LOBLOLLY PINE IMPROVED PLANTING STOCK-VEGETATION CONTROL STUDY-AGE 15 RESULTS

Plantation Management Research Cooperative

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PMRC TECHNICAL REPORT 2003-1

December, 2002

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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 15 measurements for this study and the 3-yr periodic growth from ages 12 to 15 yr. 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 in both the Piedmont and Coastal Plain regions. In the Piedmont region, improved genetics significantly increased average dbh. Average dominant height was significantly increased in both physiographic regions by improved genetics. For Coastal Plain loblolly pine, improved genetics significantly increased basal area per acre while, in the Piedmont region, there was a significant interaction between competition control and genetics with respect to basal area per acre. Total volume was significantly increased by both improved genetics and competition control. In terms of total volume, increases up to 32% and 28% were obtained using complete vegetation control in the Coastal Plain and Piedmont regions, respectively. Improved genetic stock increased total volume an average of 10% and 14% in the Coastal Plain and 18% and 13% in the Piedmont for bulk lot and single family, respectively. For both total and merchantable volume the effects of competition control and improved genetics were additive. Competition control and improved genetics were also additive for total green weight and merchantable green weight. The additive nature of the effects indicates that managers should obtain the full benefit of these treatments. In both regions, neither competition control nor genetics significantly affected surviving trees per acre. Improved genetics significantly reduced the percent fusiform infection in both regions. Additionally, no significant differences were detected between bulk lot and single family plantings across all dependent variables. Improved genetics significantly decreased the percent of trees with major defects, while competition control had no impact. In both the Coastal Plain and Piedmont, competition control significantly increased the percentage of forked trees versus no competition control. Improved genetics significantly decreased the percentage of forked trees in the Coastal Plain, but had no impact in the Piedmont. The percentage of trees with sweep was significantly reduced by improved genetics in both the Coastal Plain and Piedmont, but competition control had no significant effect in either physiographic region.

The results of the 3-yr periodic growth analysis from age 12 to 15 indicated that the no competition control plots had significantly larger 3-yr growth in mean dbh in both the Piedmont and Coastal Plain regions than complete vegetation control plots. In terms of mean dominant height, improved genetic stock continued to outgrow the unimproved stock in the Piedmont. In both the Coastal Plain and Piedmont, basal area growth was significantly higher on plots without competition control than plots with competition control. Neither improved genetics nor competition control significantly affected volume growth during the 12 to 15 year period in the Coastal Plain. In the Piedmont improved genetics continued to outgrow unimproved stock in volume.

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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, making their use for yield model development questionable. In addition, 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 15 measurement analysis of loblolly pine for this study. Also included are the results of the analysis of the 3-yr growth between ages 12 and 15.

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 (Oust®) in early spring of each of the first three growing seasons, and by directed sprays of glyphosate (Accord®) 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 sixth, ninth, twelfth and fifteenth growing seasons. After the ninth, twelfth and fifteenth growing seasons all trees on the measurement plots were measured for dbh and checked for stem cankers. After the fifteenth growing season all trees were assigned a quality code. The quality codes were defect tree, forked, crook or sweep, canker, or broken top. Height to live crown was measured on all height measurement trees after the fifteenth growing season. 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 $b_{0,}$ 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).

ANALYSIS and RESULTS

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 while competition control, genetics, and their interaction 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, percent fusiform rust infection, percentage of trees defect free, 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 α =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 analyses, the df may not 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 rates.

Average DBH

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 0.6 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 (in.) by treatment.

Table 2. Test of fixed effects (reproduced from SAS® output) for average dbh (in.) in the Coastal Plain.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	21.9	3.17	0.0619
Competition Control	1	12.3	69.65	<0.0001
Genetics* Competition Control	2	21.5	0.16	0.8541

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

	No Control	Complete Control	Average
Unimproved	5.80	6.42	6.11
Bulk Lot	5.87	6.49	6.18
Single Family	5.94	6.62	6.28
Average	5.87	6.51	6.20

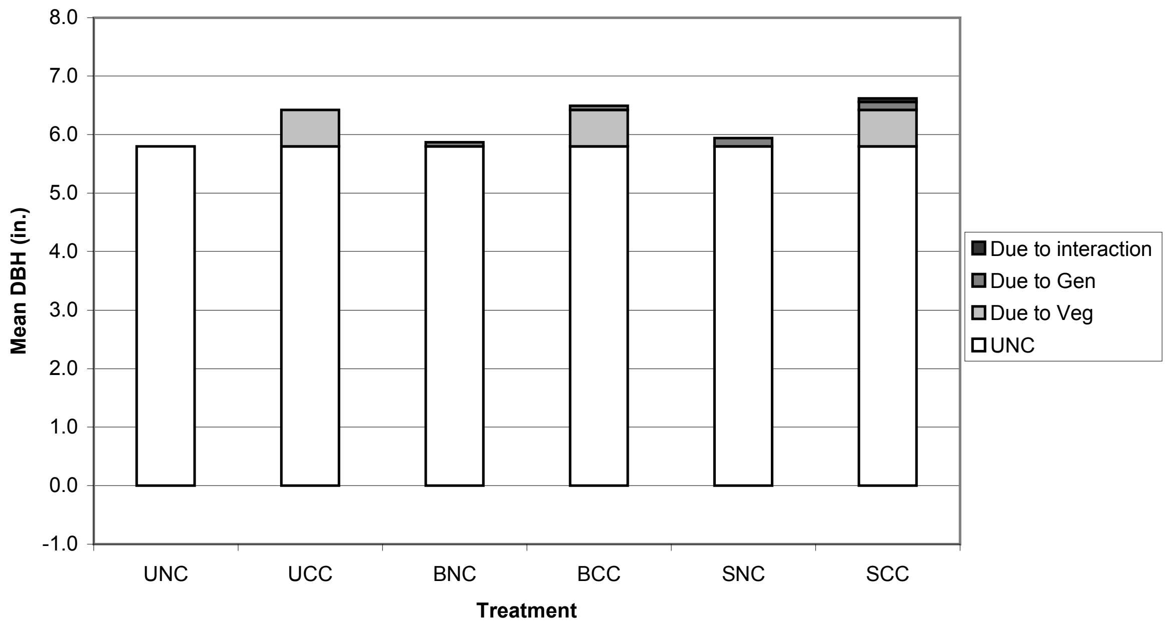

Figure 1. Mean dbh by treatment for 15-yr-old loblolly pine in the Coastal Plain.

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 improved genetics had significant effects on average dbh. Competition control significantly increased average dbh an average of 0.7 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 significantly increased average dbh 0.28 in. and single family 0.19 in. over unimproved stock. The interaction between improved genetic stock and competition control was not significant. Table 5 and Figure 2 summarize the least square means for average dbh (in.) by treatment.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	50.1	4.78	0.0126
Competition Control	1	12.1	50.50	<0.0001
Genetics* Competition Control	2	50.8	0.88	0.4207

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

	No Control	Complete Control	Average
Unimproved	6.09	6.80	6.44
Bulk Lot	6.48	6.96	6.72
Single Family	6.31	6.97	6.64
Average	6.29	6.91	6.58

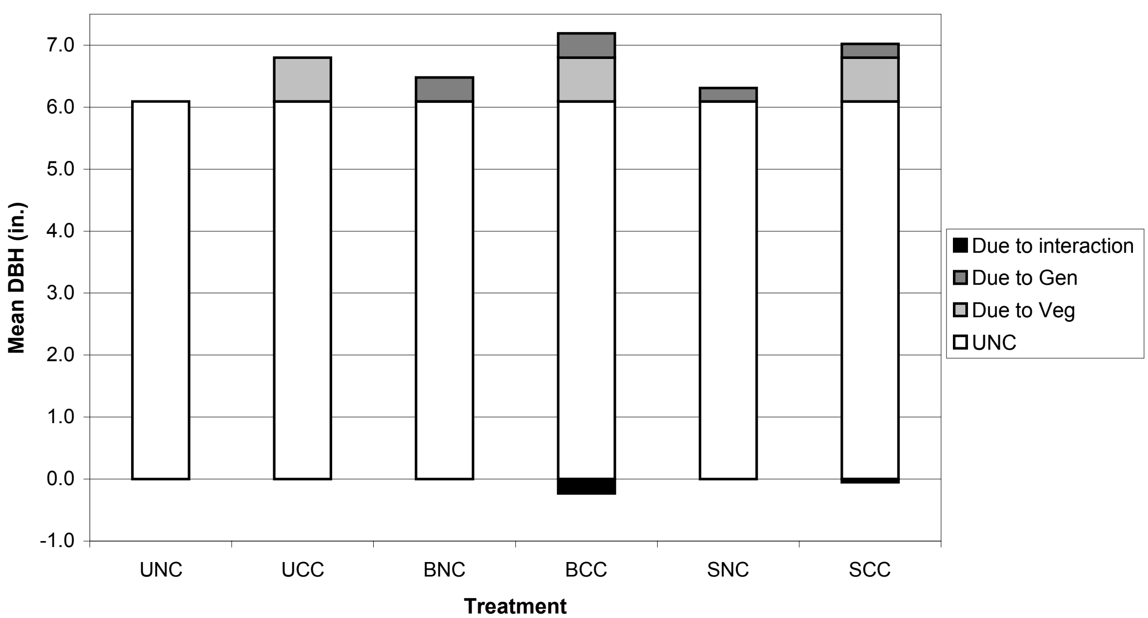

Figure 2. **Mean dbh by treatment for 15-yr-old loblolly pine in the Piedmont.**

Range and Skewness of the DBH Distribution

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. Improved 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.

Piedmont Analysis

In the Piedmont region, competition control significantly decreased the average range in dbh by 0.42 inches. Improved genetics significantly affected the skewness of the diameter distribution. While there were no differences between single family and bulk lot, or bulk lot and unimproved, single family decreased the skewness statistic by 0.17 over unimproved stock, indicating more trees in larger dbh classes.

Average Dominant Height

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 4.8 ft at age 15 across all levels of genetic stock. Improved genetic stock also significantly increased average dominant height. While there was no significant difference between single family and bulk lot, dominant height increased by 3.8 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 (ft) by treatment.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	42	19.54	<0.0001
Competition Control	1	12.2	42.6	<0.0001
Genetics* Competition Control	2	42.1	0.29	0.7508

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

	No Control	Complete Control	Average
Unimproved	44.6	48.9	46.8
Bulk Lot	47.6	52.4	50.0
Single Family	48.0	53.3	50.6
Average	46.7	51.5	49.4

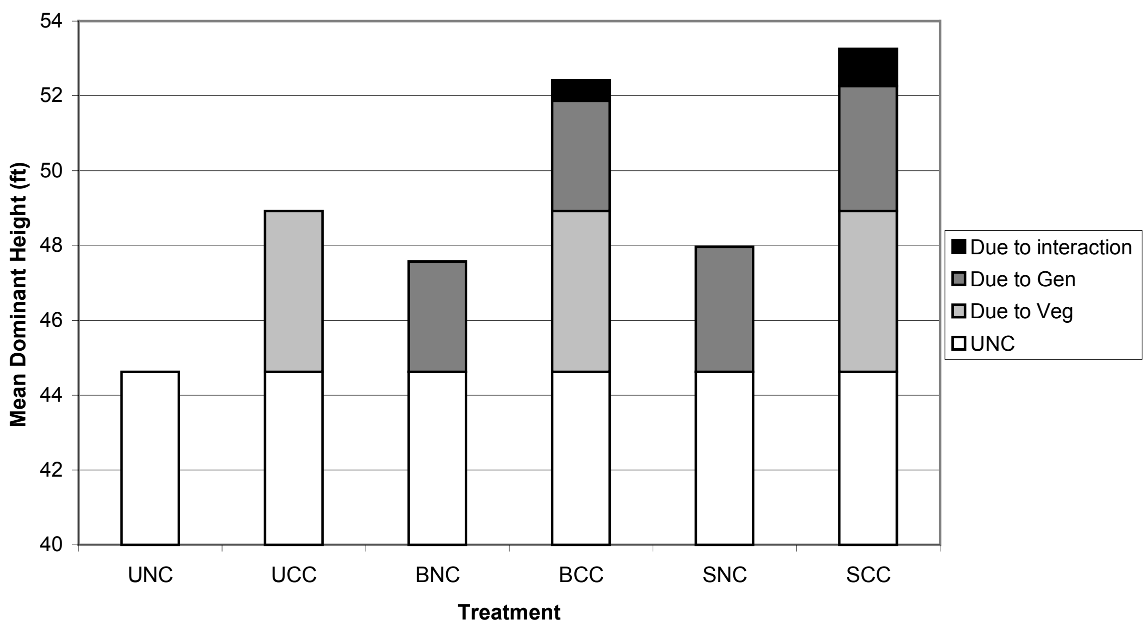

Figure 3. Mean dominant height by treatment for 15-yr-old loblolly pine in the Coastal Plain.

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 4.3 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 5.4 ft and single family 4.3 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 (ft) by treatment.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24.4	25.88	<.0001
Competition Control	1	66.9	58.37	<.0001
Genetics* Competition Control	2	67.4	0.90	0.4099

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

	No Control	Complete Control	Average
Unimproved	42.8	48.1	45.5
Bulk Lot	49.1	52.6	50.8
Single Family	47.6	51.9	49.8
Average	46.5	50.8	48.7

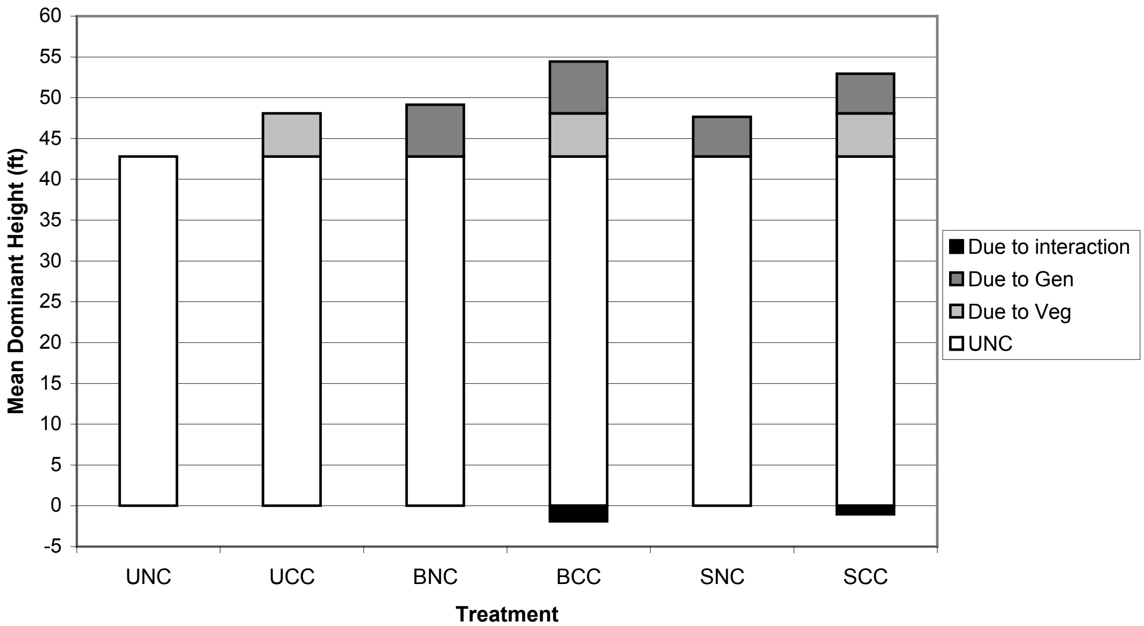

Figure 4. **Mean dominant height by treatment for 15-yr-old loblolly pine in the Piedmont.**

Basal Area per Acre

Coastal Plain Analysis

Both improved 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 26 ft^2/ac across all levels of genetic stock. Improved genetic stock also significantly increased 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 6.5 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 5). Table 11 summarizes the least square means for basal area per acre (ft^2).

Table 10. Test of fixed effects (reproduced from SAS® output) for basal area (ft²/ac) in the Coastal Plain.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	36	3.31	0.0480
Competition Control	1	12.9	82.59	<0.0001
Genetics* Competition Control	2	36.6	1.21	0.3085

Table 11. Summary of least squares means for basal area (ft²/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	129.6	152.2	140.9
Bulk Lot	130.4	156.7	143.7
Single Family	132.1	162.8	147.5
Average	130.7	157.3	144.8

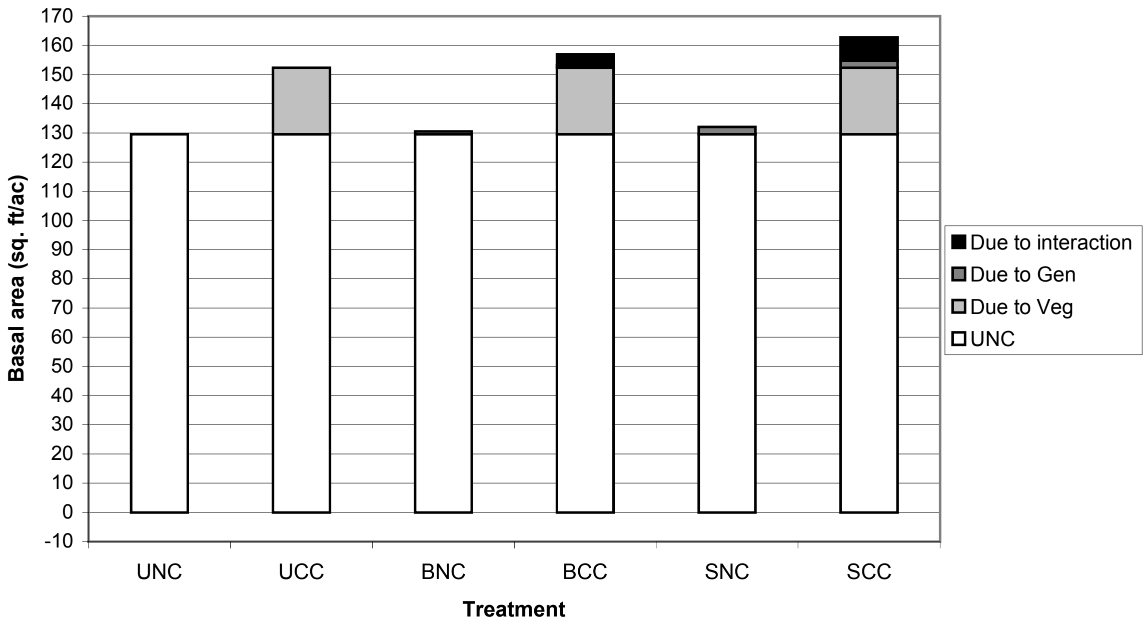

Figure 5. Basal area per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

The interaction between vegetation control and genetic stock had a 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	23.5	3.74	0.0390
Competition Control	1	11.8	39.49	<0.0001
Genetics* Competition Control	2	52.1	4.14	0.0214

Figure 6 graphically shows that mean basal area with complete vegetation control does not receive significant additional gain due to genetics. These results suggest that managers using less intensive competition control in the Piedmont may benefit more with respect to basal area per ac and survival from improved seedlings than mangers using vegetation control. In the case of no vegetation control there was no significant difference between bulk lot and single family, or between single family and unimproved, but bulk lot increased basal area 10.0 ft^2/ac over unimproved stock. With unimproved genetic stock, complete vegetation control increased basal area 38.9 ft^2/ac. Competition control increased basal area 24.5 ft^2/ac and 20.2 ft^2/ac for single family and bulk lot genetic stock, respectively. Table 13 and Figure 7 summarize the least square means for basal area (ft^2/ac) by treatment.

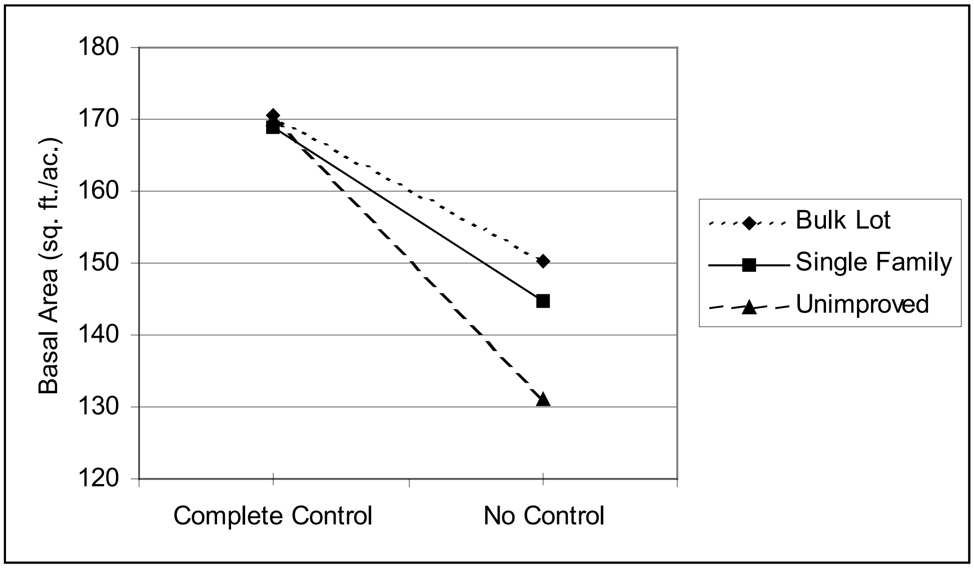

Figure 6. **The interaction between competition control and genetic stock on basal area per acre in the Piedmont.**

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

	No Control	Complete Control	Average
Unimproved	131.0	169.9	150.4
Bulk Lot	150.9	170.5	160.4
Single Family	144.6	169.1	156.9
Average	142.0	169.8	154.9

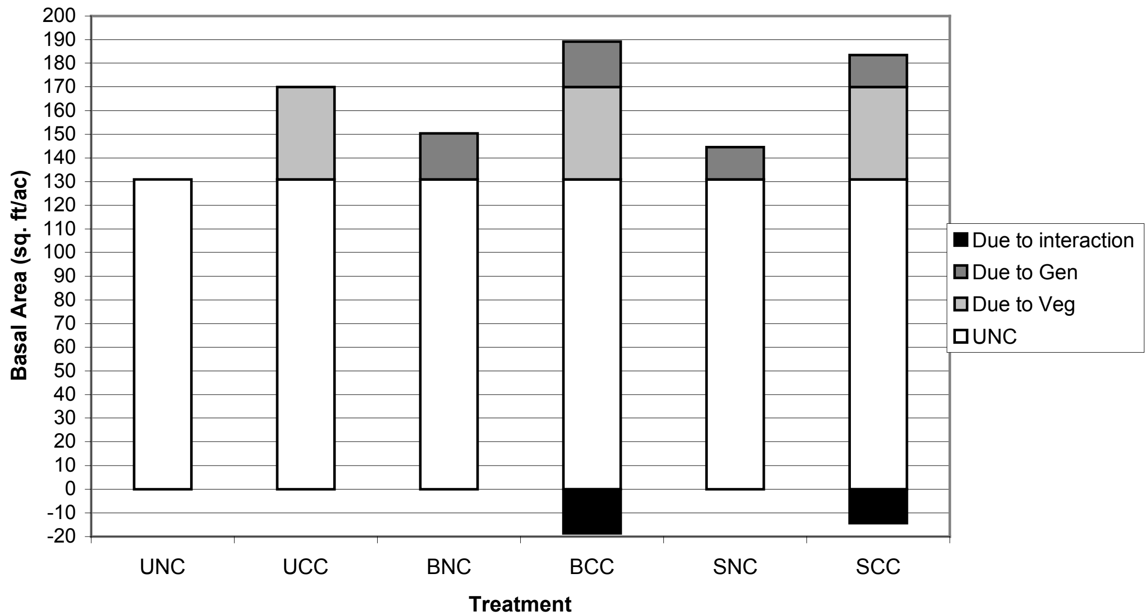

Figure 7. Basal area per acre by treatment for 15-yr-old loblolly pine in the Piedmont.

Total Volume per Acre

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 941 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 437 ft^3/ac and 313 ft^3/ac, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 15 and Figure 8 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 (ft³/ac) in the Coastal Plain.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	40.8	11.96	<.0001
Competition Control	1	13.2	75.25	<.0001
Genetics* Competition Control	2	41.2	0.93	0.4037

Table 15. Summary of least squares means for total volume (ft³/ac) in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	2772	3604	3188
Bulk Lot	3043	3958	3501
Single Family	3088	4163	3625
Average	2968	3908	3478

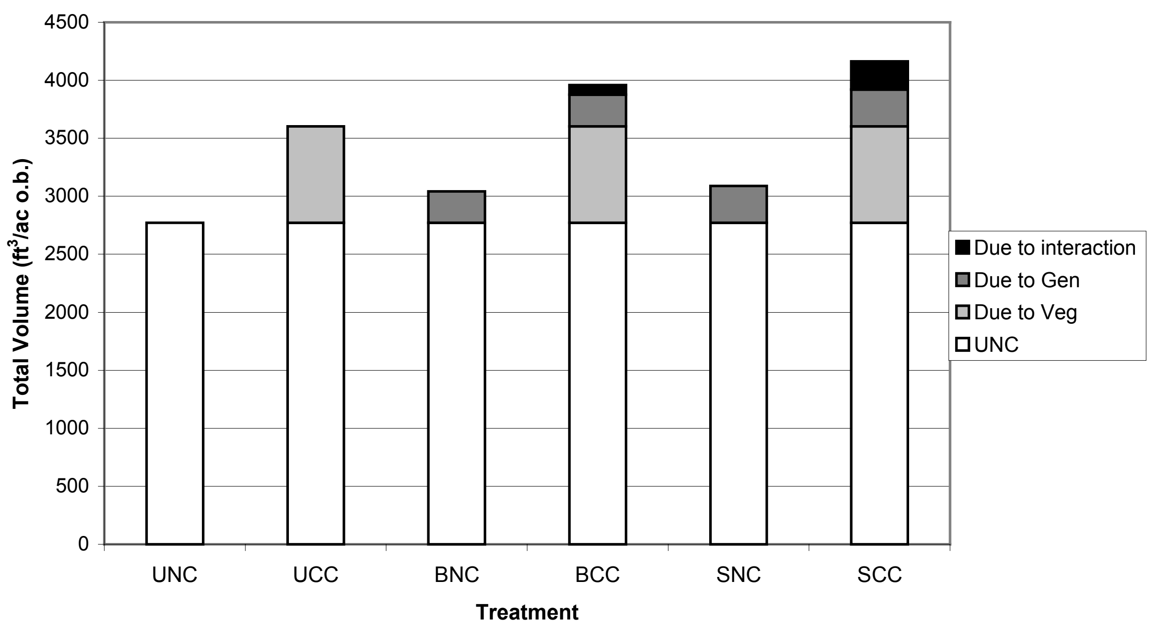

Figure 8. Total Volume per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

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 892 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 591 ft^3/ac and single family 418 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant at the alpha = 0.05 level, although there was a significant interaction at the alpha= 0.10 level. Table 17 and Figure 9 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	23.9	12.42	0.0002
Competition Control	1	11.5	42.38	<.0001
Genetics* Competition Control	2	53.3	2.63	0.0815

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

	No Control	Complete Control	Average
Unimproved	2731	3902	3317
Bulk Lot	3571	4243	3907
Single Family	3319	4150	3734
Average	3207	4098	3624

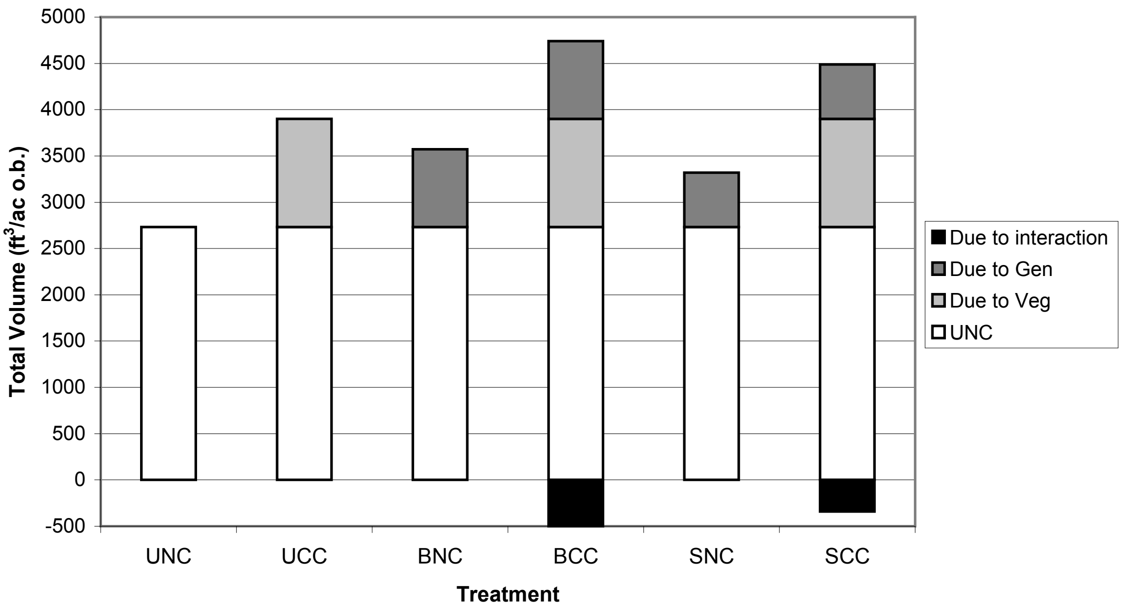

Figure 9. **Total Volume per acre by treatment for 15-yr-old loblolly pine in the Piedmont.**

Merchantable Volume

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 970 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 303 ft^3/ac and single family 436 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 19 and Figure 10 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	41.4	11.67	<.0001
Competition Control	1	13.1	78.08	<.0001
Genetics* Competition Control	2	41.7	0.86	0.4310

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	2540	3405	2973
Bulk Lot	2804	3748	3276
Single Family	2858	3958	3408
Average	2734	3704	3258

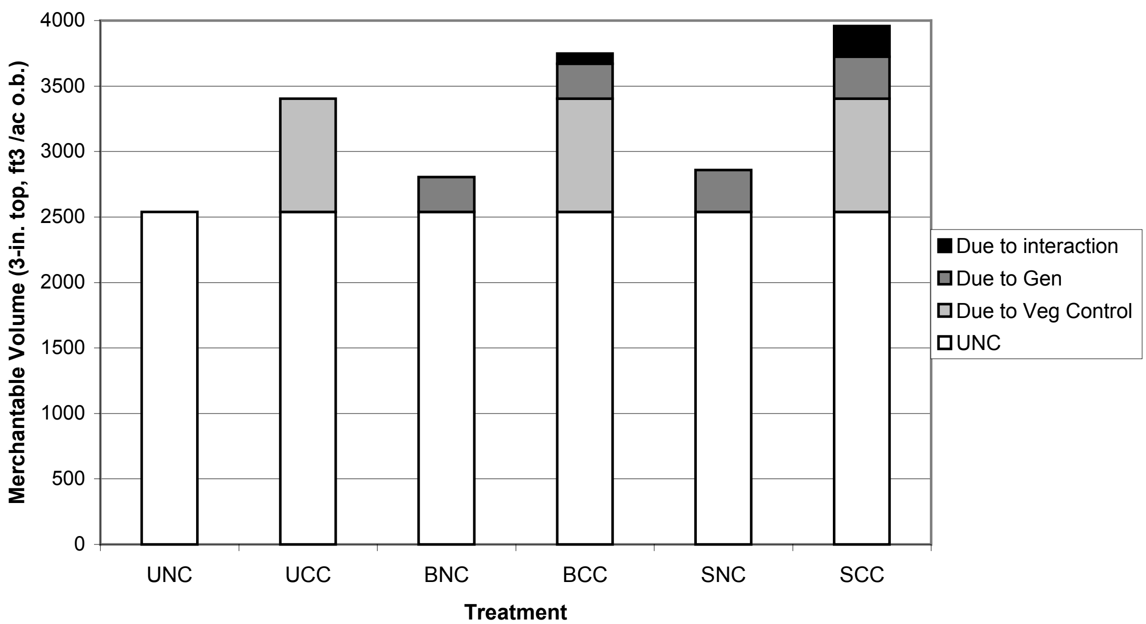

Figure 10. Merchantable volume (3-in. top) per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

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 918 ft^3/ac across all genetic stock. No significant difference was detected between bulk lot and single family, but bulk lot increased merchantable yield 591 ft^3/ac and single family 416 ft^3/ac over unimproved stock. The interaction between genetic stock and competition control was not significant at the alpha= 0.05 level, but was significant at the alpha= 0.10 level. Table 21 and Figure 11 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24.2	12.37	<.0001
Competition Control	1	11.5	47.53	<.0001
Genetics* Competition Control	2	53.5	2.51	0.0904

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	2528	3720	3124
Bulk Lot	3367	4063	3715
Single Family	3107	3974	3540
Average	3000	3919	3431

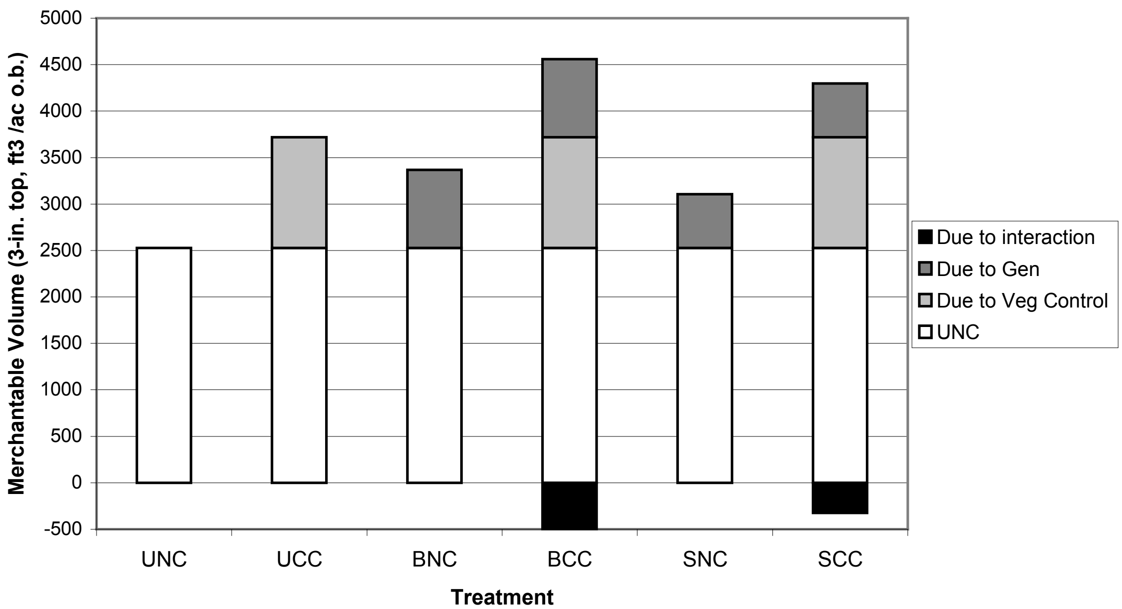

Figure 11. Merchantable volume (3-in. top) per acre by treatment for 15-yr-old loblolly pine in the Piedmont.

Total Green Weight per Acre

Coastal Plain Analysis

Table 22 gives the results of the tests of fixed effects for total green weight per acre in the Coastal Plain. Competition control significantly increased yield in the Coastal Plain an average of 26.6 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 12.7 tons/ac and 9.1 tons/ac, respectively over unimproved stock. The interaction between competition control and genetic stock was not significant. Table 23 and Figure 12 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	40.8	12.43	<.0001
Competition Control	1	13.2	74.79	<.0001
Genetics* Competition Control	2	41.2	0.93	0.4046

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

	No Control	Complete Control	Average
Unimproved	75.9	99.4	87.6
Bulk Lot	83.8	109.7	96.7
Single Family	85.1	115.5	100.3
Average	81.6	108.2	96.0

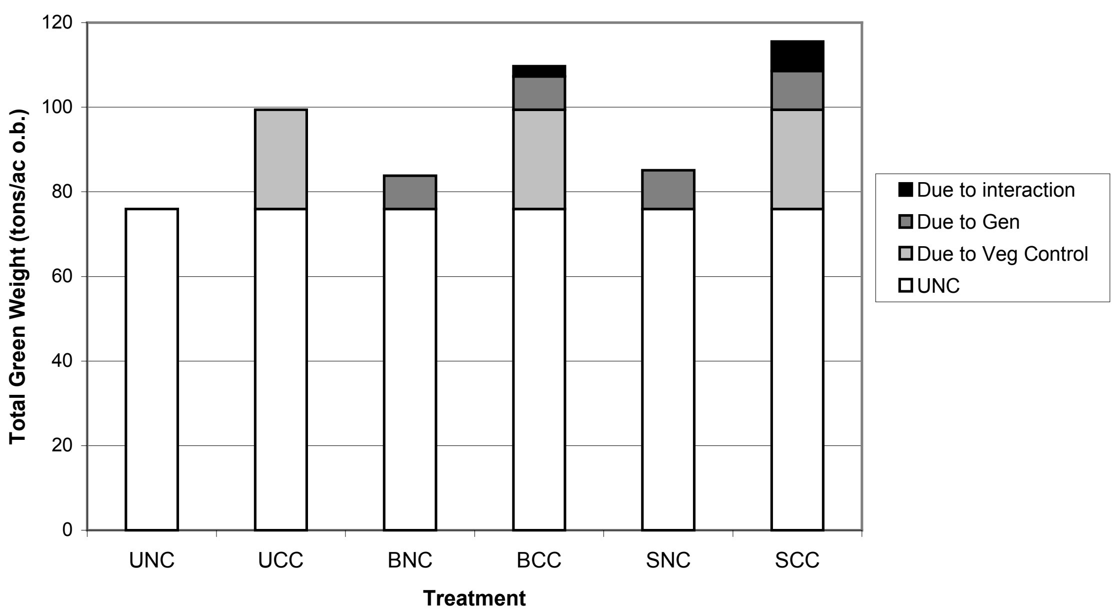

Figure 12. Total green weight per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

Table 24 gives the results of the tests of fixed effects for total green weight 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 24.9 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 16.9 tons/ac and single family 11.8 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 25 and Figure 13 summarize the least square means for total volume by treatment.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24	12.96	0.0002
Competition Control	1	11.5	43.3	<.0001
Genetics* Competition Control	2	53.4	2.42	0.0988

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

	No Control	Complete Control	Average
Unimproved	70.0	102.3	86.1
Bulk Lot	93.5	112.4	103.0
Single Family	86.2	109.7	98.0
Average	83.3	108.1	94.9

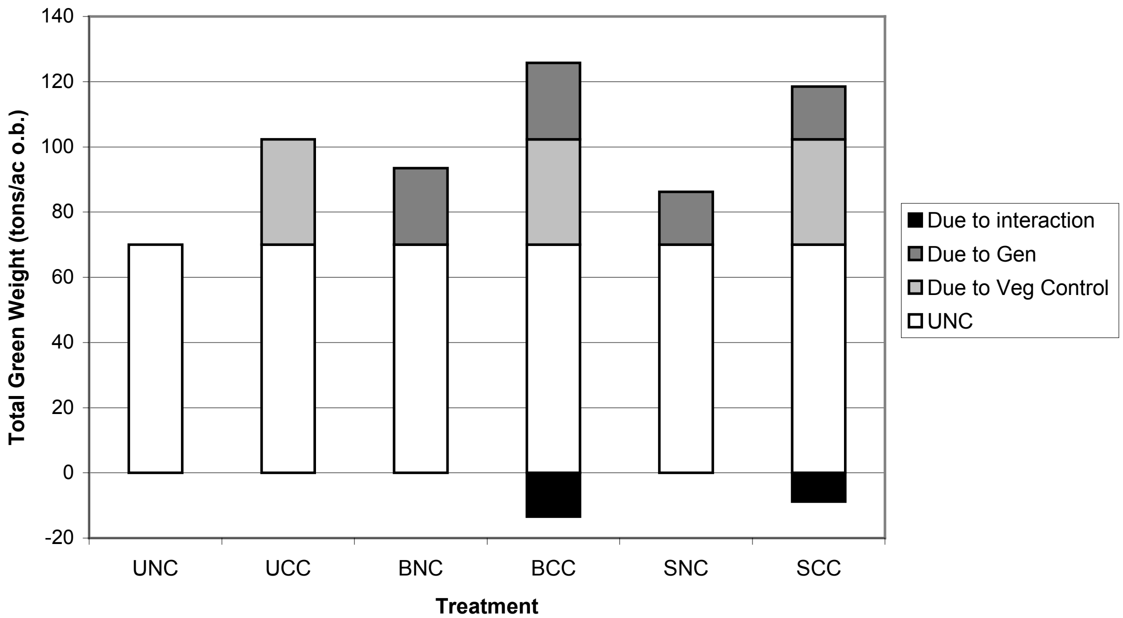

Figure 13. Total green weight per acre by treatment for 15-yr-old loblolly pine in the Piedmont.

Merchantable Green Weight per Acre

Coastal Plain Analysis

Results for merchantable green weight were basically the same as for total green weight. In the Coastal Plain, competition control significantly increased merchantable green weight (3-in. top) an average of 27.3 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 8.8 tons/ac and single family 12.5 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 27 and Figure 14 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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	41.4	12.10	<.0001
Competition Control	1	13.1	77.26	<.0001
Genetics* Competition Control	2	41.7	0.86	0.4319

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	69.1	93.5	81.3
Bulk Lot	76.8	103.3	90.1
Single Family	78.3	109.3	93.8
Average	74.7	102.0	89.5

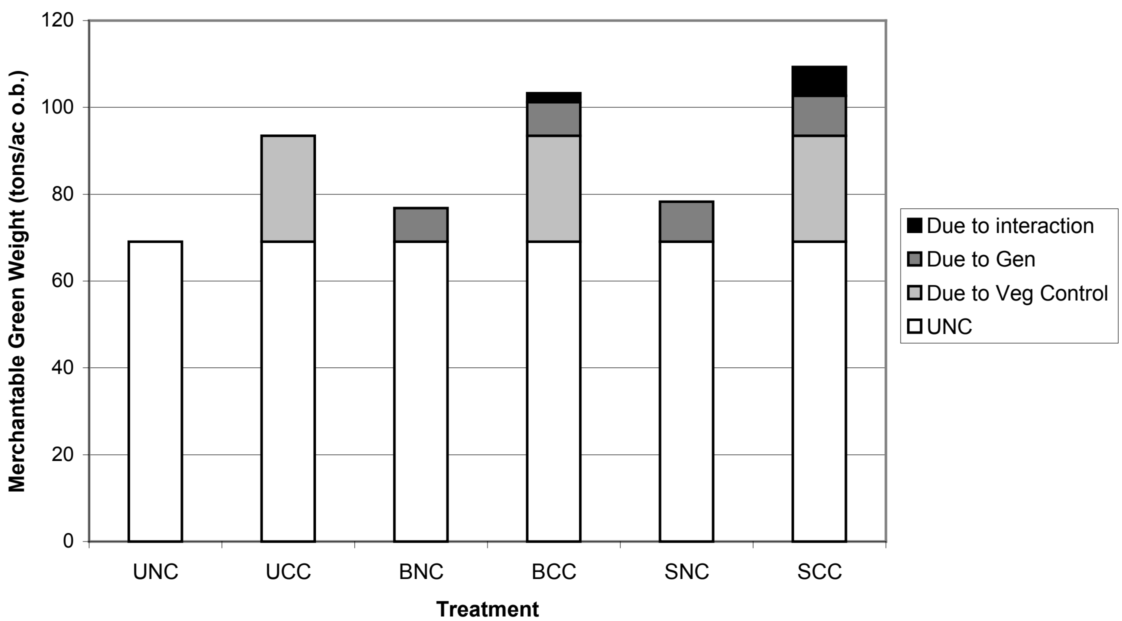

Figure 14. Merchantable green weight (3-in. top) per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

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 green weight to a 3-in. top an average of 25.3 tons/ac across all genetic stock. No significant difference was detected between bulk lot and single family, but bulk lot increased merchantable yield 16.7 tons/ac and single family 11.7 tons/ac over unimproved stock. The interaction between genetic stock and competition control was not significant. Table 29 and Figure 15 summarize the least square means for merchantable green weight.

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 Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24.2	12.84	0.0002
Competition Control	1	11.5	47.74	<.0001
Genetics* Competition Control	2	53.5	2.31	0.1087

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	64.4	96.8	80.6
Bulk Lot	87.7	106.9	97.3
Single Family	80.2	104.3	92.3
Average	77.4	102.7	89.3

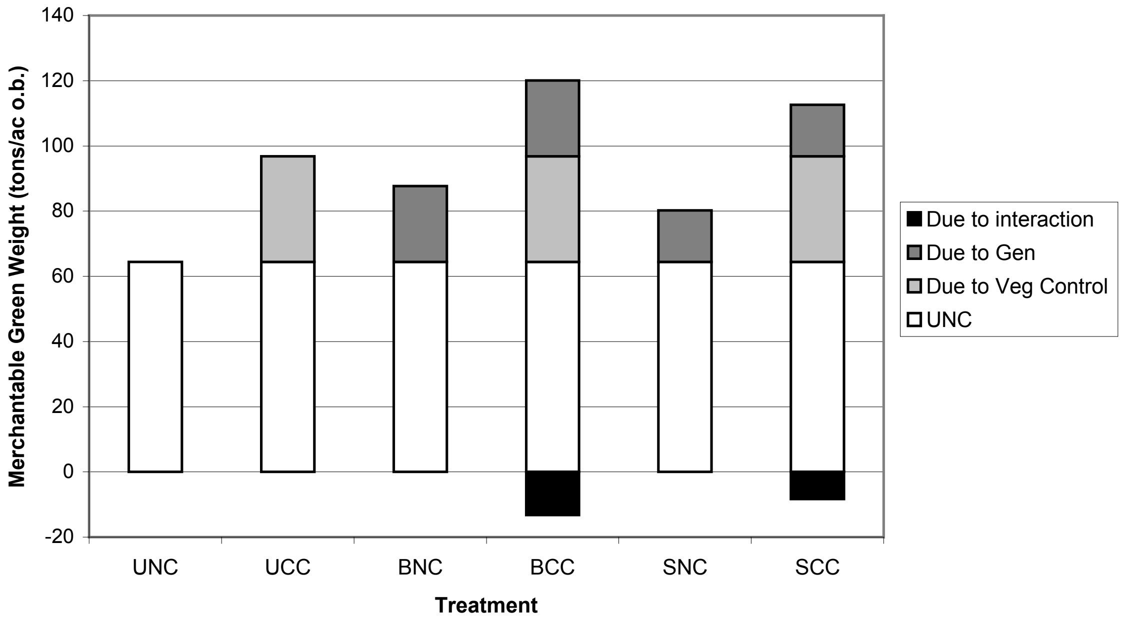

Figure 15. Merchantable green weight (3-in. top) per acre by treatment for 15-yr-old loblolly pine in the Piedmont.

Trees per Acre

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 655 surviving trees per acre after 15 years in the Coastal Plain region. Table 31 and Figure 16 give the least squares means for trees per acre in the coastal plain.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	14.5	0.12	0.8919
Competition Control	1	8.02	0.35	0.5727
Genetics* Competition Control	2	50.6	0.83	0.4398

Table 31. Summary of least squares means for trees per acre in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	668	646	657
Bulk Lot	655	655	655
Single Family	650	653	651
Average	658	651	655

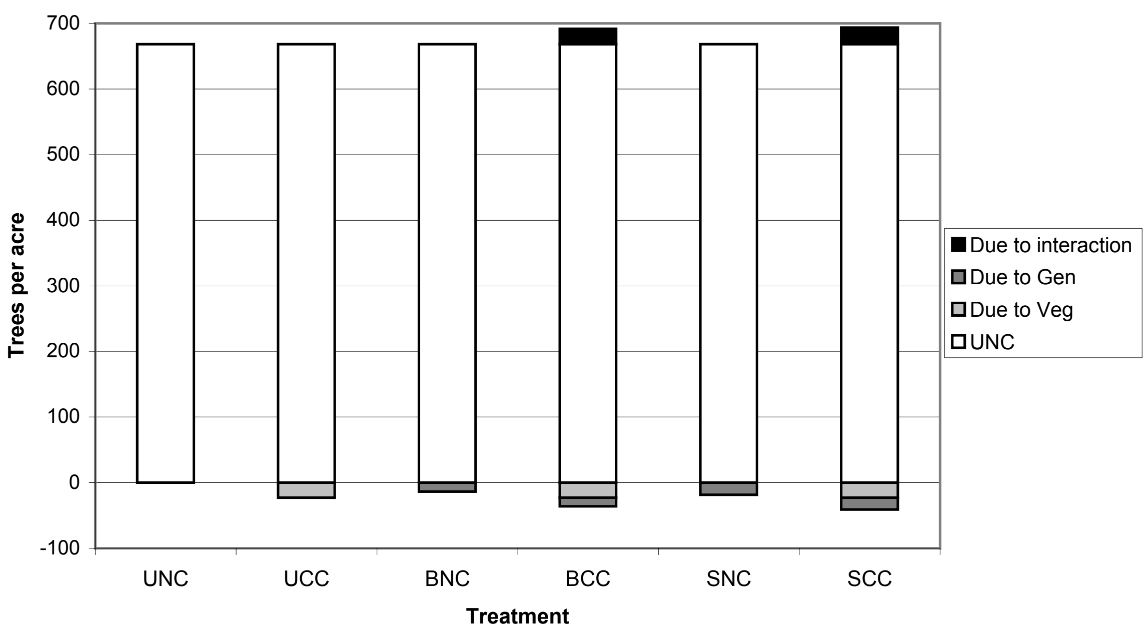

Figure 16. Trees per acre by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

There were no significant differences in trees per acre due to genetics or competition control in the Piedmont (Table 32). There was an average of 623 surviving trees per acre after 15 years in the Piedmont. Table 33 and Figure 17 gives the least square treatment means.

Table 32. Test of fixed effects (reproduced from SAS® output) for trees per acre in the Piedmont.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	20.2	0.08	0.9227
Competition Control	1	11.5	0.63	0.4420
Genetics* Competition Control	2	52.1	2.90	0.0641

Table 33. Summary of least squares means for trees per acre in the Piedmont.

	No Control	Complete Control	Average
Unimproved	604	650	627
Bulk Lot	622	622	622
Single Family	625	622	623
Average	617	631	623

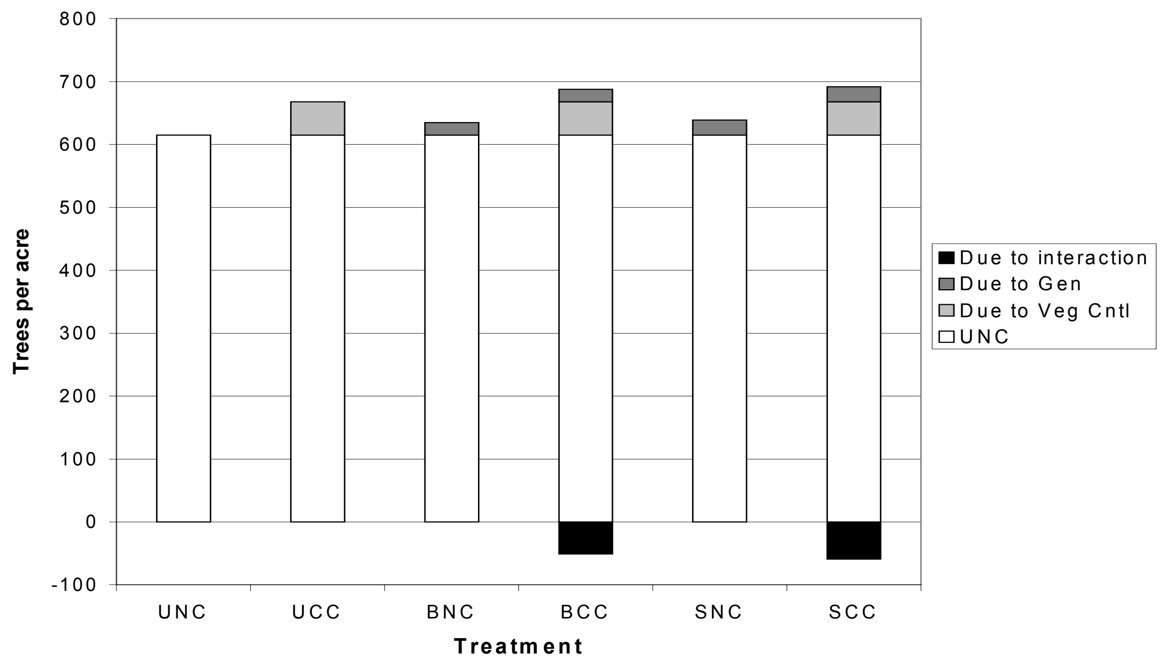

Figure 17. **Trees per acre by treatment for 15-yr-old loblolly pine in the Piedmont.**

Percent Fusiform Infection

Coastal Plain Analysis

Genetic improvement significantly contributed to reduced percent fusiform infections in the Coastal Plain (Table 34). There were no significant differences between bulk lot and single family but both reduced percent fusiform infections from 19.2% to 8.6% and 9.7%, respectively over unimproved stock. Vegetation control did not significantly affect the fusiform rust infection level (Figure 18). Table 35 shows the summary of least squares means for fusiform infection in the Coastal Plain.

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

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24.2	41.22	<.0001
Competition Control	1	12.6	0.48	0.4999
Genetics* Competition Control	2	54.9	0.10	0.9009

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

	No Control	Complete Control	Average
Unimproved	18.7%	19.7%	19.2%
Bulk Lot	8.4%	8.8%	8.6%
Single Family	9.2%	10.2%	9.7%
Average	12.1%	12.9%	12.1%

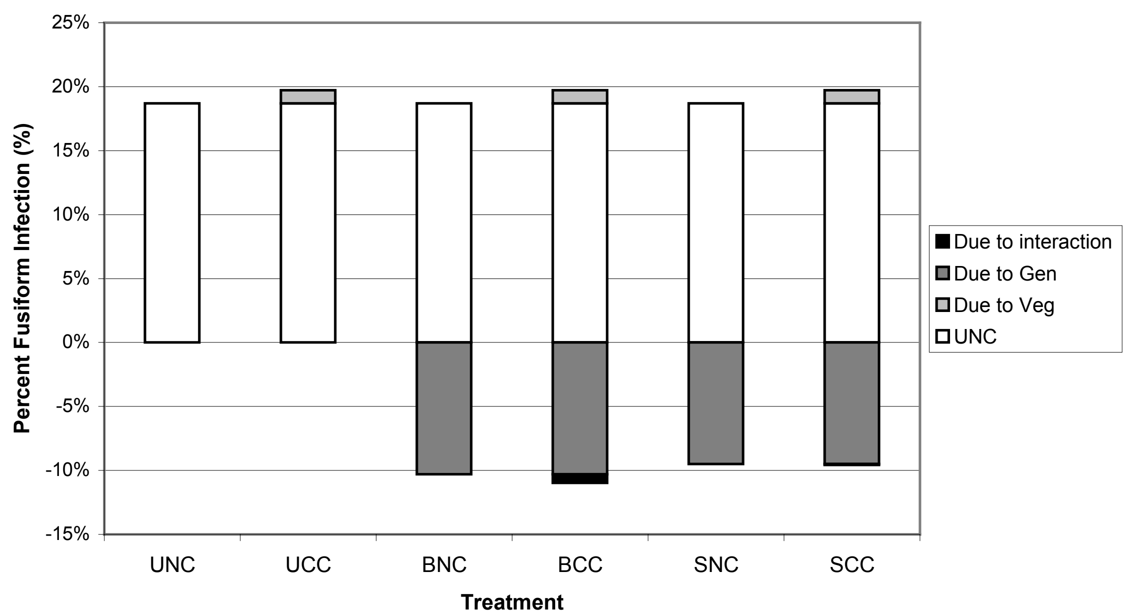

Figure 18. Percent fusiform rust infection by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

Results for the Piedmont analysis are very similar to those for the Coastal Plain. Genetic improvement significantly contributed to reduced percent fusiform infection (Table 36). There were no significant differences between bulk lot and single family but both decreased percent fusiform infections from 21.5% to 12.1% and 13.8%, respectively over unimproved stock. Vegetation control did not significantly affect the rust infection level (Table 37 and Figure 19).

Table 36. Test of fixed effects (reproduced from SAS® output) for percent fusiform infection in the Piedmont.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	24.3	16.25	<.0001
Competition Control	1	11.7	0.37	0.5554
Genetics* Competition Control	2	23.2	0.94	0.4057

Table 37. Summary of least squares means for percent fusiform infection in the Piedmont.

	No Control	Complete Control	Average
Unimproved	21.5%	21.5%	21.5%
Bulk Lot	12.3%	12.0%	12.1%
Single Family	12.8%	14.9%	13.8%
Average	15.5%	16.1%	15.8%

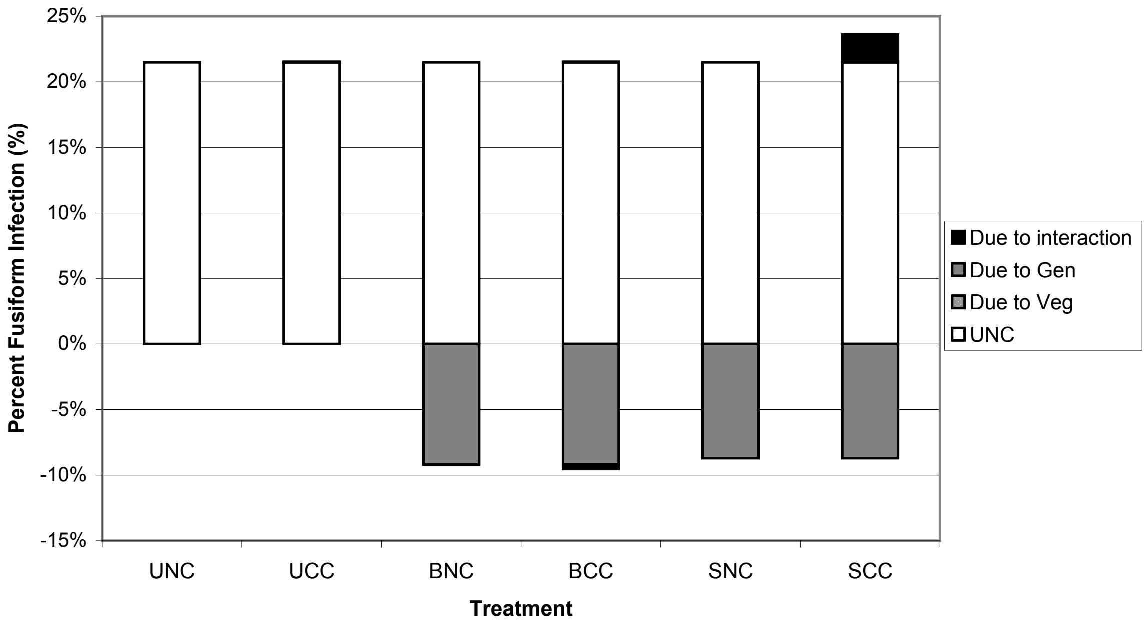

Figure 19. Percent fusiform rust infection by treatment for 15-yr-old loblolly pine in the Piedmont.

Percentage of Trees Defect Free

Coastal Plain Analysis

Genetic improvement significantly affected the percentage of trees that were free from any major defects in the Coastal Plain (Table 38). There were no significant differences between bulk lot and single family, but both decreased defects by 14.7% and 17.1%, respectively over unimproved stock. Vegetation control did not significantly affect the condition of the main stem (Figure 20). Table 39 shows a summary of the least squares means in the Coastal Plain.

Table 38. **Test of fixed effects (reproduced from SAS® output) for percentage of trees without major defects in the Coastal Plain.**

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	83.5	23.04	<.0001
Competition Control	1	12.6	0.15	0.7072
Genetics* Competition Control	2	82	0.12	0.8900

Table 39. **Summary of least squares means for percentage of trees without major defects in the Coastal Plain.**

	No Control	Complete Control	Average
Unimproved	9.4%	11.7%	10.6%
Bulk Lot	25.4%	25.1%	25.3%
Single Family	27.2%	28.0%	27.6%
Average	20.7%	21.6%	21.6%

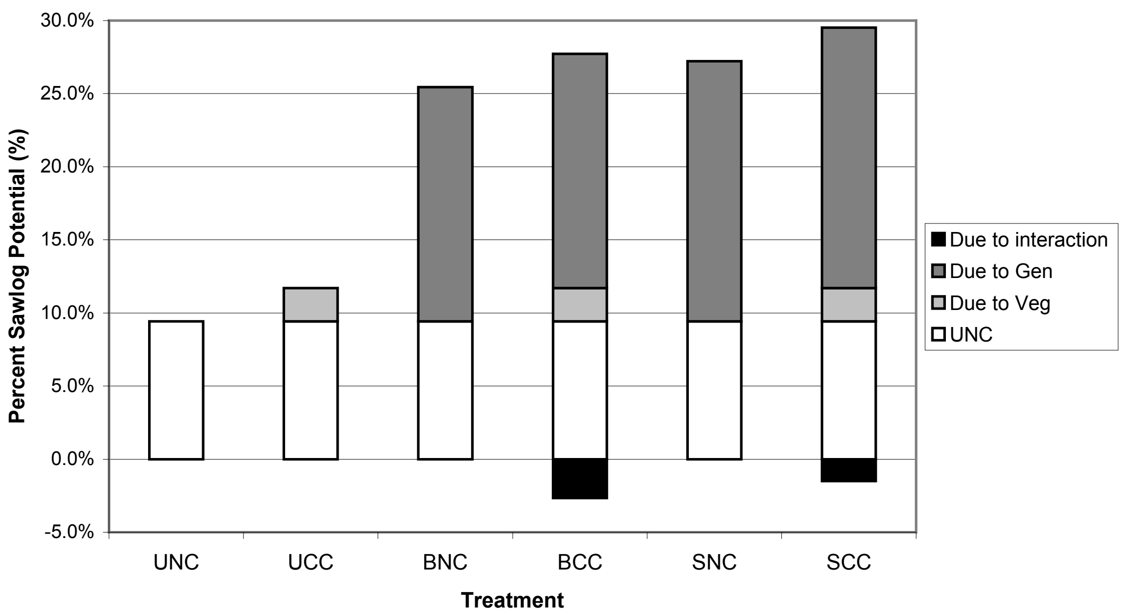

Figure 20. **Percentage of trees without major defects by treatment for 15-yr-old loblolly pine in the Coastal Plain.**

Piedmont Analysis

Genetic improvement significantly affected the percentage of trees that were free from any defects on the main bole in the Piedmont (Table 40). There were no significant differences between bulk lot and single family, but both decreased defects by 10.6% and 9.9%, respectively over unimproved stock. Vegetation control did not significantly affect the condition of the main stem (Figure 21). Table 41 shows a summary of least squares means for percentage of trees without defect in the Piedmont.

Table 40. Test of fixed effects (reproduced from SAS® output) for percentage of trees without major defects in the Piedmont.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	23	11.27	<.0001
Competition Control	1	33.6	0.48	0.4921
Genetics* Competition Control	2	33.5	0.27	0.7674

Table 41. Summary of least squares means for percentage of trees without major defects in the Piedmont.

	No Control	Complete Control	Average
Unimproved	5.7%	6.1%	5.9%
Bulk Lot	17.2%	15.8%	16.5%
Single Family	17.0%	14.6%	15.8%
Average	13.3%	12.2%	13.0%

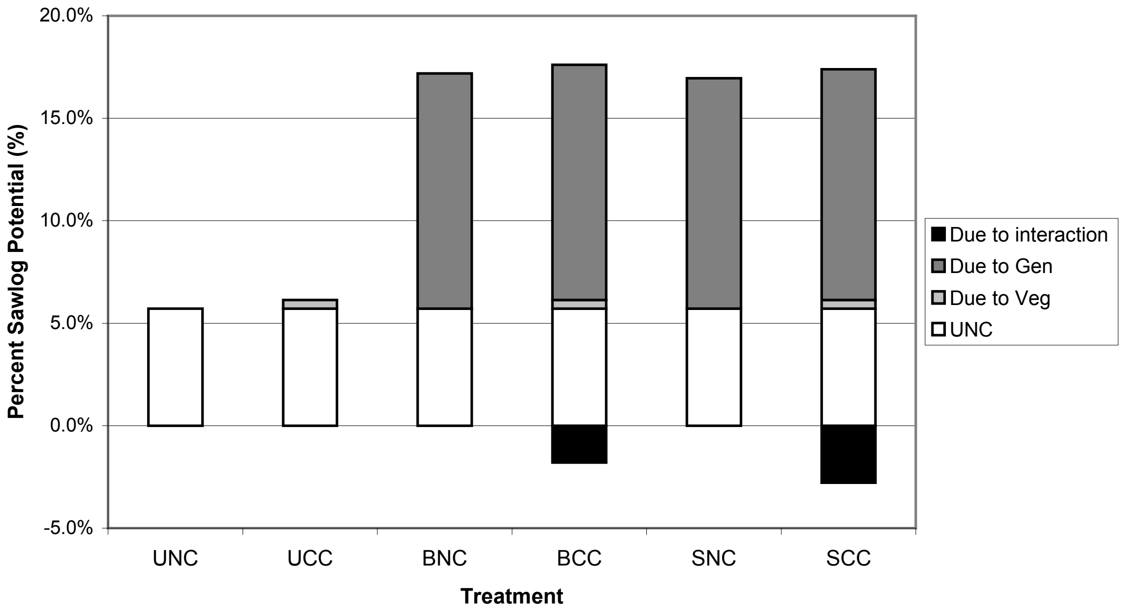

Figure 21. Percentage of trees without major defects by treatment for 15-yr-old loblolly pine in the Piedmont.

Percentage of Forked Trees

Coastal Plain Analysis

Genetic improvement and vegetation control significantly affected the percentage of trees that were forked in the Coastal Plain (Table 42). Vegetation control increased forking by 2% versus no vegetation control. There were no significant differences between bulk lot and single family, but both decreased forking by 2.1% and 1.4%, respectively over unimproved stock (Figure 22). Table 43 shows a summary of least squares means for percentage of forked trees in the Coastal Plain.

Table 42. Test of fixed effects (reproduced from SAS® output) for percentage of forked trees in the Coastal Plain.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	27.6	4.69	0.0176
Competition Control	1	12.7	19.76	0.0007
Genetics* Competition Control	2	59.6	0.89	0.4176

Table 43. Summary of least squares means for percentage of forked trees in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	2.0%	3.4%	2.7%
Bulk Lot	3.4%	6.2%	4.8%
Single Family	3.2%	5.0%	4.1%
Average	2.9%	4.9%	3.9%

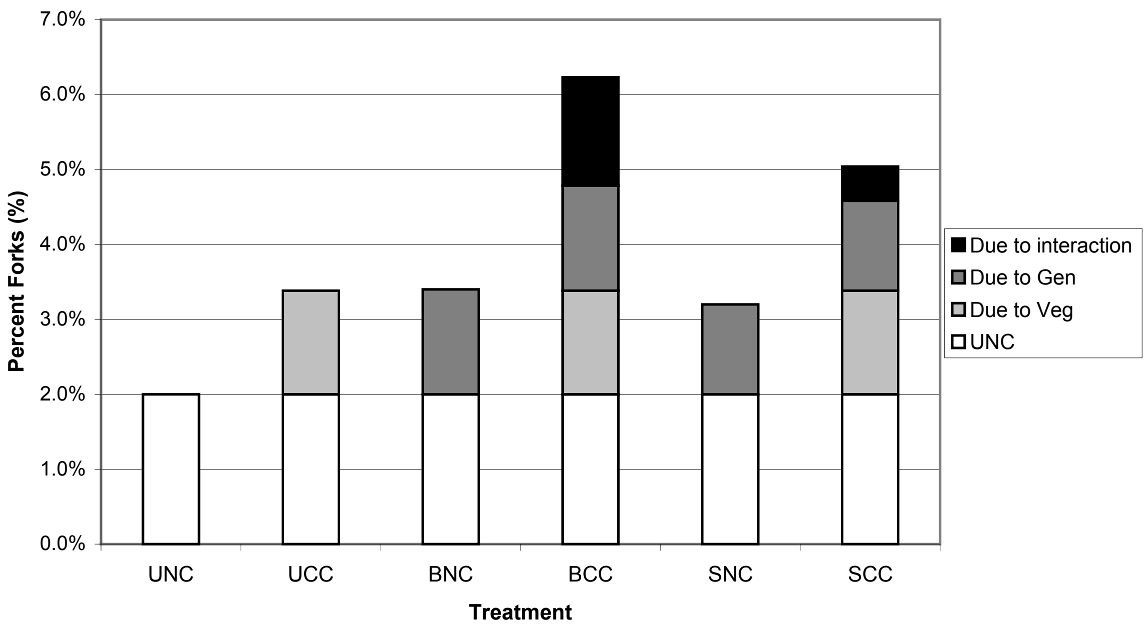

Figure 22. Percentage of forked trees by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

Vegetation control significantly increased the percentage of trees that were forked in the Piedmont (Table 44). Plots with no vegetation control had an average of 3.4% less forking than plots with vegetation control (Table 45). Improved genetics did not significantly affect the percentage of forking in the Piedmont (Figure 23).

Table 44. Test of fixed effects (reproduced from SAS® output) for percentage of forked trees in the Piedmont.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	23.4	1.46	0.2532
Competition Control	1	11.9	19.22	0.0009
Genetics* Competition Control	2	51.3	1.56	0.2202

Table 45. Summary of least squares means for percentage of forked trees in the Piedmont.

	No Control	Complete Control	Average
Unimproved	2.6%	5.3%	3.9%
Bulk Lot	2.9%	7.6%	5.2%
Single Family	3.4%	6.3%	4.9%
Average	3.0%	6.4%	4.7%

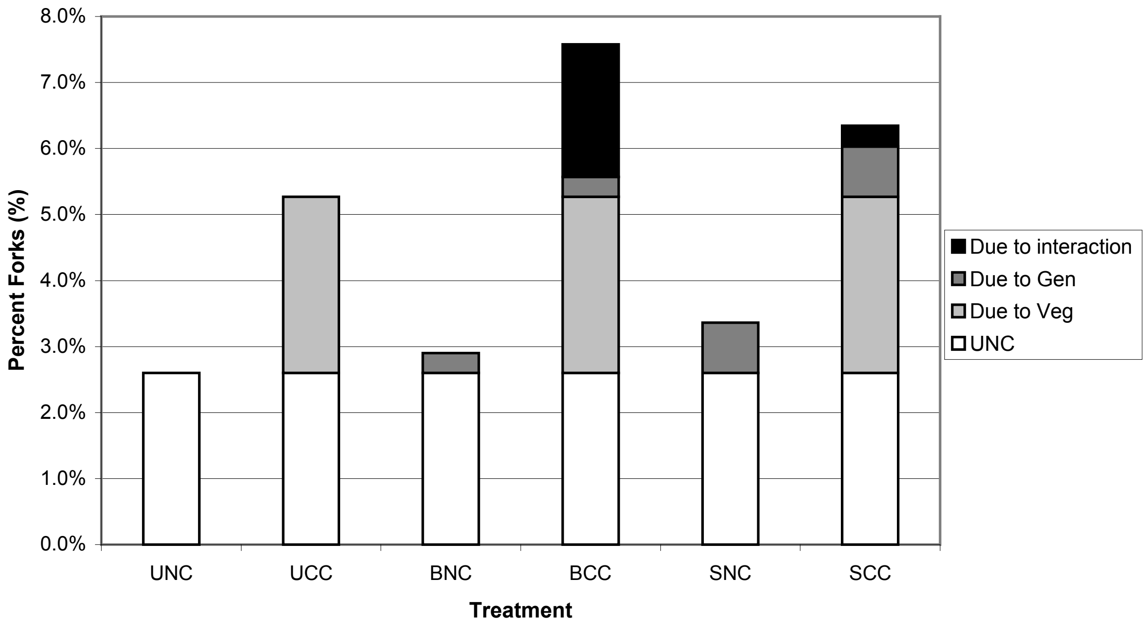

Figure 23. Percentage of forked trees by treatment for 15-yr-old loblolly pine in the Piedmont.

Percentage of Trees with Sweep

Coastal Plain Analysis

Genetic improvement significantly affected the percentage of trees that had sweep in the Coastal Plain (Table 46). There were no significant differences between bulk lot and single family, but both decreased sweep by 13.0% and 14.8%, respectively over unimproved stock (Figure 24). Vegetation control had no significant affect on sweep in the Coastal Plain (Table 47).

Table 46. Test of fixed effects (reproduced from SAS® output) for percentage of trees with sweep in the Coastal Plain.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	83.9	14.76	<.0001
Competition Control	1	12.8	1.09	0.3159
Genetics* Competition Control	2	82.8	0.07	0.9294

Table 47. Summary of least squares means for percentage of trees with sweep in the Coastal Plain.

	No Control	Complete Control	Average
Unimproved	82.0	78.1	80.0
Bulk Lot	68.0	66.3	67.1
Single Family	66.7	63.8	65.2
Average	72.2	69.4	70.5

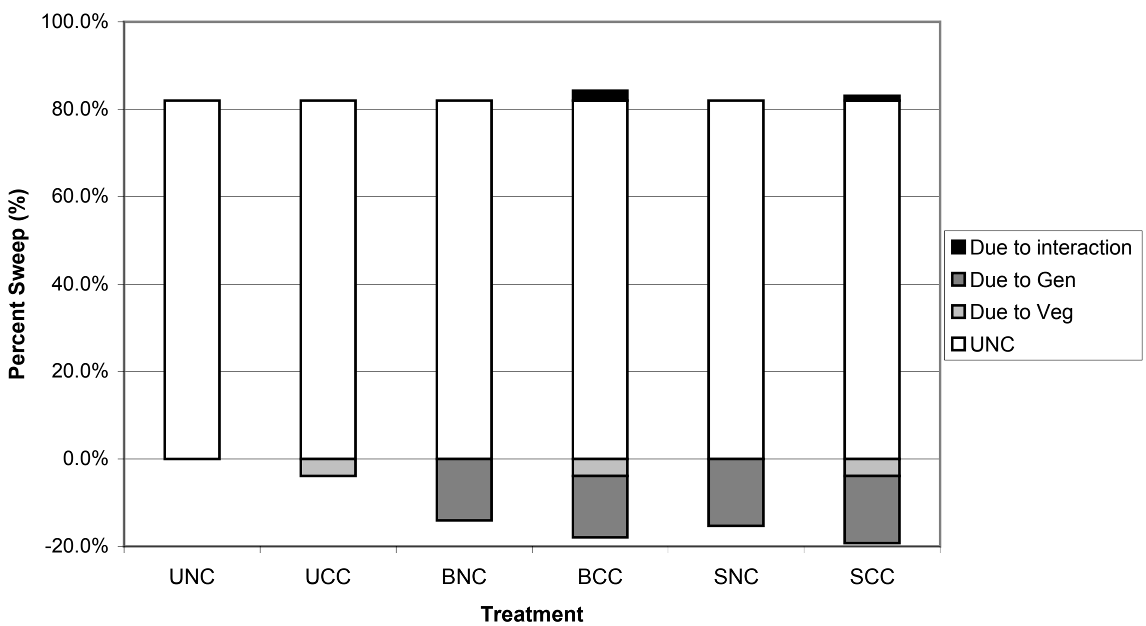

Figure 24. Percentage of trees with sweep by treatment for 15-yr-old loblolly pine in the Coastal Plain.

Piedmont Analysis

Improved genetics significantly affected the percentage of trees with sweep in the Piedmont (Table 48). There were no significant differences between bulk lot and single family, but both decreased sweep by 8.7% and 7.8%, respectively over unimproved stock (Figure 25). Vegetation control did not significantly affect the percentage of sweep in the Piedmont (Table 49).

Table 48. Test of fixed effects (reproduced from SAS® output) for percentage of trees with sweep in the Piedmont.

Source	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Genetics	2	23.4	7.25	0.0035
Competition Control	1	33.6	2.15	0.1517
Genetics* Competition Control	2	33.5	0.71	0.5005

Table 49. Summary of least squares means for percentage of trees with sweep in the Piedmont.

	No Control	Complete Control	Average
Unimproved	84.5	80.0	82.2
Bulk Lot	75.2	71.9	73.6
Single Family	74.4	74.6	74.5
Average	78.0	75.5	76.3

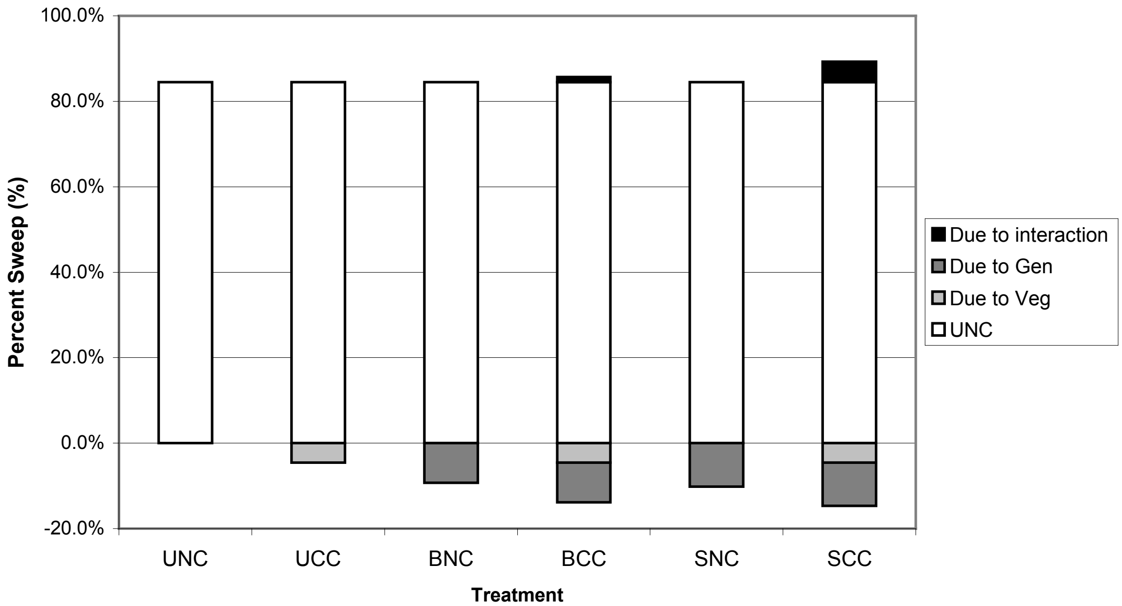

Figure 25. Percentage of trees with sweep by treatment for 15-yr-old loblolly pine in the Piedmont.

THREE YEAR PERIODIC GROWTH

An analysis was conducted to examine the 3-yr periodic growth between ages 12 and 15 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.

Table 50. Average growth (in.) in mean dbh from age 12 to 15 due to genetics. Different letters indicate a significant difference between complete vegetation control and no control.

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
12 to 15 yr	0.58 (a)	0.67 (b)	0.58 (a)	0.72 (b)

The 3-yr periodic growth in mean dbh between ages 12 and 15 are significantly larger for no competition control than complete control in both the Piedmont and Coastal Plain regions (Table 50). Maximum mean dbh growth was attained between the ages of three and six for both complete control and no competition control in both the Coastal Plain and Piedmont regions. The no competition control plots have had larger 3-yr periodic growth rates than the complete control plots since age six. These results indicate that the mean dbh for the two different competition control treatments are converging over time (Figures 26 and 27). 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 endures 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-yr periodic growth rates are significantly higher for the no competition control plots, the absolute difference in dbh between the treatments at age 15 average 0.64 in. and are considerably larger than the differences in the periodic growth, 0.14 inches. There are no significant differences between mean dbh growth with respect to genetics in either region.

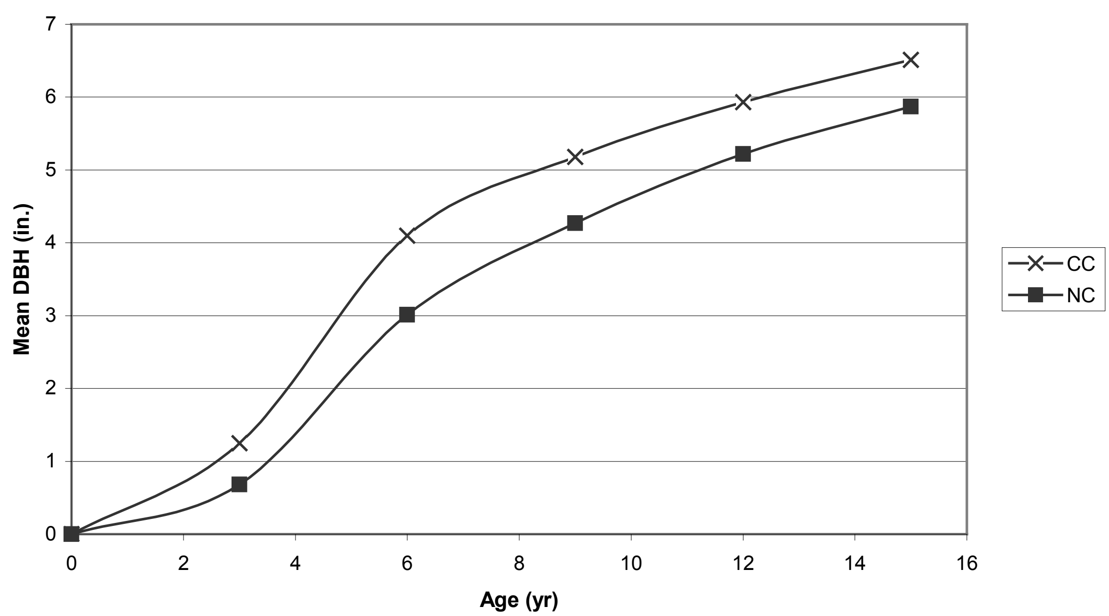

Figure 26. Mean dbh for the two competition control treatments in the Coastal Plain.

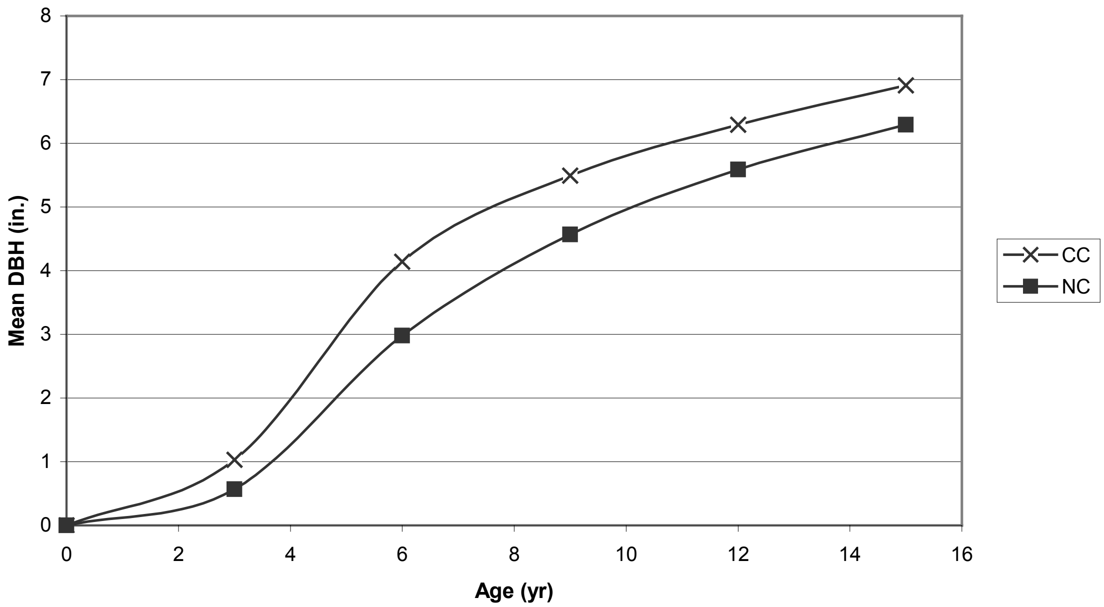

Figure 27. Mean dbh for the two competition control treatments in the Piedmont.

In terms of mean dominant height, competition control significantly affected the 12 to 15 yr. growth rate in the Piedmont and was borderline significant in the Coastal Plain, with a p-value of 0.0502 (Table 51). This was not the case for the 6 to 9 yr. and 9 to 12 yr. periods, in which competition control was not significant in either region. Genetics does not significantly affect the 12 to 15 yr. growth rate in the Coastal Plain, but is significant in the Piedmont (Table 52). Maximum 3-yr periodic dominant height growth was attained in the 3 to 6 year growth period on the complete control plots in both the Coastal Plain and Piedmont. Growth rates on the no competition control plots did not significantly decline until after the 9 to 12 year growth period in both the Coastal Plain and Piedmont regions. This again indicates that the complete control plots are at a different stage in stand development than the no competition control plots. Figure 28 shows the dominant height growth for competition control in the Coastal Plain. The effects of both competition control and improved genetics in the Piedmont can be seen in Figure 29.

Table 51. **Average growth (ft) in mean dominant height from age 12 to 15 due to competition control. Different letters indicate a significant difference between competition control treatments.**

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
12 to 15 yr	7.36 (a)	7.82 (a)	8.07 (a)	8.72 (b)

Table 52. **Average growth (ft) in mean dominant height from age 12 to 15 due to genetics. Different letters indicate a significant difference between genetic treatments.**

3-yr period	Coastal Plain			Piedmont		
	UI	BL	SF	UI	BL	SF
12 to 15 yr	7.57 (a)	7.66 (a)	7.52 (a)	8.00 (a)	8.44 (a,b)	8.75 (b)

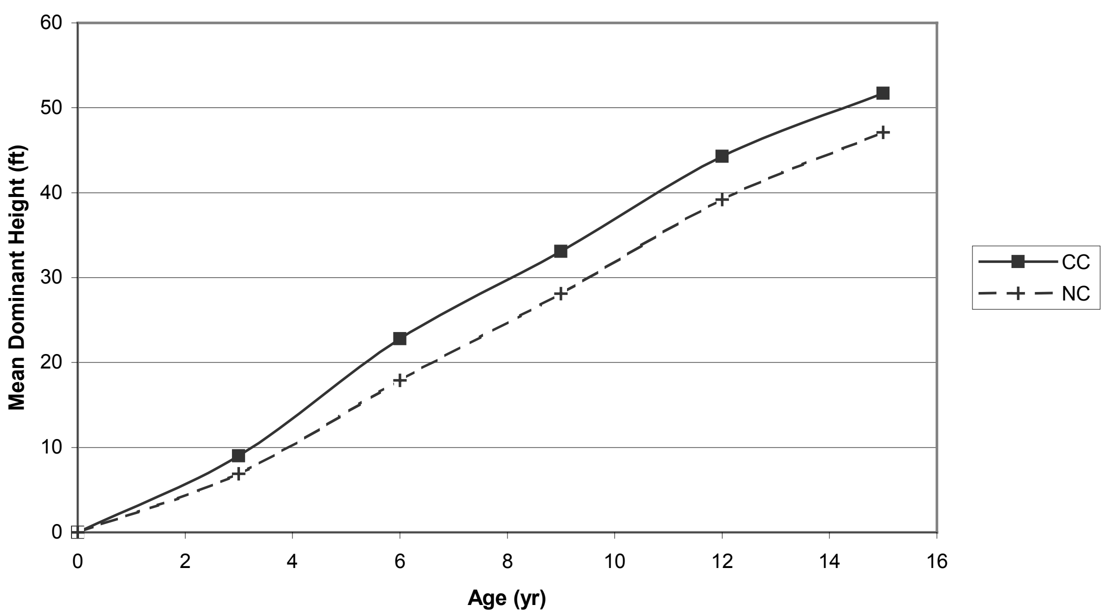

Figure 28. **Mean dominant height for the two competition control treatments in the Coastal Plain.**

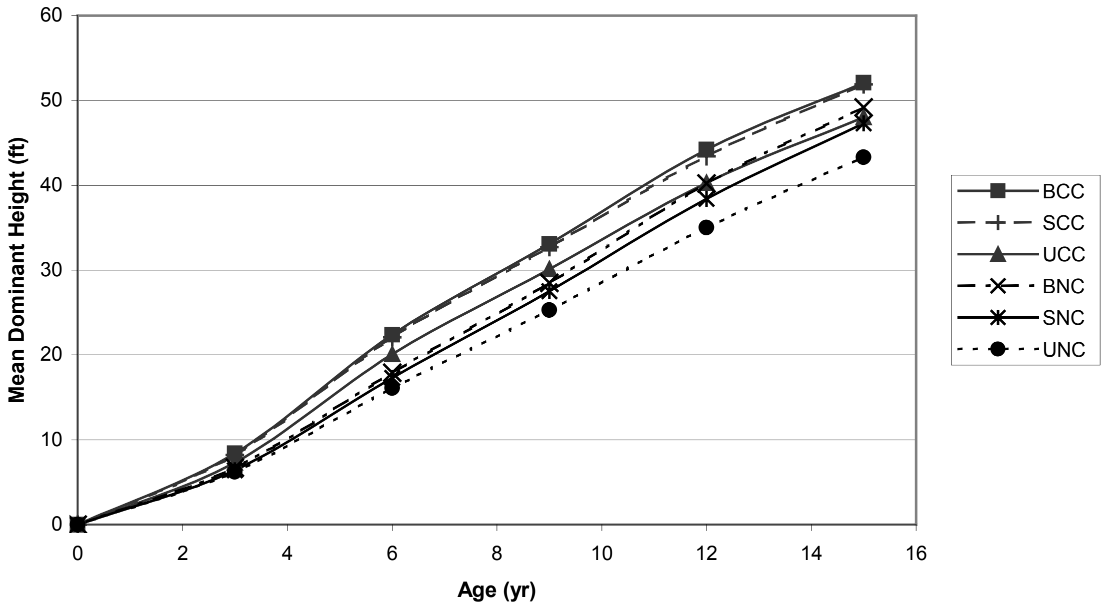

Figure 29. Mean dominant height for the six treatments in the Piedmont.

There were significant differences between mean growth of basal area per acre for competition control in both regions during the period between 6 and 9 yrs. 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 in the Coastal Plain, while in the Piedmont region, no control had significantly greater growth than the complete control. In the 12 to 15 year growth period, no competition control significantly outgrew competition control in both physiographic regions (Table 53). These results indicate that in both regions, basal area per acre is no longer diverging and, in fact, basal area growth between the competition control treatments has begun to converge (Figure 30 and 31). Even with this convergence, the absolute gain in basal area per acre at age 15 ranges from 26 to 28 ft^2, illustrating the large gains due to complete vegetation control at earlier stages of stand development. There were no significant differences due to genetics in periodic growth of basal area per acre for either region.

Table 53. **Average difference (ft^2) in mean basal area growth for the 12 to 15 yr. growth period. Different letters indicate a significant difference between complete vegetation control and no control.**

3-yr period	Coastal Plain		Piedmont	
	CC	NC	CC	NC
12 to 15 yr	23.19 (a)	27.09 (b)	22.94 (a)	26.32 (b)

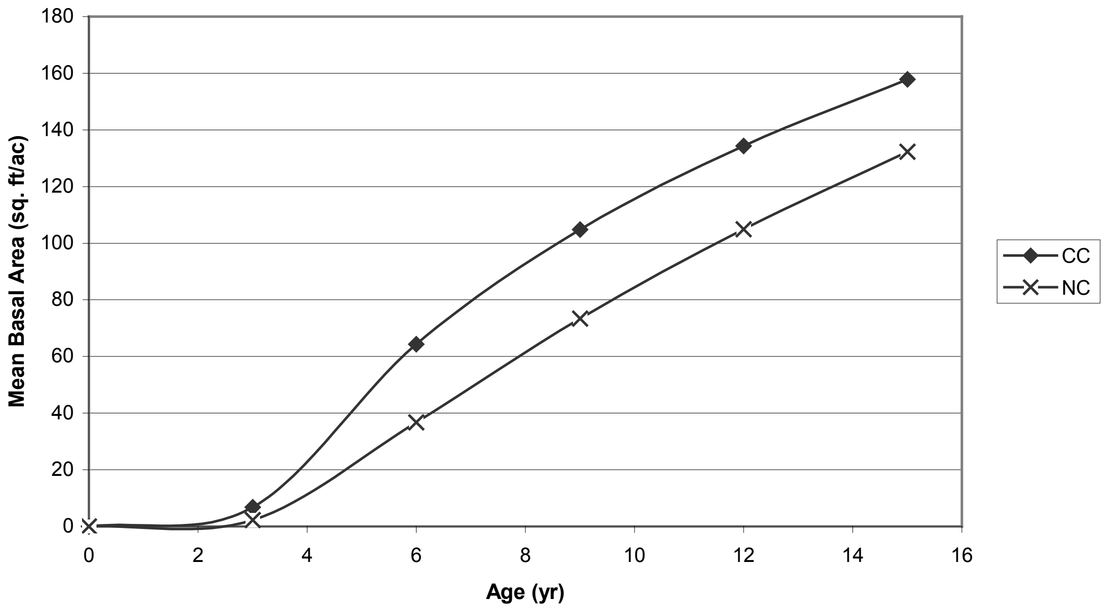

Figure 30. **Mean basal area per acre for the two competition control treatments in the Coastal Plain.**

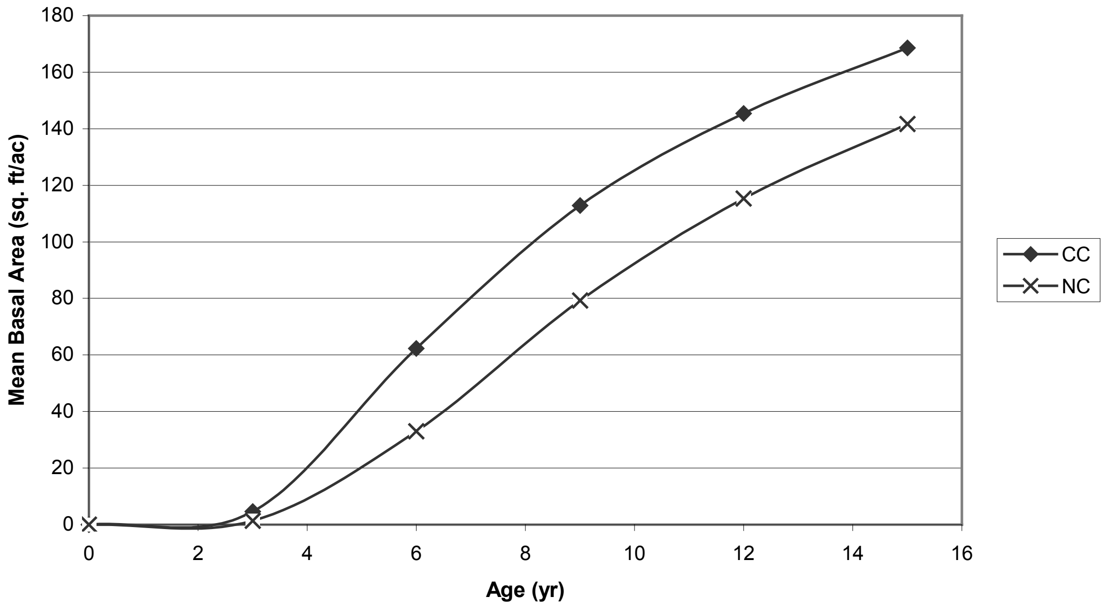

Figure 31. **Mean basal area per acre for the two competition control treatments in the Piedmont.**

In the Coastal Plain region, neither genetics nor competition control significantly increased volume growth during the 12 to 15 year growth period. In the 6 to 9 and 9 to 12 year periods, both genetics and competition control significantly increased volume growth. This indicates that volume gains due to genetics and competition control have slowed, and possibly stabilized. During the period from 6 to 9 yrs, both competition control and genetics additively increased volume growth in the Piedmont region, while during the period from 9 to 12, the interaction between genetics and competition control was significant. From 12 to 15 years, improved genetics was significant, while the interaction was no longer significant, with a p-value of 0.0637 (Table 54). The effects of improved genetics can be seen in Figure 32.

Table 54. **Average growth (ft^3/ac) in mean total volume for different genetic stock for the 12 to 15 yr. growth period in the Piedmont. Different letters indicate a significant difference between treatments.**

3-yr period	Piedmont		
	UI	BL	SF
12 to 15 yr	936 (b)	1079 (a)	1083 (a)

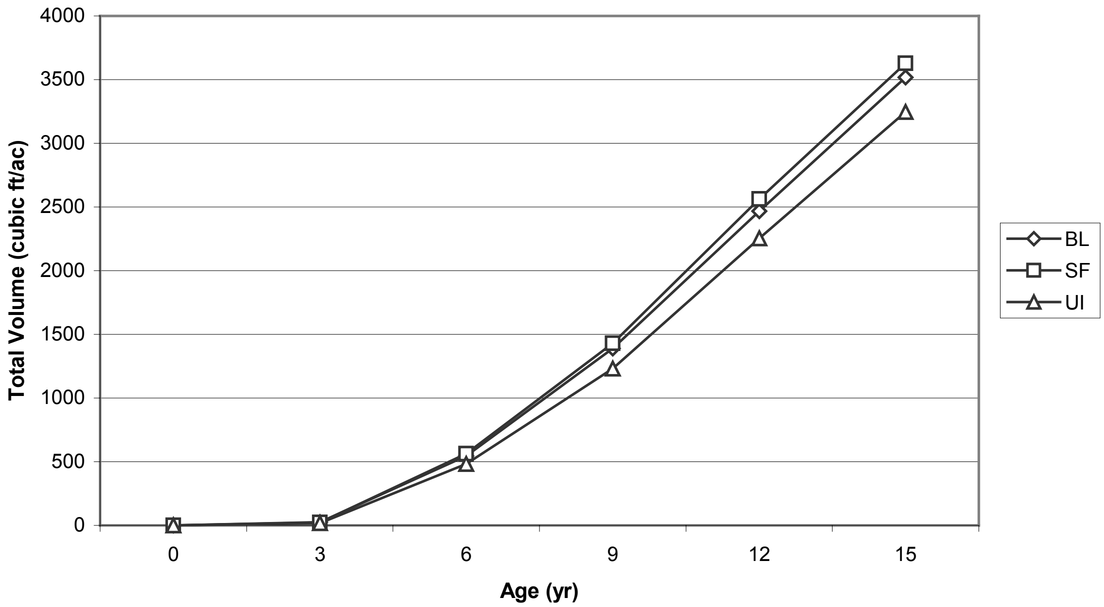

Figure 32. Total volume (ft^3/ac) for three levels of genetic stock in the Piedmont.

In the Coastal Plain region, 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 percent during the period from 9 to 12 and 12 to 15 years. In the Piedmont region, the interaction between competition control and genetics in fusiform rust percent was significant during the period from 6 to 9 yrs. During the period between 9 and 12 and 12 to 15 years there were no significant differences in change in mean fusiform infection percent in the Piedmont region due to competition control or improved genetics.

CONCLUSIONS

Competition control significantly increased DBH in both the Coastal Plain and Piedmont. Genetics was significant in the Piedmont, but had no significant effect on DBH in the Coastal Plain. Dominant height was significantly and additively affected by both competition control and genetics in both physiographic regions. Basal area was additively affected by genetics and competition control in the Coastal Plain, but there was a significant interaction effect present in the Piedmont. Total volume, merchantable volume, total green weight and merchantable green weight were all additively affected by improved genetics and competition control in both the Coastal Plain and the Piedmont. Trees per acre were not significantly affected by competition control or improved genetics in either physiographic region. Fusiform rust was significantly reduced in both physiographic regions by improved genetics, but was not affected by competition control. For the first time at age 15 an evaluation of tree quality was made. Genetics significantly impacted the number of trees with no major defects in both physiographic regions. Competition control was not a significant factor with regard to tree defects. Forking was significantly affected by both improved genetics and competition control in the Coastal Plain, but only affected by competition control in the Piedmont. Main stem sweep was significantly reduced by improved genetics in both the Coastal Plain and the Piedmont.

The results of the 3-yr periodic growth analysis showed that the no competition control plots had significantly larger 3-yr growth in mean dbh in both the Piedmont and Coastal Plain regions. In terms of mean dominant height, the no competition control plots significantly outgrew the competition control plots from age 12 to 15 in the Piedmont, and were borderline significant in the Coastal Plain. Genetics was not significant in the Coastal Plain, but improved genetics continues to have greater dominant height growth rates than the unimproved genetics in the Piedmont. Plots with no competition control had higher average basal area per acre growth rates than the competition control plots in both the Piedmont and Coastal Plain. Genetics did not significantly affect the growth rate of basal area in either physiographic region. Fusiform rust infection was not significantly affected by either competition control or improved genetics for the 12 to 15 year growth period. Total volume per acre growth rates were not significantly affected by improved genetics or competition control in the Coastal Plain. In the Piedmont, improved genetics continues to outgrow the unimproved genetic stock. Competition control had no significant effect on total volume per acre growth rates in the Piedmont.

The results of this study show that there is a clear benefit from using intensive competition control and improved genetics. In terms of total green weight, increases up to 33% and 30% at age 15 can be obtained from using complete vegetation control in the

Coastal Plain and Piedmont regions, respectively. Improved genetic stock can increase total green weight an average of 10% to 15% in the Coastal Plain and 14% to 20% in the Piedmont. For the age 15 analyses, the gains in total volume, merchantable volume, total green weight and merchantable green weight 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.

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