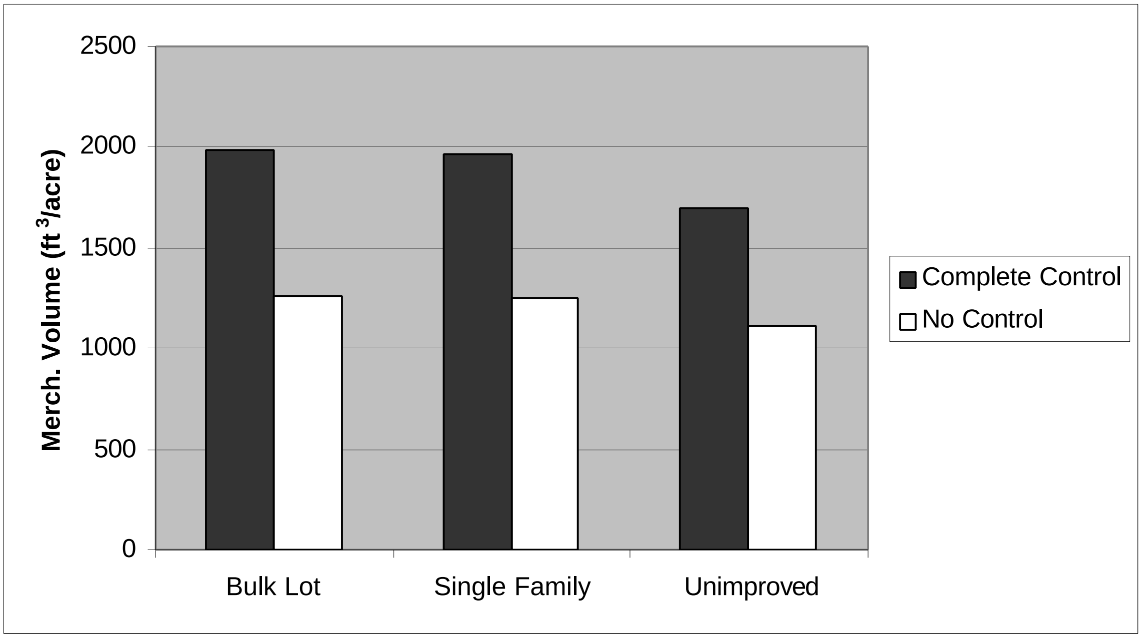

Figure 5. Merchantable volume (3-in. top) per acre by treatment for 12-yr-old slash pine.

3.7 Trees per Acre

There were no significant differences in trees per acre due to genetics or competition control in the Coastal Plain (Table 12). There was an average of 654 surviving trees per acre after 12 years for all slash pine installations (Figure 6).

Table 12. Test of fixed effects for trees per acre for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	80.9	0.31	0.7350
Competition Control	1	83.7	3.43	0.0677
Genetics* Competition Control	2	84.1	1.53	0.2232

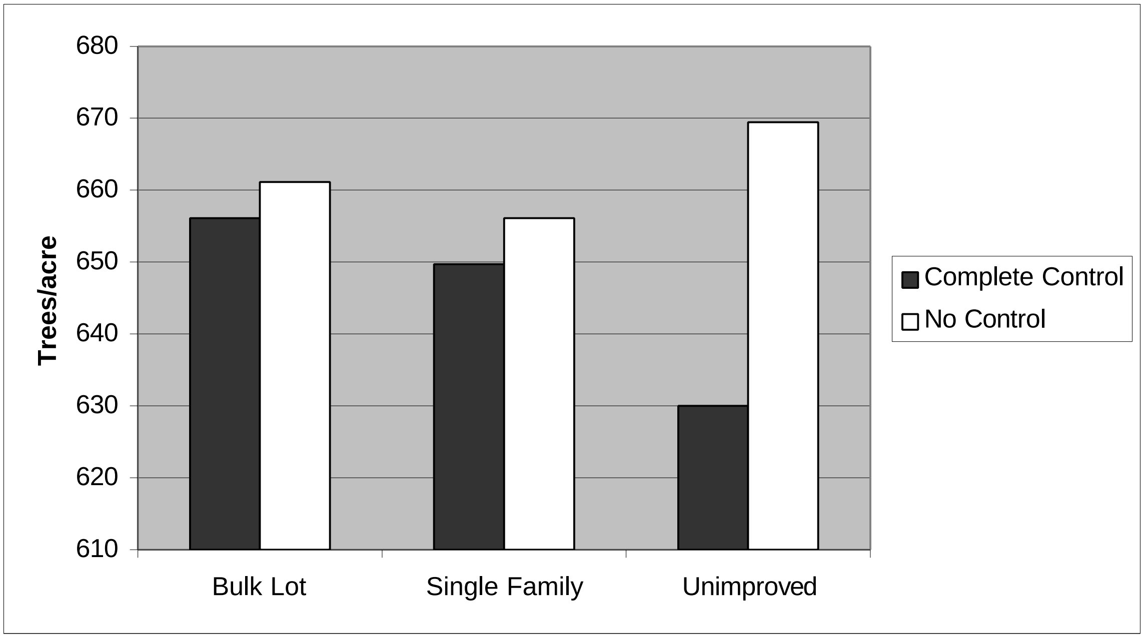

Figure 6. Trees per acre by treatment for 12-yr-old slash pine.

3.8 Percent Fusiform Infection

Genetic improvement significantly contributed to reduced percent fusiform infections in the slash pine plots (Table 13). There were no significant differences between bulk lot and single family, but both reduced percent fusiform infections from 19% to 14% and 12.7%, respectively, over unimproved stock. Vegetation control significantly increased the rust infection level by 7.3% over the no vegetation control treatment (Table 14, Figure 7).

Table 13. Test of fixed effects for percent fusiform infection for slash pine at age 12.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	32.8	5.00	0.0127
Competition Control	1	17.2	31.97	0.0001
Genetics* Competition Control	2	69.1	1.24	0.2963

Table 14. Summary of least squares means for percent fusiform infection for slash pine at age 12.

	No Control	Complete Control	Average
Unimproved	14.6%	23.5%	19.0%
Bulk Lot	10.7%	17.3%	14.0%
Single Family	9.5%	15.9%	12.7%
Average	11.6%	18.9%	15.3%

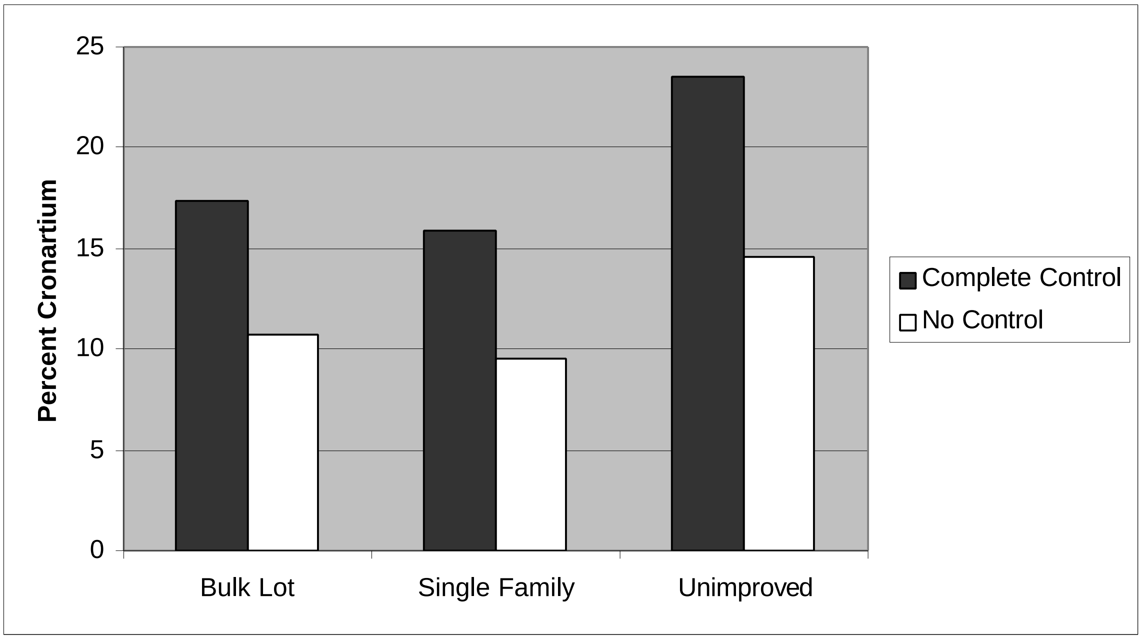

Figure 7. Percent fusiform rust infection by treatment for 12-yr-old slash pine.

4 THREE-YEAR PERIODIC GROWTH

An analysis was conducted to examine the 3-year periodic growth, between ages 6 and 9, and 9 and 12, of the dependent variables. The objective was to determine whether genetics and competition control are continuing to contribute to increased growth rates or whether the treatment combination means are converging over time.

The 3-year periodic growth in mean dbh between ages 6 and 9, and 9 and 12 are not significantly different for the competition control treatments (Table 15). These results indicate that the advantage in mean dbh for the competition control treatment is being maintained over time (Figure 8).

Table 15. Average difference (in.) in mean dbh growth for the two 3-year periods. Different letters indicate a significant difference between complete vegetation control and no control.

3-year period	CC	NC
6 to 9	1.03 (a)	1.06 (a)
9 to 12	0.65 (a)	0.66 (a)

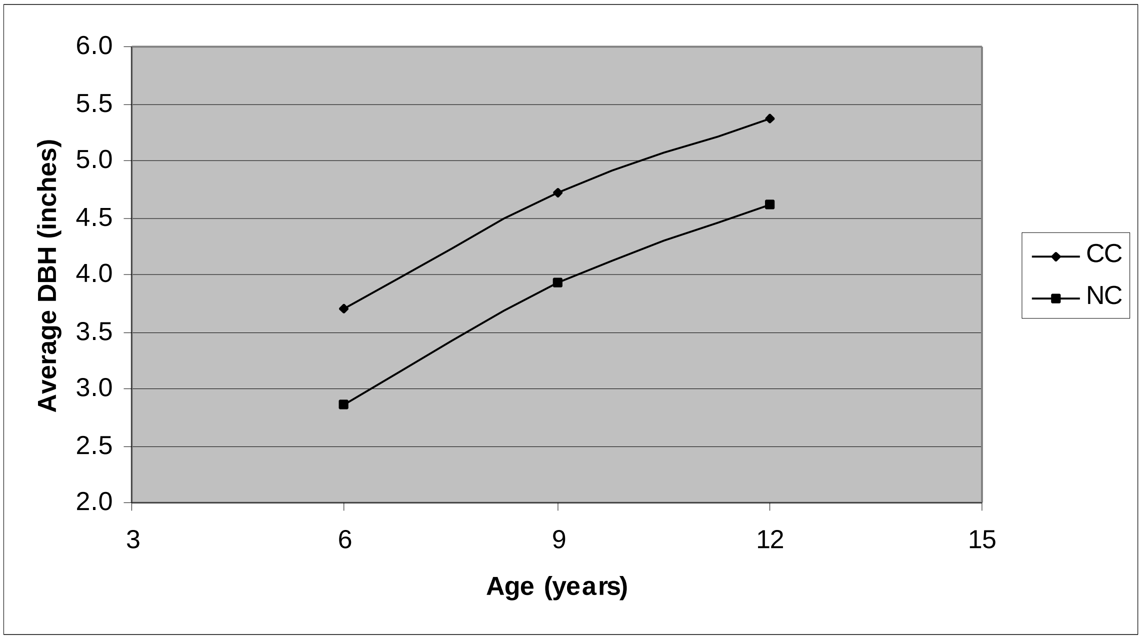

Figure 8. Mean dbh for the two competition control treatments for slash pine.

In terms of mean dominant height, improved genetic stock continues to outgrow the unimproved stock (Table 16). Figure 9 shows that mean dominant height for the improved versus unimproved genetic stock continues to diverge. The dominant height growth curves for the single family and bulk lot improved treatments are nearly identical. There was no significant difference in dominant height growth during the 3-year period from 9 to 12 attributed to competition control, indicating that the mean periodic dominant height growth for the two competition control treatments are no longer diverging (Table 17, Figure 10).

Table 16. Average difference (ft) in mean dominant height growth for the two 3-year periods. Different letters indicate a significant difference between genetic treatments.

3-yr period	UI	BL	SF
6 to 9 yr	9.71 (a)	10.22 (a)	10.20 (a)
9 to 12 yr	8.01 (a)	8.64 (b)	8.50 (a,b)

Table 17. Average difference (ft) in mean dominant height growth for the two 3-year periods. Different letters indicate a significant difference between complete vegetation control and no control treatments.

3-year period	CC	NC
6 to 9	10.42 (a)	9.66 (b)
9 to 12	8.44 (a)	8.33 (a)

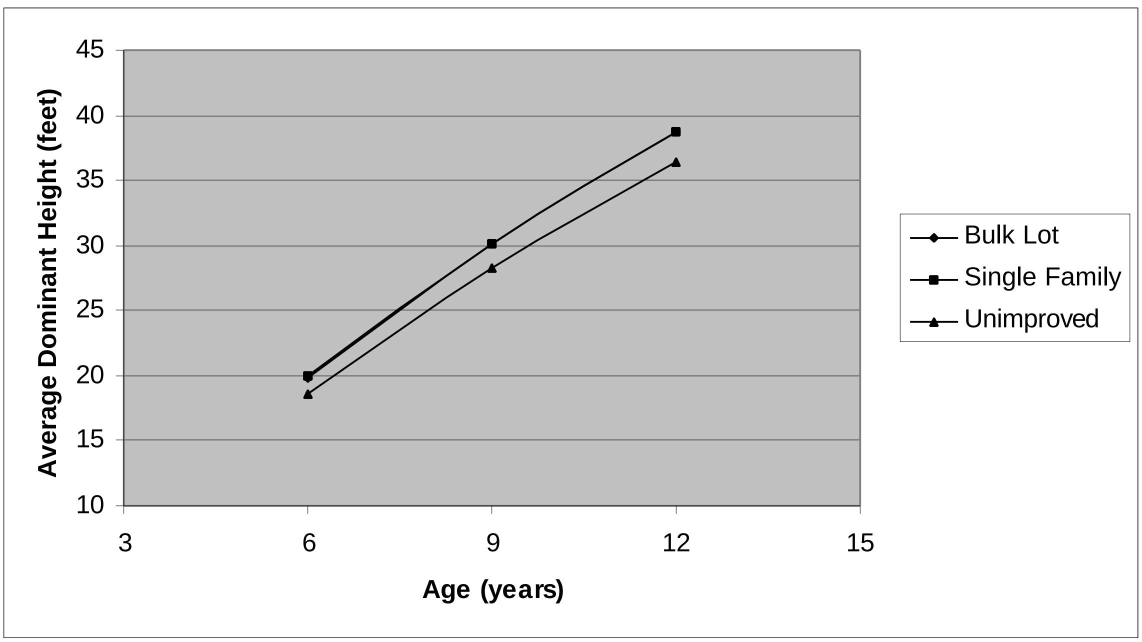

Figure 9. Mean dominant height for the two competition control treatments for slash pine.

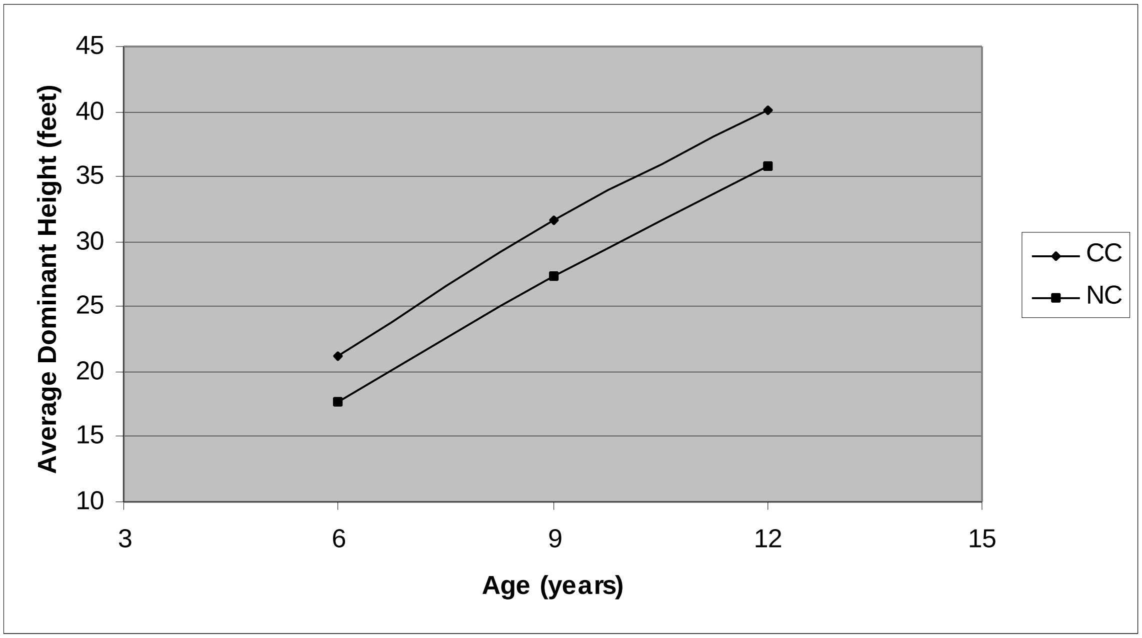

Figure 10. Mean dominant height for the three genetic treatments for slash pine.

There were significant differences between mean growth of basal area per acre for competition control during the period between 6 and 9 years. Complete control was still exceeding no control in growth. During the period between 9 and 12 years there was no significant difference between competition control treatments. These results indicate that the early gains in basal area per acre due to competition control are being maintained (Figure 11 and 12). The absolute gain in basal area per acre at age 12 averages approximately 22 ft^2/acre, indicating the large gains due to the complete control of competing vegetation.

Table 18. Average difference (ft^2) in mean basal area growth for the two 3-year periods. Different letters indicate a significant difference between complete vegetation control and no control.

3-yr period	CC	NC
6 to 9 yr	35.54 (a)	29.51 (b)
9 to 12 yr	21.85 (a)	19.85 (a)

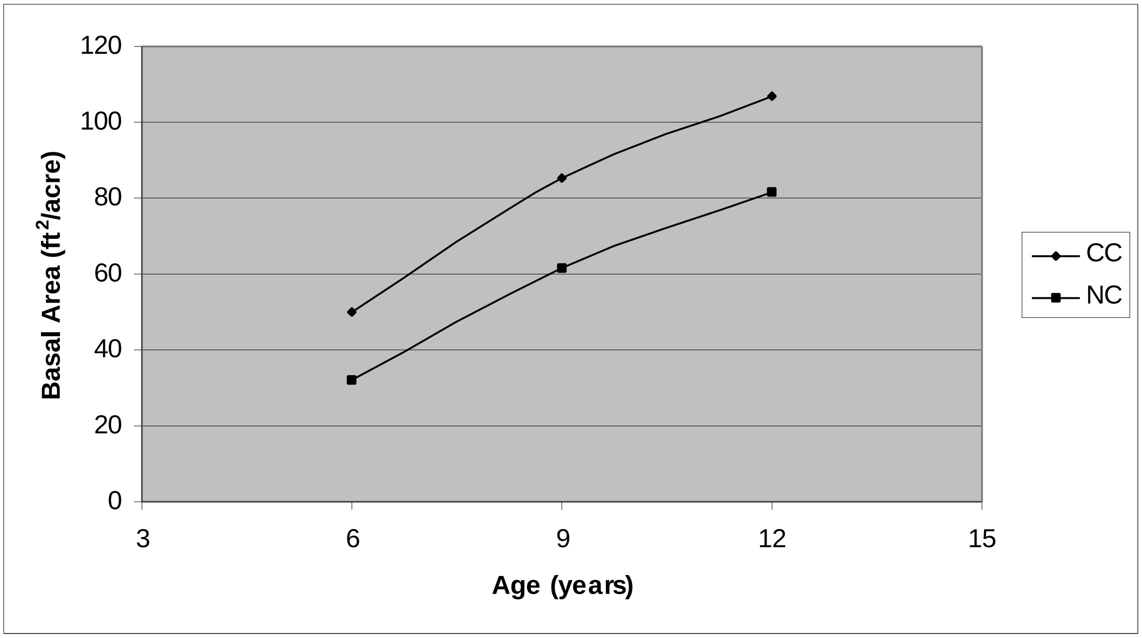

Figure 11. Mean basal area per acre for the two competition control treatments for slash pine.

Genetics and competition control continued to significantly increase volume growth during both periods (Tables 19 and 20, Figure 12). During the period from 6 to 9 years, both competition control and genetics additively increased volume growth for slash pine. It is obvious from these results that volume growth curves have not yet reached their inflection points for any of the treatment combinations.

Table 19. Average difference (ft^3/acre) in total volume for the two 3-year periods. Different letters indicate a significant difference between genetic treatments.

3-yr period	UI	BL	SF
6 to 9 yr	638 (a)	687 (a,b)	696 (b)
9 to 12 yr	616 (a)	696 (b)	678 (b)

Table 20. Average difference (ft^3/acre) in total volume growth for the two 3-year periods. Different letters indicate a significant difference between complete vegetation control and no control treatments.

3-year period	CC	NC
6 to 9	789 (a)	558 (b)
9 to 12	737 (a)	589 (a)

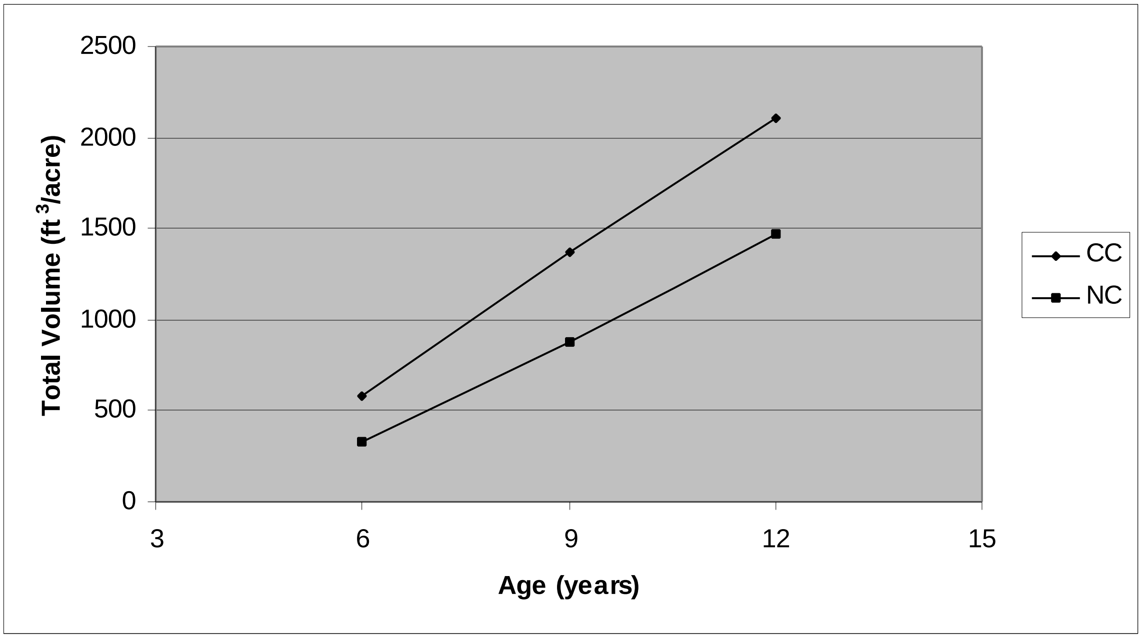

Figure 12. Total volume (ft^3/ac) for two competition control treatments for slash pine.

Improved genetics continued to significantly reduce mean fusiform infections during the period from 6 to 9 yrs, and while not significantly different, the improved genetic stock also had a smaller increase in infection percentage during the period from 9 to 12 years.

5 CONCLUSIONS

Competition control significantly increased average tree characteristics and basal area per acre for slash pine. Improved genetics had no significant effect on average dbh or basal area per acre. Average dominant height was significantly increased by improved genetics. Total and merchantable volume were significantly increased by both improved genetics and competition control, and the effects are additive in nature. Neither competition control nor genetics significantly affected trees per acre. Improved genetics significantly reduced the percent fusiform infection while competition control significantly increased the infection rate.

The results of the 3-year period growth analysis showed that there were no significant differences in dbh growth due to the competition control treatments. This indicates that the early gains due to competition control are being maintained through age 12 for slash pine. In terms of mean dominant height, improved genetic stock continued to outgrow unimproved stock. During the 3-year period between 9 and 12 years, there were no significant differences in dominant height growth between competition control and no competition control plots. Genetics and competition control continued to significantly increase volume growth during both periods. During the period from 6 to 9 years, both competition control and genetics additively increased volume growth.

The results of this study show that there is a clear benefit from using intensive competition control and improved genetics. In terms of total volume, increases up to 50% can be obtained from using complete vegetation control. Improved genetic stock can increase total volume an average of 12% to 13%. These volume percentage gains fall in the range estimated by progeny test conducted by Talbert et al. (1985). For the age 12 analyses, the gains in total and merchantable volume due to genetics and competition control were determined to be additive in nature which indicates managers can expect to receive the full benefit of both improved genetics and competition control if they use both treatments.

A separate analysis on this study will be completed to attempt to correlate growth with quantity and type of vegetation present on the plots. In addition, models will be developed with the intent of helping managers better estimate future gains from competition control, genetics and their interaction. This study is scheduled to be remeasured at age 15.

6 LITERATURE CITIED

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