LOBLOLLY PINE IMPROVED PLANTING STOCK-VEGETATION CONTROL STUDY: AGE 18 RESULTS

Plantation Management Research Cooperative

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EXECUTIVE SUMMARY

A designed experimental study was established at 16 locations in the Coastal Plain region of Georgia and northern Florida, and at 15 locations in the Piedmont region of South Carolina, Georgia and Alabama with the objective of evaluating the impacts of first generation genetic improvement, and of combining genetic improvement and vegetation control on yields of loblolly pine. A mixed model approach was used to analyze the age 18 measurements for this study and the 3-yr periodic growth from ages 15 to 18 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 dbh in the Coastal Plain an average of 0.56 in. across all levels of genetic stock. There were no significant effects of genetics on average dbh. In the Piedmont both vegetation control and genetics had significant effects on average dbh. Competition control significantly increased average dbh an average of 0.49 in. across all genetic stock. Bulk lot increased average dbh 0.24 in. and single family 0.20 in. over unimproved stock.

Competition control significantly increased average dominant height in the Coastal Plain an average of 4.0 ft at age 18 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 4.1 ft and 3.2 ft, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant. Similarly, in the Piedmont, both vegetation control and improved genetic stock had significant effects on average dominant height. Competition control significantly increased average dominant height an average of 3.9 ft across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased average dominant height 5.8 ft and single family 4.8 ft over unimproved stock. The interaction between genetic stock and competition control was not significant.

Both genetics and vegetation control significantly affected basal area per acre in the Coastal Plain. Competition control significantly increased basal area an average of 23.1 ft^2/ac across all levels of genetic stock. Genetic stock did not significantly increase basal area per acre as it had done in past measurements. The vegetation control treatment had the only significant effect on basal area per acre in the Piedmont increasing an average of 18.7 ft^2/ac across all genetic stock.

Competition control significantly increased yield in the Coastal Plain an average of 913 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 446 ft^3/ac and 344 ft^3/ac, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant.

In the Piedmont, both vegetation control and improved genetic stock had significant and additive effects on total volume. Competition control significantly increased yield an average of 715 ft^3/ac across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased yield 649 ft^3/ac and single family 639 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. The same factors were significant for merchantable volume as for total volume.

Competition control significantly increased yield in the Coastal Plain an average of 26 tons/ac across all levels of genetic stock. Genetic stock also significantly increased total green weight per acre. While there was no significant difference between single family and bulk lot, they increased yield by 13 tons/ac and 10 tons/ac, respectively, over unimproved stock. The interaction between competition control and genetic stock was not significant. In the Piedmont, both vegetation control and improved genetic stock had significant and additive effects on total green weight. Competition control significantly increased yield an average of 19 tons/ac across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased yield 19 tons/ac and single family 20 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. The same factors were significant for merchantable green weight as for total green weight.

There were no significant differences in trees per acre surviving at age 18 from either competition control or genetic stock in neither the Coastal Plain nor the Piedmont.

Genetic improvement significantly reduced fusiform rust infection rates in the Coastal Plain. There were no significant differences between improved genetics treatments, but both reduced percent fusiform infections from 20.9% for unimproved stock to 9.2% for bulk lot and 9.7% for single family. The vegetation control treatment significantly increased the rust infection level, but only by 1.4%. The Piedmont region had slightly different results. Genetic improvement significantly contributed to reduced percent fusiform. There were no significant differences between bulk lot and single family, but both decreased percent fusiform infections from 22.9% to 13.7% and 14.9%, respectively, over unimproved stock. Vegetation control did not significantly affect the rust infection level.

Genetic improvement led to significant increases in the proportion of trees without major defects in the Coastal Plain. For the unimproved treatment, 24.6% of trees were defect-free while bulk lot plots had an average of 47.2% and single family plots had an average of 43.9% defect-free trees. Vegetation control did not significantly affect the proportion of defect-free trees. Results for the Piedmont analysis are very similar to those for the Coastal Plain. Genetic improvement significantly contributed to increased proportion of defect-free trees. There were no significant differences between bulk lot and single family but both increased proportion of defect-free trees from 27.5% to 47.0% and 46.1%, respectively, over unimproved stock. Vegetation control did not significantly affect the proportion of defect-free trees.

There was a significant difference between mean growth of basal area per acre for competition control in the Coastal Plain region between the ages of 15 and 18 years. The no vegetation control treatments outgrew the complete control treatment plots by 4.3 ft^2/ac over the three-year period though, as discussed earlier, the competition control average basal area per acre is still substantially larger at age 18. There were no significant differences in per-acre basal area growth in the Piedmont region.

In both physiographic regions, neither genetics nor competition control treatments significantly affected growth in total volume, merchantable volume, total green weight or merchantable green weight between the ages of 15 and 18 years. Previous analyses (prior to the age of 12) showed significantly greater yield growth rates due to genetic and vegetation control treatments. This is likely the result of the faster early growth from both competition control and improved genetic stock resulting in age-18 stands that are further along in development than their respective untreated counterparts. Calculation of relative spacing and stand density index for the different treatments result in values that emphasize this point.

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1. INTRODUCTON

The Plantation Management Research Cooperative (PMRC) was established at the University of Georgia in 1976 with the objectives of (1) developing growth and yield models for site-prepared pine plantations and (2) designing and implementing experiments that will lead to increased site productivity and development of growth and yield models incorporating site and management practices for pine plantations in the Southeast.

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 loblolly 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 evaluate the impact of first generation genetic improvement on yields for planning purposes,

(2) to evaluate the impact on yields of combining genetic improvement and vegetation control, and

(3) to evaluate single family genetically-improved plantations versus bulk lot genetically-improved plantations.

This paper summarizes the results of the age 18 measurement analysis of loblolly pine for this study. Also included are the results of the analysis of the 3-year growth between ages 15 and 18.

2. STUDY DESIGN

A designed experimental study was established at 16 locations in the Coastal Plain region of Georgia and northern Florida, and at 15 locations in the Piedmont region of South Carolina, Georgia and Alabama. Genetically-improved seed were obtained by polling the PMRC membership to determine the top ten families by region for each company. The six top-ranked families for each region were tentatively scheduled for inclusion in the study. The families were then checked by personnel at the North Carolina State University Industry Cooperative 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. North Carolina State University tree improvement cooperative identification for families chosen for inclusion in the PMRC Improved Planting Stock-Vegetation Control Study by region.

Coastal Plain	Piedmont
7-34	12-12
10-5	5-5
17-5	12-9
10-25	12-7
7-56	1-14
7-2	15-42

Unimproved seed was obtained from International Forest Seed Company. This unimproved seed was obtained in the same regions encompassed by the study and from areas other than seed orchards or seed production areas. There were two separate lots of unimproved seed corresponding to the regions in the study.

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. Each plot was 0.4 ac in size with a centrally-located 0.2 ac 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 as needed during the growing season.

Seedlings were hand-lifted and planted in January, 1987 at a density of 700-750 trees per acre. Every third pine tree on the measurement plot was measured for total height (ft) after the third growing season and was measured for dbh to the nearest 0.1 in., total height, and checked for stem cankers caused by fusiform rust (*Cronartium quercum* f. sp. *fusiforme*) after the 6th, 9th, 12th, 15th and 18th growing seasons. After the 9th, 12th, 15th and 18th growing seasons, all trees on the measurement plots were measured for dbh and checked for stem cankers. After the 15th and 18th growing seasons, all trees were assigned a quality code to indicate future suitability (or unsuitability) for solid wood products. Quality codes included defect tree, forked, crook or sweep, canker and broken top. Height-to-live-crown measurements were taken after the 15th and 18th growing seasons. 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 and merchantable (3-in. top ob) tree volumes and weights were estimated using total and merchantable volume and weight equations developed by Pienaar, *et. al.* (1987).

3. AGE 18 ANALYSIS OF VARIANCE

Installations 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. A mixed model approach was used for the analysis because it allows for the mixed effects and unbalanced nature of this design. 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 or single family. The analyses for the Coastal Plain and Piedmont regions were completed separately on the following dependent variables: average dbh, range in dbh, skewness statistic of the dbh distribution, average dominant height, surviving trees per acre, basal area per acre, total and merchantable stem volume, total and merchantable stem green weight, percent fusiform rust infection, percentage of defect-free trees, crook/sweep percent and percentage of forked trees. In the discussion of the results, effects of genetic improvement are calculated by averaging across both vegetation control treatments, and vegetation control effects are determined by averaging across all genetics treatments. All statistical tests were conducted at the $\alpha=0.05$ significance level. To obtain the correct degrees of freedom (df) for this analysis, the Satterthwaite option in SAS®'s PROC MIXED procedure was used. Unlike traditional analysis of variance, the degrees of freedom may not necessarily be an integer.

Two outlier installations were removed from both the Coastal Plain and Piedmont analyses on all dependent variables because they exhibited extremely low growth and survival rates.

3.1 Average DBH

3.1.1 Coastal Plain Analysis

Table 2 gives the results of the tests of fixed effects for average dbh in the Coastal Plain. Competition control significantly increased average dbh in the Coastal Plain an average of 0.56 in. 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 (reproduced from SAS® output) for average dbh (in.) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	17.6	1.00	0.3892
Competition Control	1	9.8	40.19	<0.0001
Genetics* Competition Control	2	50.1	0.50	0.6095

Table 3. Summary of least squares means for average dbh (in.) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	6.36	6.89	6.62
Bulk Lot	6.40	6.90	6.65
Single Family	6.41	7.05	6.73
Average	6.39	6.95	6.68

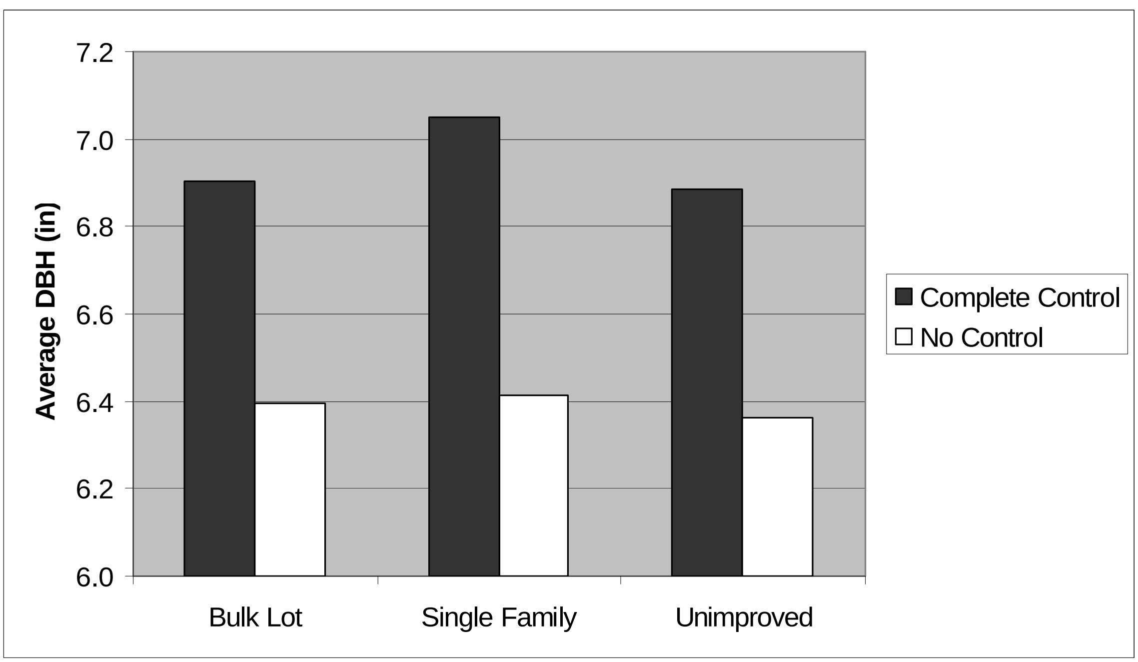

Figure 1. Mean dbh by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.1.2 Piedmont Analysis

The results of the tests of fixed effects for average dbh in the Piedmont are given in Table 4. Both vegetation control and genetics had significant effects on average dbh. Competition control significantly increased average dbh an average of 0.49 in. across all genetic stock. A t-test on the differences of least square means detected no significant difference between bulk lot and single family, but bulk lot increased average dbh 0.24 in. and single family 0.20 in. over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 5 and Figure 2 summarize the least square means for average dbh by treatment.

Table 4. Test of fixed effects (reproduced from SAS® output) for average dbh (in.) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	25.7	3.51	0.0451
Competition Control	1	12.1	30.63	<0.0001
Genetics* Competition Control	2	57.6	0.50	0.6110

Table 5. Summary of least squares means for average dbh (in.) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	6.73	7.30	7.02
Bulk Lot	7.07	7.46	7.26
Single Family	6.96	7.47	7.22
Average	6.92	7.41	7.14

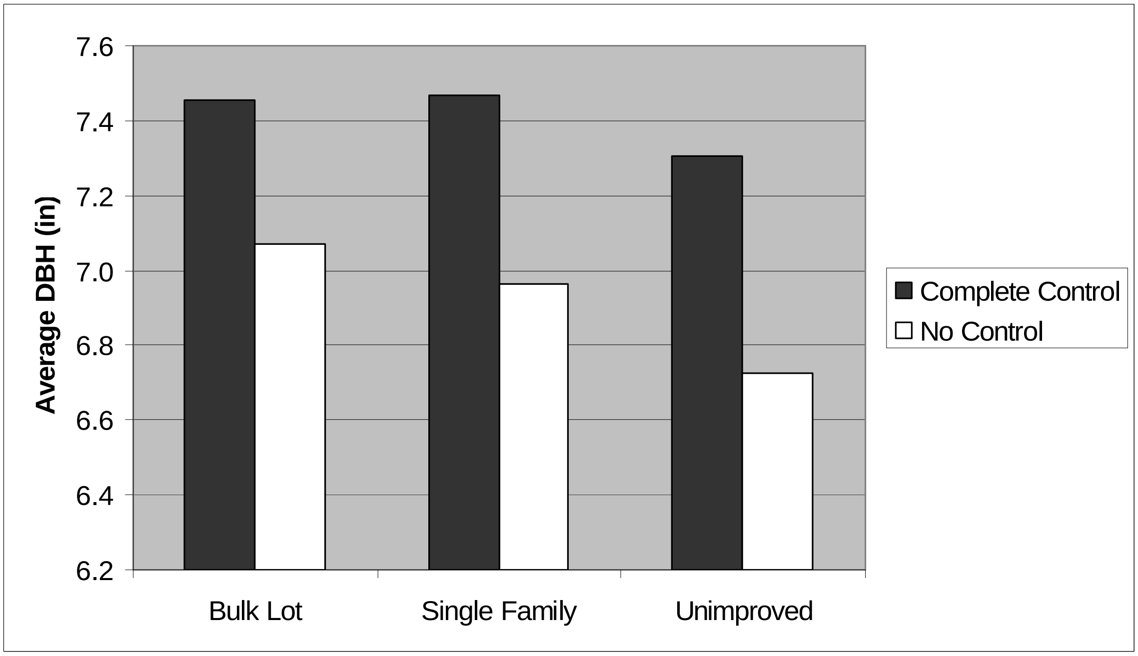

Figure 2. Mean dbh by treatment for 18-yr-old loblolly pine in the Piedmont.

3.2 Range and Skewness of the DBH Distribution

3.2.1 Coastal Plain Analysis

There were no significant differences between the mean range of the dbh distributions for each treatment combination due to genetics or competition control in the Coastal Plain. Genetics significantly affected the skewness of the distribution. While there were no differences between single family and bulk lot, both significantly decreased the skewness statistic over unimproved stock. This indicated that improved genetics skewed the dbh distribution to the left, resulting in a dbh distribution with fewer trees in smaller dbh classes and more trees in larger dbh classes.

3.2.2 Piedmont Analysis

In the Piedmont region, neither the average range in dbh nor the skewness statistic was affected by genetics or competition control.

3.3 Average Dominant Height

3.3.1 Coastal Plain Analysis

Table 6 gives the results of the tests of fixed effects for average dominant height in the Coastal Plain. Competition control significantly increased average dominant height in the Coastal Plain an average of 4.0 ft at age 18 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 4.1 ft and 3.2 ft, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 7 and Figure 3 summarize the least square means for average dominant height by treatment.

Table 6. Test of fixed effects (reproduced from SAS® output) for average dominant height (ft) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	34.0	11.26	0.0002
Competition Control	1	10.5	27.19	0.0003
Genetics* Competition Control	2	34.4	0.53	0.5907

Table 7. Summary of least squares means for average dominant height (ft) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	51.6	54.6	53.1
Bulk Lot	54.2	58.4	56.3
Single Family	54.7	59.6	57.2
Average	53.5	57.5	55.9

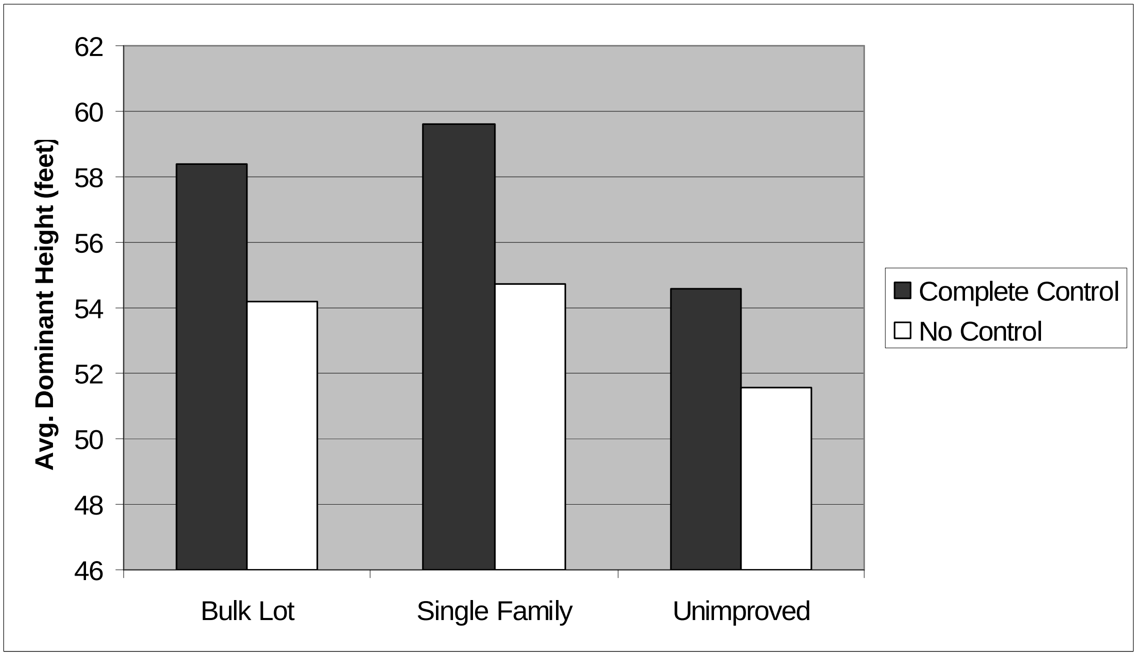

Figure 3. Mean dominant height by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.3.2 Piedmont Analysis

The results of the tests of fixed effects for average dominant height in the Piedmont are given in Table 8. Both vegetation control and improved genetic stock had significant effects on average dominant height. Competition control significantly increased average dominant height an average of 3.9 ft across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased average dominant height 5.8 ft and single family 4.8 ft over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 9 and Figure 4 summarize the least square means for average dominant height by treatment.

Table 8. Test of fixed effects (reproduced from SAS® output) for average dominant height (ft) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	25.4	26.82	<0.0001
Competition Control	1	66.4	39.54	<0.0001
Genetics* Competition Control	2	66.9	1.18	0.3141

Table 9. Summary of least squares means for average dominant height (ft) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	49.7	54.8	52.2
Bulk Lot	56.7	59.5	58.1
Single Family	55.2	58.8	57.0
Average	53.8	57.7	55.7

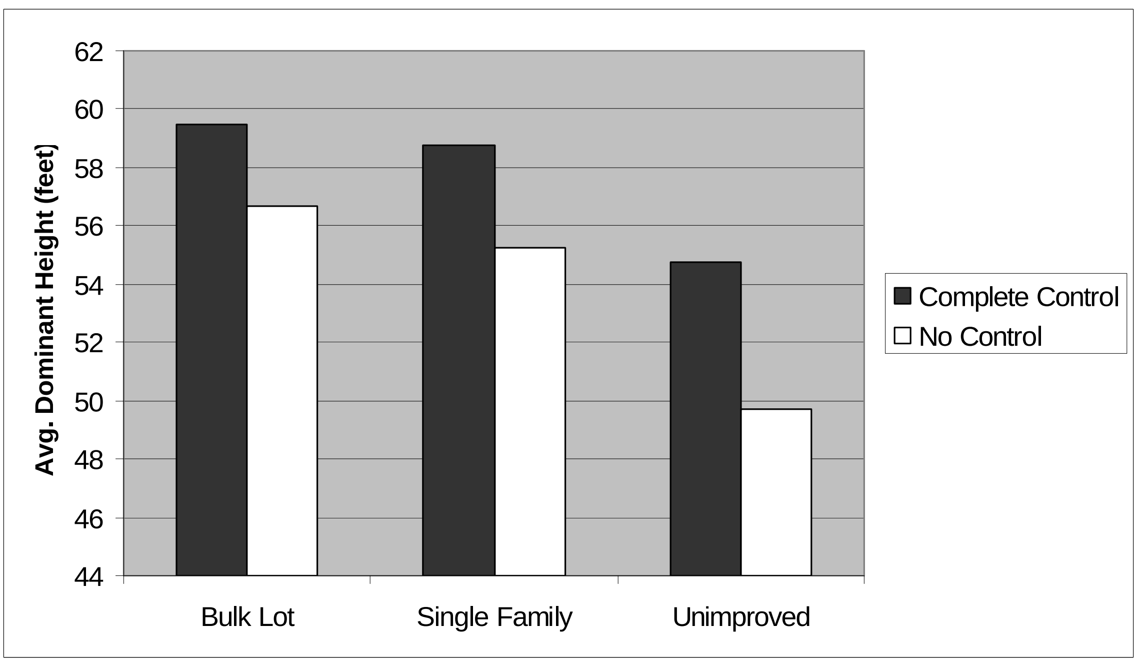

Figure 4. Mean dominant height by treatment for 18-yr-old loblolly pine in the Piedmont.

3.4 Basal Area per Acre

3.4.1 Coastal Plain Analysis

Both genetics and vegetation control significantly affected basal area per acre in the Coastal Plain (Table 10). Competition control significantly increased basal area an average of 23.1 ft^2/ac across all levels of genetic stock. Genetic stock did not significantly increase basal area per acre as it had done in past measurements. The interaction between competition control and genetic stock was not significant, indicating the effects are additive in nature (Figure 5). Table 11 summarizes the least square means for basal area per acre.

Table 10. Test of fixed effects (reproduced from SAS® output) for basal area (ft^2/ac) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	32.9	1.99	0.1523
Competition Control	1	11.1	48.78	<0.0001
Genetics* Competition Control	2	33.1	0.65	0.5280

Table 11. Summary of least squares means for basal area (ft^2/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	145.5	166.3	155.9
Bulk Lot	149.3	170.6	160.0
Single Family	148.5	175.6	162.1
Average	147.8	170.9	160.1

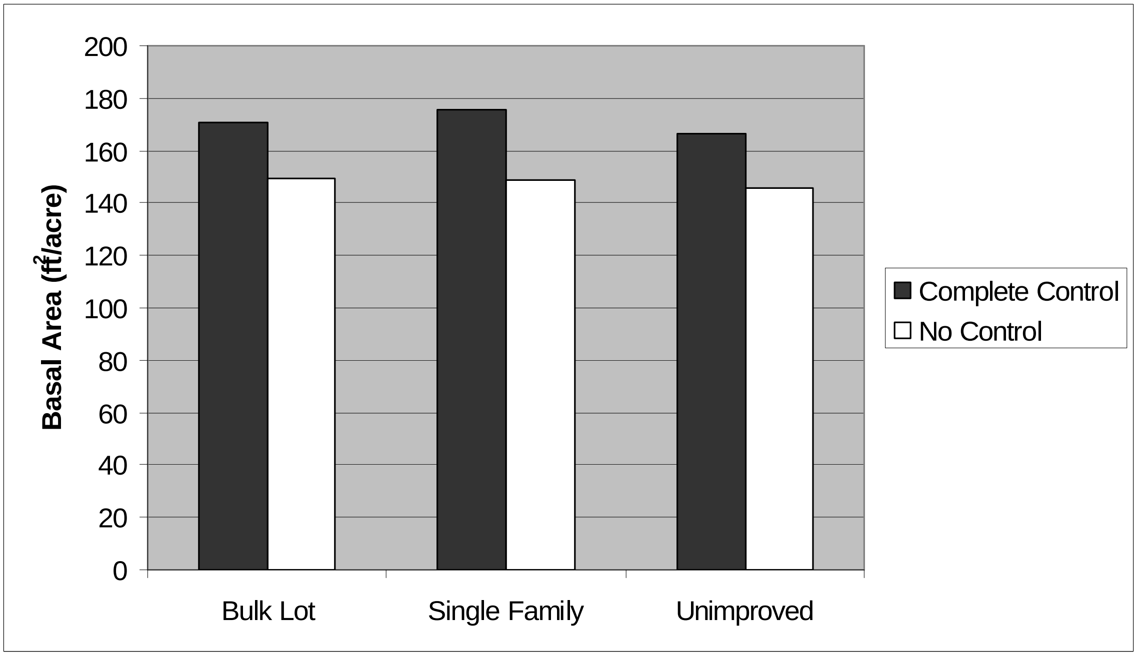

Figure 5. Basal area per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.4.2 Piedmont Analysis

The vegetation control treatment had the only significant effect on basal area per acre in the Piedmont (Table 12).

Table 12. Test of fixed effects (reproduced from SAS® output) for basal area (ft^2/ac) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	76.8	1.67	0.1948
Competition Control	1	12.7	7.34	0.0182
Genetics* Competition Control	2	76.0	1.95	0.1487

Figure 6 graphically shows that mean basal area with complete vegetation control does not receive significant additional gain due to genetics. In past measurements, there was a significant interaction between vegetation control and genetic stock with regards to per acre basal area in the Piedmont region. Figure 6 suggests there may be some interaction between genetics and vegetation control since improved genetics resulted in increased basal area with no vegetation control. As stated earlier, these results were not statistically significant. Table 13 and Figure 6 summarize the least square means for basal area (ft^2/ac) by treatment.

Table 13. Summary of least squares means for basal area (ft^2/ac) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	146.7	182.2	164.4
Bulk Lot	165.7	182.0	173.8
Single Family	176.7	180.9	178.8
Average	163.0	181.7	172.4

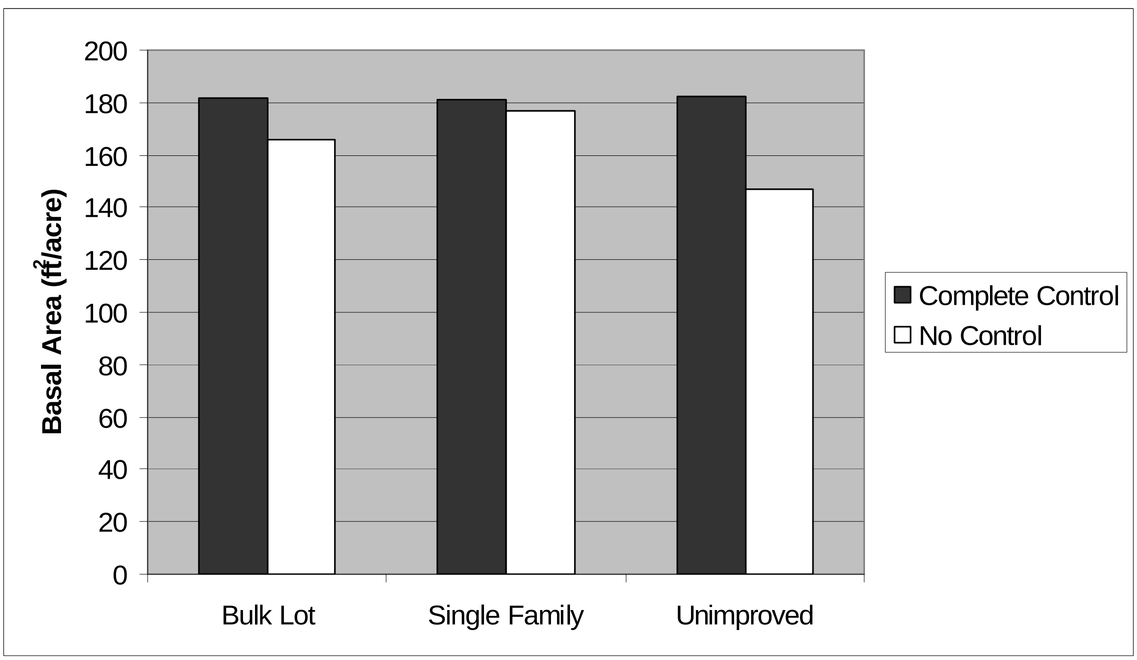

Figure 6. Basal area per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.5 Total Volume per Acre

3.5.1 Coastal Plain Analysis

Table 14 gives the results of the tests of fixed effects for total outside bark volume per acre in the Coastal Plain. Competition control significantly increased yield in the Coastal

Plain an average of 913 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 446 ft^3/ac and 344 ft^3/ac, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 15 and Figure 7 summarize the least square means for total volume per acre by treatment.

Table 14. Test of fixed effects (reproduced from SAS® output) for total volume (ft^3/ac) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	34.0	6.50	0.0041
Competition Control	1	11.2	37.35	<0.0001
Genetics* Competition Control	2	34.2	0.42	0.6606

Table 15. Summary of least squares means for total volume (ft^3/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	3623	4465	4044
Bulk Lot	3963	4813	4388
Single Family	3967	5013	4490
Average	3851	4764	4358

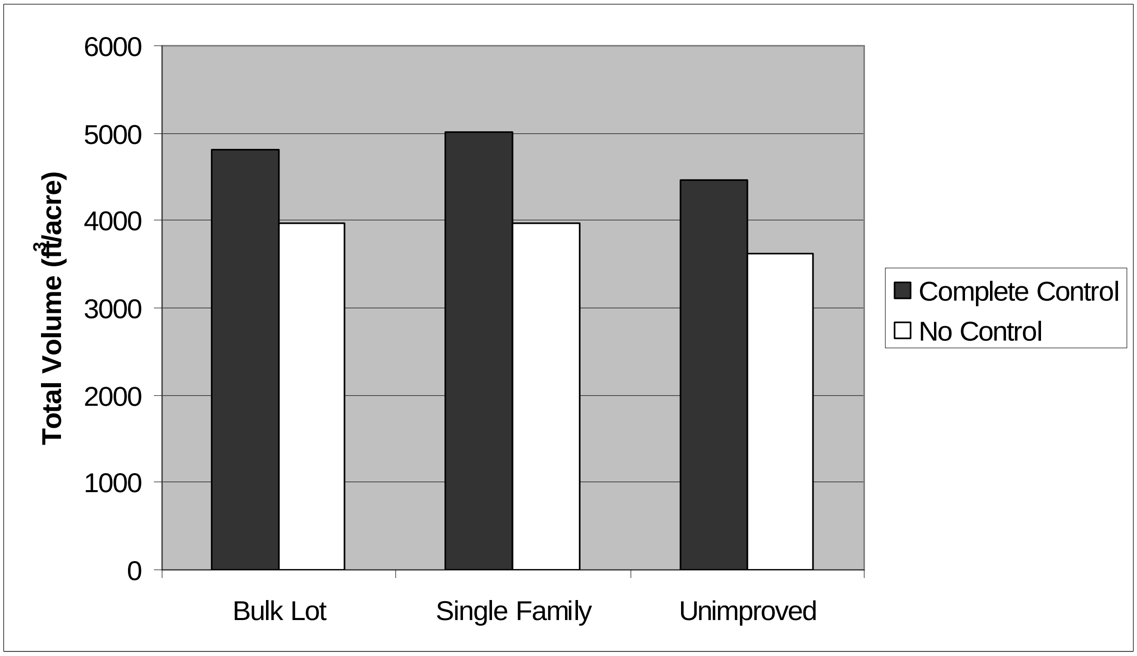

Figure 7. Total Volume per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.5.2 Piedmont Analysis

Table 16 gives the results of the tests of fixed effects for total volume in the Piedmont. Both vegetation control and improved genetic stock had significant and additive effects on total volume. Competition control significantly increased yield an average of 715 ft^3/ac across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased yield 649 ft^3/ac and single family 639 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 17 and Figure 8 summarize the least square means for total volume by treatment.

Table 16. Test of fixed effects (reproduced from SAS® output) for total volume (ft^3/ac) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	76.0	6.67	0.0022
Competition Control	1	12.5	15.25	0.0020
Genetics* Competition Control	2	75.2	1.97	0.1461

Table 17. Summary of least squares means for total volume (ft^3/ac) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	3497	4670	4083
Bulk Lot	4459	5005	4732
Single Family	4510	4935	4722
Average	4155	4870	4504

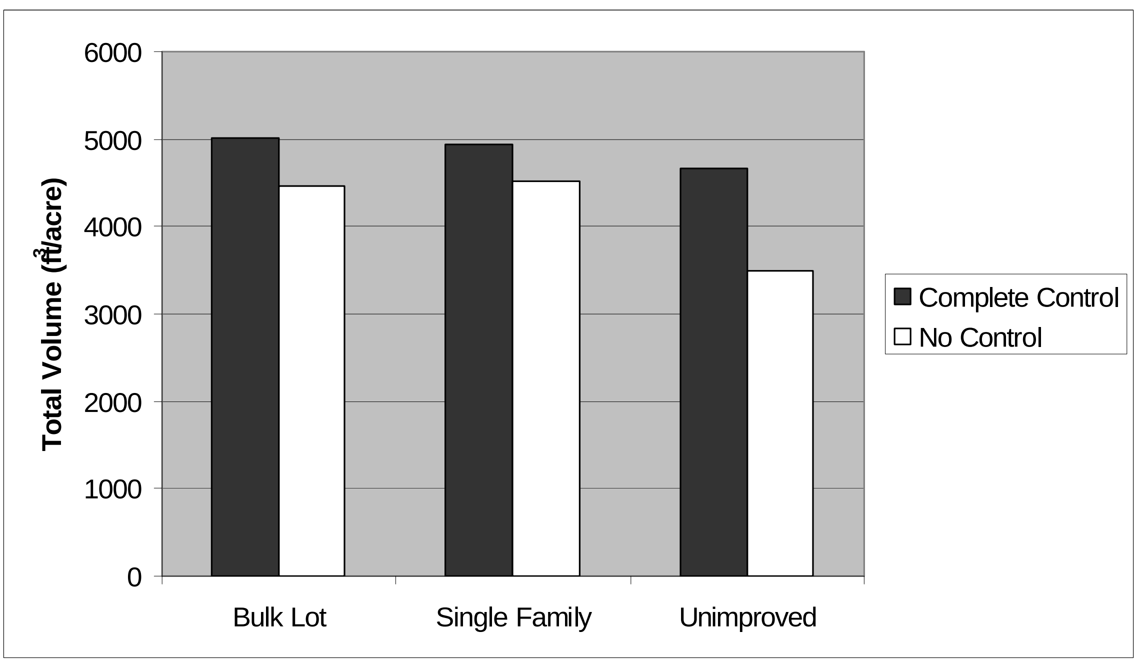

Figure 8. Total Volume per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.6 Merchantable Volume

3.6.1 Coastal Plain Analysis

Results for merchantable volume were essentially the same as for total volume. In the Coastal Plain, competition control significantly increased merchantable volume (3-in. top) an average of 940 ft^3/ac. across all levels of genetic stock (Table 18). 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 334 ft^3/ac and single family 438 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 19 and Figure 9 summarize the least square means for merchantable volume by treatment.

Table 18. Test of fixed effects (reproduced from SAS® output) for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	33.8	6.27	0.0048
Competition Control	1	11.1	37.87	<0.0001
Genetics* Competition Control	2	34.0	0.41	0.6687

Table 19. Summary of least squares means for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	3404	4280	3842
Bulk Lot	3738	4613	4176
Single Family	3744	4815	4280
Average	3629	4569	4150

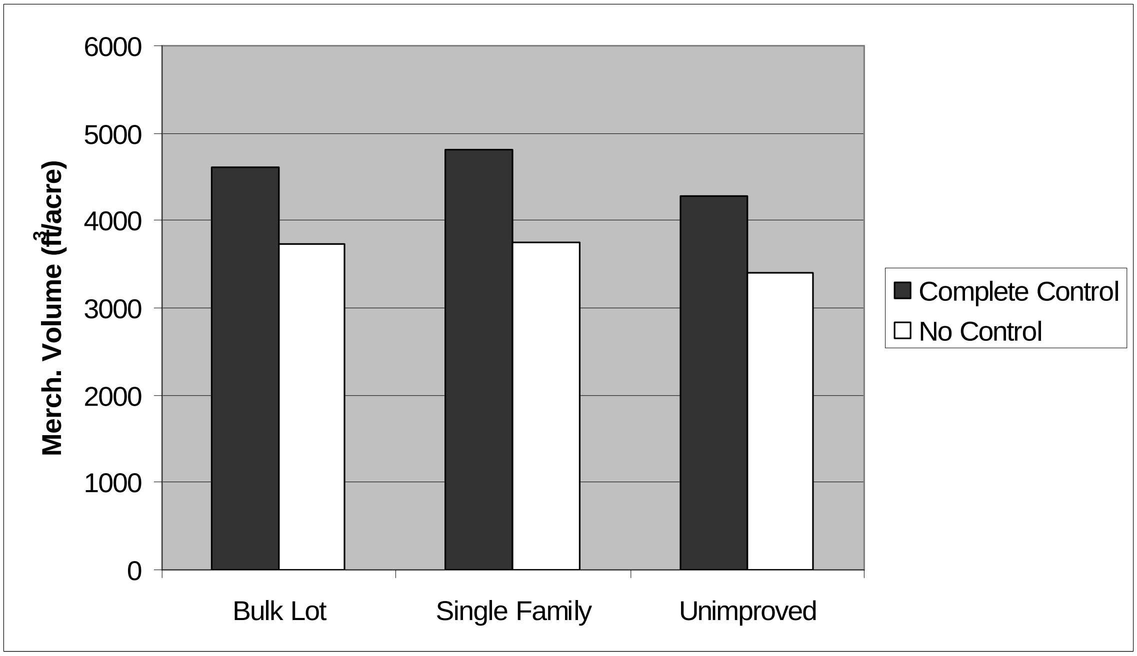

Figure 9. Merchantable volume (3-in. top) per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.6.2 Piedmont Analysis

Table 20 gives the results of the tests of fixed effects for merchantable volume in the Piedmont. Both vegetation control and genetics had significant and additive effects on merchantable volume. Competition control significantly increased merchantable outside bark yield to a 3-in. top an average of 737 ft^3/ac across all genetic stock. No significant difference was detected between bulk lot and single family, but bulk lot increased merchantable yield 650 ft^3/ac and single family 634 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 21 and Figure 10 summarize the least square means for merchantable volume.

Table 20. Test of fixed effects (reproduced from SAS® output) for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	76.0	6.60	0.0023
Competition Control	1	12.5	16.55	0.0014
Genetics* Competition Control	2	75.1	1.89	0.1588

Table 21. Summary of least squares means for merchantable volume o.b. to a 3-in. top o.b. (ft^3/ac) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	3310	4497	3903
Bulk Lot	4270	4836	4554
Single Family	4308	4767	4537
Average	3963	4700	4322

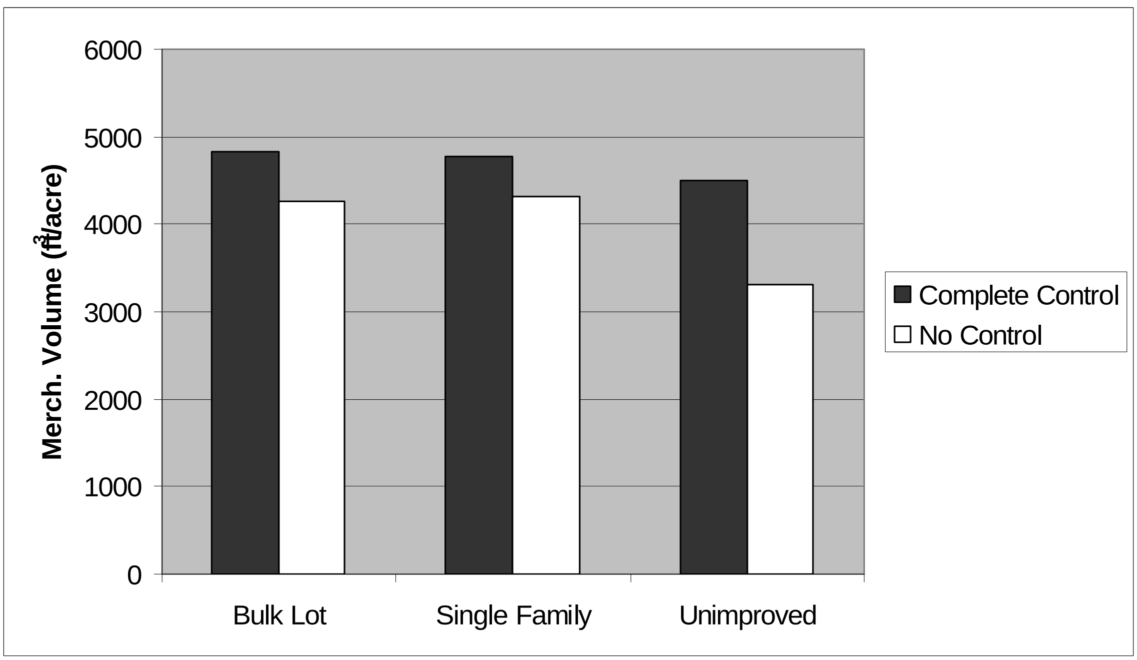

Figure 10. Merchantable volume (3-in. top) per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.7 Total Green Weight per Acre

3.7.1 Coastal Plain Analysis

Table 22 gives the results of the tests of fixed effects for total outside bark green weight per acre in the Coastal Plain. Competition control significantly increased yield in the Coastal Plain an average of 26 tons/ac across all levels of genetic stock. Genetic stock also significantly increased total green weight per acre. While there was no significant difference between single family and bulk lot, they increased yield by 13 tons/ac and 10 tons/ac, respectively, over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 23 and Figure 11 summarize the least square means for total green weight per acre by treatment.

Table 22. Test of fixed effects (reproduced from SAS® output) for total green weight (tons/ac) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	34.1	6.75	0.0034
Competition Control	1	11.2	36.69	<0.0001
Genetics* Competition Control	2	34.4	0.40	0.6708

Table 23. Summary of least squares means for total green weight (tons/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	100.0	124.4	112.3
Bulk Lot	110.3	134.5	122.4
Single Family	110.4	140.2	125.3
Average	107.0	133.0	121.4

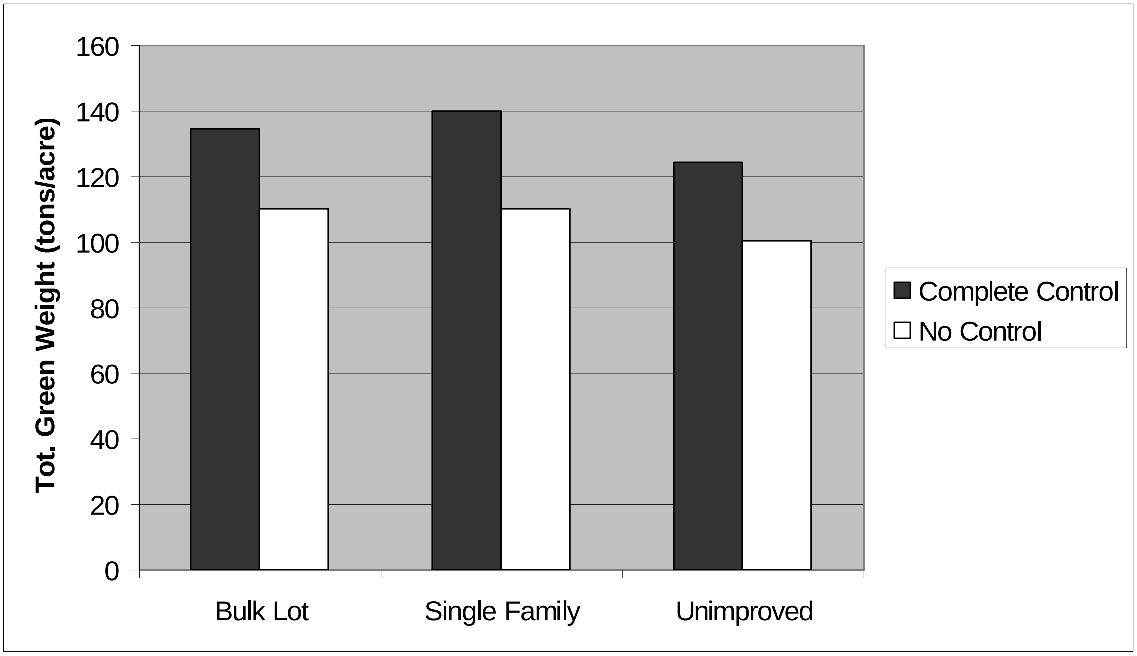

Figure 11. Total green weight per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.7.2 Piedmont Analysis

Table 24 gives the results of the tests of fixed effects for total, outside bark green weight in the Piedmont. Both vegetation control and improved genetic stock had significant and additive effects on total green weight. Competition control significantly increased yield an average of 19 tons/ac across all genetic stock. A t-test on the differences of least square means detected no significant differences between bulk lot and single family, but bulk lot increased yield 19 tons/ac and single family 20 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 25 and Figure 12 summarize the least square means for total green weight by treatment.

Table 24. Test of fixed effects (reproduced from SAS® output) for total green weight (tons/ac) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	76.2	5.85	0.0043
Competition Control	1	12.5	11.41	0.0052
Genetics* Competition Control	2	75.4	1.65	0.1994

Table 25. Summary of least squares means for total green weight (tons/ac) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	92.0	124.7	108.4
Bulk Lot	119.9	135.3	127.6
Single Family	122.8	133.1	127.9
Average	111.6	131.0	121.1

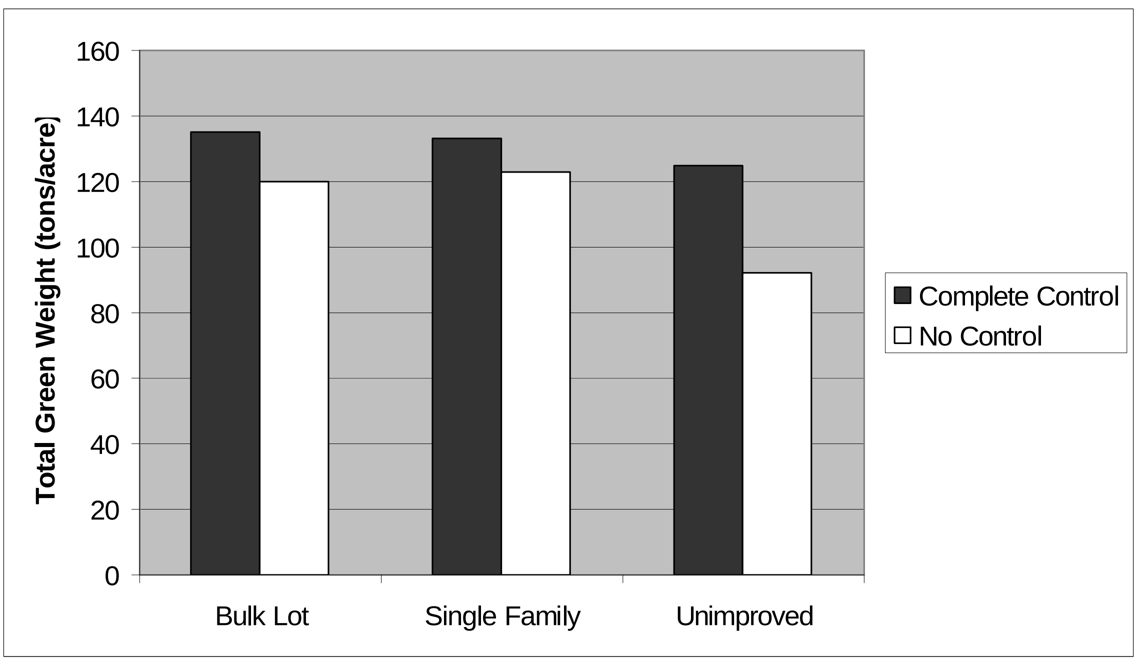

Figure 12. Total green weight per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.8 Merchantable Green Weight

3.8.1 Coastal Plain Analysis

Results for merchantable green weight showed the same trends as observed in the total green weight analysis. In the Coastal Plain, competition control significantly increased merchantable green weight (3-in. top) an average of 27 tons/ac across all levels of genetic stock (Table 26). 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 10 tons/ac and single family 13 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 27 and Figure 13 summarize the least square means for merchantable green weight by treatment.

Table 26. Test of fixed effects (reproduced from SAS® output) for merchantable green weight o.b. to a 3-in. top o.b. (tons/ac) in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	33.9	6.50	0.0041
Competition Control	1	11.1	37.07	<0.0001
Genetics* Competition Control	2	34.2	0.39	0.6792

Table 27. Summary of least squares means for merchantable green weight o.b. to a 3-in. top o.b. (tons/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	93.7	118.7	106.2
Bulk Lot	103.5	128.3	115.9
Single Family	103.7	134.0	118.9
Average	100.3	127.0	115.1

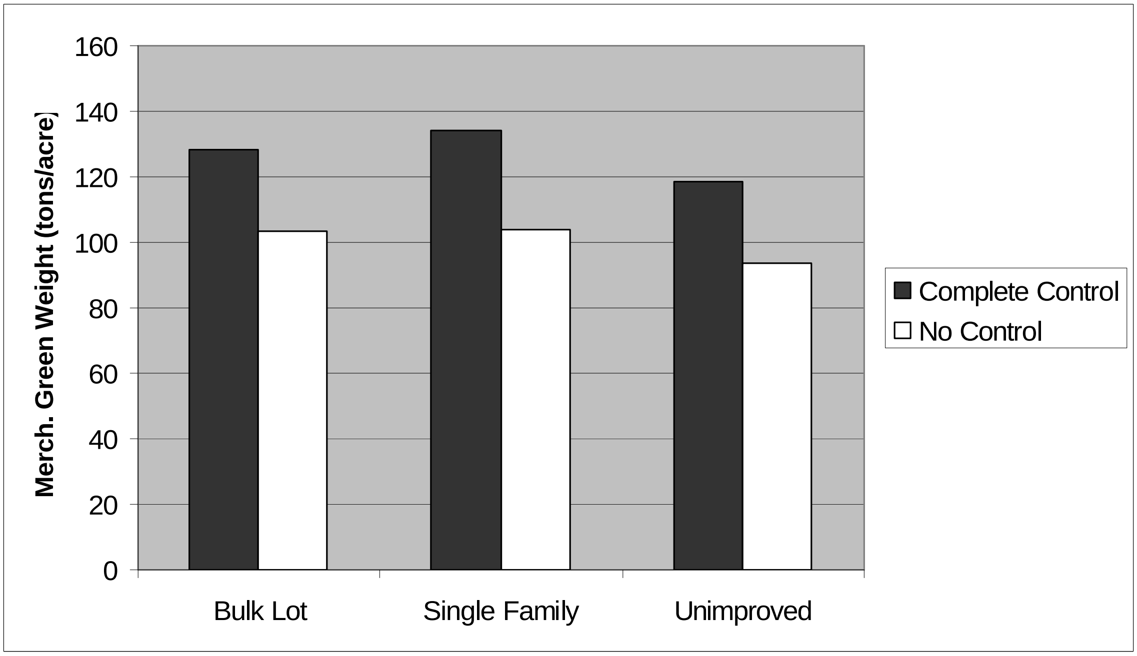

Figure 13. Merchantable green weight (3-in. top) per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.8.2 Piedmont Analysis

Table 28 gives the results of the tests of fixed effects for merchantable green weight in the Piedmont. Both vegetation control and genetics had significant and additive effects on merchantable green weight. Competition control significantly increased merchantable outside bark yield to a 3-in. top an average of 20 tons/ac across all genetic stock. No significant difference was detected between bulk lot and single family, and both improved genetics treatments increased merchantable yield by 19 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 29 and Figure 14 summarize the least square means for merchantable volume.

Table 28. Test of fixed effects (reproduced from SAS® output) for merchantable green weight o.b. to a 3-in. top o.b. (tons/ac) in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	76.2	5.76	0.0047
Competition Control	1	12.6	12.05	0.0043
Genetics* Competition Control	2	75.4	1.57	0.2148

Table 29. Summary of least squares means for merchantable green weight o.b. to a 3-in. top o.b. (tons/ac) in the Piedmont.

	No Control	Complete Control	Average
Unimproved	86.6	119.4	103.0
Bulk Lot	114.2	130.0	122.1
Single Family	116.8	127.8	122.3
Average	105.9	125.7	115.6

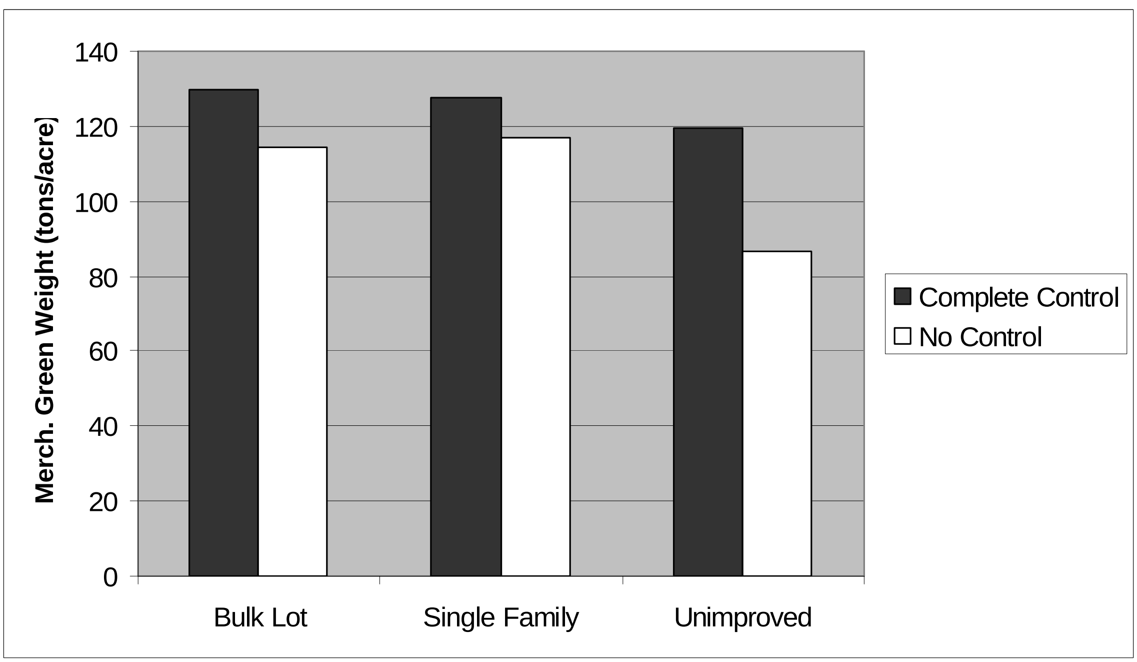

Figure 14. Merchantable green weight (3-in. top) per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.9 Trees per Acre

3.9.1 Coastal Plain Analysis

There were no significant differences in trees per acre due to genetics or competition control in the Coastal Plain (Table 30). There was an average of 630 surviving trees per acre after the 18^{th} growing season in the Coastal Plain region (Figure 15).

Table 30. Test of fixed effects (reproduced from SAS® output) for trees per acre in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	13.7	0.43	0.6613
Competition Control	1	6.37	1.03	0.3464
Genetics* Competition Control	2	43.5	0.07	0.9313

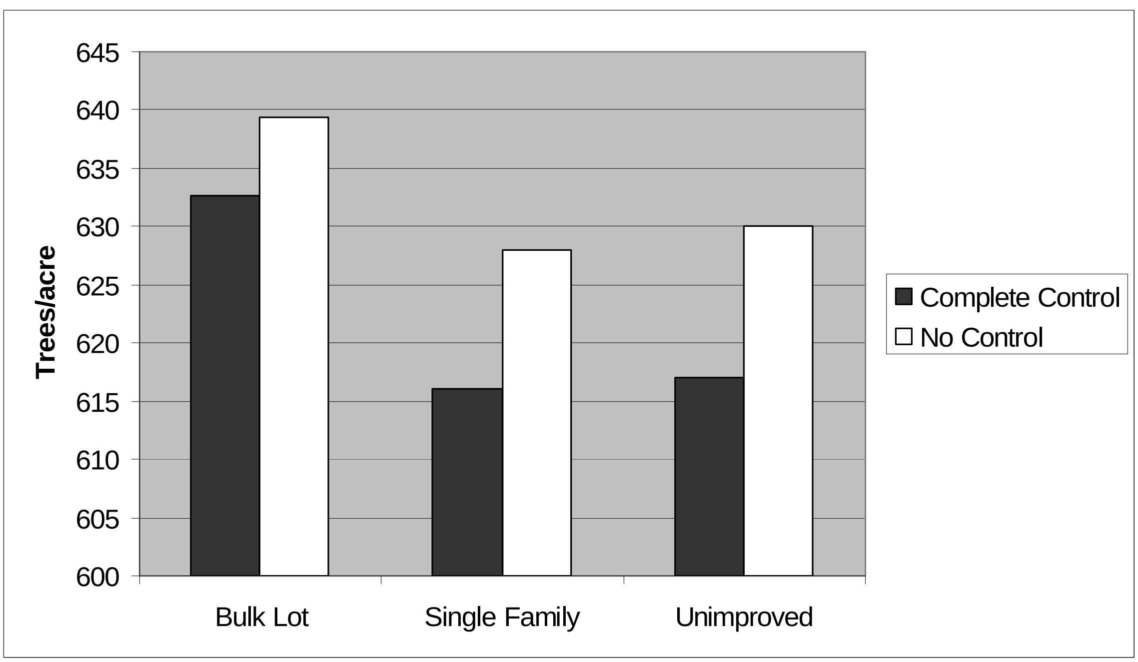

Figure 15. Trees per acre by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.9.2 Piedmont Analysis

There were no significant differences in trees per acre due to genetics or competition control in the Coastal Plain (Table 31). There was an average of 607 surviving trees per acre after the 18th growing season in the Piedmont region (Figure 16).

Table 31. Test of fixed effects (reproduced from SAS® output) for trees per acre in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	71.4	0.77	0.4650
Competition Control	1	11.7	0.03	0.8765
Genetics* Competition Control	2	70.8	1.65	0.1992

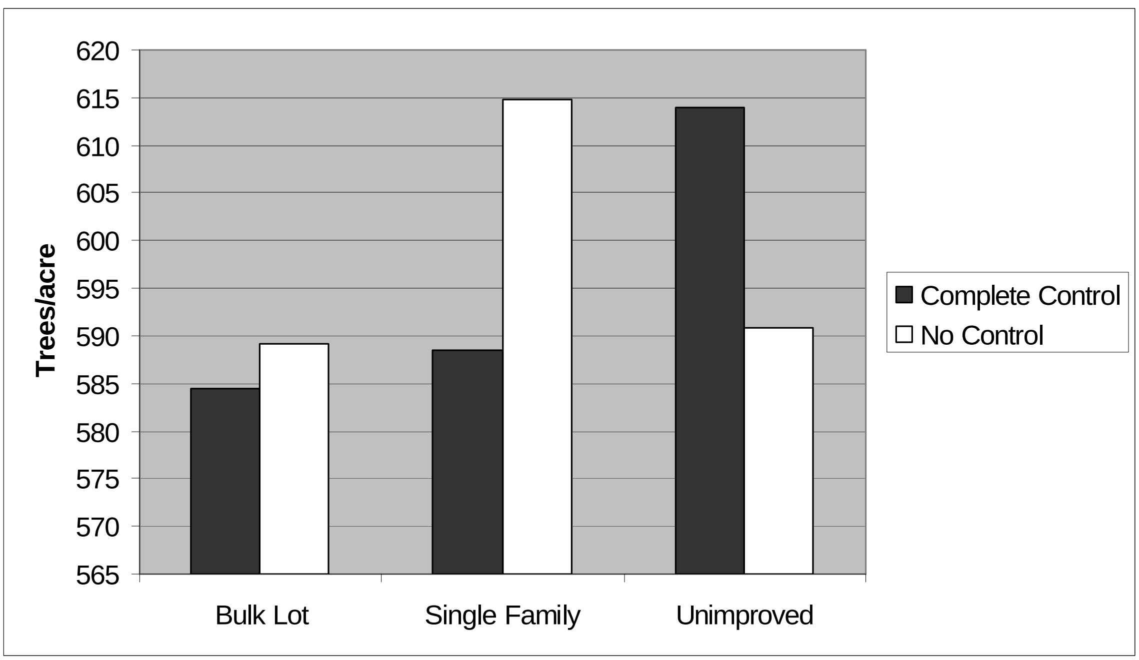

Figure 16. Trees per acre by treatment for 18-yr-old loblolly pine in the Piedmont.

3.10 Percent Fusiform Infection

3.10.1 Coastal Plain Analysis

Fusiform infection rates ranged from 0.8% to 37% in the Costal Plain region. Genetic improvement significantly reduced infection rates (Table 32). There were no significant differences between improved genetics treatments, but both reduced percent fusiform infections from 20.9% for unimproved stock to 9.2% for bulk lot and 9.7%for single family. The vegetation control treatment significantly increased the rust infection level, but only by 1.4%. The results are shown in Table 33 and Figure 17.

Table 32. Test of fixed effects (reproduced from SAS® output) for percent fusiform infection in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	20.4	48.10	<0.0001
Competition Control	1	54.8	4.30	0.0428
Genetics* Competition Control	2	54.7	0.94	0.3972

Table 33. Summary of least squares means for percent fusiform infection in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	19.6%	22.2%	20.9%
Bulk Lot	8.9%	9.4%	9.2%
Single Family	9.2%	10.2%	9.7%
Average	12.6%	14.0%	12.8%

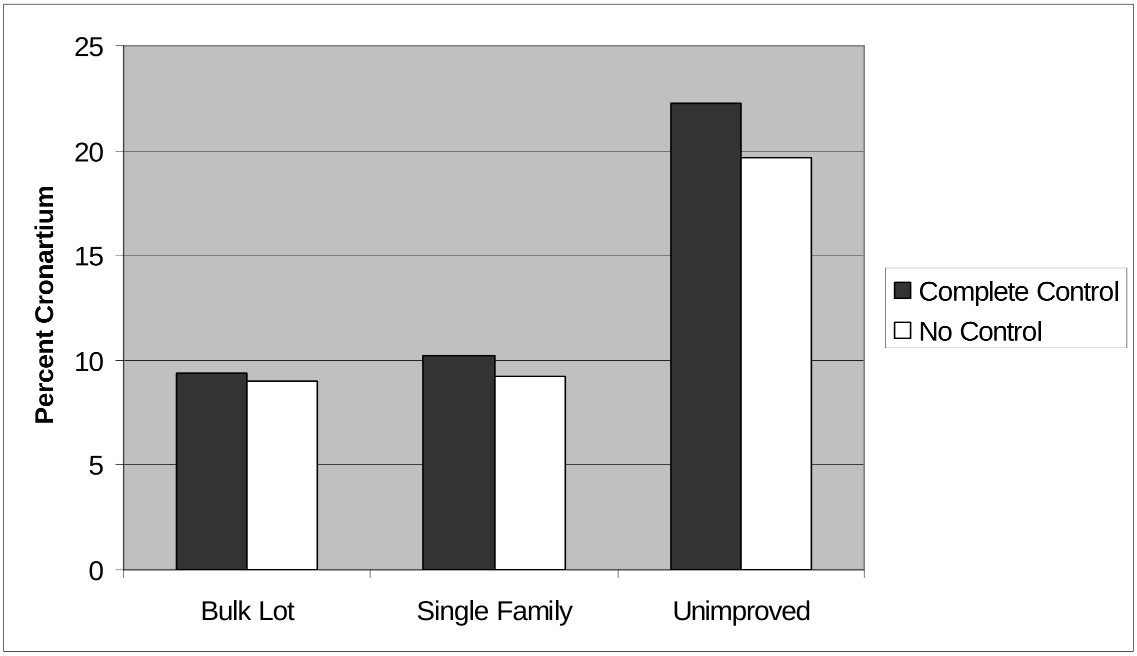

Figure 17. Percent fusiform rust infection by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.10.2 Piedmont Analysis

In the Piedmont region, infection rates ranged from 0.8% to 42%. Genetic improvement significantly contributed to reduced percent fusiform (Table 34). There were no significant differences between bulk lot and single family but both decreased percent fusiform infections from 22.9% to 13.7% and 14.9%, respectively, over unimproved stock. Vegetation control did not significantly affect the rust infection level. Average infection rates by treatment are shown in Table 35 and Figure 18.

Table 34. Test of fixed effects (reproduced from SAS® output) for percent fusiform infection in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	23.7	15.73	<0.0001
Competition Control	1	11.2	0.45	0.5163
Genetics* Competition Control	2	53.0	0.12	0.8849

Table 35. Summary of least squares means for percent fusiform infection in the Piedmont.

	No Control	Complete Control	Average
Unimproved	22.5%	23.3%	22.9%
Bulk Lot	13.7%	13.8%	13.7%
Single Family	14.5%	15.3%	14.9%
Average	16.9%	17.4%	17.3%

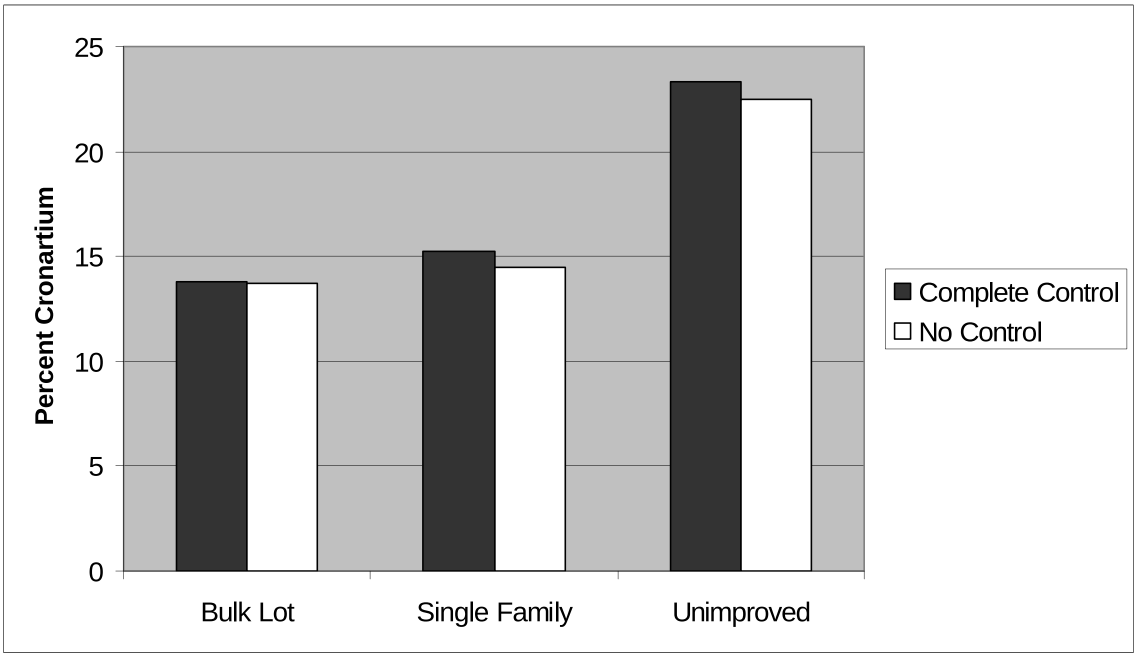

Figure 18. Percent fusiform rust infection by treatment for 18-yr-old loblolly pine in the Piedmont.

3.11 Percent Defect-Free Trees

3.11.1 Coastal Plain Analysis

Genetic improvement led to significant increases in the proportion of trees without major defects (Table 36). For the unimproved treatment, 24.6% of trees were defect free while bulk lot plots had an average of 47.2% and single family plots had an average of 43.9% defect-free trees. Vegetation control did not significantly affect the proportion of defect-free trees (Figure 19). Table 37 shows a summary of least-squares means in the Coastal Plain.

Table 36. Test of fixed effects (reproduced from SAS® output) for percent defect-free trees in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	23.1	20.58	<0.0001
Competition Control	1	63.4	2.32	0.1326
Genetics* Competition Control	2	63.7	0.59	0.5587

Table 37. Summary of least squares means for percent defect-free trees in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	25.3%	24.0%	24.6%
Bulk Lot	51.3%	43.1%	47.2%
Single Family	45.3%	42.6%	43.9%
Average	40.6%	36.6%	39.4%

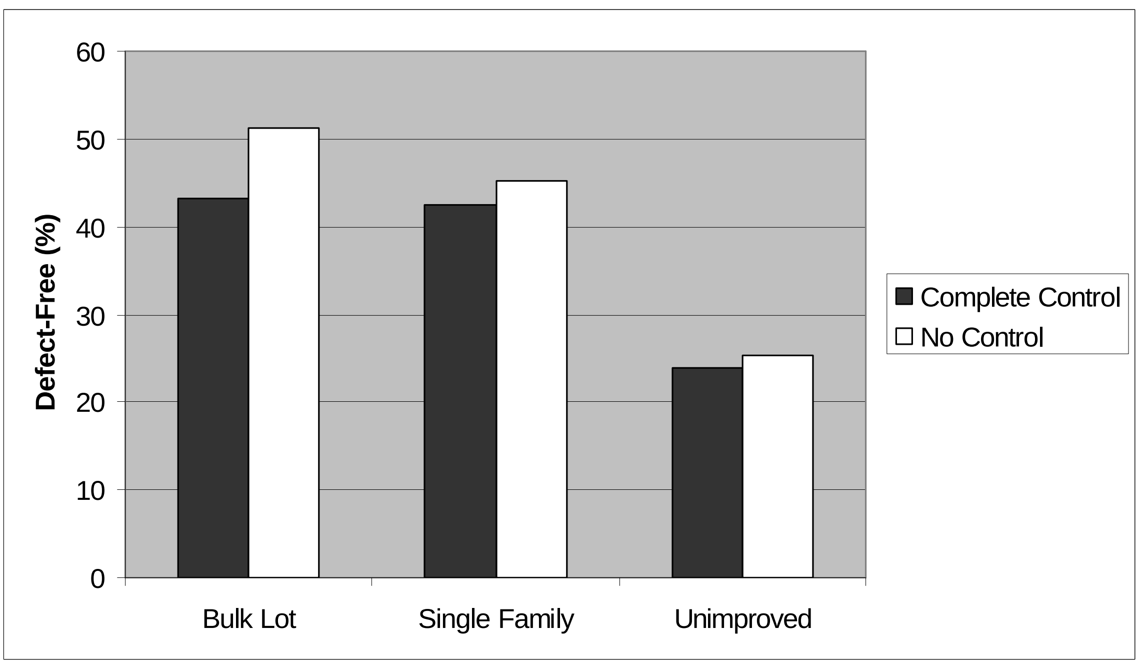

Figure 19. Percent defect-free trees by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.11.2 Piedmont Analysis

Results for the Piedmont analysis are very similar to those for the Coastal Plain. Genetic improvement significantly contributed to increased proportion of defect-free trees (Table 38). There were no significant differences between bulk lot and single family but both increased proportion of defect-free trees from 27.5% to 47.0% and 46.1%, respectively, over unimproved stock. Vegetation control did not significantly affect the proportion of defect-free trees (Figure 20). Table 39 shows a summary of least-squares means in the Piedmont.

Table 38. Test of fixed effects (reproduced from SAS® output) for percent defect-free trees in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	23.2	12.32	0.0002
Competition Control	1	11.1	3.04	0.1089
Genetics* Competition Control	2	21.2	0.70	0.5076

Table 39. Summary of least squares means for percent defect-free trees in the Piedmont.

	No Control	Complete Control	Average
Unimproved	28.7%	26.2%	27.5%
Bulk Lot	48.0%	45.9%	47.0%
Single Family	50.1%	42.1%	46.1%
Average	42.3%	38.1%	40.8%

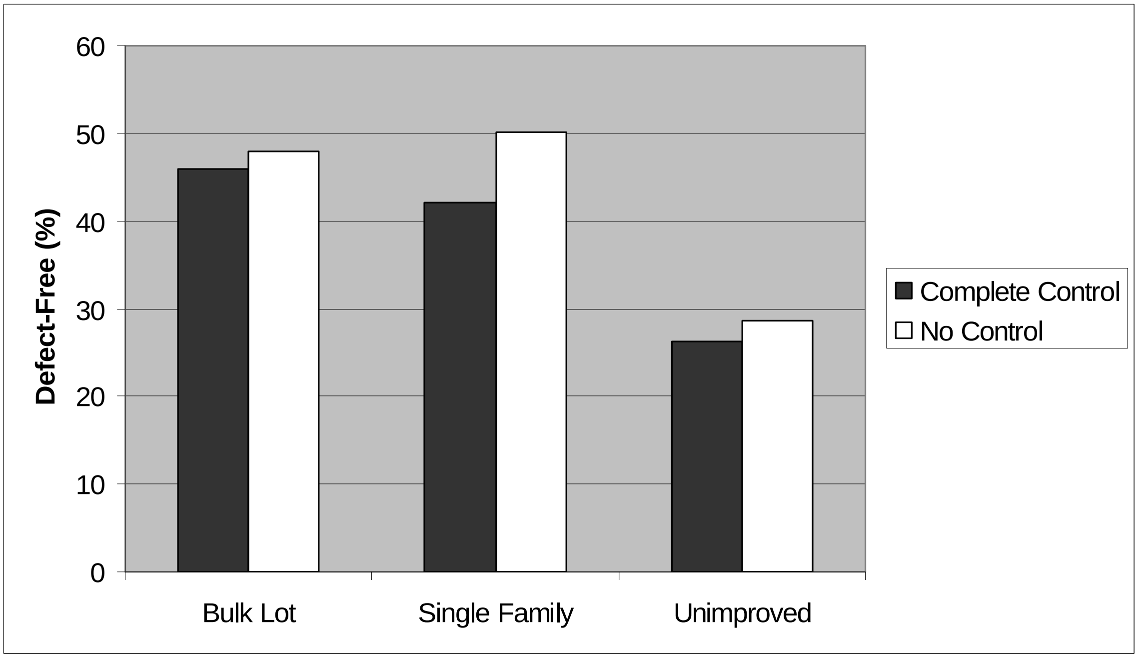

Figure 20. Percent defect-free trees by treatment for 18-yr-old loblolly pine in the Piedmont.

3.12 Percent Forked Trees

3.12.1 Coastal Plain Analysis

Genetic improvement and vegetation control significantly affected the proportion of forked trees in the Coastal Plain (Table 40). There were no significant differences between bulk lot and single family, but both increased percent of forked trees from 1.4% to 2.7% and 1.8%, respectively, over unimproved stock. The vegetation control treatment led to, on average, an increase of 1.1% in forked trees. Least-squares means for the Coastal Plain region are shown in Table 41 and Figure 21.

Table 40. Test of fixed effects (reproduced from SAS® output) for percent forked trees in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	34.2	3.56	0.0395
Competition Control	1	62.4	12.96	0.0006
Genetics* Competition Control	2	62.4	1.12	0.3341

Table 41. Summary of least squares means for percent forked trees in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	1.1%	1.6%	1.4%
Bulk Lot	1.9%	3.5%	2.7%
Single Family	1.2%	2.4%	1.8%
Average	1.4%	2.5%	2.0%

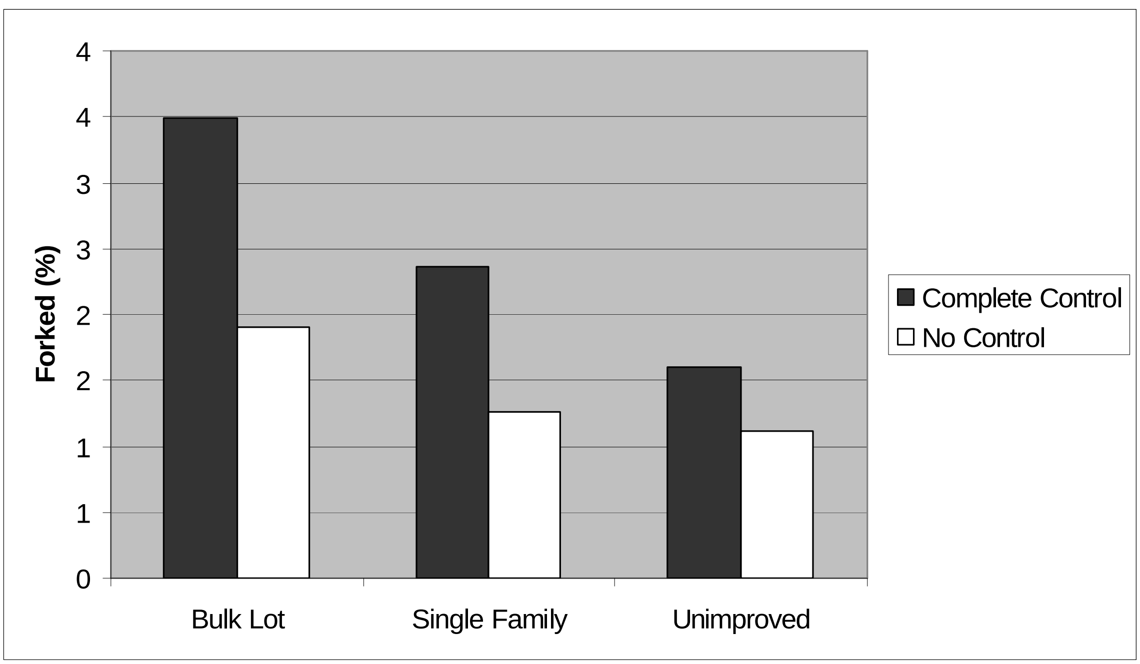

Figure 21. Percent forked trees by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.12.2 Piedmont Analysis

In the Piedmont region, vegetation control had the only significant effect on the percentage of forked trees. Complete vegetation control led to an increase in forked trees of 3.2% over the no vegetation control treatment (Table 42). Least-squares means for the Piedmont region are shown in Table 43 and Figure 22.

Table 42. Test of fixed effects (reproduced from SAS® output) for percent forked trees in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	22.1	2.84	0.0801
Competition Control	1	11.7	24.49	0.0004
Genetics* Competition Control	2	53.6	1.09	0.3442

Table 43. Summary of least squares means for percent forked trees in the Piedmont.

	No Control	Complete Control	Average
Unimproved	1.8%	4.2%	3.0%
Bulk Lot	2.5%	6.6%	4.5%
Single Family	2.0%	5.1%	3.6%
Average	2.1%	5.3%	3.6%

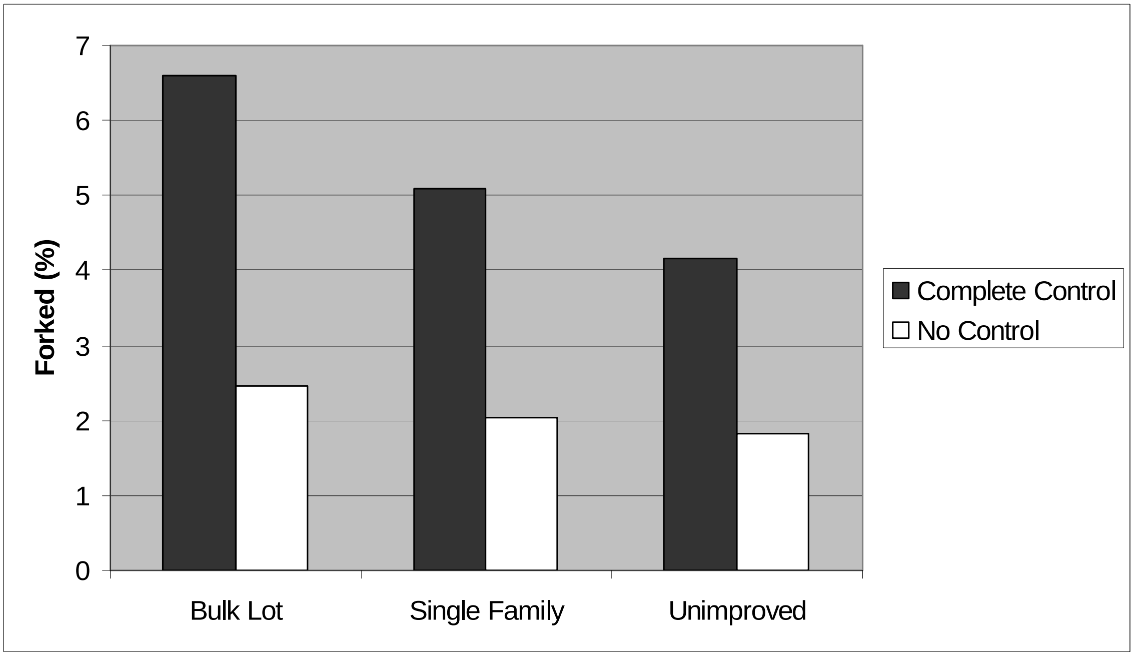

Figure 22. Percent forked trees by treatment for 18-yr-old loblolly pine in the Piedmont.

3.13 Percent of Trees with Crook or Sweep

3.13.1 Coastal Plain Analysis

Genetic improvement significantly contributed to reduced percent of trees with crook or sweep in the Coastal Plain (Table 44). There were no significant differences between bulk lot and single family, but both reduced crook and sweep from 66.5% to 46.9% and 50.9%, respectively, over unimproved stock. Vegetation control did not significantly affect the percent of trees with crook or sweep. Least-squares means are shown in Table 45 and Figure 23.

Table 44. Test of fixed effects (reproduced from SAS® output) for percent of trees with crook or sweep in the Coastal Plain.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	22.8	13.37	0.0001
Competition Control	1	62.4	1.12	0.2942
Genetics* Competition Control	2	62.6	0.47	0.6299

Table 45. Summary of least squares means for percent of trees with crook or sweep in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	66.0%	67.1%	66.5%
Bulk Lot	43.7%	50.1%	46.9%
Single Family	50.4%	51.3%	50.9%
Average	53.4%	56.2%	54.2%

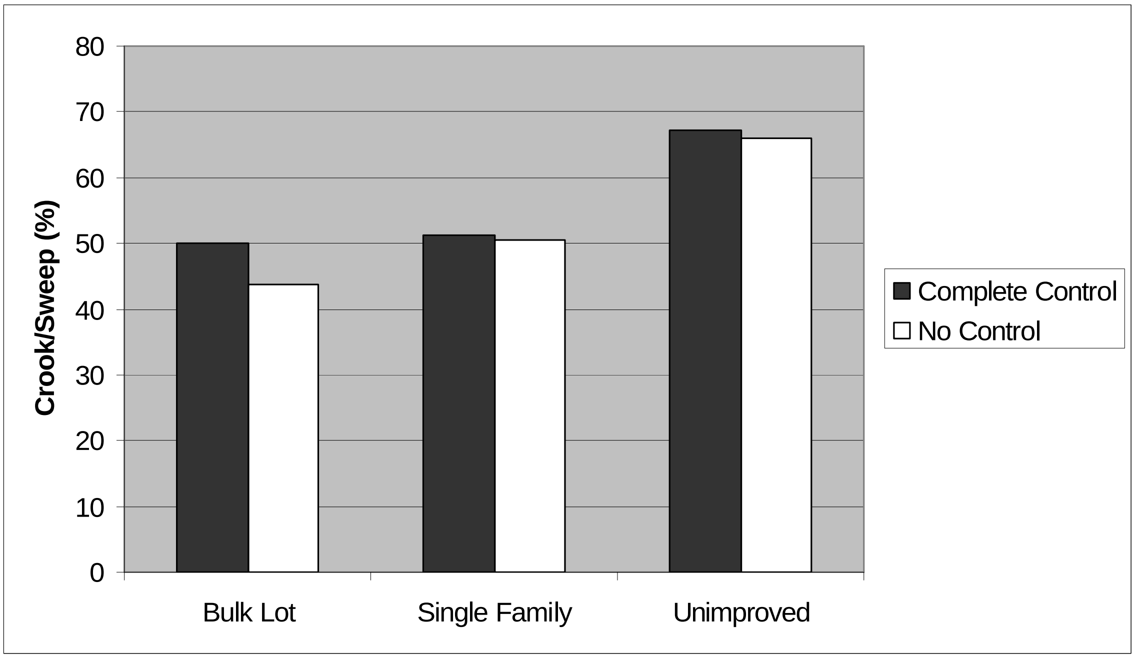

Figure 23. Percent of trees with crook or sweep by treatment for 18-yr-old loblolly pine in the Coastal Plain.

3.13.2 Piedmont Analysis

Results for the Piedmont analysis are very similar to those for the Coastal Plain. Genetic improvement significantly contributed to reduced percent of trees with crook or sweep (Table 46). There were no significant differences between bulk lot and single family, but both decreased crook and sweep from 62.5% to 43.8% and 45.2%, respectively, over unimproved stock. Vegetation control did not significantly affect the percent of trees with crook or sweep (Table 47, Figure 24).

Table 46. Test of fixed effects (reproduced from SAS® output) for percent of trees with crook or sweep in the Piedmont.

Source	Numerator Df	Denominator Df	Type III F	Pr > F
Genetics	2	23.3	13.22	0.0001
Competition Control	1	11.1	0.91	0.3601
Genetics* Competition Control	2	21.3	1.18	0.3268

Table 47. Summary of least squares means for percent of trees with crook or sweep in the Piedmont.

	No Control	Complete Control	Average
Unimproved	62.4%	62.6%	62.5%
Bulk Lot	44.0%	43.6%	43.8%
Single Family	41.5%	48.8%	45.2%
Average	49.3%	51.7%	49.9%

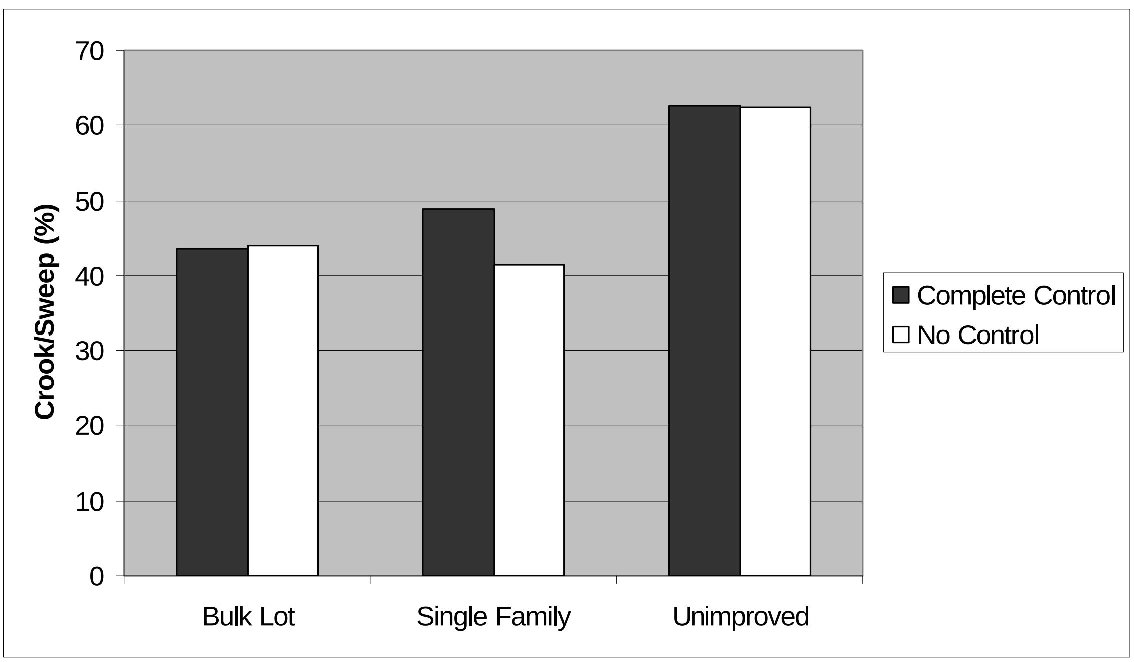

Figure 24. Percent of trees with crook or sweep by treatment for 12-yr-old loblolly pine in the Piedmont.

4. THREE YEAR PERIODIC GROWTH

An analysis was conducted to examine the 3-year periodic growth of the dependent variables between ages 15 and 18. 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.

4.1 Average Dbh

The 3-year periodic growth in mean dbh between ages 15 and 18 were found to be significantly larger for no competition control plots than complete control plots in both the Piedmont and Coastal Plain regions (Table 48).

Table 48. Average difference (in.) in mean dbh growth between ages 15 and 18. Different letters indicate a significant difference between complete vegetation control and no control.

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
15 to 18 yrs	0.44 (a)	0.52 (b)	0.50 (a)	0.63 (b)

These results indicate that the mean dbh for the two different competition control treatments are converging over time (Figures 25 and 26). This convergence may indicate that the two competition control treatments are at different stages of stand development. The complete control treatment exhibited significantly greater dbh growth rates early in stand development and now, as the stand matures, the complete control is starting to exhibit slightly lower growth rates as it experiences intraspecific competition. This stage of development is characterized by a reduction in individual tree growth rates relative to their potential in the absence of competitive interaction (Long and Smith, 1984). It is important to note that while the 3-year periodic growth rates are significantly higher for the no competition control plots, the absolute difference in dbh between the treatments at age 18 averaged 0.49 to 0.56 inches. No significant differences were detected between mean dbh growth during this period with respect to genetics in either region.

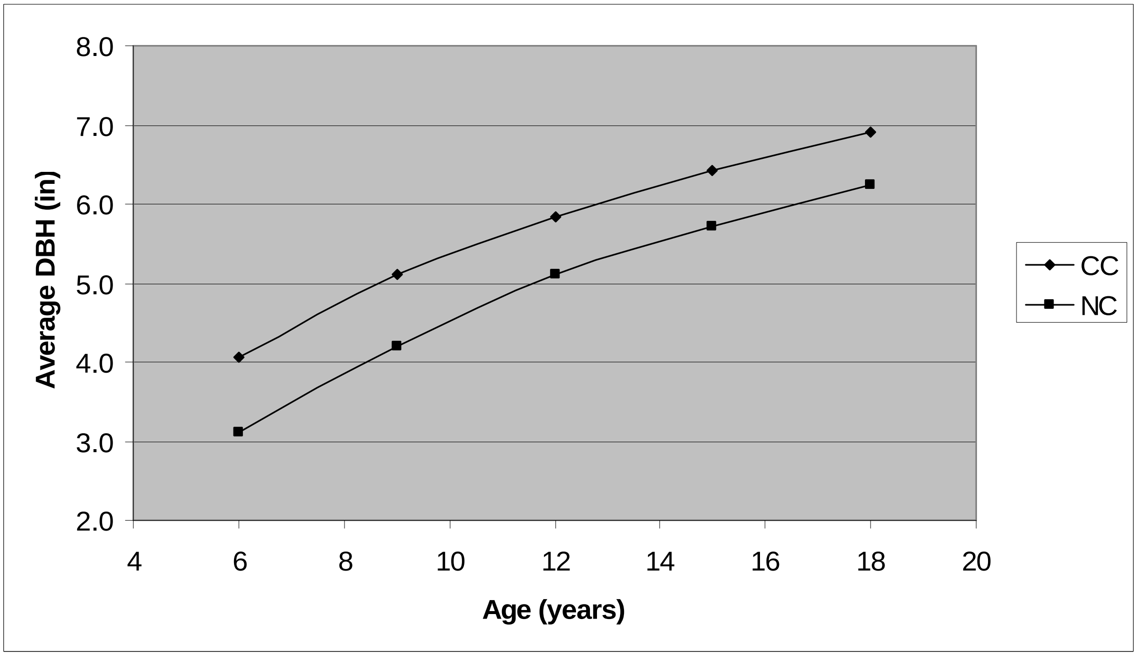

Figure 25. Mean dbh growth for the two competition control treatments in the Coastal Plain.

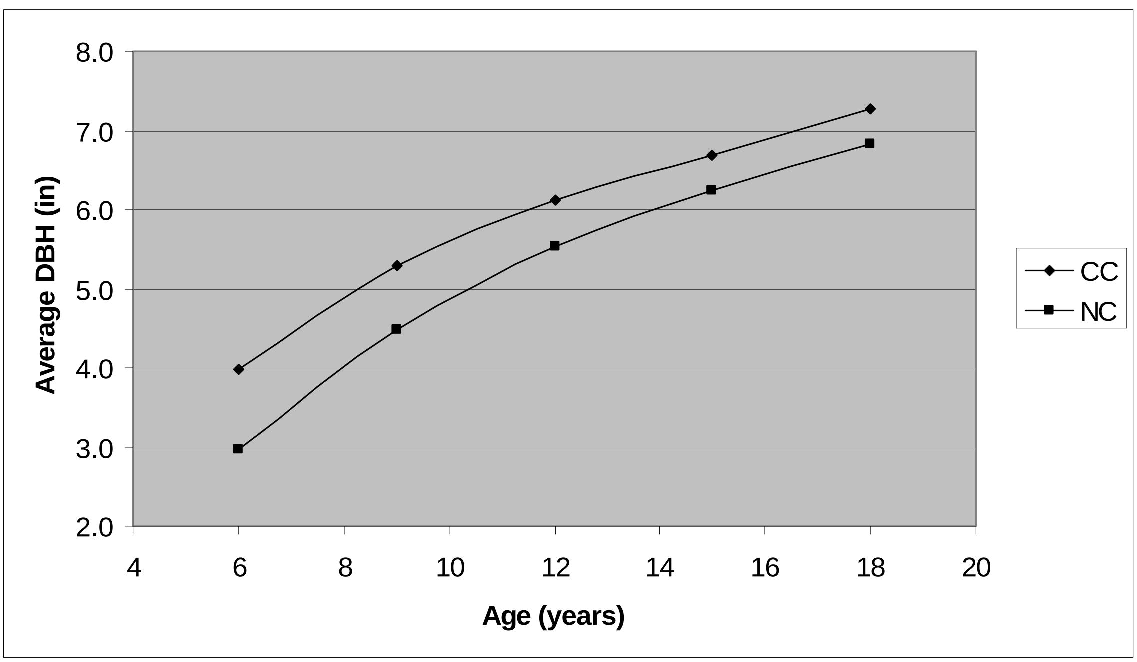

Figure 26. Mean dbh growth for the two competition control treatments in the Piedmont.

4.2 Average Dominant Height

In terms of mean dominant height, the competition control treatment now significantly affects the growth rate in both physiographic regions (Table 49). Figures 27 and 28 show that the mean dominant height growth rate for the no competition control treatment plots is now greater than the growth rate for the complete control treatment plots. This is a change from previous years when there was no significant difference in dominant height growth rates due to vegetation control but there were significant differences due to genetics.

Table 49. Average difference (in.) in average dominant height between ages 15 and 18 years. Different letters indicate a significant difference between complete vegetation control and no control.

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
15 to 18 yrs	6.28 (a)	6.97 (b)	6.80 (a)	7.22 (b)

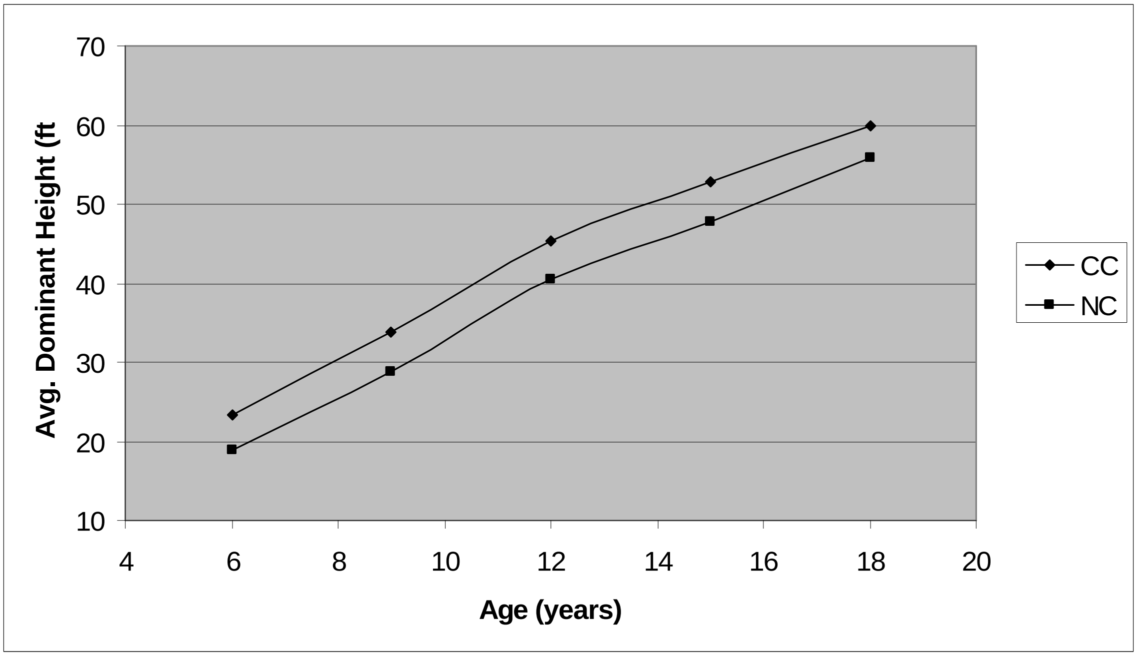

Figure 27. Mean dominant height growth for the two competition control treatments in the Coastal Plain.

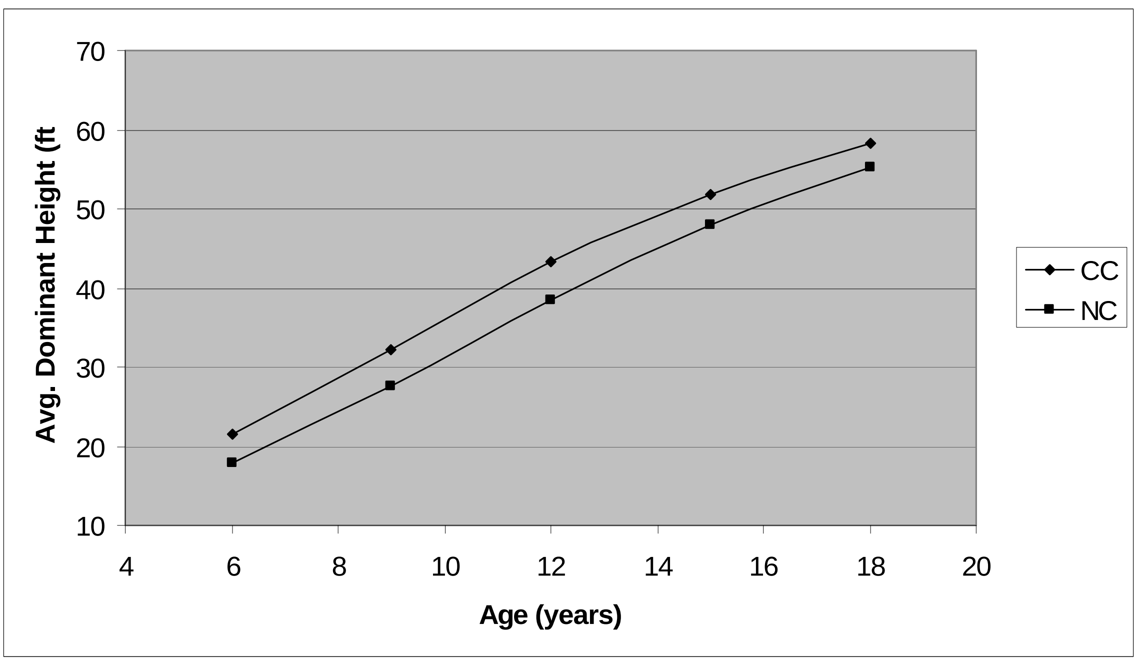

Figure 28. Mean dominant height growth for the two competition control treatments in the Piedmont.

4.3 Per-Acre Basal Area

There was a significant difference between mean growth of basal area per acre for competition control in the Coastal Plain region between the ages of 15 and 18 years (Table 50). The no vegetation control treatments outgrew the complete control treatment plots by 4.3 ft^2/ac over the three-year period. There were no significant differences in per-acre basal area growth in the Piedmont region. Figures 29 and 30 show the per-acre basal area development curves by vegetation control treatment for the two regions

Table 50. Average difference (ft^2) in mean basal area growth between ages 15 and 18 years. Different letters indicate a significant difference between complete vegetation control and no control.

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
15 to 18 yrs	12.41 (a)	16.67 (b)	12.86 (a)	21.43 (a)

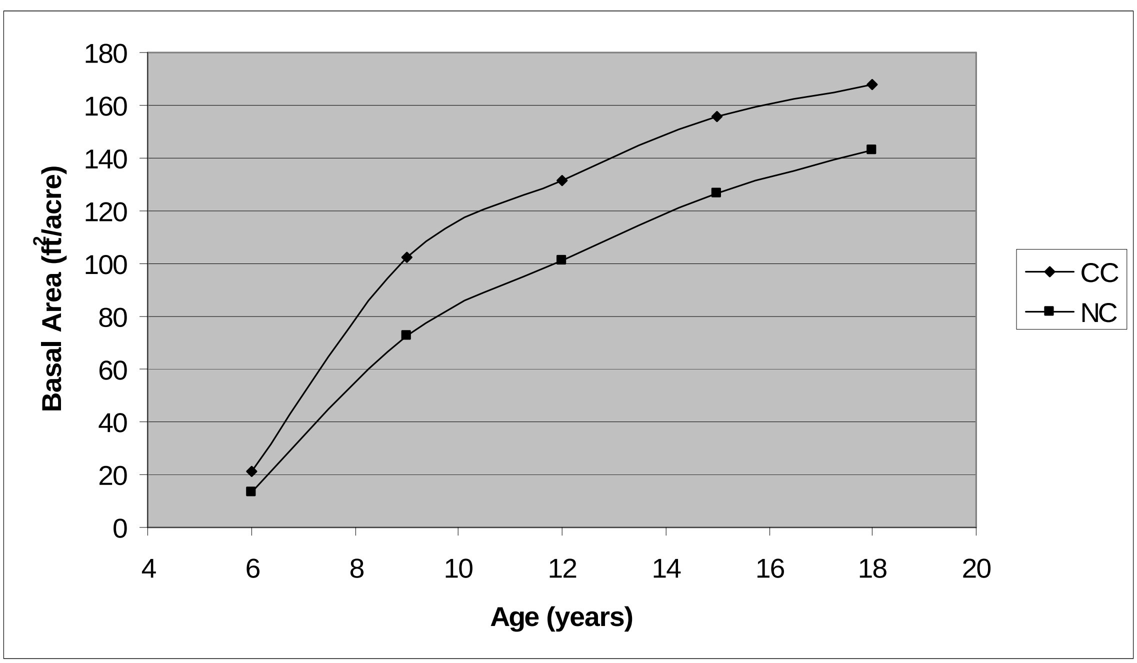

Figure 29. Mean basal area per acre for the two competition control treatments in the Coastal Plain.

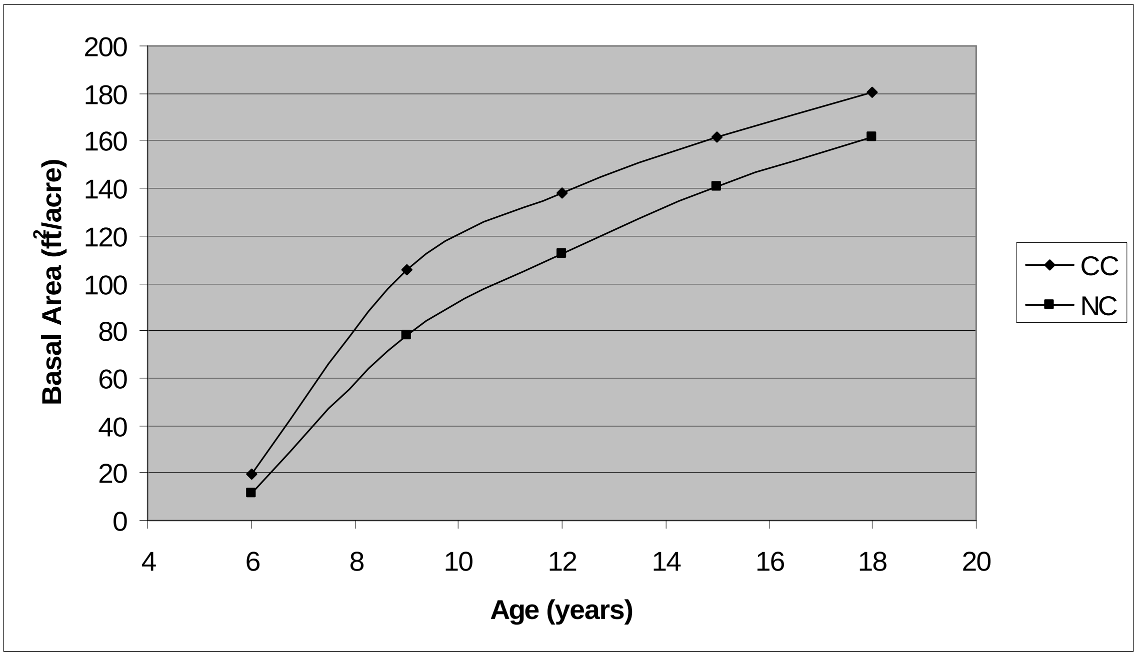

Figure 30. Mean basal area per acre for the two competition control treatments in the Piedmont.

4.4 Per-Acre Volume and Weight Yield

In both physiographic regions, neither genetics nor competition control treatments significantly affected growth in total volume, merchantable volume, total green weight or merchantable green weight between the ages of 15 and 18 years. Previous analyses (prior to the age of 12) showed significantly greater yield growth rates due to genetic and vegetation control treatments. Figures 31 and 32 show the growth in total outside bark volume by treatment for the coastal plain and Piedmont regions.

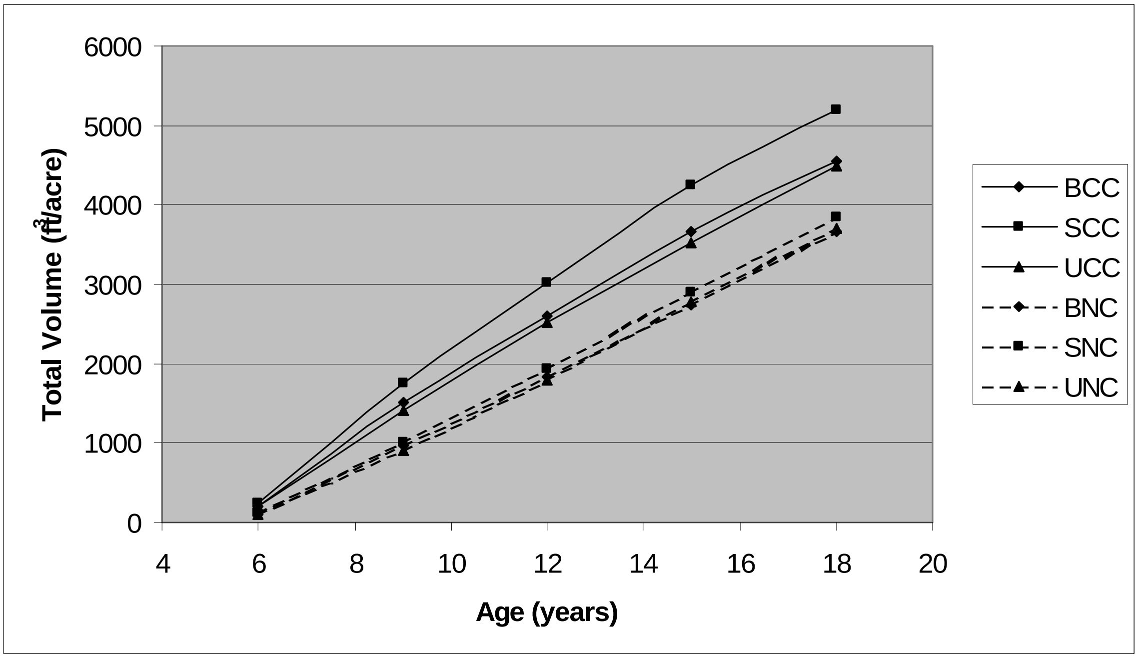

Figure 31. Total volume (ft^3/ac) for the six different treatment combinations in the Coastal Plain.

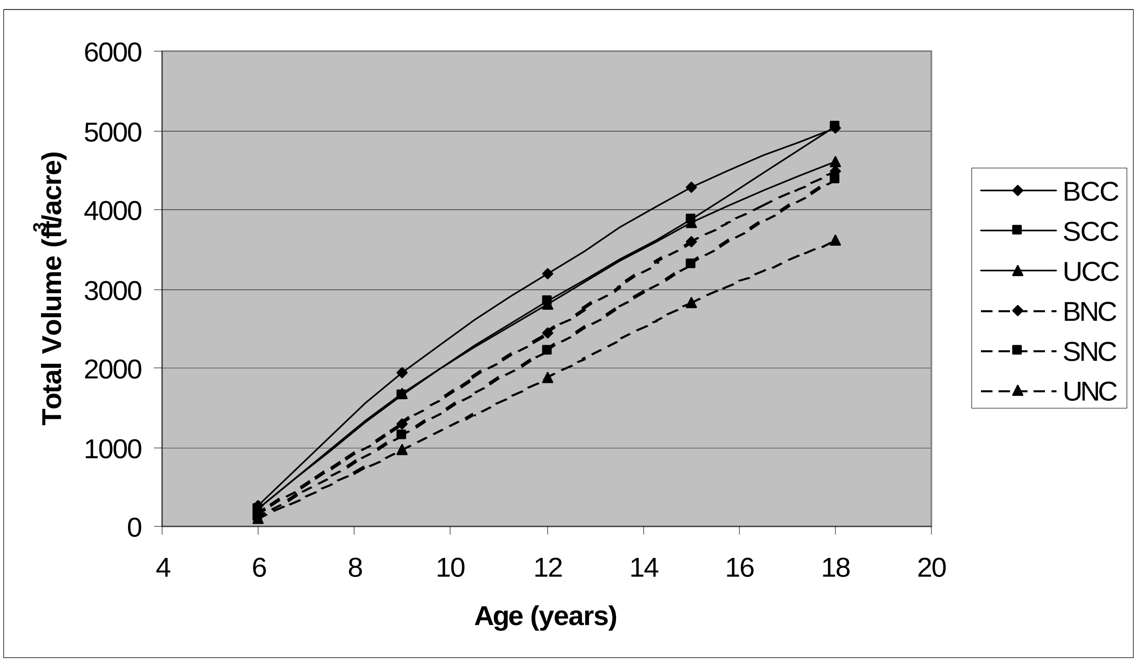

Figure 32. Total volume (ft^3/ac) for the six different treatment combinations in the Piedmont.

5. LIMITING DENSITY RELATIONSHIPS

5.1 Relative Spacing

Relative spacing (RS) is defined as the ratio between the average distance between trees and the average dominant height of a stand:

$$RS = \frac{\sqrt{43560 / TPA}}{HD}$$

Clutter *et.al.* (1983) point out that regardless of site quality, stands of a given species tend to approach a common, minimum relative spacing level over time. Figures 33 and 34 show relative spacing curves, by treatment, for the Coastal Plain and Piedmont regions. The relative spacing values break out logically with regard to treatment. Since neither genetics nor vegetation control has ever had a significant effect on survival, but has had significant effects on average dominant height, the relative spacing values, in the early years, should reflect the differences in average dominant height. This is illustrated in Figures 33 and 34 as relative spacing at age six decreases with increasing treatment intensity. By age nine, the relative spacing values had begun to converge and this trend has continued through age 18.

5.2 Stand Density Index

Stand density index (SDI) is defined as the relationship between the number of trees per acre and the average tree size. In fully-stocked, even-aged stands, the relationship between the number of trees per acre and the quadratic mean dbh (D_q) should appear linear in logarithmic coordinates. This implies a theoretical, limiting number of trees for a given D_q. Reineke (1933) observed this relationship for a variety of species and determined the slope of the limiting line was approximately -1.6. Therefore, SDI can be calculated as:

$$SDI = TPA\left(\frac{D_q}{10}\right)^{1.6}$$

Figures 35 and 36 show SDI values over age, by treatment, for the Coastal Plain and Piedmont regions.

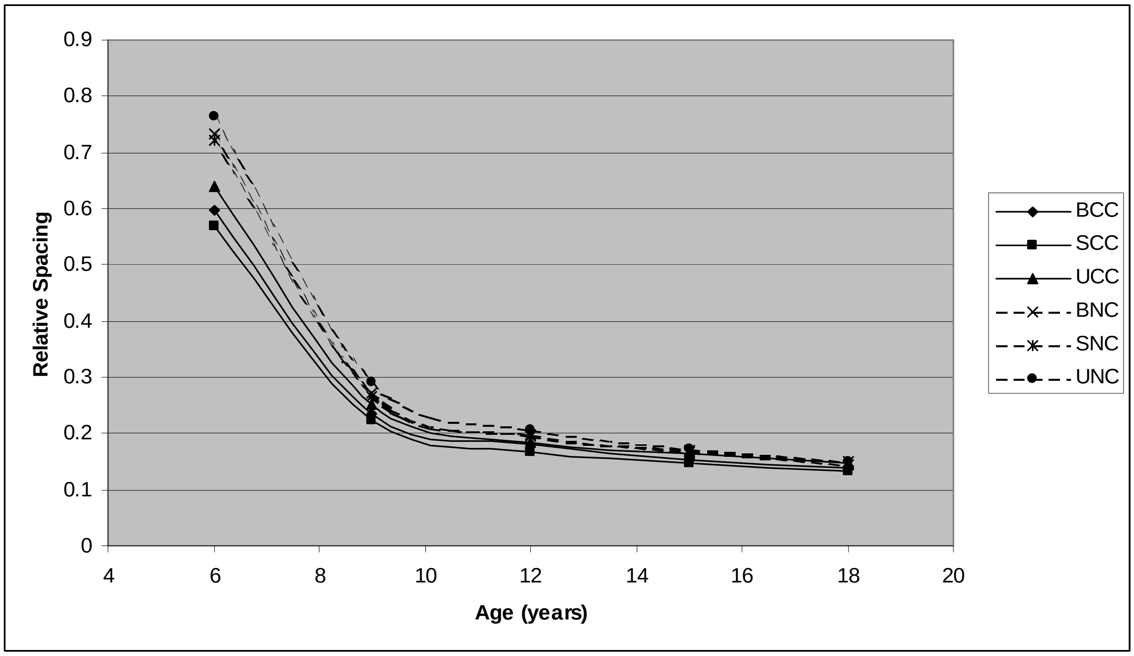

Figure 33. Relative spacing over age by treatment for the Coastal Plain.

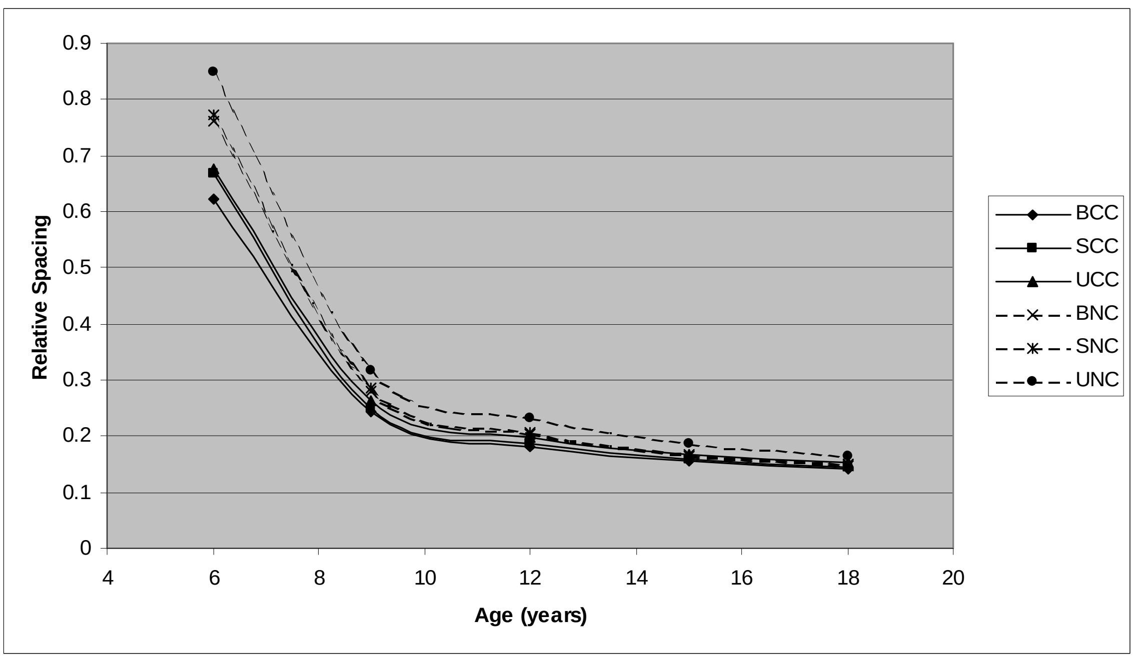

Figure 34. Relative spacing over age by treatment for the Piedmont.

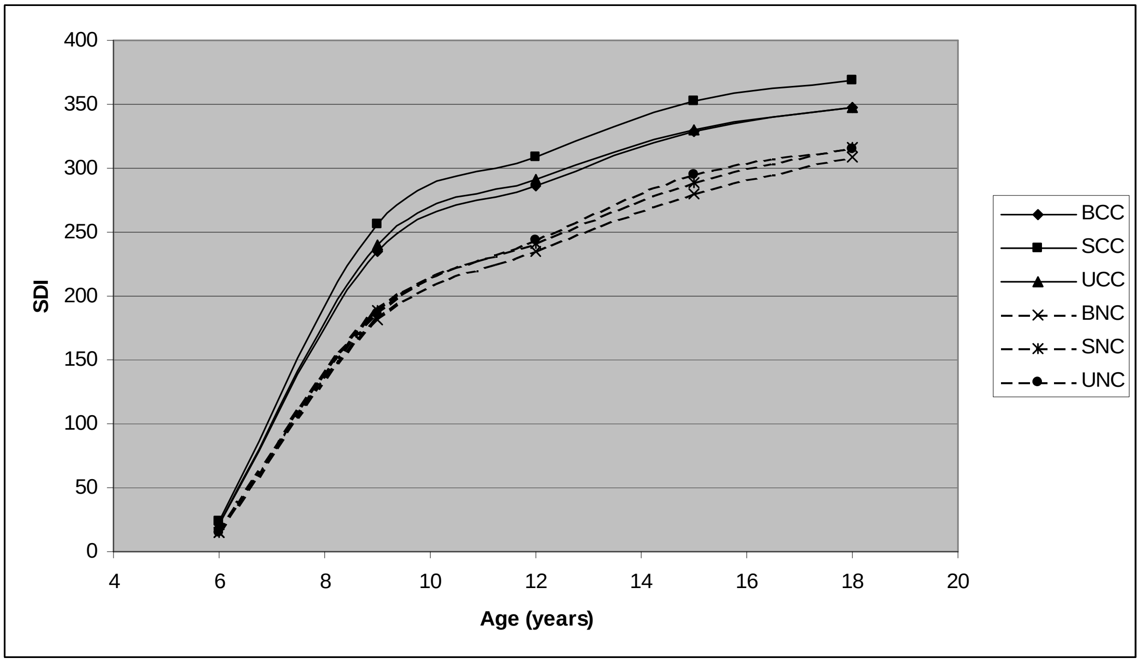

Figure 35. Stand density index over age by treatment for the Coastal Plain.

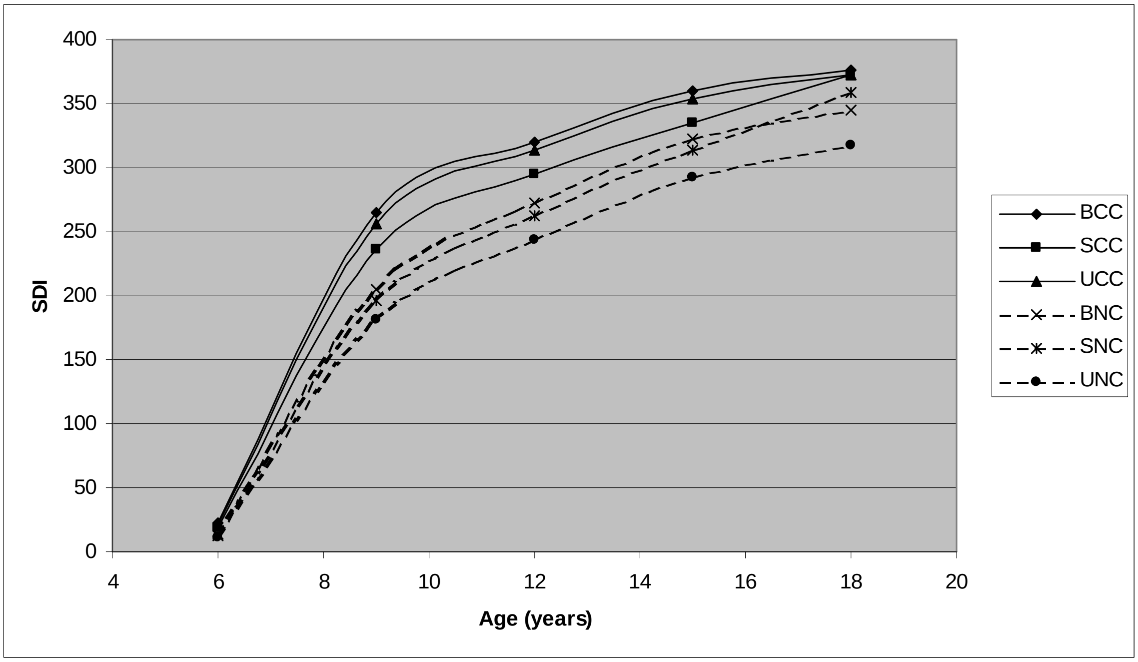

Figure 36. Stand density index over age by treatment for the Coastal Plain.

6. CONCLUSIONS

The age 18 results of the improved planting stock/competition control study are remarkably consistent with previous analyses at ages 12 and 15. For most of the stand characteristics analyzed, both genetic improvement and competition control are significant factors that improve the growth and yield for treated stands. There was not an analysis in which a significant interaction was found. This means that genetic improvement improves growth across both levels of competition control (none and total), and that competition control improves growth across all levels of genetic improvement (none, bulk lot, and single family). The responses for genetic improvement and competition control appear to be additive.

The evaluation of periodic growth found that dbh, dominant height, and basal area growth from age 15 to 18 was either not different across treatments or that the untreated periodic growth was greater. The magnitude of the growth differences was such that it will take many years before the total values were the same. The volume and weight growth was not different between treatments though, in previous years, the periodic growth for treated stands had been higher. The cumulative effect of those early growth gains for both genetic improvement and competition control is that those treated stands are at a different level of stand development and intraspecific competition is slowing the periodic growth. Again, the number of years till the untreated could catch up would be quite large.

The results of fusiform rust infection level analysis points to the continuing importance of planting genetically-improved planting stock. The infection levels are roughly half of the unimproved stands. Other wood quality variables such as percent defect, percent fork, etc. also point to value gains from using genetically improved stock above and beyond the volume or weight gains.

7. LITERATURE CITIED

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