SLASH PINE SITE PREPARATION STUDY:

RESULTS THROUGH AGE 26

Plantation Management Research Cooperative

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EXECUTIVE SUMMARY

Long-term effects of site preparation treatments (chopping, burning, and bedding), complete competition control and repeated fertilization on growth and stand development of slash pine (*Pinus elliottii* Engelm.*)* plantations were examined in a designed study that was established in 1979 at 20 locations distributed on Spodosol and non-Spodosol soils in the flatwoods region of the Lower Coastal Plain of the southeastern USA. Cumulative average height, average dominant height, average dbh, average crown length and ratio, trees per acre, percent cronartium infection, stand basal area, total volume, merchantable volume, total stem green weight and merchantable green weight at three year intervals from age 5 to age 26 are reported.

Treatments significantly affected all response variables at each assessment. The Spodosol vs. non-Spodosol main effect was not significant but significant soil group × treatment interactions were found for average height through age 14, stand basal area through age 20, and stand volume and stem green weight for ages 8 to 20.

Complete vegetation control and repeated fertilization provided positive and significant responses in height, dbh, basal area, volume and green weight, with greater responses occurring on Spodosols than on non-Spodosols. Complete vegetation control provided the largest cumulative growth gains through year 17 and year 23 on non-Spodosols and Spodosols, respectively. Thereafter, the gains from repeated fertilization had caught or surpassed the gains from complete vegetation control. On Spodosols, fertilization always provided much larger gains on treatments without vegetation control than on treatments with vegetation control. On non-Spodosols, growth responses to vegetation control and repeated fertilization treatments were additive on chopped, burned and bedded areas and appeared less than additive on plots that were chopped and burned, but not bedded.

A significant positive response to bedding occurred through year 23 on Spodosols and year 20 on non-Spodosols. Broadcast burning and chopping treatments had a significant positive impact on slash pine growth on non-Spodosols but not on Spodosols.

Complete vegetation control significantly increased crown length on Spodosols through age 20 and on non-Spodosols through age 23, and significantly decreased crown ratio on Spodosols. Fertilization significantly increased crown length on Spodosols at early ages and then on both soil groups, but had no significant effects on crown ratio. Bedding treatment significantly decreased both crown length and crown ratio on non-Spodosols through age 23.

Complete vegetation control was the only treatment that significantly and consistently increased the levels of cronartium infection, and it also significantly increased stand mortality after age 17. Chopping significantly improved survival at age 5; bedding significantly improved survival through 20 growing seasons. Results of this study emphasize the need for site-specific site preparation prescriptions.

Responses to each treatment (chopping, burning, bedding, complete competition control, and repeated fertilization) for each response variable were described in terms of response type, maximum response magnitude, and age of maximum response.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

1 INTRODUCTION

Slash pine (*Pinus elliottii* Engelm.), a fast-growing commercial pine native to the southeastern United States, has been widely grown in plantations. Intensive management practices that include deployment of genetically improved seedlings, mechanical and chemical site preparation, and fertilization are commonly used to increase productivity in slash pine plantations. Various site preparation methods can be used alone or in combination with each other to reduce the competition, improve the soil environment, and facilitate quality tree planting. Where brush and small residual hardwoods are abundant, prescribed burning is often used in combination with either chemical site preparation or mechanical treatments such as chopping. Chemical site preparation has become a standard practice on many cut-over sites with sufficient brush or arborescent competitors. Bedding is frequently done in order to improve soil aeration on poorly drained sites. Post-plant herbicide treatment, for control of either herbaceous or woody competitors, has become a common practice in commercial plantations in the southern U.S. The soils used for pine plantations in the flatwoods of northern Florida and southern Georgia tend to be naturally deficient in N and P, thus the application of N and P fertilizer commonly elicit significant growth response in pines. Forest fertilization in the southern United States has increased greatly since the 1960s. For the 1998 through 2004 period, more than 1.2 million acres of southern pine plantations were fertilized annually (Fox et al. 2007).

Several studies have shown that site preparation, understory competition control, and fertilization can influence the growth of pine plantations (Jokela et al. 2000, 2004). Although long-term studies on the impact of various early silvicultural treatments are limited, different patterns of responses, in terms of magnitude and duration, to site preparation, herbicide release treatment, and fertilization have been reported (Nilsson and Allen 2003). Site preparation and herbicide treatments can result in growth gains that increase throughout the rotation (Zutter and Miller 1998); early growth gains that are maintained but do not increase after an initial response (Lauer et al. 1993; Mason and Milne 1999); early growth gains and are later lost; no growth gain or even a negative growth response (Allen 1996; Nilsson and Allen 2003). Depending on the element, application rate and site characteristics, fertilization may result in either short- or long-term increase in nutrient availability and increased growth of planted seedlings/trees (Nilsson and Allen 2003; Jokela et al. 2004). Fertilization at the time of planting may also have no effect or even lead to negative response. Despite the wealth of possible types of treatment combinations and associated responses over an array of sites and environmental conditions, the weight of evidence leads to a general conclusion that more intensive methods provided consistently better growth than check plots or low intensity methods (Shiver at al. 1990).

Intensive cultural treatments are implemented to increase financial returns through rapid growth rates and shorter pine crop rotations. Financial returns associated with the specific silvicultural treatments depend on the magnitude and duration of growth response, costs associated with the treatments, and the stumpage values of the timber produced (Fox at al. 2007). Forest landowners and managers need specific information on long-term responses of plantations to site preparation treatments rather than general conclusion in order to make efficient site-specific silvicultural regimes. Forest researchers and managers also believed that it is necessary to include effects of establishment practices in growth and yield models (Piennaar and Rheney 1995; Mason

et al. 1997). Unfortunately, this has rarely been achieved over full rotation periods due to lack of long-term data. In order to make assumptions appropriate for response models, there is a need to accumulate knowledge of or to understand better the long-term patterns in crop response that are related to treatments and sites.

In 1979, the Plantation Management Research Cooperative (PMRC) at the University of Georgia initiated a study in the flatwoods area of southern Georgia and northern Florida. The objective of the study was to evaluate the effects of three commonly used site preparation treatments (i.e., burning, chopping, and bedding) alone and in combination with complete vegetation control and repeated fertilization on the growth and yield of slash pine plantations. The study was also one of the first in the Southeast to demonstrate the potential effects of excellent competition control with herbicide applications on the growth of pine plantations. It has, therefore, been followed with great interest throughout its life.

This report presents responses of tree and stand characteristics through 26 growing seasons, with the intent to contribute knowledge on long-term response of slash pine plantations to different silvicultural treatments. The objectives of this research were to (1) evaluate the effect of different combinations of different site preparation methods and early cultural treatments on the growth and yield of slash pine plantations; (2) evaluate the interaction of the treatments with soil groups; (3) separate the effects of burning, chopping, bedding, fertilization, and complete vegetation control; and (4) describe the long-term patterns of these responses. This publication builds on previous PMRC reports on the Slash Pine Site Preparation Study, most notably PMRC Report 2003-3. The current report includes results at age 26 and an analysis of response trends over time.

2 MATERIALS AND METHODS

2.1 Study installations

The study was installed at 20 separate locations throughout the flatwoods in the Lower Coastal Plain in northern Florida and southern Georgia. The twenty locations were originally stratified equally over soils with a spodic horizon (Spodosols) and soils without a spodic horizon (non-Spodosols). One non-Spodosols was moderately well drained, while all other locations were somewhat poorly drained or wetter (Shiver et al. 1990).

At each location 12 half-acre treatment plots were surveyed into existing plantations that were at least 20 years old and were available for clearcutting. Within each plot, dominant and codominant trees were measured for total height and site index was calculated using an equation developed by Newberry and Pienaar (1978). In order to ensure site homogeneity within an installation, the maximum allowable range in site index among the plots was five feet. Soil profiles were also checked for homogeneity. Site indexes (age 25) across installations ranged from 54 to 80 feet.

Existing plantations were harvested in 1978 and plots were site prepared in 1978-79. First generation genetically improved slash pine seedlings grown in a single nursery were hand planted at a spacing of 8 ft × 10 ft during the winter of 1979-80. To ensure adequate survival, two seedlings were planted at each planting location. After two growing seasons, one tree was removed from all planting spots where two trees had survived. The result was reasonably uniform spacing with a density of approximately 545 trees per acre on most plots.

Each location had 11 treatments (Table 1). One of the treatments 2-11 was selected for replication at each location for a total of 12 plots. The treatments allow evaluation of impacts of the following individual treatment: chopping, burning, bedding, fertilization, and vegetation control (herbicide applications), as well as various treatment combinations. The control plot had no site preparation at all. It was simply harvested and planted. The chopped treatment was a single pass with a water filled drum chopper. This treatment was included with and without a broadcast burn. Treatment 6, chop, burn, and bed, consisted of chopping, a broadcast burn, and then a double pass with a bedding harrow. With the exception of the control, all of these treatments were tested with and without fertilization treatment. The fertilizer treatment consisted of 250 pounds of diammonium phosphate (DAP) per acre applied at the beginning of the second growing season. After the 12^{th} growing season, 200 pounds of nitrogen per acre in the form of urea and 100 pounds of potassium in the form of KCL were applied. After the 17^{th} growing season, 625 pounds per acre of a 16-4-8 turf fertilizer were applied. This converts to 100, 25 and 50 pounds per acre of N, P and K, respectively. The herbicide treatment targeted complete control of all competing vegetation until crown closure. Vegetation was sprayed with a 3% solution of Roundup® prior to site preparation. After pines were planted, they were shielded and repeated applications of Roundup®, Garlon® and sometimes diesel fuel on buds were used to keep plots as free of competition as possible.

Table 1. Treatment regimes.

Treat. Number	Treat. Type	Treatment Description
1	CNTL	Control: no site preparation
2	UCHP	Unfertilized, and chopped (a single pass with a rolling drum chopper after harvest of previous plantation)
3	FCHP	Fertilized, and chopped
4	UCHB	Unfertilized, chopped, and burned (Treatment 1 followed by a broadcast burn)
5	FCHB	Fertilized, chopped, and burned
6	UCBB	Unfertilized, chopped, burned and bedded (treatment 4 followed by a double-pass bedding operation)
7	FCBB	Fertilized, chopped, burned and bedded
8	UCBH	Unfertilized, chopped, burned, and herbicide (Treatment 4 followed by complete control of competing vegetation with herbicide as required)
9	FCBH	Fertilized, chopped, burned, and herbicide
10	UBHB	Unfertilized, chopped, burned, bedded, and herbicide (treatment 6 followed by complete herbicide)
11	FBHB	Fertilized, chopped, burned, bedded, and herbicide

Five years after installation, 18 installations, 9 non-Spodosols and 9 Spodosols, remained for analysis. During the period from age 8 to age 20, 16 installations, 7 non-Spodosols and 9 Spodosols, remained. At age 23, 15 installations, 6 non-Spodosols and 9 Spodosols, remained. Finally, 26 years after installation, 14 installations, 6 non-Spodosols and 8 Spodosols, remained for analysis.

2.2 Measurements

A 0.2-acre rectangular measurement plot was established within each 0.5-acre treatment plot. Measurements were taken after 2, 5, 8, 11, 14, 17, 20, 23, and 26 growing seasons. At each measurement all trees that were at least 4.5 feet tall were measured for dbh to the nearest 0.1 inch and checked for stem cankers of cronartium (*Cronartium fusiforme* Hedge. And Hunt ex Cumm.). Every other tree was tagged and measured for total height to the nearest foot. Total height of the untagged trees was estimated from the following height-diameter regression equation separately fitted for height measured trees at each measurement in every plot:

$$\ln(HT) = b_0 + b_1 DBH^{-1}, \quad (1)$$

where HT is the total tree height, DBH is tree diameter at breast height, and b0 and b1 are parameters to be estimated from each plot at each measurement. Total and merchantable (trees with dbh > 4 inches to a 3-inch top outside bark) volumes and weights were calculated using individual tree volume equations developed by Pienaar *et al.* (1996).

Crown height was measured on all tagged trees at ages 14, 17, 20, 23, and 26. Crown height was defined as the height to the base of the live crown. The average crown length for a plot was obtained by subtracting the crown height from the total height of each tree and averaging these values for all trees on the plot.

2.3 Data Analysis

Analysis of variance (ANOVA) for a split plot design was used to test for significant sources of variation with the remeasurement data between the age of 5 and 26 years, respectively. Soil groups represent the whole plots and treatments represent the splits. The split plot analysis was carried out using a mixed model. The location (installation) and its interactions were regarded as random factors and the treatment and soil effects were considered fixed. This approach allows for inferences across all sites represented by the sample of sites included in this study. The following hypotheses were tested: (1) there are no differences among treatments; (2) there are no differences between soil groups; and (3) there are no soil × treatment interactions. One-degree-of-freedom contrast analyses were conducted to evaluate the effects of chopping, burning, bedding, fertilization and vegetation control (herbicide). Treatment gains due to chopping, burning, bedding, fertilization and herbicide were computed by the difference of least squares means method to account for the unbalanced nature of this data. Analyses were conducted on average height, average dominant height, average dbh, average crown length and ratio, average percent cronartium infection, trees per acre, stand basal area, stand total volume and merchantable volume, total stem green weight and merchantable green weight.

It was found that the responses of average height, average dominant height, average dbh, stand basal area, volume and green weight to fertilization might be different between treatments with and without vegetation control. Thus, one contrast analysis was done by soil group to test if there was significant difference in response to fertilization on treatments with and without vegetation control. To further examine the treatment interactions, the difference between the response to the combination of fertilization and competition control and the sum of the responses to these treatments when applied independently was also analyzed by soil group and for chopped, burned plots and chopped, burned and bedded plots, respectively. All references to statistical significance refer to an alpha level of 0.05.

Response patterns over time were characterized by response type, maximum response, and age at time of maximum response. Four general response types have been identified. Least square means for each response variables are presented by treatment and measurement age in Appendixes 1 through 12.

3 RESULTS

3.1 Average height

Analyses of variance for average height indicated that there were significant differences among treatments and that there were not significant differences in average height between Spodosol and non-Spodosol soils through 26 growing seasons (Table 2). The interaction of soil group and treatment was significant through 14 growing seasons; thereafter, the interaction was no longer significant for average height.

The fertilization and herbicide contrasts indicated that both fertilization and herbicide treatments significantly increased average height on both Spodosols (SP) and non-Spodosols (NS) during the life of study (Table 3). The gains in average height from herbicide treatment were greater than that from fertilization treatment on non-Spodosols through age 20 and on Spodosols through age 23, respectively. Thereafter, the average height gain from fertilization treatment had caught or surpassed the gain from herbicide treatment. At age 26, the fertilization and herbicide treatments provided significant gains of 7.6 and 7.2 feet on Spodosols, and of 5.0 and 4.3 feet on non-Spodosols, respectively. The gains in average height from both fertilization and herbicide treatments on Spodosols were greater than those on non-Spodosols (Figure 1).

Bedding significantly increased average height on both Spodosols and non-Spodosols through 14 growing seasons. The positive bedding effect on height was still significant on Spodosols through ages 23, during that period it was not significant on non-Spodosols, and at age 26 it was no longer significant on either Spodosols or non-Spodosols. In general, the bedding treatment provided greater average height gains on Spodosols than on non-Spodosols.

The burning treatment on Spodosols resulted in a nonsignificant negative height response through 14 growing seasons and then a nonsignificant positive height

response. On non-Spodosols, however, the average height response to burning was positive, and significant during the period from age 8 to age 20.

Chopping on non-Spodosols significantly increased average height at ages 11, 14 and 23; while on Spodosols the chopping effects were small and not significant during the life of study.

Table 2. **Summary of ANOVA p-values for tests of soil, treatment (TRT) and their interaction (SOIL×TRT) for average height (HT), average dominant height (HD), DBH, crown length (CRNLEN), crown ratio (CRNRAT), percent cronartium infection (CRON), basal area (BA), trees per acre (TPA), total volume per acre (TVOB), merchantable volume per acre (MVOB), total stem green weight (TGW), and merchantable green weight (MGW) at different ages.**

Variable	Effect	Age 5	Age 8	Age 11	Age 14	Age 17	Age 20	Age 23	Age 26
HT	SOIL	0.907	0.491	0.478	0.437	0.577	0.639	0.560	0.459
	TRT	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	**0.025**	**0.005**	**0.002**	**0.006**	0.087	0.199	0.382	0.153
HD	SOIL	0.874	0.417	0.350	0.399	0.465	0.548	0.453	0.422
	TRT	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	**0.021**	**0.005**	**0.008**	**0.022**	0.154	0.208	0.299	0.139
DBH	SOIL	0.894	0.204	0.225	0.142	0.137	0.156	0.159	0.101
	TRT	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.052	0.057	0.079	0.093	0.246	0.324	0.202	0.420
CRNLEN	SOIL				0.575	0.124	0.394	0.086	0.316
	TRT				**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT				0.127	0.412	**0.002**	0.275	0.336
CRNRAT	SOIL				0.511	0.155	0.835	**0.034**	0.548
	TRT				**<0.001**	**<0.001**	**0.033**	**<0.001**	**<0.001**
	SOIL×TRT				0.122	0.314	**<0.001**	0.055	**0.007**
CRON	SOIL	0.051	0.179	0.154	0.250	0.173	0.162	0.080	0.092
	TRT	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.568	0.577	0.477	0.618	0.690	0.936	0.583	0.763
BA	SOIL	0.716	0.426	0.657	0.898	0.793	0.802	0.540	0.782
	TRT	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	**0.049**	**0.015**	**0.018**	**0.007**	**0.017**	**0.047**	0.315	0.488
TPA	SOIL	0.314	0.240	0.123	0.068	0.084	0.125	0.154	0.112
	TRT	**<0.001**	**0.003**	**0.008**	**0.008**	**0.024**	**0.020**	**0.002**	**0.006**
	SOIL×TRT	0.225	0.156	0.182	0.214	0.253	0.203	0.296	0.436
TVOB	SOIL	0.722	0.459	0.567	0.803	0.888	0.878	0.960	0.722
	TRT	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.188	**0.033**	**0.015**	**0.002**	**0.010**	**0.028**	0.273	0.283
MVOB	SOIL	0.747	0.382	0.446	0.701	0.805	0.813	0.901	0.671
	TRT	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.996	0.065	**0.008**	**0.002**	**0.010**	**0.030**	0.280	0.292
TGW	SOIL	0.709	0.488	0.595	0.843	0.940	0.944	0.987	0.786
	TRT	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.190	**0.029**	**0.013**	**0.001**	**0.008**	**0.022**	0.249	0.236
MGW	SOIL	0.760	0.405	0.473	0.741	0.856	0.876	0.951	0.732
	TRT	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	SOIL×TRT	0.996	0.057	**0.007**	**0.001**	**0.008**	**0.024**	0.256	0.244

Table 3. **Responses in average height (ft.) from chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.6	0.0	1.4	0.9	**2.5***	0.6	**2.9***	0.0	2.7	-0.3	1.3	-0.4
Burn	0.2	-0.3	**1.8***	-0.7	**2.1***	-0.4	**2.3***	-0.1	**3.1***	0.4	**3.1***	0.6
Bed	**2.3***	**2.1***	**1.9***	**2.7***	**1.8***	**3.0***	**1.8***	**2.9***	1.2	**2.4***	1.0	**2.7***
Herbicide	**3.4***	**5.0***	**4.6***	**7.2***	**4.8***	**7.9***	**4.2***	**7.7***	**4.2***	**7.1***	**4.0***	**7.5***
Fertilization	**1.4***	**1.7***	**1.7***	**2.3***	**2.1***	**2.6***	**2.9***	**3.3***	**3.6***	**4.8***	**5.4***	**6.1***

Treatment	Age 23		Age 26	
	NS	SP	NS	SP
Chop	**5.4***	-0.7	3.9	-1.3
Burn	2.3	1.0	3.0	0.8
Bed	0.3	**2.4***	0.9	1.7
Herbicide	**4.5***	**6.6***	**4.3***	**7.2***
Fertilization	**5.5***	**6.7***	**5.0***	**7.6***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

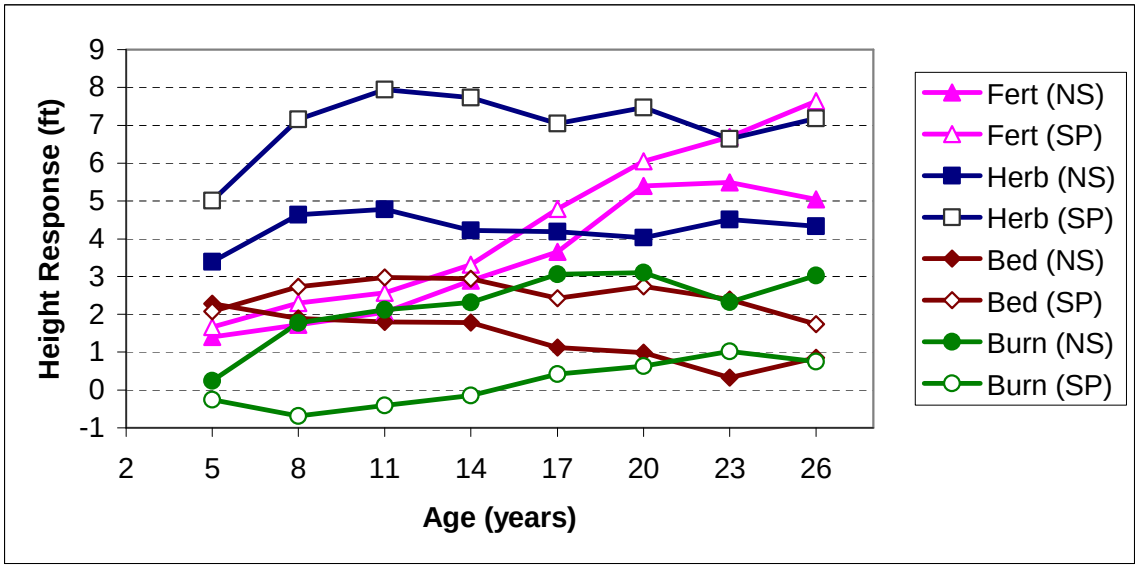

Figure 1. **Average height responses to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns of height responses to individual treatments are presented in Table 4.

Table 4. Attributes of temporal patterns in response in mean height to individual treatments.

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ft)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ft)	Age at Maximum Response (yrs)
Chop	B	2.9	14			
Burn	B	3.1	17			
Bed	C	2.0	5	B	3.0	11
Herbicide	B	4.8	11	B	7.9	11
Fertilization	B	5.5	23	A	7.6	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, average heights ranged from a high of 72.8 feet for the chop, burn, bed, herbicide, and fertilization (FBHB) treatment to 56.6 feet for the control on non-Spodosols (Figure 2). On Spodosols, the range in mean height was from 70.3 feet to FBHB to 5.3 feet for chop only (UCP) treatment. The average height values were well correlated with treatment intensity. Fertilization provided a positive response on all treatments with greater gains on treatments without vegetation control. On Spodosols, the chop, burn and fertilize treatment (FCHB) had about the same average height as the chop, burn and herbicide treatment (UCBH); on non-Spodosols, FCHB had the same average height as and as the chop, burn, herbicide and fertilization treatment (FCBH). The chop, burn, bed and fertilize treatment (FCBB) had the same average height as the chop, burn, bed and herbicide treatment (UBHB) on both soil groups.

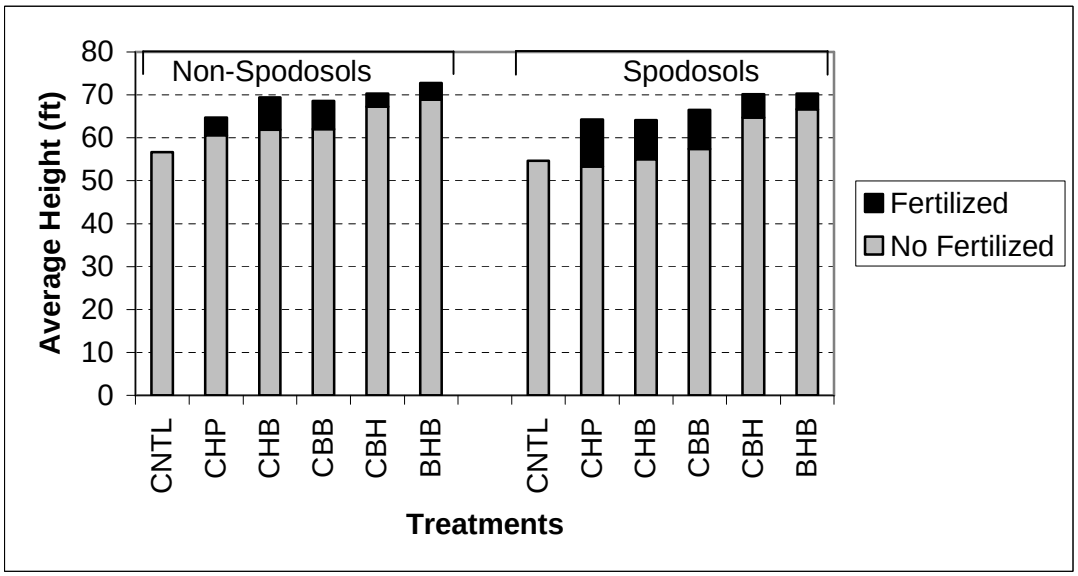

Figure 2. Least square means of average height after 26 years for different treatments on the two soil groups with and without fertilization.

3.2 Average dominant height

Trends in average dominant height closely resemble the trends found in average height. Both herbicide and fertilization treatments significantly increased average dominant height on both Spodosols and non-Spodosols during the life of study (Table 5). The gains in average dominant height from herbicide treatment were greater than that from fertilization treatment on non-Spodosols through age 20 and on Spodosols through age 23, respectively. Thereafter, the average dominant height gain from fertilization treatment had caught or surpassed the gain from herbicide treatment. At age 26, the fertilization and herbicide treatments provided significant gains of 7.6 and 6.3 feet on Spodosols, and of 5.3 and 3.6 feet on non-Spodosols, respectively. The gains in average dominant height from both fertilization and herbicide treatments on Spodosols were greater than those on non-Spodosols (Figure 3).

Table 5. Responses in average dominant height (ft.) from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.8	0.5	1.7	1.0	**3.0***	0.7	**3.9***	0.2	3.2	0.1	1.9	0.3
Burn	0.2	-0.4	**1.6***	-0.6	**1.9***	-0.2	1.6	0.1	**2.8***	0.4	**3.7***	0.5
Bed	**2.4***	**2.2***	**2.0***	**2.8***	**1.7***	**2.9***	**1.5***	**2.6***	0.8	**2.4***	0.6	**2.4***
Herbicide	**3.5***	**5.2***	**4.6***	**7.1***	**4.9***	**7.7***	**4.6***	**7.4***	**4.2***	**6.6***	**3.5***	**6.7***
Fertilization	**1.5***	**1.8***	**1.7***	**2.2***	**2.0***	**2.5***	**3.2***	**3.3***	**3.7***	**4.8***	**5.2***	**5.8***

Treatment	Age 23		Age 26	
	NS	SP	NS	SP
Chop	**5.6***	-0.1	2.6	-0.8
Burn	2.4	0.4	3.2	0.2
Bed	0.2	**2.6***	0.4	1.8
Herbicide	**4.5***	**6.7***	**3.6***	**6.3***
Fertilization	**5.4***	**6.7***	**5.3***	**7.6***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

Bedding significantly increased dominant height on non-Spodosols through age 14 and on Spodosols through age 23. The bedding treatment provided greater dominant height gains on Spodosols than on non-Spodosols.

Burning effects on dominant height on Spodosols were not significant. On non-Spodosols, the burning treatment significantly increased dominant height during the period from age 8 to age 20. Chopping on non-Spodosols significantly increased dominant height at ages 11, 14 and 23; while on Spodosols the chopping effects were not significant.

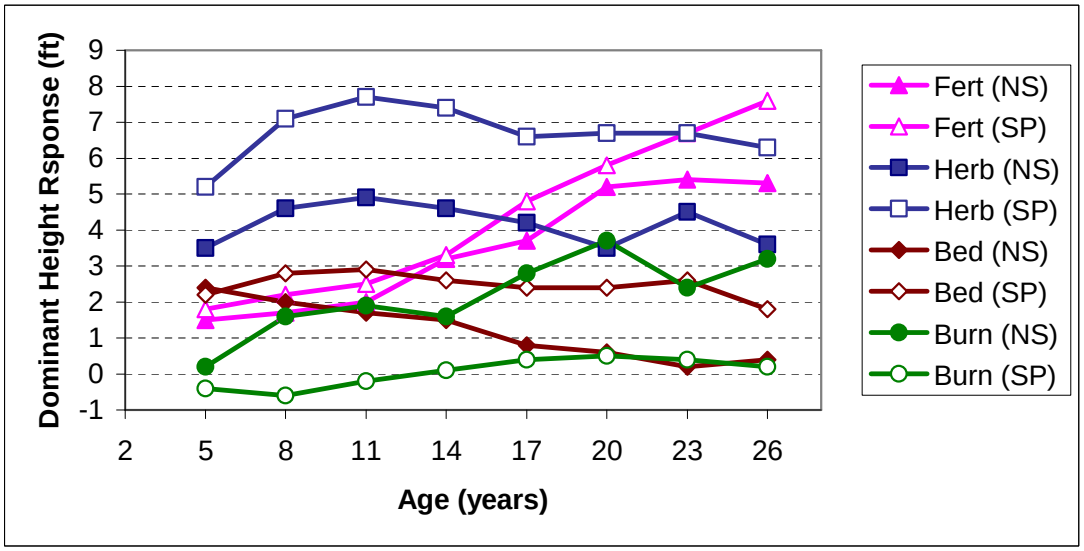

Figure 3. **Average dominant height responses to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns of dominant height responses to individual treatments are presented in Table 6.

Table 6. **Attributes of temporal patterns in response in dominant height to individual treatments.**

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ft)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ft)	Age at Maximum Response (yrs)
Chop	B	3.9	14			
Burn	B	3.7	17			
Bed	C	2.4	5	B	2.9	11
Herbicide	B	4.9	11	B	7.7	11
Fertilization	B	5.4	23	A	7.6	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, dominant heights ranged from a high of 76.2 feet for the chop, burn, bed, herbicide, and fertilization (FBHB) treatment to 61.3 feet for the control on non-Spodosols (Figure 4). On Spodosols, the range in mean height was from 73.7 feet for FBHB to 57.9 feet for chop only (UCHP) treatment. The average height values were well correlated with treatment intensity. Fertilization provided a positive response on all

treatments with greater gains on treatments without vegetation control. On Spodosols, the chop, burn and fertilize treatment (FCHB) had about the same dominant height as the chop, burn and herbicide treatment (UCBH); on non-Spodosols, FCHB had almost the same dominant height as and as the chop, burn, herbicide and fertilization treatment (FCBH). The chop, burn, bed and fertilize treatment (FCBB) had the same dominant height as the chop, burn, bed and herbicide treatment (UBHB) on Spodosols; on non-Spodosols, FCBB had higher dominant height than UBHB.

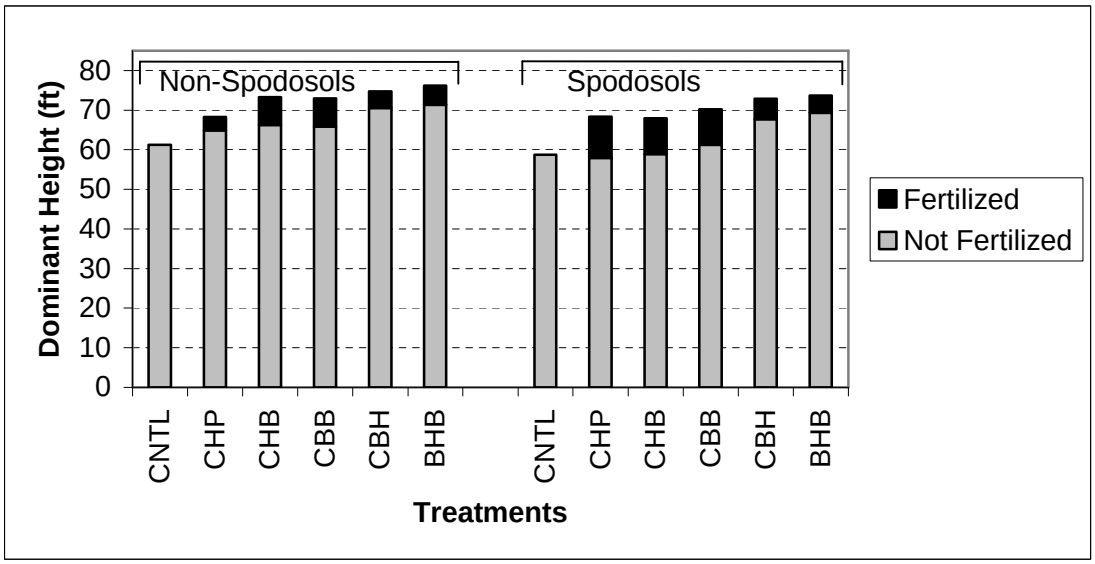

Figure 4. **Least square means of average dominant height after 26 years for different treatments on the two soil groups with and without fertilization.**

3.3 Average tree Dbh

There were significant differences among treatments, but soil group and the interaction of soil group and treatment were not significant for average dbh over the range of measured ages (Table 2). However, contrast analysis to separate treatments for dbh was conducted by soil groups since it was necessary to do so for average height. Both the herbicide and fertilization treatments significantly increased average dbh (Table 7, Figure 5). The dbh gains from herbicide treatment were greater than those from fertilization over the study period.

Bedding significantly increased average dbh through age 8 on both soil groups; over the period from age 11 to 20, the bedding effect on dbh was positive and significant on Spodosols, but was small and nonsignificant on non-Spodosols; at ages 23 and 26, the bedding effect was not significant on either soil groups.

On non-Spodosols, the positive burning effect was significant only at ages 8 and 11. On Spodosols, burning resulted in a nonsignificant negative dbh response at early ages and then a nonsignificant positive dbh response. A positive and significant chopping effect on dbh was found only on non-Spodosols from ages 8 to 17.

Table 7. **Responses in average tree dbh (in.) from chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.15	0.07	**0.37***	0.14	**0.45***	0.05	**0.53***	0.00	**0.51***	-0.05
Burn	0.08	-0.08	**0.31***	-0.07	**0.32***	0.00	0.14	0.05	0.13	0.06
Bed	**0.51***	**0.40***	**0.19***	**0.35***	0.07	**0.26***	0.04	**0.21***	-0.07	**0.18***
Herbicide	**1.11***	**1.39***	**1.16***	**1.41***	**1.02***	**1.24***	**0.89***	**1.07***	**0.88***	**0.99***
Fertilization	**0.33***	**0.38***	**0.31***	**0.38***	**0.33***	**0.31***	**0.45***	**0.41***	**0.55***	**0.56***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	0.35	-0.03	0.53	-0.10	0.53	-0.06
Burn	0.21	0.09	0.07	0.15	0.06	0.08
Bed	-0.13	**0.20***	-0.17	0.18	-0.15	0.17
Herbicide	**0.92***	**1.03***	**1.07***	**0.97***	**1.03***	**1.06***
Fertilization	**0.64***	**0.66***	**0.62***	**0.74***	**0.73***	**0.75***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

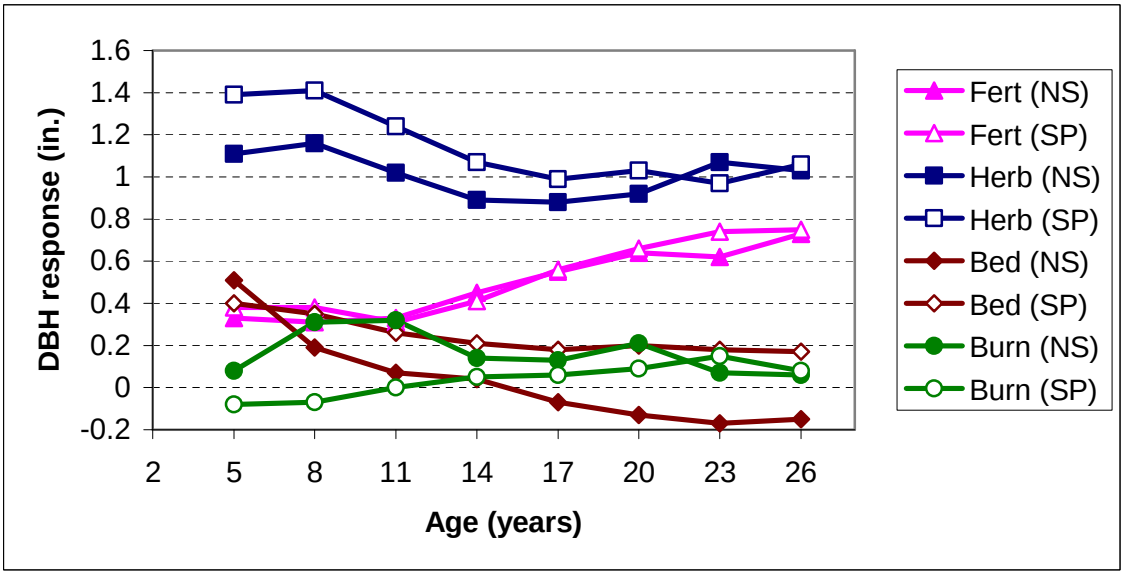

Figure 5. **Average Dbh response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns in dbh response to individual treatments are presented in Table 8.

Table 8. Attributes of temporal patterns in response in mean dbh to individual treatments.

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (inches)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (inches)	Age at Maximum Response (yrs)
Chop	B	0.53	14	No Response		
Burn	C	0.32	11	No Response		
Bed	D	0.51	5	C	0.40	5
Herbicide	C	1.16	8	C	1.41	8
Fertilization	A	0.73	26	A	0.75	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, the chop, burn, herbicide and fertilization treatment (FCBH) and chop, burn, bed, herbicide and fertilization treatment (FBHB) resulted in about the same average dbh on a given soil class, 9.4 inches on non-Spodosols and 8.4 inches on Spodosols (Figure 6). The control treatment's average dbh was 7.0 inches on non-Spodosols and 6.4 inches on Spodosols. The average dbh of the chop, burn, bed, and fertilize (FCBB) plots was less than the average dbh of the treatment regimes including herbicides, with or without fertilization. As observed for average and dominant height, the gains from fertilization on treatments without vegetation control were larger than the gains from fertilization on treatments with vegetation control.

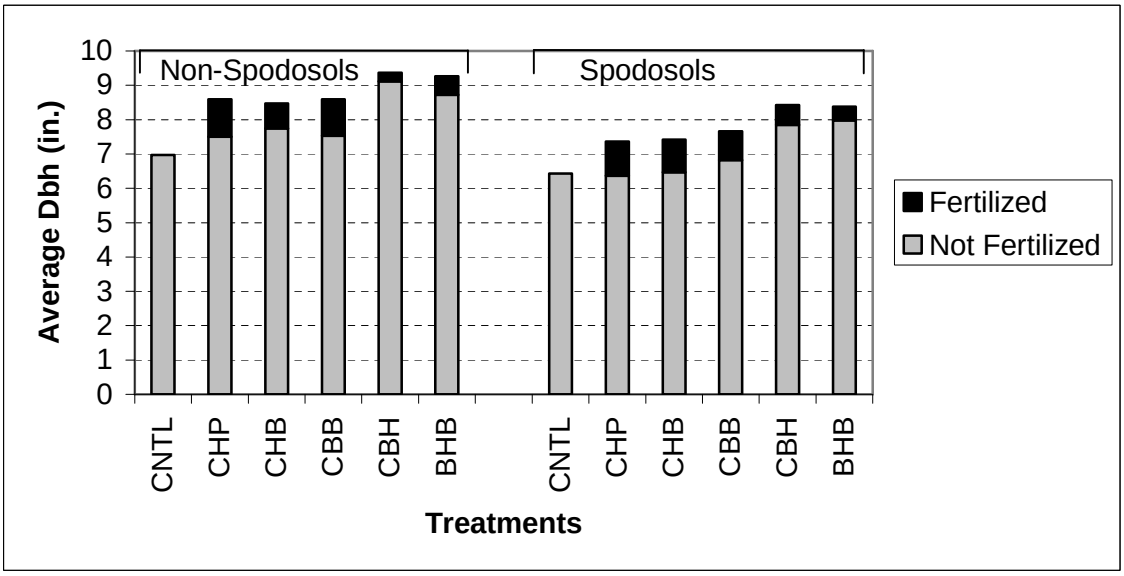

Figure 6. Least square means of average dbh after 26 years for different treatments on the two soil groups with and without fertilization.

3.4 Average crown length

Treatments significantly affected crown length during the period from age 14 to age 26; there was significant soil group and treatment interaction on average crown length at age 20 (Table 2).

Herbicide treatment significantly increased crown length on Spodosols through age 20 and on non-Spodosols through age 23. At ages 14 and 17, fertilization treatment significantly increased crown length on Spodosols; thereafter, its positive effects on crown length were significant on both soil groups (Table 9).

The bedding treatment significantly decreased average crown length on non-Spodosols through age 23, and significantly increased crown length on Spodosols at age 20. Both the chopping and burning treatments had no significant effects on crown length (Table 9).

Table 9. Responses in average crown length (ft.) from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 14		Age 17		Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.8	-0.2	1.7	-0.5	-0.7	0.8	0.8	-0.2	1.7	-1.5
Burn	1.5	0.1	0.2	0.2	1.1	0.3	-0.7	0.0	0.3	0.4
Bed	**-1.4***	0.6	**-1.6***	-0.2	**-2.2***	**1.2***	**-1.6***	0.3	0.2	0.6
Herbicide	**1.7***	**2.1***	**2.1***	**1.4***	**2.2***	**1.1***	**1.7***	0.5	0.1	-0.5
Fertilization	0.7	**1.4***	0.7	**1.1***	**1.3***	**2.1***	**1.8***	**1.7***	**2.1***	**2.1***

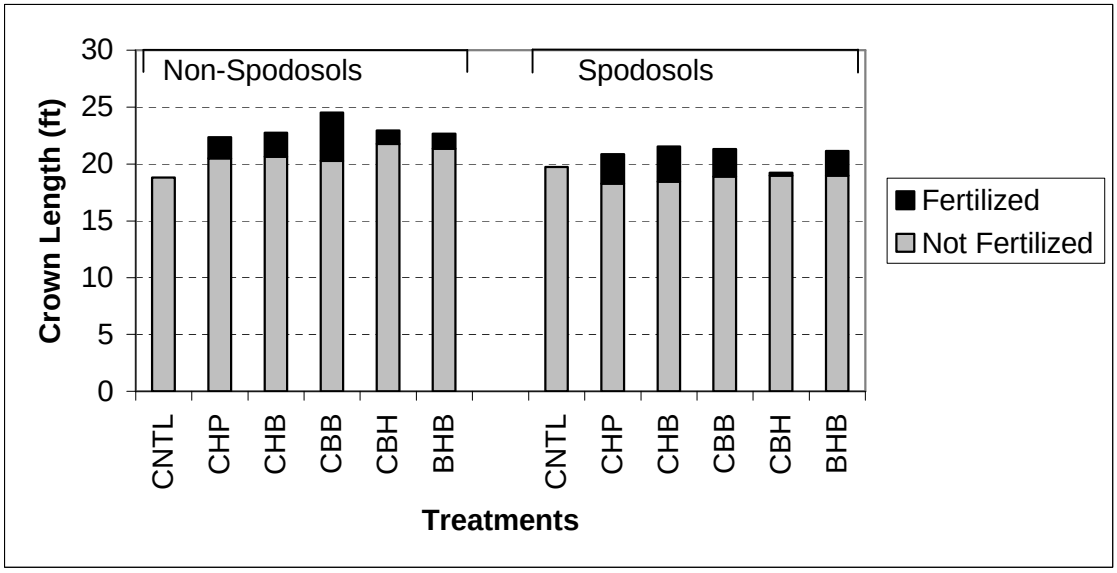

Figure 7. Least square means of average crown length after 26 years for different treatments on the two soil groups with and without fertilization.

After 26 growing seasons, crown length ranged from a high of 24.5 feet for the chop, burn, bed and fertilization (FCBB) treatment to 18.8 feet for the control on non-Spodosols (Figure 7). On Spodosols, the range in mean crown length was from 21.6 feet for the chop, burn and fertilization (FCHB) to 18.3 feet for chop only (UCHP) treatment. At age 26, only fertilization significantly increased crown length with gains of 2.1 feet. After 26 growing seasons the gains from fertilization on treatments without vegetation control were slightly larger, on average, than the gains from fertilization on treatments with vegetation control.

3.5 Average crown ratio

Treatments significantly affected average crown ratio from age 14 to age 26; and the effect of soil group was also significant at age 20. There was a significant soil × treatment interaction for average crown ratio at ages 20 and 26 (Table 2).

The herbicide treatment significantly decreased crown ratio on Spodosols, and its effects were nonsignificant on non-Spodosols (Table 10). The fertilization treatment had nonsignificant effects on crown ratio on both soil groups, except at age 17 fertilization significantly decreased crown ratio on Spodosols. The bedding treatment significantly decreased crown ratio on non-Spodosols from age 14 to age 23, and on Spodosols at age 17. As found on average crown length, both chopping and burning treatments had no significant effects on average crown ratio.

Table 10. Responses in average crown ratio from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 14		Age 17		Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	-0.02	-0.01	0.01	-0.01	-0.02	0.01	-0.03	0.00	0.01	-0.02
Burn	0.02	0.00	-0.02	0.00	0.00	0.00	-0.02	0.00	-0.01	0.01
Bed	**-0.04***	-0.01	**-0.03***	**-0.02***	**-0.04***	0.01	**-0.02***	-0.01	0.00	0.00
Herbicide	-0.01	**-0.03***	0.01	**-0.02***	0.02	**-0.02***	0.00	**-0.02***	-0.01	**-0.03***
Fertilization	-0.01	0.00	-0.01	**-0.01***	0.00	0.00	0.00	0.00	0.01	0.00

After 26 growing seasons, average crown ratios ranged from 0.29 to 0.33 on non-Spodosols and from 0.26 to 0.33 on Spodosols (Figure 8). All treatment regimes still had crown ratios greater than the minimum value of approximately 0.22 suggested as critical for dbh growth in a slash pine pruning study (Bennett, 1955). Average crown ratio on plots with herbicide treatment was lower than on other plots.

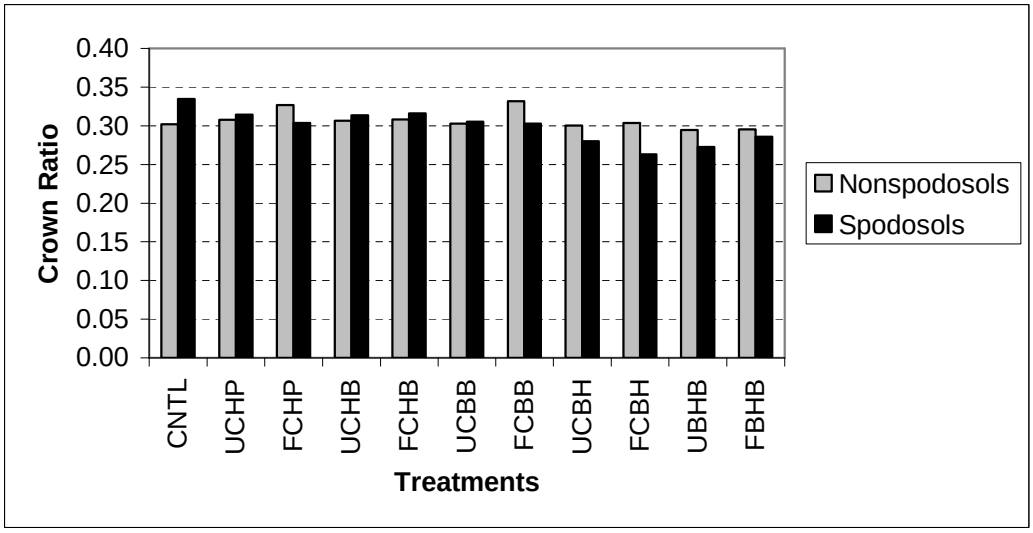

Figure 8. **Least square means for average crown ratio by treatment and soil group for all installations at age 26.**

3.6 Average percent cronartium infection

The only significant source of variation in fusiform rust infection was treatment (Table 2). Herbicide was the only treatment that significantly increased infection rate at all measured ages; after 26 growing seasons, herbicide increased infection rate by 9.7% over that on plots with no herbicide (Table 11). Both the chopping and fertilization treatments increased infection rate, although their effects were not significant. Burning and bedding also had no significant effects on infection rate except that bedded plots had significantly more trees with rust at age 5 and burned plots had significantly greater infection rates at age 14.

Table 11. **Responses in average percent cronartium infection with chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5	Age 8	Age 11	Age 14	Age 17	Age 20	Age 23	Age 26
Chop	0.7	3.4	2.0	1.4	2.7	2.3	2.9	2.7
Burn	-0.3	0.4	1.7	3.4*	2.4	0.7	1.1	0.5
Bed	1.9*	0.3	0.3	-1.4	-0.3	-0.4	-1.2	-1.7
Herbicide	4.7*	8.2*	7.7*	6.7*	7.6*	8.5*	9.2*	9.7*
Fertilization	0.5	0.4	0.5	1.1	1.3	1.2	1.4	2.0

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

The four treatment regimes that included herbicide had the highest infection percentages (Figure 9). Treatments with herbicide application had relatively high infection rates. There was a general increase in rust infection rate as treatment intensity increased. After 26 growing seasons, the average infection percentages by treatment ranged from 10.3% for the control to 25.6% for the chop, burn, herbicide, and fertilize (FCBH) treatment.

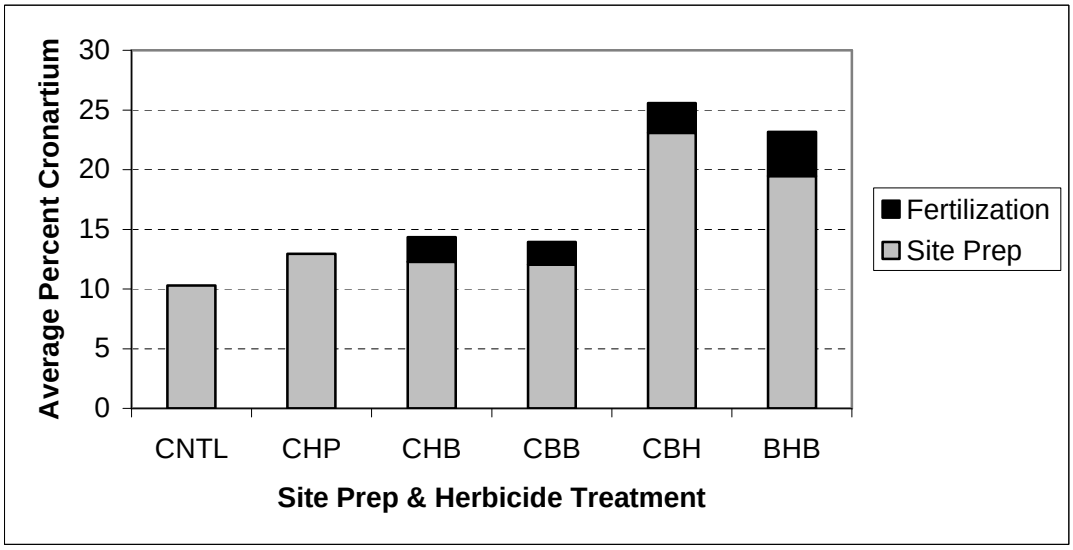

Figure 9. **Least square means for average percent cronartium infection by treatment for all installations at age 26.**

3.7 Average trees per acre (TPA)

Analyses of variance for survival, in terms of TPA, indicated that there were significant differences among treatments and that soil group and its interaction with treatment were not significant during the life of study (Table 2). Bedding significantly increased TPA through age 20, but its positive effect was not significant at ages 23 and 26 (Table 12). Chopping significantly increased TPA at age 5; thereafter its positive effect was no longer significant. The herbicide treatment significantly decreased TPA at ages 17 to 26; and at age 26, herbicide plots had 38 less TPA than the nontreated counterparts. Burning and fertilization treatments had no significant effects on survival.

Table 12. **Responses in trees per acre from chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5	Age 8	Age 11	Age 14	Age 17	Age 20	Age 23	Age 26
Chop	**51***	21	17	20	17	10	7	6
Burn	11	21	14	14	9	9	6	1
Bed	**40***	**26***	**26***	**24***	**23***	**20***	19	10
Herbicide	2	-19	-15	-16	**-19***	**-28***	**-37***	**-38***
Fertilization	19	4	5	2	-4	-7	-10	-11

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

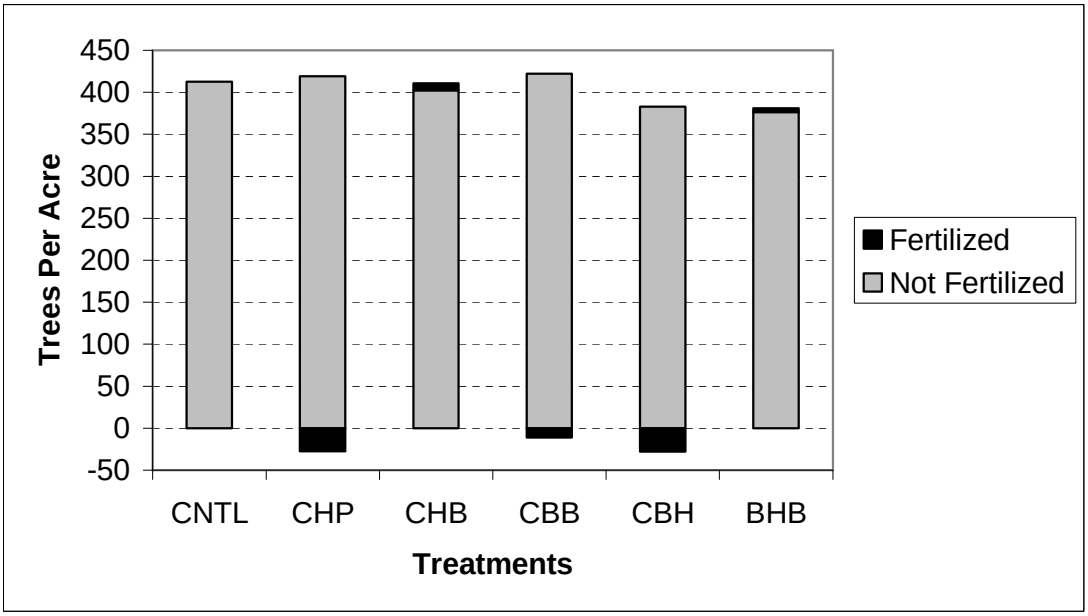

Figure 10. Least square means of trees per acre by treatment for all installations at age 26.

After 26 growing seasons, average trees per acre (TPA) ranged from a low of 355 for the chop, burn, herbicide, and fertilize (FCBH) treatment to a high of 422 for the chop, burn, and bed (UCBB) treatment (Figure 10). Although there was little correlation between treatment intensity and TPA at age 26, the treatments with vegetation control had more mortality.

3.8 Basal area per acre

The treatments significantly affected per acre basal area through 26 growing seasons and there was a significant interaction of soil group and treatment through 20 growing seasons (Table 2). Fertilization and herbicide treatments significantly increased per acre basal area on both Spodosols and non-Spodosols for all assessment periods (Table 13). On Spodosols, the gains in basal area from herbicide were greater than those observed from fertilization during the life of study. On non-Spodosols, herbicide treatment provided greater basal area than did fertilization treatment through 14 growing seasons, and thereafter fertilization resulted in similar or greater basal area response than herbicide treatment. Stand basal area response to fertilization and herbicide treatments on Spodosols was greater than that observed on non-Spodosols (Figure 11). This follows the same response pattern observed for average height. At age 26, fertilization and herbicide treatments significantly increased basal area by 18.6 ft^2/acre and 14.4 ft^2 /acre, respectively, on non-Spodosols and by 23.5 ft^2/acre and 23.8 ft^2 /acre on Spodosols.

Table 13. Responses in per acre basal area (ft^2) from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	1.75	0.19	4.70	1.97	9.11	0.66	12.86	0.58	14.09	0.17
Burn	1.53	-0.33	**9.46***	-0.34	**12.96***	0.62	**12.90***	2.71	**13.63***	2.56
Bed	**7.91***	**5.50***	**8.49***	**7.96***	**8.90***	**8.08***	**11.25***	**7.63***	**9.19***	**7.92***
Herbicide	**14.05***	**19.04***	**20.91***	**29.95***	**21.01***	**32.73***	**16.51***	**32.41***	**14.52***	**32.11***
Fertilization	**3.74***	**4.64***	**6.64***	**7.69***	**8.53***	**8.72***	**11.67***	**12.82***	**15.05***	**18.20***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	10.11	1.32	14.35	-0.66	13.08	1.42
Burn	**14.76***	4.12	11.93	5.79	10.18	3.20
Bed	**9.23***	**7.51***	8.62	**7.82***	7.84	3.16
Herbicide	**13.57***	**30.81***	**14.71***	**23.91***	**14.41***	**23.83***
Fertilization	**18.16***	**21.17***	**15.94***	**23.77***	**18.58***	**23.49***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

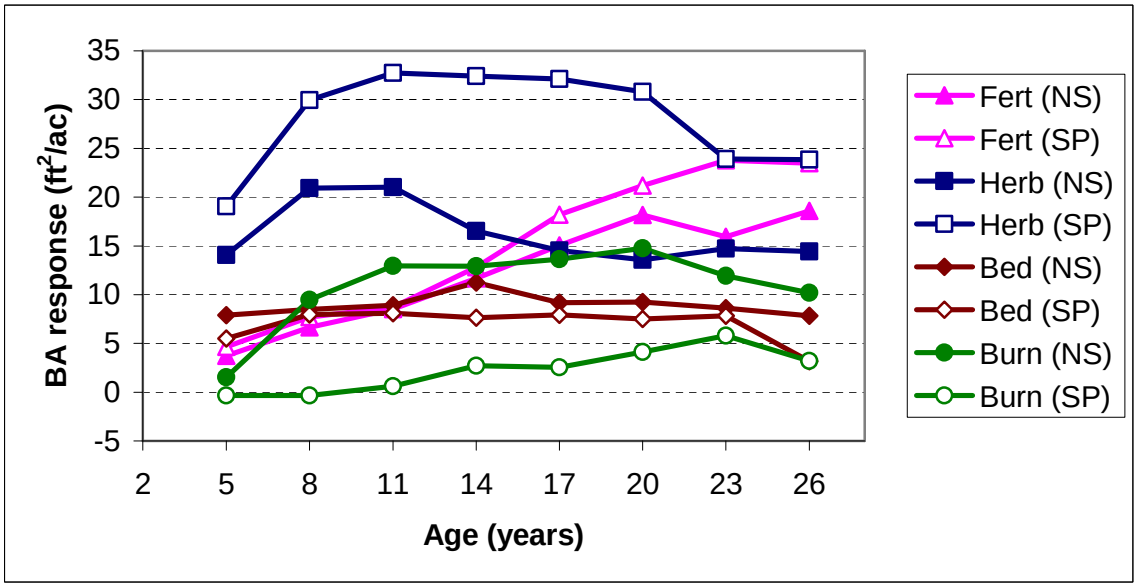

Figure 11. Average basal area per acre response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.

Bedding significantly increased basal area on both non-Spodosols and Spodosols through 20 growing seasons. At age 23, bedding provided significant positive effect on

basal area only on Spodosols; at age 26, the positive bedding effect was no longer significant. The gains in basal area from bedding on Spodosols was smaller that on non-Spodosols. Basal area response contrasts with height response gains from bedding that were greater on Spodosols than on non-Spodosols.

The significant and positive burning effects on basal area were found only on non-Spodosols through 20 growing seasons; while the effect of burning was not significant on Spodosols (Table 13).

Chopping had nonsignificant effects on basal area, due to the extreme variation in response. On some sites, basal area response to chopping was positive while on others it was negative.

Attributes of temporal patterns in basal area per acre response to individual treatments are detailed in Table 14.

Table 14. Attributes of temporal patterns in response in basal area per acre to individual treatments.

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ft^2/acre)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ft^2/acre)	Age at Maximum Response (yrs)
Chop	B	14	17	No Response		
Burn	C	15	20	No Response		
Bed	C	11	14	C	8	11
Herbicide	C	21	11	C	33	11
Fertilization	A	19	26	A	24	23

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, the fertilized, chop, burn and bed treatment (FCBB) had the same or more per acre basal area than the unfertilized plots containing the herbicide treatment (Figure 12). This indicated that repeated fertilizations can produce more basal area than early complete vegetation control. Again, the gains from fertilization on treatments without vegetation control were greater than those on treatments with vegetation control. The most intensive treatment, chop, burn, bed, herbicide and fertilize (FBHB), produced almost 64 ft^2/acre and 54 ft^2/acre more basal area than the control plots on non-Spodosols and Spodosols, respectively, at age 26.

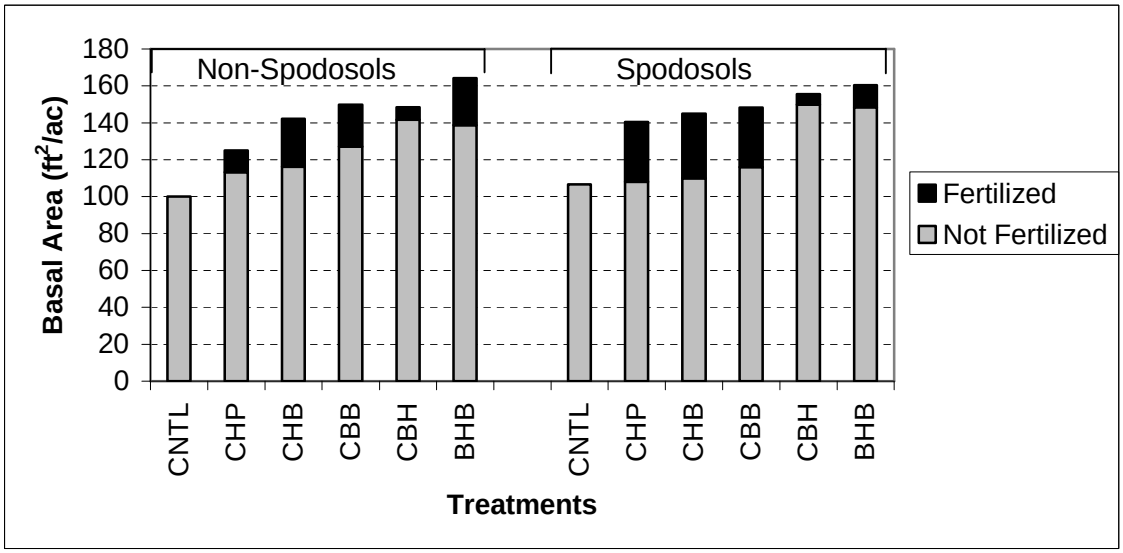

Figure 12. **Least square means of basal area per acre after 26 years for different treatments on the two soil groups with and without fertilization.**

3.9 Total volume per acre

For average total outside bark stem volume, there were significant differences among treatments and nonsignificant differences between soil groups for each assessment period. The interaction of soil group and treatment was significant from age 8 through age 20 (Table 2). The herbicide and fertilization treatments consistently and significantly increased total volume through 26 growing seasons (Table 15). Both fertilization and herbicide resulted in more volume yield on Spodosols than that on non-Spodosols. On non-Spodosols, herbicide treatment provided a greater overall increase in total volume than fertilization through age 14, and then the fertilization treatment resulted in greater volume than the herbicide treatment. On Spodosols, a greater volume response to herbicide treatment than to fertilization treatment continued until age 20; at ages 23 and 26, the total volume gains from fertilization treatment had surpassed the gains from herbicide treatment (Figure 13).

Bedding significantly increased total volume on non-Spodosols through 20 growing seasons and on Spodosols through 23 growing seasons. This same pattern was also observed for stand basal area. The positive and significant effects of burning on total volume were found only on non-Spodosols before age 23.

Even though chopping effects were not significant due to extreme variability, there were large differences in total volume associated with this treatment on non-Spodosols and only small differences on Spodosols.

Table 15. **Responses in total volume per acre (ft^3/ac) from chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	13	-6	53	15	163	0	281	-7	355	-13
Burn	11	0	**136***	-3	**255***	16	**342***	59	**441***	80
Bed	**80***	**60***	**149***	**143***	**204***	**202***	**299***	**247***	**265***	**274***
Herbicide	**144***	**190***	**369***	**509***	**496***	**752***	**491***	**931***	**497***	**1029***
Fertilization	**37***	**42***	**116***	**124***	**199***	**190***	**343***	**355***	**504***	**598***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	279	27	540	-27	493	-5
Burn	**525***	130	**457***	188	436	117
Bed	**279***	**305***	254	**377***	277	175
Herbicide	**502***	**1106***	**577***	**955***	**599***	**1021***
Fertilization	**705***	**794***	**703***	**976***	**801***	**1069***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

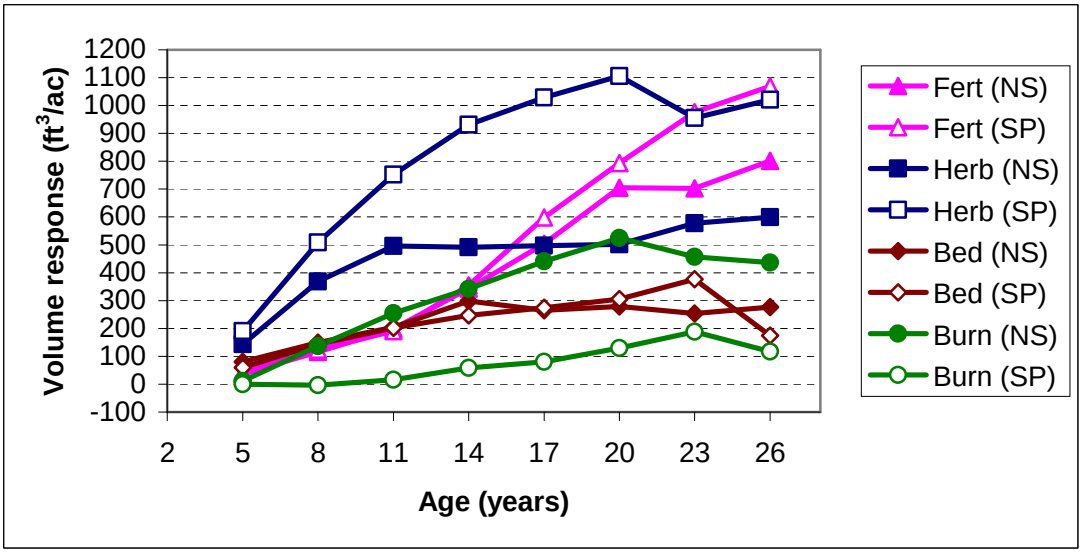

Figure 13. **Average total volume per acre response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns in total volume per acre response to individual treatments are summarized in Table 16.

Table 16. Attributes of temporal patterns in response in total volume per acre to individual treatments.

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ft^3/acre)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ft^3/acre)	Age at Maximum Response (yrs)
Chop	B	540	23	No Response		
Burn	C	525	20	C	188	23
Bed	B	299	14	C	377	23
Herbicide	A	599	26	C	1106	20
Fertilization	A	801	26	A	1069	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, average total volume ranged from a low of 2790 ft^3/acre on the control plots to a high of 5360 ft^3/acre on non-Spodosols and 5130 ft^3/acre on Spodosols for the most intensive treatment (Figure 14). Fertilization and herbicide treatments significantly increased total volume per acre on non-Spodosols by 801 and 599 ft^3/acre, and on Spodosols by 1069 and 1021 ft^3/acre, respectively (Table 15).

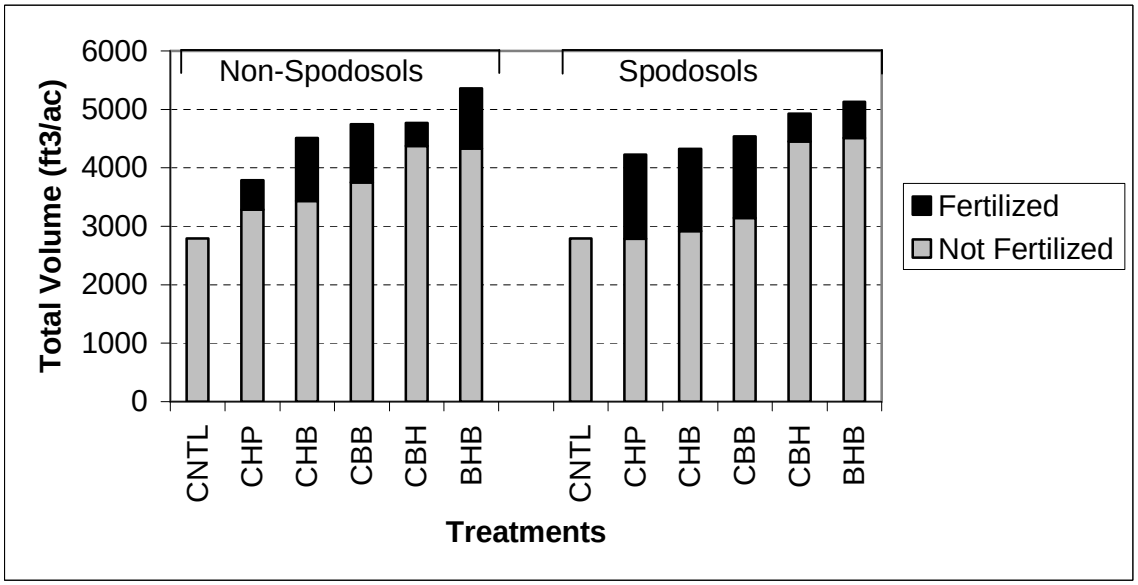

Figure 14. Least square means of total volume after 26 years for different treatments on the two soil groups with and without fertilization.

3.10 Merchantable volume per acre

Trends in merchantable volume per acre closely resembles the trends found in total volume per acre. For merchantable volume, there were significant differences among treatments in the life of study. The interaction of soil group and treatment was significant from age 11 through age 20 (Table 2).

The herbicide treatment consistently and significantly increased merchantable volume on both soil groups through 26 growing seasons. The fertilization treatment also consistently and significantly increased merchantable volume on both soil groups from age 8 through age 26 (Table 17). Both fertilization and herbicide treatments resulted in more merchantable volume yield on Spodosols than on non-Spodosols. The gains in merchantable volume from herbicide treatment were greater than the gains from fertilization treatment on non-Spodosols through age 17 and on Spodosols through age 23 (Figure 15).

Bedding significantly increased merchantable volume on non-Spodosols through age 20 and on Spodosols through age 23. The same pattern was also observed for stand basal area and total volume. The positive and significant effects of burning on merchantable volume were found only on non-Spodosols before age 23.

Although chopping effects were not significant, there were large gains in merchantable volume on non-Spodosols.

Table 17. Responses in merchantable volume per acre (ft^3/ac) from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	2	-4	25	-28	161	2	293	1	370	-19
Burn	3	3	**124***	11	**260***	22	**343***	62	**446***	85
Bed	**27***	**21***	**136***	**126***	**194***	**202***	**291***	**249***	**253***	**275***
Herbicide	**70***	**59***	**451***	**578***	**539***	**817***	**522***	**965***	**522***	**1055***
Fertilization	13	9	**125***	**110***	**208***	**201***	**350***	**365***	**513***	**610***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	291	27	548	-28	504	-6
Burn	**528***	132	**461***	189	441	120
Bed	**268***	**307***	248	**339***	271	181
Herbicide	**532***	**1135***	**605***	**987***	**625***	**1054***
Fertilization	**716***	**804***	**713***	**988***	**813***	**1081***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

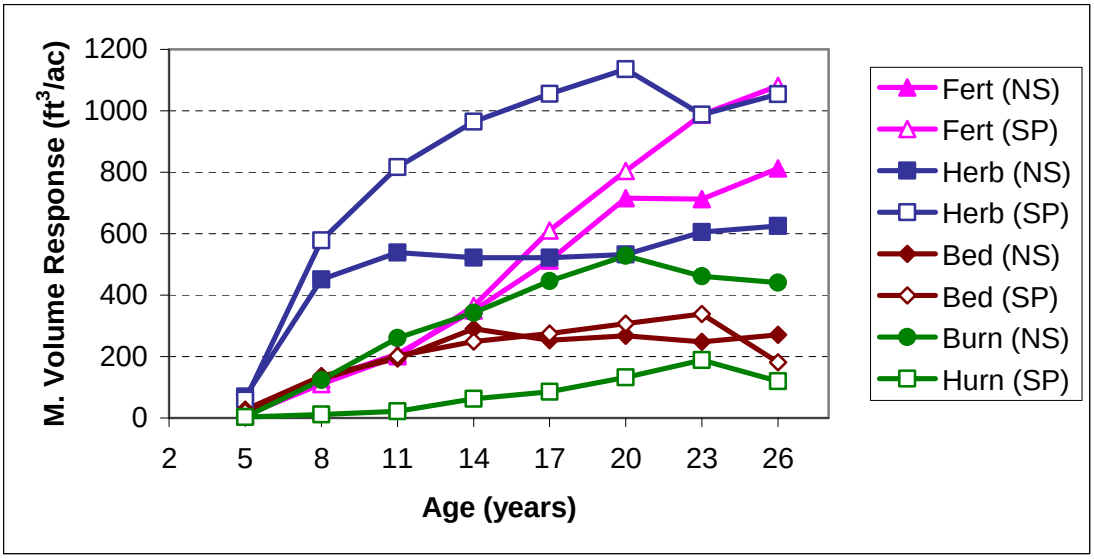

Figure 15. **Average merchantable volume per acre response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns in merchantable volume per acre response to individual treatments are summarized in Table 18.

Table 18. **Attributes of temporal patterns in response in merchantable volume per acre to individual treatments.**

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ft^3/acre)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ft^3/acre)	Age at Maximum Response (yrs)
Chop	B	548	23	No Response		
Burn	C	528	20	C	189	23
Bed	B	291	14	C	339	23
Herbicide	A	625	26	C	1135	20
Fertilization	A	813	26	A	1081	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, average merchantable volume ranged from a low of 2640 ft^3/acre on the control plots to a high of 5276 ft^3/acre on non-Spodosols and 5029 ft^3/acre on Spodosols for the most intensive treatment (Figure 16). Fertilization and herbicide treatments significantly increased merchantable volume per acre on non-Spodosols by 813 and 625 ft^3/acre, and on Spodosols by 1081 and 1054 ft^3/acre, respectively (Table 17).

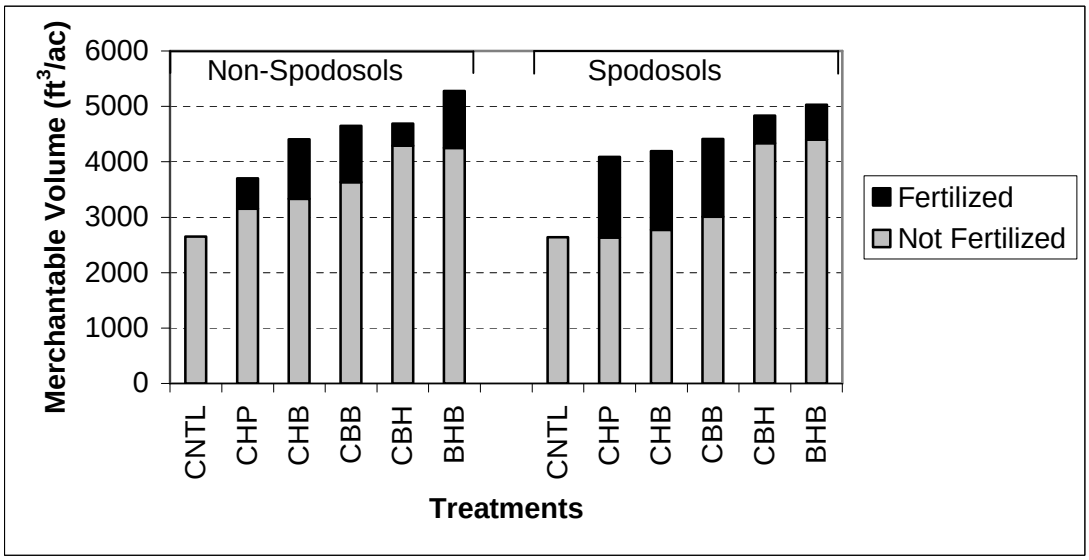

Figure 16. **Least square means of merchantable volume after 26 years for different treatments on the two soil groups with and without fertilization.**

3.11 Total stem green weight per acre

Trends in total stem green weight per acre closely resembles the treads found in total and merchantable volumes. For total stem green weight, there were significant differences among treatments for each assessment period. The interaction of soil group and treatment was significant from age 8 through to age 20 (Table 2). The herbicide and fertilization treatments consistently and significantly increased total stem green weight through 26 growing seasons (Table 19). Both fertilization and herbicide resulted in more total green tons on Spodosols than that on non-Spodosols. On non-Spodosols, herbicide treatment provided a greater overall increase in total green weight than fertilization through age 14, and then the fertilization treatment resulted in greater weight than the herbicide treatment. On Spodosols, a greater weight response to herbicide treatment than to fertilization treatment continued until age 20; thereafter, total stem green weight gains from fertilization treatment had surpassed the gains from herbicide treatment (Figure 17).

Bedding significantly increased total green weight on non-Spodosols through 20 growing seasons and on Spodosols through 23 growing seasons. The positive and significant effects of burning on total volume were found only on non-Spodosols before age 23.

Chopping effects on total green weight were not significant due to extreme variability on both soil groups, although relative larger positive gains in total green weight were found on non-Spodosols rather than on Spodosols.

Table 19. **Responses in stem total green weight per acre (ton/ac) from chopping, burning, bedding, fertilization and herbicide at different ages.**

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.3	-0.2	1.4	0.4	4.7	0.0	8.1	-0.2	10.4	-0.4
Burn	0.3	0.0	**3.8***	-0.1	**7.4***	0.4	**10.2***	1.7	**13.5***	2.5
Bed	**2.2***	**1.6***	**4.3***	**4.1***	**6.1***	**6.0***	**9.1***	**7.6***	**8.2***	**8.5***
Herbicide	**3.8***	**5.1***	**10.2***	**14.3***	**14.2***	**21.9***	**14.3***	**27.8***	**14.6***	**31.0***
Fertilization	**1.0***	**1.1***	**3.3***	**3.5***	**5.8***	**5.6***	**10.2***	**10.6***	**15.1***	**18.1***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	8.2	0.8	16.7	-0.8	15.2	-0.4
Burn	**16.3***	4.0	**14.3***	5.7	13.8	3.7
Bed	**8.8***	**9.6***	8.1	**10.7***	8.9	5.7
Herbicide	**14.7***	**33.7***	**16.9***	**29.2***	**17.6***	**31.3***
Fertilization	**21.5***	**24.4***	**21.7***	**30.3***	**24.6***	**33.6***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

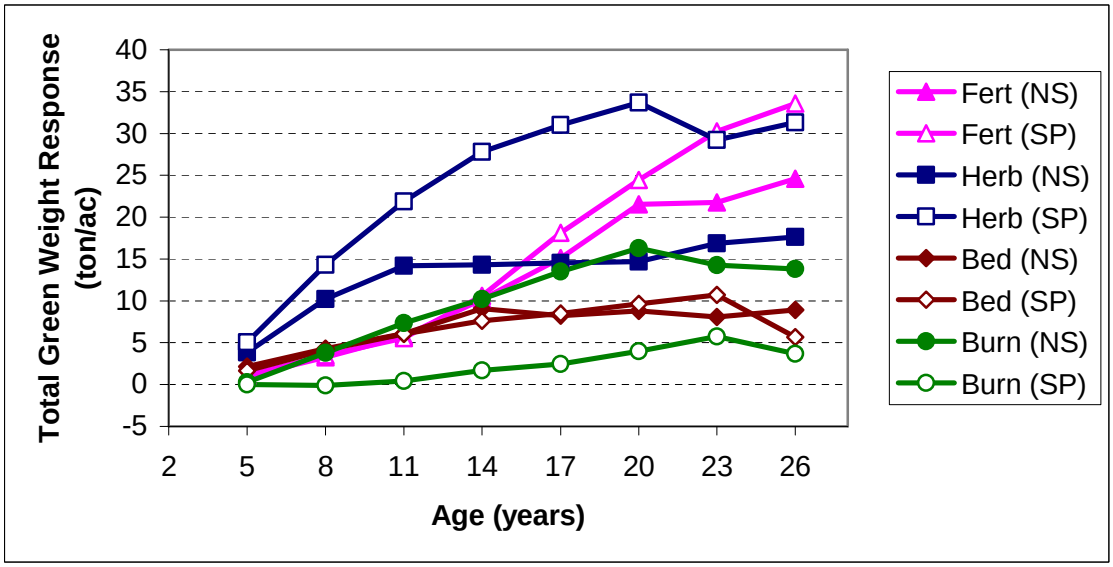

Figure 17. **Total stem green weight per acre response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns in total stem green weight per acre response to individual treatments are summarized in Table 20.

Table 20. Attributes of temporal patterns in response in total stem green weight per acre to individual treatments.

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ton/acre)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ton/acre)	Age at Maximum Response (yrs)
Chop	B	16.7	23	No Response		
Burn	C	16.3	20	C	5.7	23
Bed	B	8.8	14	C	10.7	23
Herbicide	A	17.6	26	C	33.7	20
Fertilization	A	24.6	26	A	33.6	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, average total stem green weight ranged from a low of 84 ton/acre on the control plots to a high of 163 ton/acre on non-Spodosols and 157 ton/acre on Spodosols for the most intensive treatment (Figure 18). Fertilization and herbicide treatments significantly increased stem green weight on non-Spodosols by 24.6 and 17.6 ton/acre, and on Spodosols by 33.6 and 31.3 ton/acre, respectively (Table 19).

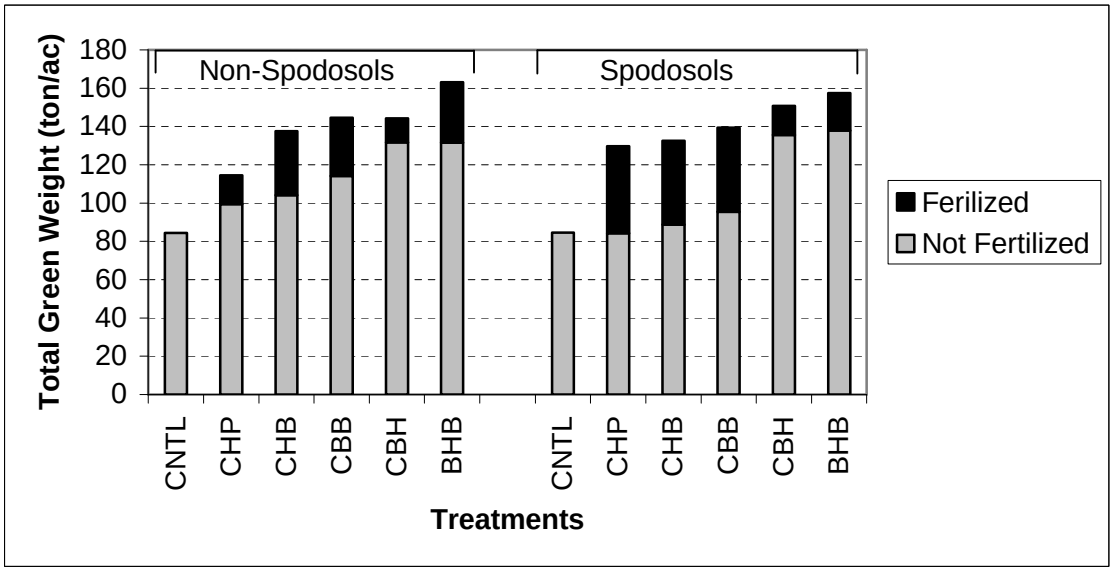

Figure 18. Least square means of total stem green weight after 26 years for different treatments on the two soil groups with and without fertilization.

3.12 Merchantable green weight per acre

Trends in merchantable green weight per acre had the trends as merchantable volume per acre. Treatments significantly affected merchantable green weight over the whole study period. The interaction of soil group and treatment was significant from age 11 through to age 20 (Table 2).

The herbicide treatment significantly increased merchantable green weight on both soil groups through 26 growing seasons. The fertilization treatment also resulted in a significant increase in merchantable green weight on both soil groups from age 8 through to age 26 (Table 21). Both fertilization and herbicide treatments resulted in more merchantable green weight on Spodosols than on non-Spodosols. The gains in merchantable green weight from herbicide treatment were greater than the gains from fertilization treatment on non-Spodosols through age 17 and on Spodosols through age 23 (Figure 19).

Bedding significantly increased merchantable green weight on non-Spodosols through age 20 and on Spodosols through age 23. The same pattern was also observed for stand basal area, total and merchantable volume, and total green weight. The positive and significant effects of burning on merchantable green weight were found only on non-Spodosols before age 23.

Although chopping effects were not significant, there were large gains in merchantable green weight on non-Spodosols.

Table 21. Responses in merchantable green weight per acre (ton/ac) from chopping, burning, bedding, fertilization and herbicide at different ages.

Treatment	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Chop	0.0	-0.1	0.7	-0.8	4.6	0.0	8.4	0.0	10.8	-0.6
Burn	-0.1	0.1	**3.4***	0.3	**7.4***	0.6	**10.2***	1.8	**13.6***	2.6
Bed	**0.7***	**0.6***	**3.9***	**3.6***	**5.8***	**6.0***	**8.8***	**7.6***	**7.9***	**8.5***
Herbicide	**1.9***	**1.6***	**12.4***	**16.1***	**15.3***	**23.5***	**15.1***	**28.6***	**15.2***	**31.6***
Fertilization	0.4	0.2	**3.5***	**3.1***	**6.0***	**5.8***	**10.3***	**10.8***	**15.3***	**18.4***

Treatment	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Chop	8.5	0.8	16.9	-0.9	15.4	-0.4
Burn	**16.3***	4.0	**14.4***	5.7	13.9	3.7
Bed	**8.4***	**9.7***	7.8	**10.7***	8.7	5.8
Herbicide	**15.5***	**34.4***	**17.7***	**30.1***	**18.4***	**32.2***
Fertilization	**21.8***	**24.6***	**22.0***	**30.5***	**24.9***	**33.8***

* indicates the responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

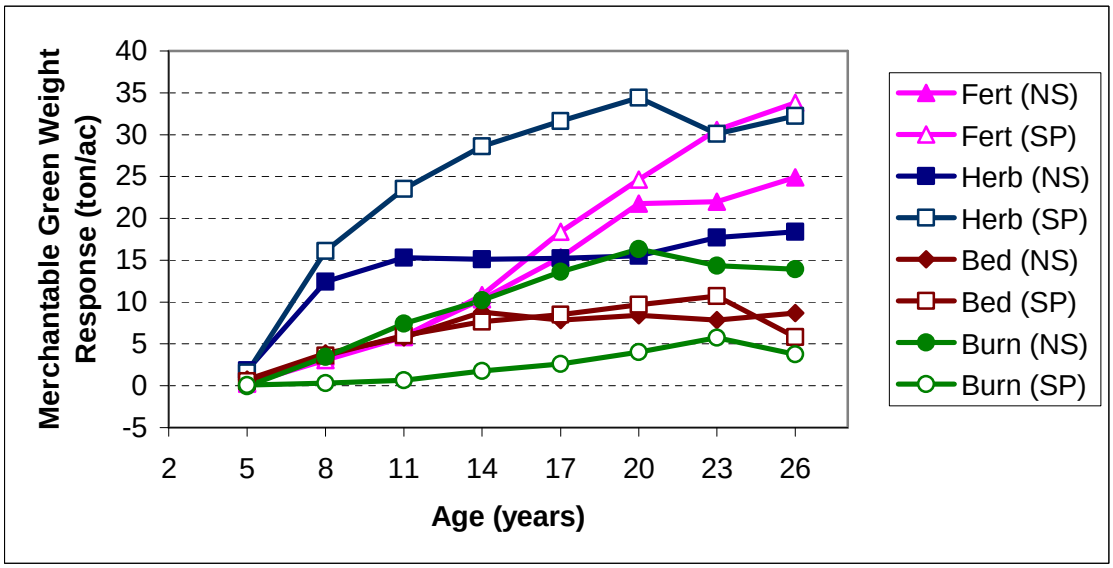

Figure 19. **Total stem green weight per acre response to fertilization (Fert), herbicide (Herb), bedding (Bed), and burning (Burn) treatments between ages 5 and 26 on non-Spodosol (NS) and Spodosol (SP) soils.**

Attributes of temporal patterns in merchantable green weight per acre response to individual treatments are summarized in Table 22.

Table 22. **Attributes of temporal patterns in response in merchantable stem green weight per acre to individual treatments.**

Treatment	Non-Spodosols			Spodosols		
	Response Type[a]	Maximum Response (ton/acre)	Age at Maximum Response (yrs)	Response Type[a]	Maximum Response (ton/acre)	Age at Maximum Response (yrs)
Chop	B	16.9	23	No Response		
Burn	C	16.3	20	C	5.7	23
Bed	B	8.8	14	C	10.7	23
Herbicide	A	18.4	26	C	34.4	20
Fertilization	A	24.9	26	A	33.8	26

[a] Type A – response magnitude increase with time; Type B – response peak is attained and maintained; Type C – response peaks and diminishes somewhat with time; Type D – response peaks and with time diminishes to zero or negative.

After 26 growing seasons, average merchantable green weight ranged from a low of 80 ton/acre on the control plots to a high of 160 ton/acre on non-Spodosols and 154 ton/acre on Spodosols for the most intensive treatment (Figure 20). Fertilization and

herbicide treatments significantly increased merchantable green weight on non-Spodosols by 24.9 and 18.4 ton/acre and on Spodosols by 33.6 and 32.2 ton/acre, respectively (Table 21).

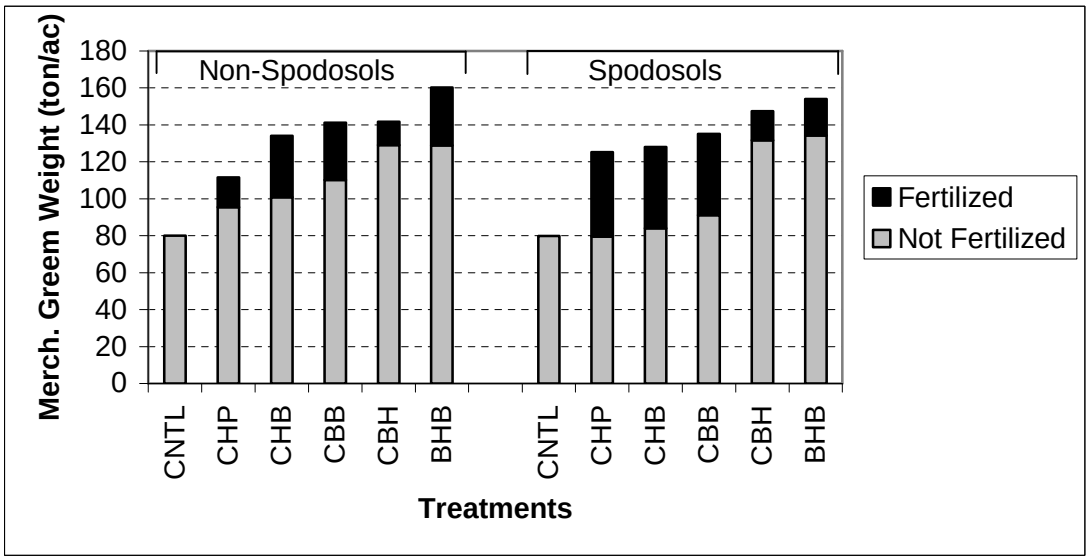

Figure 20. Least square means of merchantable stem green weight after 26 years for different treatments on the two soil groups with and without fertilization.

3.13 Treatment interactions

The differences in responses of average height, dominant height, dbh, basal area, total volume and merchantable volume, total stem green weight and merchantable green weight to fertilization on treatments without and with vegetation control are shown in Table 23. On Spodosols, fertilization in the absence of vegetation control always resulted in larger increases in these variables than fertilization in the presence of vegetation control; the response differences were significant, except for volume and weight responses at early ages. On non-Spodosols, there was no significant difference between responses to fertilization with and without vegetation control.

The less than additive response to the combination of fertilization and competition control on Spodosols was evident on plots that were chopped and burned or chopped, burned and bedded. In contrast, response patterns on non-Spodosols indicate that competition control and fertilization responses were additive on plots that were chopped, burned and bedded and less than additive on plots that were chopped and burned but not bedded, although this less than additive observed on non-Spodosols was not significant at the alpha level of 0.05 (Tables 24 and 25). The temporal patters of total volume responses to individual fertilization and competition control and response to the combination of them are presented by soil group and sepratively for chopped, burned plots and chopped, burned and bedded plots in Figure 21 and Appendix 13. Responses in stem total green tons to individual fertilization and competition and the combination of

them on chopped, burned plots and chopped, burned and bedded plots are presented in Appendix 14. The magnitude and trend of these responses depended on soil group and whether the plots were bedded or not.

Table 23. The difference in responses in average height and dominant height (ft), average Dbh (in.), stand basal area (ft^2/ac), total volume and merchantable volume (ft^3/ac), total stem green weight and merchantable green weight (ton/ac) from fertilization between treatments with and without vegetation control by soil group and age.

Variable	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Height (ft)	-0.1	**2.8***	0.0	**3.3***	0.0	**3.9***	1.3	**4.1***	1.9	**4.3***
Dominant Height (ft)	-0.1	**3.0***	-0.7	**3.0***	0.0	**3.6***	0.9	**3.6***	1.7	**3.4***
Dbh (in)	-0.05	**0.55***	0.01	**0.48***	0.07	**0.46***	0.08	**0.51***	0.20	**0.54***
Basal Area (ft^2/ac)	-2.00	**4.42***	-2.06	**6.87***	1.74	**8.99***	2.38	**11.73***	5.07	**14.59***
Total Volume (ft^3/ac)	-24	35	-43	100	10	**204***	58	**317***	162	**416***
Merch. Volume (ft^3/ac)	-24	-19	-45	66	2	**220***	47	**333***	160	**426***
Total Gr. Wt. (tons/ac)	-0.6	1.0	-1.2	2.9	0.2	**6.0***	1.7	**9.5***	4.9	**12.5***
Merch Gr. Wt tons/ac)	-0.7	-0.5	-1.3	1.9	-0.1	**6.4***	1.3	**9.9***	4.8	**12.7***

Variable	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Height (ft)	2.5	**4.1***	3.5	3.2	3.6	**4.5***
Dominant Height (ft)	1.3	**4.1***	1.9	2.8	2.6	**4.2***
Dbh (in)	0.22	**0.48***	0.41	**0.45***	0.50	**0.40***
Basal Area (ft^2/ac)	2.86	**16.53***	1.09	**17.21***	8.19	**24.92***
Total Volume (ft^3/ac)	130	**493***	89	**520***	326	**854***
Merch. Volume (ft^3/ac)	130	**502***	95	**531***	335	**850***
Total Gr. Wt. (tons/ac)	4.1	**15.0***	2.8	**15.7***	9.9	**26.5***
Merch Gr. Wt tons/ac)	4.1	**15.1***	3.0	**16.0***	10.0	**26.3***

* indicates the differences in responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

Table 24. The difference between the response to the combination of fertilization and herbicide and the sum of responses to fertilization and herbicide on plots that were chopped, burned, and bedded.

Variable	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Height (ft)	0.5	**-3.2***	1.0	**-3.9***	0.9	**-4.4***	-0.5	**-5.1***	-0.8	**-4.6***
Dominant Height (ft)	0.6	**-3.3***	2.0	**-3.9***	0.8	**-4.5***	0.2	**-5.1***	-0.7	-3.6
Dbh (in)	0.08	**-0.63***	0.11	**-0.56***	-0.04	**-0.55***	-0.02	**-0.6***	-0.07	**-0.62***
Basal Area (ft^2/ac)	3.39	-5.27	7.14	-7.63	3.49	-8.46	3.57	-9.53	2.68	-9.32
Total Volume (ft^3/ac)	41	-46	126	-133	99	-230	85	-340	37	-339
Merch. Volume (ft^3/ac)	38	23	108	-136	96	**-267**	91	**-362**	35	-361
Total Gr. Wt. (tons/ac)	1.1	-1.3	3.6	-3.8	3.1	-6.8	2.5	-10.4	1.0	-10.3
Merch Gr. Wt tons/ac)	1.0	0.6	3.1	-3.8	3.0	**-7.8**	2.7	**-10.9**	0.9	-10.9

Variable	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Height (ft)	-2.3	**-4.9***	-4.7	-2.9	-2.6	**-5.4***
Dominant Height (ft)	-1.2	**-5.9***	-2.1	-2.8	-2.3	-4.5
Dbh (in)	-0.23	**-0.58***	-0.4	-0.52	-0.52	-0.42
Basal Area (ft^2/ac)	2.1	-10.04	13.08	-7.6	2.76	**-20.4***
Total Volume (ft^3/ac)	18	-388	267	-229	34	**-778***
Merch. Volume (ft^3/ac)	9	-405	245	-250	8	**-776***
Total Gr. Wt. (tons/ac)	0.4	-12.0	7.6	-6.7	1.1	**-24.5***
Merch Gr. Wt tons/ac)	0.1	-12.4	6.9	-7.3	0.4	**24.3***

* indicates the differences in responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

Table 25. The difference between the response to the combination of Fertilization and herbicide and the sum of responses to fertilization and herbicide on plots that were chopped and burned.

Variable	Age 5		Age 8		Age 11		Age 14		Age 17	
	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Height (ft)	-0.2	**-2.3***	-1.1	-2.8	-1.0	**-3.5**	-2.1	-3.1	-3.0	**-4.0***
Dominant Height (ft)	-0.3	**-2.7***	-0.6	-2.2	-0.8	-2.7	-2	-2.1	-2.6	-3.2
Dbh (in)	0.03	**-0.47***	-0.12	-0.4	-0.1	-0.37	-0.14	-0.43	-0.33	-4.5
Basal Area (ft^2/ac)	0.60	-3.57	-3.01	-6.12	-6.96	-9.51	-8.32	**-13.94***	-12.83	**-19.87***
Total Volume (ft^3/ac)	7	-25	-39	-68	-119	-178	-201	-295	-361	**-492***
Merch. Volume (ft^3/ac)	11	15	-18	5	-101	-174	-184	-305	-355	**-491***
Total Gr. Wt. (tons/ac)	0.2	-0.7	-1.1	-1.9	-3.4	-5.2	-5.9	-8.7	-10.8	**-14.7***
Merch Gr. Wt tons/ac)	0.3	0.4	-0.5	0.1	-2.8	-5.0	-5.4	-8.9	-10.6	**-14.6***

Variable	Age 20		Age 23		Age 26	
	NS	SP	NS	SP	NS	SP
Height (ft)	-2.7	-3.3	-2.2	-3.4	-4.6	-3.7
Dominant Height (ft)	-1.4	-2.4	-1.7	-2.8	-2.8	-3.9
Dbh (in)	-0.22	-0.39	-0.43	-0.38	-0.48	-0.38
Basal Area (ft^2/ac)	-7.82	**-23.02***	-15.26	**-26.81***	-19.14	**-29.43***
Total Volume (ft^3/ac)	-277	**-598***	-446	**-810***	-686	**-930***
Merch. Volume (ft^3/ac)	-269	**-598***	-435	**-812***	-679	**-924***
Total Gr. Wt. (tons/ac)	-8.5	**-17.9***	-13.2	**-24.7***	-20.9	**-28.6**
Merch Gr. Wt tons/ac)	-8.3	**-17.8***	-12.9	**-24.7***	-20.6	**-28.3**

* indicates the differences in responses were found to be significant in the contrast analysis at $\alpha = 0.05$.

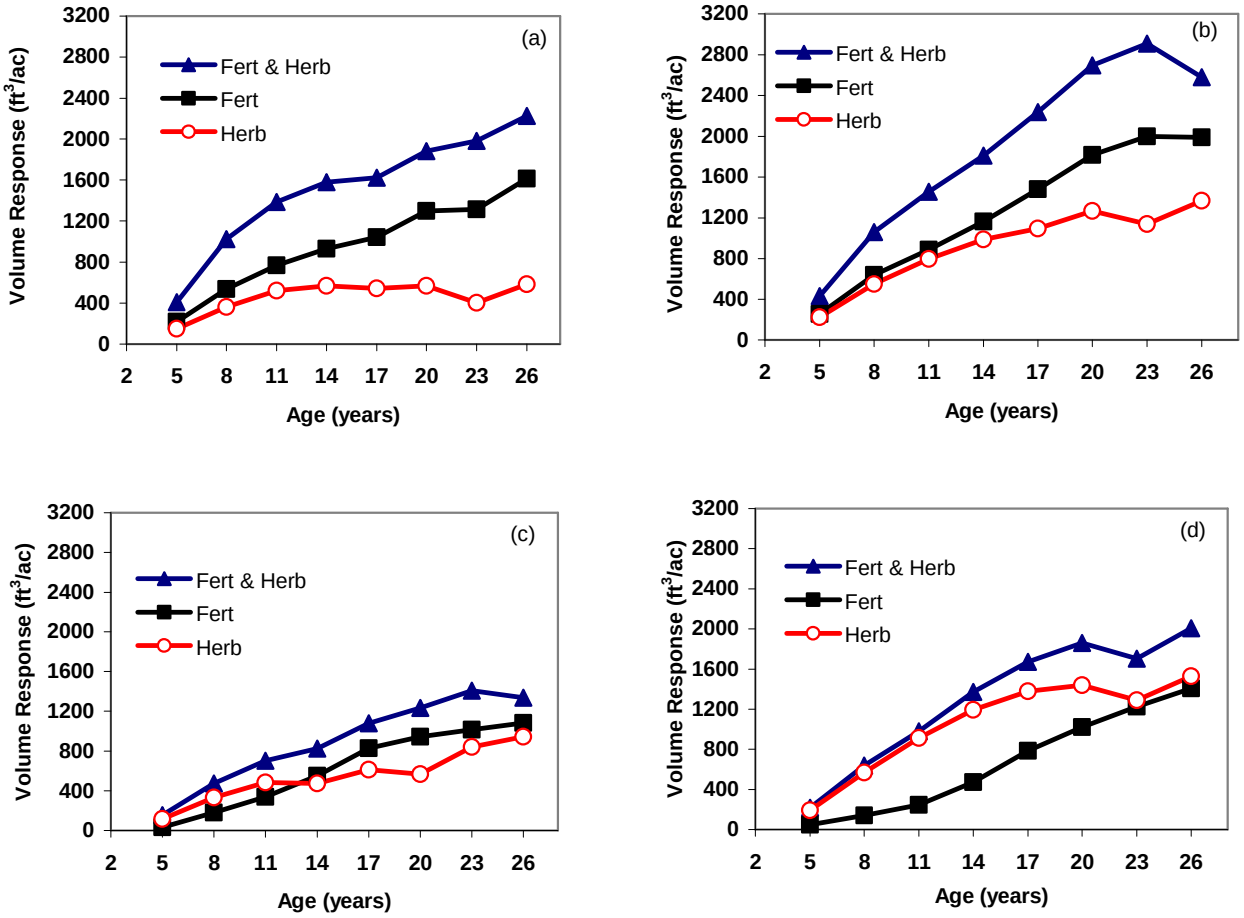

Figure 21. **Total volume responses to individual fertilization and competition control (herbicide) and to the combination of them (Fert & Herb) on (a) the chopped, burned and bedded plots on non-Spodosols, (b) the chopped, burned and bedded plots on Spodosols, (c) the chopped and burned plots on non-Spodosols, and (d) the chopped and burned plots on Spodosols .**

4 DISCUSSION AND CONCLUSIONS

Treatment effects were significant throughout the 26-year assessment period for all response variables. By age 26, tree and stand attributes did not differ between Spodosols and non-Spodosols soils; however treatment impact did differ significantly between these soil groups for height through age 14, stand basal area through age 20, and stand volume and stem green weight from age 8 to age 20. For average dbh,

percent cronartium infection, and trees per acre, there was not significant soil group × treatment interaction over the 26-year study period.

The fertilization and herbicide treatments provided positive and significant gains in average and dominant height, dbh, stand basal area, stand total and merchantable volume, total stem green and merchantable green weight on both Spodosol and non-Spodosol soil groups during the study period. Complete and sustained competition control resulted in greater cumulative responses in height, stand basal area, volume and weight than repeated fertilization on Spodosols during the first 20 years and on non-Spodosols during the first 17 years for height and 14 years for stand basal area, volume and weight. After these periods, cumulative gains from repeated fertilization had caught or surpassed the gains from complete vegetation control.

These results reflect responses from repeated nutrient additions and sustained competition control. The increase in response over time to repeated nutrient additions highlights the importance of nutrient management throughout the rotation to enhance productivity. The observed trends in response to complete vegetation control and repeated fertilization are similar to those observed for loblolly pine on two sites in the Lower Coastal Plain as reported by Borders et al (2004). In that study, both complete competition control and annual fertilization provided substantial growth gains during the 15-year period reported, with cumulative responses from fertilization increasing markedly throughout the period and cumulative responses to complete vegetation control showing modest or little increase after about age 10. The lack of strong additional response to complete vegetation control at older plantation ages indicates that nutrition, rather than competition, has become the factor limiting productivity. Growth gains from fertilization of mid-rotation slash pine stands are well documented (Martin et al., 1999).

Results from this study show that the gains in average and dominant heights, dbh, basal area, total and merchantable volume, total stem green and merchantable green weight from both fertilization and herbicide treatment were greater on Spodosols than on non-Spodosols. These findings confirmed the conclusion of Swindel et al. (1988) that nutrients and competition control were strongly growth limiting factors on Florida Spodosols.

Bedding responses were more persistent on Spodosols than on non-Spodosols. Cumulative responses to bedding on Spodosols were significant through year 23 for height, stand basal area, stand volume and stem green weight and through age 20 for dbh. This compares with significant cumulative responses on non-Spodosols through age 20 for stand basal area, volume and green weight, age 14 for height, and age 8 for dbh. Bedding significantly increased survival, regardless of soil, through age 20. Bedding generally resulted in greater average height, dominant height and average dbh responses on Spodosols than on non-Spodosols, and greater basal area responses on non-Spodosols than on Spodosols. Sarigumba (1985) reported slash pine height responses to bedding on Spodosols and non-Spodosols at age 25 somewhat greater than those observed in the present study.

Effects of burning for non-Spodosols on average and dominant height, dbh, basal area, volume and weight were positive over the life of the study. In contrast, burning did not significantly impact slash pine performance on Spodosols. Average tree height was slightly shorter on burned plots as compared to unburned plots through age 14; leading

to the speculation that burning may have negatively affected a rather poor nutrient system by burning the litter layer during site preparation (Shiver et al. 1990).

Some positive and significant chopping effects on height and dbh were found only for non-Spodosols. The chopping effects on stand basal area, volume, and stem green weight were nonsignificant.

This study provides a unique opportunity to assess temporal patterns of responses to individual treatments. The repeated fertilization regime promoted long-term responses that generally increased throughout the rotation. Complete and sustained competition control resulted in large volume and stem green weight gains that increased throughout the 26 year period, and height, dbh, and basal area responses that peaked during the study period. Responses to bedding generally peaked and showed a gradual decline. The responses observed to treatments of burning and chopping occurred only on non-Spodosols. Peak responses to burning were either maintained (height and basal area per acre) or diminished (dbh, volume and green weight per acre) over time. The peak response to chopping was maintained over time.

Nilsson and Allen (2003), reporting on loblolly pine volume responses to site preparation intensity, establishment fertilization, and herbaceous weed control treatments on a variety of soils through age 18, reported that more intensive site preparation maintained higher growth rates throughout the study period and attributed this sustained growth response to a reduction in competition from hardwoods, a finding consistent with those from the study reported here. They also observed that cumulative responses to early herbaceous weed control and fertilization treatments had peaked well before age 18. Similarly, Jokela et al. (2000) reported that loblolly and slash pine growth responses to fertilization and weed control at establishment generally declined from age 5 to age 8 in a regional trial series containing 21 locations. The long term responses to competition control and fertilization observed in the study reported here reflect the sustained competition control and repeated fertilization that resulted in relatively competition free conditions and good nutrition status on the respective treatments over the duration of the study.

Increased pine growth rates are often associated with higher cronartium infection rates Zutter et al. (1987). Results from this study indicate that complete vegetation control was the only treatment that significantly and consistently increased the levels of cronartium infection over the range of measured ages. Fertilization appeared to increase infection rate, although its effect was not significant. Treatments with vegetation control and fertilization had the highest infection percentages. The PMRC improved planting stock/herbicide study results at age 12 indicate that increased growth without increased cronartium infection is possible with genetically improved stock (Harrison et al. 2001).

Complete vegetation control had no significant effect on survival at early ages, but significantly increased stand mortality in the later period. Bedding treatment significantly improved the survival of slash pine plantations through age 20. Both fertilization and burning had no significant effects on survival. Chopping significantly improved survival through age 5; thereafter, its positive effect was no longer significant.

Complete vegetation control significantly increased crown length on Spodosols through age 20 and on non-Spodosols through age 23, and significantly decreased crown ratio

on Spodosols during the study period. Fertilization significantly increased crown length on Spodosols at early ages, and repeated fertilization resulted in significant increase in crown length on both Spodosols and non-Spodosols. In general, fertilization had no significant effects on crown ratio on either soil groups. Bedding significantly decreased both crown length and crown ratio on non-Spodosols through age 23. Both the chopping and burning treatments had no significant effects on crown length and crown ratio.

When several cultural treatments are carried out, the expected responses could be additive, non-additive or synergistic. Results from this long-term study clearly indicate significant and long-term interactions in slash pine responses to repeated fertilization and complete and sustained competition control on Spodosols. Response to the combination of these treatments is much less (less than additive) than the sum of the responses observed to these treatments when applied independently. Both competition control and fertilization, act, in part, to enhance nutrient supply to the planted pines on these very nutrient limited Spodosols.

The results demonstrate the complex nature of pine responses to different treatments and their various combinations. These response relations, combined with those found in similar studies, are useful to managers in making and justifying silvicultural decisions. The marked temporal patterns in response also indicate the importance of having a well coordinated silvicultural regime that provides desired growing conditions (good nutrition, lack of competition, appropriate stocking) throughout the rotation through well timed silvicultural treatments, including thinning and final harvest.

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APPENDIXES

Appendix 1. Least square means of Average Height (ft.) by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	**CNTL**	8.8	8.9	17.6	16.7	25.3	24.8	34.4	34.1	41.3	40.9	46.5	45.6	50.7	51.0	56.6	54.7
2	**UCHP**	9.4	8.9	19.0	17.6	27.8	25.4	37.3	34.1	43.9	40.5	47.8	45.2	56.1	50.3	60.6	53.3
3	**FCHP**	10.8	10.4	20.4	20.2	29.6	28.9	40.4	38.8	47.6	47.2	55.0	53.2	60.4	59.4	64.7	64.3
4	**UCHB**	9.5	8.1	20.2	16.4	29.3	24.5	39.1	34.0	45.9	40.7	51.5	45.9	57.1	51.8	61.9	55.0
5	**FCHB**	11.2	10.7	22.8	20.0	32.4	28.9	43.3	38.6	51.8	47.9	57.5	53.8	64.0	59.9	69.4	64.1
6	**UCBB**	11.9	10.0	22.4	20.1	31.7	28.9	41.3	38.1	47.8	45.3	51.8	50.1	56.3	55.0	62.0	57.4
7	**FCBB**	12.9	13.5	23.3	24.2	32.8	33.1	44.0	43.6	51.1	51.1	58.1	57.5	64.4	62.3	68.6	66.5
8	**UCBH**	12.8	14.5	24.8	26.2	34.1	35.5	44.0	44.9	51.0	51.3	56.3	56.2	62.1	60.6	67.3	64.7
9	**FCBH**	14.3	14.9	26.4	27.0	36.2	36.4	46.2	46.4	53.9	54.4	59.7	60.8	66.9	65.3	70.3	70.2
10	**UBHB**	15.3	16.3	27.0	28.0	36.4	37.7	46.1	46.8	53.0	53.2	57.5	58.8	63.7	62.8	68.9	66.6
11	**FBHB**	16.8	16.6	29.0	28.2	38.4	37.5	48.3	47.2	55.5	54.4	61.6	61.2	67.1	67.1	72.8	70.3

Appendix 2. Least square means of Dominant Height (ft.) by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	**CNTL**	8.3	8.1	18.0	17.0	26.3	25.4	35.7	35.4	43.8	42.6	48.9	47.5	53.8	53.6	61.3	58.7
2	**UCHP**	9.1	8.5	19.7	17.9	29.3	26.1	39.6	35.7	46.9	42.6	50.8	47.8	59.4	53.5	64.9	57.9
3	**FCHP**	10.7	10.4	20.9	20.6	30.6	29.8	41.9	40.2	49.4	49.2	56.2	55.4	62.8	62.1	68.3	68.4
4	**UCHB**	9.2	7.5	20.7	17.0	30.3	25.9	40.2	36.1	48.0	43.0	54.2	48.5	60.1	54.4	66.3	58.9
5	**FCHB**	11.0	10.6	23.1	20.2	33.4	29.6	44.6	39.8	53.9	49.6	60.1	55.8	66.9	62.0	73.3	67.9
6	**UCBB**	11.9	9.9	23.1	20.5	32.7	29.6	42.4	39.2	49.4	47.0	54.5	52.0	60.1	57.4	65.9	61.2
7	**FCBB**	12.9	13.5	23.7	24.5	33.9	33.9	44.9	44.7	53.1	52.6	60.3	59.5	67.0	64.9	73.0	70.2
8	**UCBH**	12.7	14.5	25.2	26.3	35.3	36.1	45.6	46.0	53.0	52.4	58.0	57.6	65.2	62.4	70.5	67.7
9	**FCBH**	14.1	14.8	26.9	27.3	37.7	37.0	47.9	47.6	56.3	55.8	62.5	62.5	70.3	67.2	74.7	72.9
10	**UBHB**	15.2	16.3	27.2	28.4	37.4	38.3	47.2	47.8	54.5	54.3	58.9	60.4	65.7	64.7	71.4	69.3
11	**FBHB**	16.8	16.6	29.9	28.6	39.5	38.2	49.9	48.3	57.5	56.2	63.6	62.0	70.5	69.4	76.2	73.7

Appendix 3. Least square means of Dbh (in.) by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	1.33	1.37	2.86	2.76	3.93	3.92	4.92	4.82	5.59	5.42	6.12	5.79	6.53	6.24	6.98	6.43
2	UCHP	1.48	1.44	3.23	2.91	4.38	3.96	5.45	4.82	6.10	5.37	6.47	5.75	7.06	6.13	7.51	6.37
3	FCHP	1.82	1.79	3.53	3.31	4.83	4.48	6.25	5.49	7.06	6.30	7.49	6.70	8.05	7.16	8.59	7.36
4	UCHB	1.54	1.24	3.47	2.74	4.75	3.95	5.78	4.85	6.42	5.45	6.90	5.85	7.35	6.30	7.75	6.47
5	FCHB	1.92	1.83	3.91	3.35	5.12	4.50	6.20	5.56	7.00	6.33	7.47	6.78	7.90	7.29	8.47	7.42
6	UCBB	2.13	1.74	3.74	3.32	4.82	4.49	5.83	5.36	6.39	5.89	6.68	6.28	7.11	6.66	7.53	6.83
7	FCBB	2.35	2.47	3.93	3.93	5.12	4.93	6.22	5.86	6.92	6.55	7.43	7.02	8.03	7.47	8.59	7.66
8	UCBH	2.63	3.03	4.64	4.58	5.78	5.59	6.75	6.32	7.48	6.81	7.93	7.21	8.74	7.55	9.12	7.84
9	FCBH	3.03	3.15	4.97	4.79	6.04	5.78	7.02	6.61	7.73	7.24	8.28	7.75	8.87	8.16	9.36	8.43
10	UBHB	3.19	3.28	4.89	4.78	5.89	5.78	6.74	6.53	7.30	7.04	7.71	7.47	8.27	7.81	8.72	7.98
11	FBHB	3.50	3.38	5.19	4.83	6.14	5.66	7.10	6.43	7.75	7.08	8.24	7.63	8.79	8.10	9.26	8.38

Appendix 4. Least square means of Crown Length (ft.) by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	16.1	16.1	17.0	16.3	16.8	15.6	19.6	17.3	18.8	19.7
2	UCHP	16.9	15.9	18.7	15.7	16.1	16.3	20.5	17.1	20.5	18.3
3	FCHP	18.5	18.4	19.8	17.9	19.9	17.8	22.6	19.8	22.4	20.9
4	UCHB	18.8	16.4	18.6	16.0	18.0	15.7	20.2	17.6	20.6	18.4
5	FCHB	19.6	18.0	20.3	18.1	20.2	19.0	21.4	19.2	22.7	21.6
6	UCBB	17.4	17.6	17.6	17.5	17.3	17.4	19.0	17.4	20.3	18.9
7	FCBB	18.5	19.0	18.2	18.3	16.7	19.8	21.3	19.6	24.5	21.3
8	UCBH	21.4	19.3	21.8	19.4	21.9	17.9	23.1	18.1	21.8	19.0
9	FCBH	20.6	20.3	21.4	19.7	20.9	19.2	23.8	19.3	22.9	19.2
10	UBHB	19.0	19.6	19.7	18.2	18.0	18.7	19.6	18.8	21.3	19.0
11	FBHB	19.8	20.1	20.3	18.3	20.1	20.7	22.1	19.6	22.7	21.1

Appendix 5. Least square means of Crown Ratio by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	0.44	0.45	0.38	0.38	0.34	0.33	0.37	0.32	0.30	0.33
2	UCHP	0.42	0.44	0.39	0.37	0.32	0.34	0.34	0.32	0.31	0.31
3	FCHP	0.44	0.45	0.40	0.36	0.35	0.32	0.36	0.32	0.33	0.30
4	UCHB	0.46	0.46	0.38	0.37	0.33	0.33	0.33	0.32	0.31	0.31
5	FCHB	0.44	0.45	0.38	0.37	0.34	0.34	0.32	0.31	0.31	0.32
6	UCBB	0.41	0.45	0.36	0.37	0.31	0.33	0.31	0.30	0.30	0.31
7	FCBB	0.41	0.42	0.34	0.35	0.28	0.33	0.32	0.30	0.33	0.30
8	UCBH	0.46	0.42	0.41	0.37	0.38	0.31	0.35	0.29	0.30	0.28
9	FCBH	0.43	0.43	0.38	0.35	0.33	0.31	0.34	0.29	0.30	0.26
10	UBHB	0.40	0.41	0.36	0.34	0.30	0.31	0.29	0.29	0.29	0.27
11	FBHB	0.40	0.42	0.35	0.33	0.32	0.33	0.32	0.28	0.30	0.29

Appendix 6. Least square means of percentage of cronartium infection by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	13.41	2.38	14.95	7.55	16.59	8.24	12.93	6.18	11.12	6.21	12.44	5.75	13.86	6.35	14.39	6.19
2	UCHP	13.45	3.83	19.93	9.27	20.34	8.41	13.94	7.91	15.55	7.23	17.70	5.08	19.83	6.15	19.47	6.43
3	FCHP	14.61	2.07	17.06	7.82	16.87	8.61	9.44	7.87	14.00	6.16	14.59	7.32	17.65	7.72	18.42	6.95
4	UCHB	16.11	2.20	22.28	7.87	22.33	8.84	18.94	7.82	18.21	6.80	16.35	6.25	19.77	6.20	18.62	5.95
5	FCHB	12.40	2.08	18.43	7.27	22.00	7.72	19.02	7.12	20.42	7.12	17.80	7.05	21.54	8.31	19.80	8.91
6	UCBB	17.12	3.24	17.89	8.62	22.59	8.62	17.18	7.66	19.66	7.04	18.51	6.67	21.10	6.63	18.92	5.16
7	FCBB	19.01	6.64	19.52	11.61	22.53	12.48	17.57	10.81	19.65	10.15	16.85	8.46	18.65	8.14	19.97	7.89
8	UCBH	22.12	4.88	28.47	14.82	29.28	18.09	23.86	16.44	24.29	17.09	25.60	15.54	29.47	16.53	30.01	16.14
9	FCBH	21.02	9.44	25.92	20.00	29.56	18.71	25.96	19.45	27.29	19.10	27.40	17.42	31.56	18.54	32.36	18.81
10	UBHB	22.74	6.64	30.07	12.31	29.87	14.25	20.61	12.91	25.04	13.21	23.06	13.55	26.55	13.81	25.76	13.14
11	FBHB	22.36	7.33	30.05	17.39	33.09	15.55	25.37	15.19	27.92	15.59	28.62	14.77	33.53	14.12	32.63	13.68

Appendix 7. Least square means of Trees per Acre by treatment, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	372	405	430	465	424	474	393	462	395	454	403	453	387	451	377	448
2	UCHP	430	449	453	485	451	481	420	475	415	468	414	462	395	458	378	461
3	FCHP	390	484	391	478	377	482	359	465	358	459	356	460	342	451	332	451
4	UCHB	436	408	444	474	417	478	390	471	384	464	386	465	364	459	352	453
5	FCHB	473	481	490	484	469	484	437	477	421	466	410	468	391	457	364	457
6	UCBB	516	487	518	487	488	484	455	479	453	474	453	463	446	453	407	437
7	FCBB	507	507	495	506	478	505	442	488	432	475	424	462	393	450	377	446
8	UCBH	428	496	419	492	409	490	370	483	367	480	358	464	344	439	335	431
9	FCBH	448	492	437	478	420	472	385	464	376	446	366	423	343	392	324	387
10	UBHB	465	490	454	478	445	470	418	464	402	457	391	444	357	422	334	418
11	FBHB	496	515	477	512	463	513	425	500	406	488	397	465	375	442	357	405

Appendix 8. Least square means of Basal Area per acre (ft^2/ac) by treatments, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	5.13	6.07	22.37	22.02	39.77	42.76	55.65	61.90	70.53	76.44	84.70	86.17	90.88	99.87	100.10	106.66
2	UCHP	6.85	6.26	27.06	23.99	48.88	43.42	68.52	62.48	84.62	76.61	94.81	87.51	105.23	99.22	113.18	108.08
3	FCHP	8.71	9.65	28.60	30.00	49.41	54.41	73.44	79.08	92.12	103.07	106.05	118.32	113.69	132.49	125.00	140.45
4	UCHB	7.39	4.77	31.51	21.84	54.04	43.69	73.55	63.84	88.77	79.58	102.08	92.04	108.47	105.19	116.22	109.86
5	FCHB	11.29	10.54	43.10	31.46	70.20	55.39	94.18	83.14	115.19	105.21	128.26	122.03	134.27	138.10	142.26	145.06
6	UCBB	14.43	9.52	42.24	30.88	64.85	55.47	86.65	77.80	103.43	93.22	114.06	103.55	126.61	114.37	127.11	115.93
7	FCBB	16.91	17.86	44.36	44.25	71.45	69.03	95.15	94.01	115.99	114.48	130.55	127.62	137.56	141.49	149.87	148.24
8	UCBH	19.52	26.10	51.40	57.81	75.66	85.82	90.03	108.00	108.25	125.15	117.48	135.40	132.92	140.97	141.64	149.86
9	FCBH	24.02	28.34	59.99	61.35	84.87	88.02	102.33	113.34	121.83	130.88	135.84	142.32	143.45	147.03	148.51	155.55
10	UBHB	28.32	30.58	62.05	61.68	86.98	87.80	105.59	110.19	118.07	126.44	128.68	138.31	132.68	143.61	138.72	148.49
11	FBHB	34.23	33.71	71.31	67.45	97.06	92.90	117.66	116.87	133.33	138.40	147.28	152.38	156.73	163.13	164.29	160.40

Appendix 9. Least square means of total volume per acre (ft^3/ac) by treatments, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	33	44	241	229	566	596	1017	1102	1504	1568	1981	1935	2304	2461	2790	2791
2	UCHP	46	38	294	244	730	596	1298	1095	1859	1555	2260	1961	2844	2434	3283	2786
3	FCHP	63	64	333	336	774	817	1477	1525	2127	2357	2740	3010	3227	3727	3788	4227
4	UCHB	49	28	360	217	839	600	1454	1132	2020	1644	2555	2106	2986	2655	3432	2920
5	FCHB	82	76	539	357	1177	844	2004	1606	2846	2428	3497	3125	3999	3881	4511	4327
6	UCBB	106	64	519	343	1065	834	1771	1472	2401	2052	2876	2486	3466	2990	3751	3141
7	FCBB	133	141	566	566	1212	1156	2048	1989	2863	2777	3587	3421	4110	4078	4745	4541
8	UCBH	163	221	692	785	1321	1512	1927	2325	2631	3023	3122	3544	3827	3945	4372	4449
9	FCBH	204	244	832	857	1540	1580	2277	2503	3097	3315	3787	3966	4394	4359	4767	4927
10	UBHB	255	286	881	893	1584	1630	2338	2458	2946	3146	3442	3754	3868	4131	4332	4509
11	FBHB	323	317	1054	984	1831	1722	2700	2636	3444	3533	4171	4301	4779	4989	5360	5130

Appendix 10. Least square means of merchantable volume per acre (ft^3/ac) by treatments, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	0	4	77	82	397	380	862	915	1354	1406	1836	1777	2161	2307	2652	2637
2	UCHP	2	0	101	53	557	382	1155	916	1724	1387	2127	1804	2709	2279	3156	2631
3	FCHP	2	0	170	109	648	630	1368	1376	2027	2219	2640	2870	3132	3593	3699	4089
4	UCHB	0	1	172	44	700	400	1337	960	1912	1487	2444	1951	2881	2502	3331	2771
5	FCHB	0	1	346	142	1025	657	1872	1455	2730	2290	3379	2988	3882	3748	4408	4190
6	UCBB	0	1	290	113	903	638	1633	1318	2266	1903	2739	2342	3336	2849	3630	3007
7	FCBB	5	5	349	327	1054	981	1914	1839	2740	2637	3466	3286	4000	3948	4646	4411
8	UCBH	38	33	557	621	1210	1382	1829	2199	2541	2894	3032	3423	3743	3830	4291	4335
9	FCBH	51	49	713	725	1435	1466	2180	2390	3003	3205	3699	3862	4308	4264	4691	4832
10	UBHB	75	67	762	759	1472	1510	2231	2342	2842	3033	3343	3643	3780	4027	4252	4402
11	FBHB	119	94	930	836	1719	1585	2602	2501	3350	3405	4079	4180	4690	4875	5276	5029

Appendix 11. Least square means of total stem green weight per acre (tons/ac) by treatments, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	0.9	1.2	6.7	6.3	16.0	16.9	29.5	32.0	44.3	46.3	58.9	57.7	69.0	74.0	84.3	84.6
2	UCHP	1.2	1.0	8.1	6.7	20.7	16.9	37.7	31.8	54.7	45.8	67.1	58.4	85.7	73.2	99.5	84.3
3	FCHP	1.7	1.7	9.2	9.4	22.0	23.3	42.8	44.5	62.5	69.9	81.5	90.4	97.1	113.2	114.5	129.7
4	UCHB	1.3	0.7	10.0	6.0	23.8	16.9	42.3	32.9	59.7	48.5	76.2	62.8	90.0	80.1	104.1	88.7
5	FCHB	2.2	2.0	15.0	9.9	33.6	24.1	58.7	46.8	84.6	72.2	105.0	94.0	121.3	117.8	137.5	132.5
6	UCBB	2.8	1.7	14.5	9.5	30.5	23.7	51.9	42.9	71.3	61.0	86.1	74.5	104.7	90.5	114.1	95.5
7	FCBB	3.6	3.8	15.8	15.9	34.7	33.3	60.1	58.7	85.2	83.1	108.0	103.5	124.8	124.2	144.5	139.4
8	UCBH	4.3	5.9	19.1	21.9	37.5	43.3	56.0	68.4	77.5	90.0	92.9	106.5	114.5	119.4	131.8	135.5
9	FCBH	5.4	6.5	23.0	23.9	43.9	45.3	66.4	73.6	91.6	99.0	113.1	119.7	132.6	132.3	144.3	150.7
10	UBHB	6.8	7.7	24.5	25.1	45.3	47.1	68.5	72.5	87.5	94.0	102.9	113.3	116.7	125.4	131.6	137.9
11	FBHB	8.6	8.5	29.4	27.6	52.6	49.8	79.2	78.0	102.3	105.8	125.2	130.2	144.5	152.4	163.1	157.4

Appendix 12. Least square means of merchantable stem green weight per acre (tons/ac) by treatments, soil type (NS: non-Spodosols; SP: Spodosols), and measurement age.

Treatment Number	Treatment Code	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
		NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
1	CNTL	0.0	0.1	2.1	2.3	11.2	10.8	25.0	26.6	39.9	41.4	54.5	52.9	64.6	69.3	80.1	79.8
2	UCHP	0.0	0.0	2.8	1.5	15.7	10.8	33.4	26.6	50.6	40.8	63.0	53.7	81.4	68.4	95.5	79.4
3	FCHP	0.0	0.0	4.7	3.1	18.3	17.9	39.5	40.0	59.4	65.7	78.3	86.0	94.0	108.9	111.6	125.3
4	UCHB	0.0	0.0	4.8	1.2	19.8	11.3	38.8	27.8	56.3	43.8	72.7	58.1	86.6	75.3	100.8	84.1
5	FCHB	0.0	0.0	9.6	4.0	29.1	18.7	54.6	42.3	80.9	67.9	101.2	89.6	117.5	113.5	134.1	128.1
6	UCBB	0.0	0.0	8.1	3.1	25.8	18.1	47.7	38.4	67.1	56.4	81.8	70.1	100.5	86.0	110.2	91.2
7	FCBB	0.1	0.1	9.7	9.1	30.1	28.2	56.0	54.2	81.3	78.7	104.2	99.2	121.3	119.9	141.2	135.1
8	UCBH	1.0	0.9	15.3	17.2	34.2	39.4	53.0	64.4	74.6	86.0	90.0	102.6	111.7	115.6	129.1	131.7
9	FCBH	1.3	1.3	19.6	20.1	40.7	41.8	63.4	70.0	88.6	95.5	110.2	116.2	129.8	129.1	141.7	147.4
10	UBHB	2.0	1.8	21.1	21.2	41.9	43.4	65.1	68.9	84.2	90.3	99.7	109.6	113.8	121.9	128.9	134.3
11	FBHB	3.2	2.5	25.8	23.4	49.2	45.6	76.1	73.8	99.3	101.7	122.1	126.3	141.5	148.6	160.3	153.9

Appendix 13. Responses in total volume and merchantable volume per acre (ft3/ac) to the combination of repeated fertilization and complete competition control and to these treatments when applied independently on the chopped, burned and bedded plots and the chopped and burned plots by soil group (NS: non-Spodosols; SP: Spodosols).

Volume	Plot	Treatment	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
			NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Total Volume	Chop, Burn & Bed	Fertilization	217	254	536	641	767	889	928	1164	1042	1481	1296	1815	1312	1998	1611	1989
		Herbicide	150	222	363	550	520	797	567	987	544	1095	567	1268	402	1140	582	1367
		Fert & Herb	408	431	1024	1059	1386	1456	1579	1811	1623	2237	1881	2694	1981	2909	2227	2578
	Chop & Burn	Fertilization	33	48	179	140	339	245	551	473	826	784	942	1020	1013	1226	1081	1407
		Herbicide	115	192	332	567	482	912	473	1193	611	1379	568	1438	841	1289	942	1528
		Fert & Herb	155	216	472	639	701	979	823	1371	1077	1671	1232	1860	1408	1705	1336	2006
Merch. Volume	Chop, Burn & Bed	Fertilization	121	93	641	723	817	948	969	1184	1084	1502	1342	1838	1355	2026	1649	2022
		Herbicide	77	67	473	646	569	872	598	1024	575	1129	605	1300	445	1177	624	1395
		Fert & Herb	236	183	1222	1233	1483	1553	1658	1846	1694	2270	1955	2732	2044	2953	2280	2641
	Chop & Burn	Fertilization	2	0	174	99	325	257	535	496	817	803	936	1037	1001	1245	1079	1419
		Herbicide	39	32	385	577	510	982	492	1239	629	1407	589	1472	862	1328	961	1563
		Fert & Herb	52	47	541	681	735	1065	843	1430	1091	1718	1255	1910	1427	1762	1362	2058

Appendix 14. Responses in total stem green weight and merchantable green weight per acre (ton/ac) to the combination of repeated fertilization and complete competition control and to these treatments when applied independently on the chopped, burned and bedded plots and the chopped and burned plots by soil group (NS: non-Spodosols; SP: Spodosols).

Green Weight	Plot	Treatment	Age 5		Age 8		Age 11		Age 14		Age 17		Age 20		Age 23		Age 26	
			NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP	NS	SP
Total Green Weight	Chop, Burn & Bed	Fertilization	5.8	6.8	15.0	18.1	22.1	26.1	27.3	35.0	31.0	44.8	39.1	55.7	39.8	61.9	49.0	61.9
		Herbicide	4.0	6.0	10.1	15.6	14.8	23.3	16.6	29.6	16.2	33.0	16.8	38.7	12.0	34.9	17.5	42.4
		Fert & Herb	10.9	11.6	28.7	29.9	40.0	42.6	46.4	54.3	48.2	67.5	56.2	82.4	59.4	90.1	67.6	79.9
	Chop & Burn	Fertilization	0.9	1.3	5.0	3.9	9.8	7.2	16.4	13.9	24.9	23.7	28.8	31.1	31.3	37.7	33.4	43.8
		Herbicide	3.0	5.1	9.2	15.9	13.7	26.4	13.7	35.5	17.8	41.5	16.7	43.7	24.5	39.3	27.7	46.7
		Fert & Herb	4.1	5.7	13.1	17.9	20.1	28.4	24.1	40.7	32.0	50.5	36.9	56.8	42.7	52.2	40.2	62.0
Merch. Green Weight	Chop, Burn & Bed	Fertilization	3.2	2.5	17.8	20.2	23.4	27.5	28.4	35.4	32.1	45.2	40.3	56.2	40.9	62.5	50.0	62.7
		Herbicide	2.0	1.8	13.0	18.1	16.1	25.3	17.4	30.5	17.0	33.9	17.9	39.5	13.3	35.9	18.7	43.1
		Fert & Herb	6.3	4.9	33.9	34.5	42.5	45.0	48.5	55.0	50.1	68.2	58.3	83.3	61.2	91.1	69.1	81.6
	Chop & Burn	Fertilization	0.1	0.0	4.8	2.8	9.3	7.4	15.8	14.5	24.6	24.1	28.5	31.5	30.9	38.2	33.3	44.0
		Herbicide	1.0	0.9	10.5	16.0	14.4	28.2	14.2	36.6	18.3	42.1	17.3	44.4	25.1	40.3	28.2	47.6
		Fert & Herb	1.4	1.2	14.8	18.9	20.9	30.5	24.6	42.2	32.3	51.6	37.5	58.1	43.1	53.8	40.9	63.4