SLASH PINE SITE PREPARATION STUDY:

AGE 20 RESULTS

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1 INTRODUCTION

One of the first designed studies established by the PMRC was a study to evaluate growth, yield and stand structure of slash pine (*Pinus elliottii* Engelm.) plantations following different site preparation treatments alone and in combination with fertilization and vegetation control. The study was established in 1979 at 20 locations distributed geographically from north of Savannah, GA, south along the Atlantic coast to Daytona Beach, FL and across north Florida to Appalachicola on the Gulf Coast. All installations were located in the flatwoods region of the lower coastal plain province.

The 20 locations were originally stratified equally over four soil groups defined by the following characteristics:

- Poorly drained, nonspodosol
- Somewhat poorly to moderately well drained, nonspodosol,
- Poorly to moderately well drained spodosol with an underlying argillic horizon,
- Poorly to moderately well drained spodosol without an underlying argillic horizon.

Twenty years after installation, 16 of the original 20 installations remain for analysis. Of these, seven are nonspodosols and nine are spodosols.

For each installation, **2**-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 the same purpose. Site indexes across installations ranged from 54 to 80 feet.

The following treatments were applied at each location:

1. Control (harvest and plant, no site preparation) **CNTL**
2. Chop (single pass with a rolling drum chopper) **UCHP**
3. Chop, fertilize **FCHP**
4. Chop, burn (chop followed by a broadcast burn) **UCHB**
5. Chop, burn, fertilize **FCHB**
6. Chop, burn, bed (treatment 4 followed by a double-pass bed) **UCBB**

7. Chop, burn, bed, fertilize **FCBB**
8. Chop, burn, herbicide (treatment 4 followed by complete vegetation control) **UCBH**
9. Chop, burn, herbicide, fertilize **FCBH**
10. Chop, burn, bed, herbicide (treatment 6 followed by complete vegetation control) **UBHB**
11. Chop, burn, bed, herbicide, fertilize **FBHB**.

The fertilizer treatment consisted of 250 pounds of diammonium phosphate applied after the first growing season. After the 12th growing season, 200 pounds of nitrogen in the form of urea and 100 pounds of potassium in the form of KCL were applied. After the 17th 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.

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 during the winter of 1979-80 at an 8 x 10 spacing. 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.

A 1/5-acre measurement plot was established within each **2**-acre treatment plot. Measurements were made after two, five, eight, eleven, fourteen, seventeen and twenty 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 fusiform rust stem cankers. Every other tree was tagged and measured for total height to the nearest foot. At the 14, 17 and 20-year measurements, height to the base of the live crown was measured on each tagged tree.

The tagged trees were used to develop a height / diameter regression equation for each plot to estimate the height of the untagged trees. Total and merchantable (trees with dbh > 4 inches to a 3-inch top o.b.) volumes were calculated using individual tree volume equations developed by Pienaar *et.al.* (1996). Analysis of variance for a split plot design was used to test for significant sources of variation with the 20-year data. Soil groups represent the whole plots and treatments represent the splits. For the first time with these data, 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. Analyses were conducted on average individual tree characteristics (height, dbh, crown length, crown ratio) and per acre stand characteristics (basal area, total volume, merchantable volume, percent fusiform infection). An alpha level of 0.5 was used to determine statistical significance.

2 TWENTY YEAR RESULTS

2.1 Individual Tree Characteristics

Analysis of variance and one-degree-of-freedom contrast analyses to evaluate the additive effects of chopping, burning, bedding, fertilization and vegetation control were conducted on average tree height, average dbh, average crown length and average crown ratio. Treatment significantly affected all of these individual tree measures. Soil group was not significant and there were no soil group x treatment interactions for all variables except crown ratio. Average values by treatment across all soil groups and for spodosols (SP) and nonspodosols (NS) for crown ratio are shown in Table 1.

Table 1. Average height (ft.), dbh (in.), crown length (ft.) and crown ratio by treatment.

Treatment Number	Treatment Code	Height (ft.)	Dbh (in.)	Crown Length (ft.)	Crown Ratio	
					NS	SP
1	CNTL	46.49	5.87	17.72	.34	.33
2	UCHP	48.84	6.05	21.30	.32	.35
3	FCHP	54.29	7.10	18.83	.36	.32
4	UCHB	48.84	6.38	16.89	.33	.33
5	FCHB	55.41	7.08	19.53	.34	.34
6	UCBB	51.52	6.51	17.51	.31	.33
7	FCBB	57.27	7.13	18.25	.28	.33
8	UCBH	56.07	7.49	19.68	.38	.31
9	FCBH	60.41	7.93	21.08	.33	.31
10	UBHB	57.62	7.48	18.12	.30	.31
11	FBHB	60.69	7.85	20.18	.32	.33

Treatment gains due to chopping, burning, bedding, fertilization and vegetation control were computed by averaging values for the appropriate treatments and subtracting the pairs. Table 2 shows the treatment gains on average height, dbh, crown length and crown ratio. Gains marked with an asterisk (*) were found to be significant in the contrast analysis.

2.1.1 Average tree height

Average heights of all tagged trees ranged from a high of 60.7 feet on the most intensive treatment to 46.5 feet for the control. The average height values were well correlated with treatment intensity (Table 1 and Figure 1). Fertilization provided a positive response on all treatments with slightly higher gains on treatments without vegetation control. The fertilized, chop burn and bed treatment (FCBB) had about the same average height as the unfertilized vegetation control plots. Age 20 is the first time this has been the case. In the contrast analysis, fertilization, bedding and vegetation control provided significant gains of 5.11, 1.50, and 5.35 feet, respectively.

Table 2. Gains due to chopping, burning, bedding, fertilization and vegetation control on average height (ft.), dbh (in.), crown length (ft.) and crown ratio.

Treatment	Height (ft.)	Dbh (in.)	Crown Length (ft.)	Crown Ratio	
				NS	SP
Chop	2.35	0.17	3.58	-0.02	0.02
Burn	0.56	0.16	-1.85	0	0
Bed	1.50*	0.02	-0.78	-0.04*	0
Veg. Control	5.35*	0.91*	1.72	0.02	-0.02
Fertilization	5.11*	0.64*	0.88	0	0

2.1.2 Average tree dbh

Tree dbh's on the chop, chop and burn and control treatments ranged from 5.9 to 6.4 inches (Figure 2). The unfertilized chop, burn and bed treatment, an industry standard in the decades of the 1960's and 1970's, had an average dbh of 6.5 inches. With fertilizer added, the mean dbh across treatments without vegetation control was 7.1 inches. Treatments incorporating vegetation control were found to be the best with an average dbh value of 7.5 inches. These results confirm the importance of interspecific competition to dbh growth, even when that competition is composed of understory plants such as palmetto and gallberry. Removal of that competing vegetation gives the same type of response in dbh as a selective thinning. The addition of fertilization to plots having vegetation control resulted in an additional 0.4 inches of dbh growth. Unlike average height, the average dbh of the FCBB treatment plots was still less that the average dbh of the vegetation control treatments with or without fertilization.

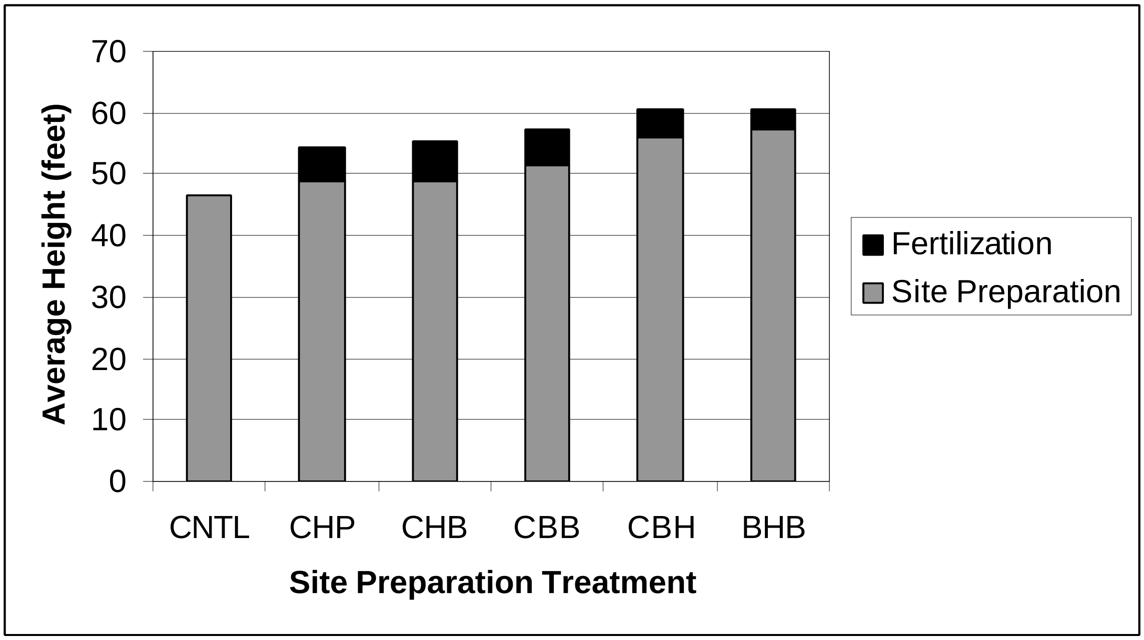

Figure 1. Average height by treatment for all installations at age 20.

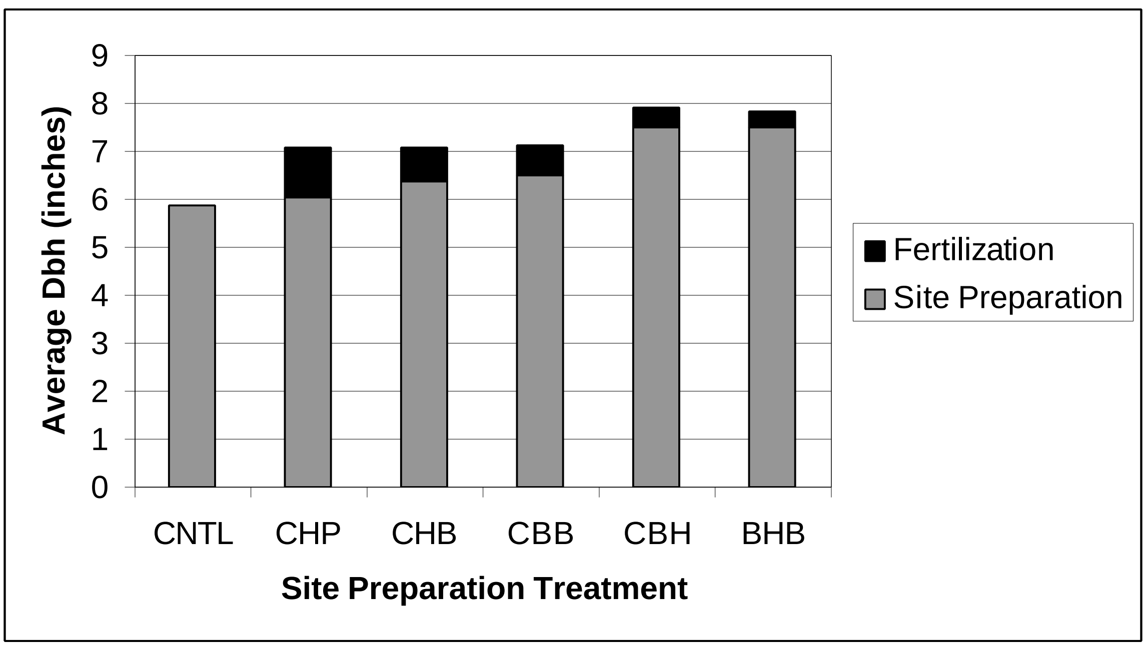

Figure 2. Average dbh by treatment for all installations at age 20.

The contrast analysis for average dbh at age 20 reinforces the significance of fertilization and vegetation control with gains of 0.64 and 0.91 inches, respectively. Again, the gains from fertilization on treatments without vegetation control were slightly larger, on average, than the gains from fertilization on treatments with vegetation control. Chopping, burning and bedding had no significant effect on average dbh.

2.1.3 Average crown length

Crown height was measured on all tagged trees after 14, 17 and 20 growing seasons. 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 (Table 1). There was not a significant difference in crown length by treatment. Unlike younger ages, some of the less intensive treatments such as fertilized chop (FCHP) had crown lengths at age 20 as long as those on the more intensively managed plots. There was relatively little variation in crown length among treatments (17.5 to 21.3 feet). Though it was not statistically significant, there was a trend for slightly longer crown lengths on the fertilized plots. Crown lengths by treatment are displayed in Figure 3. The long crown lengths on the intensively managed plots that have been maintained through age 20 are important factors stimulating early growth rates and maintaining these rapid growth rates over time.

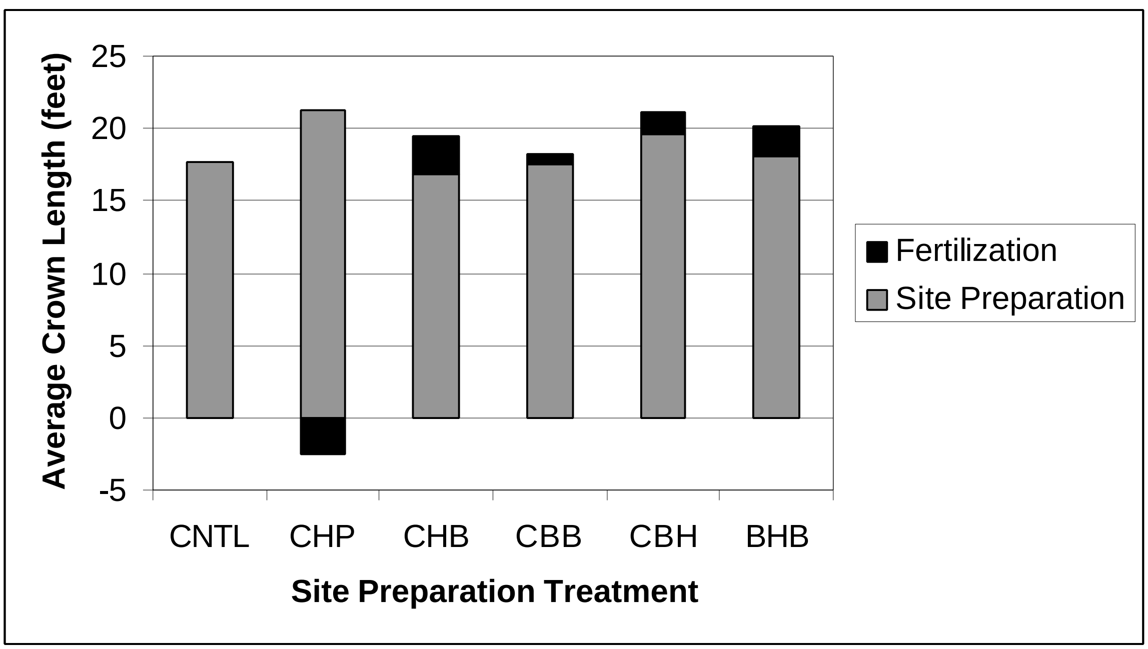

Figure 3. Average crown length by treatment for all installations at age 20.

2.1.4 Average crown ratio

There was a significant soil x treatment interaction for average crown ratio. Even so, all crown ratios except one (nonspodic, fertilize, chop, burn, bed at 0.28) ranged from 0.30 to 0.38. All treatments 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). Since these plots are not scheduled for thinning, growth can be expected to decrease over the next few years as crown ratios drop below this minimum value.

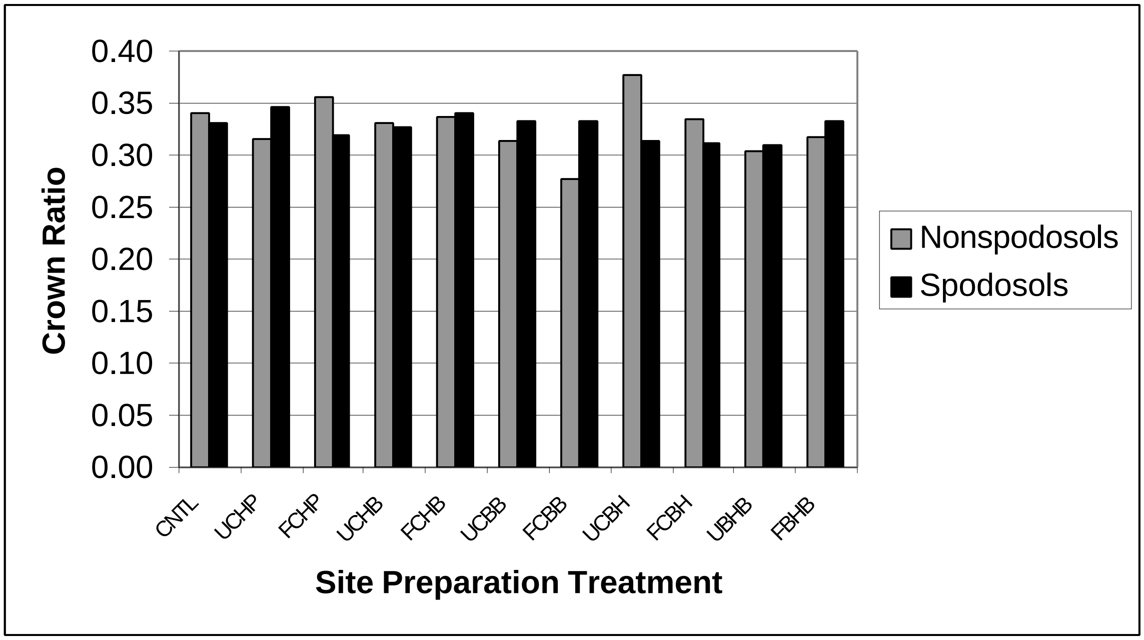

Figure 4. Average crown ratio by treatment and soil group for all installations at age 20.

2.1.5 Average percent cronartium infection

Each tree in the study was examined for the presence of fusiform stem cankers. The percentage of infected trees on each plot was calculated. The only significant source of variation was treatment. Average percent infection values are presented in Table 3. The treatments that consistently promoted rapid height growth also resulted in higher rust infection rates (Figure 5).

The average infection percentages by treatment ranged from 9.2% for the control to 22.3% for the most intensive treatment. The four treatments that included vegetation control had the highest infection percentages. This is consistent with results reported by Zutter *et.al.* (1987) who noted that increased growth rates resulted in higher cronartium infection rates. The seed used to

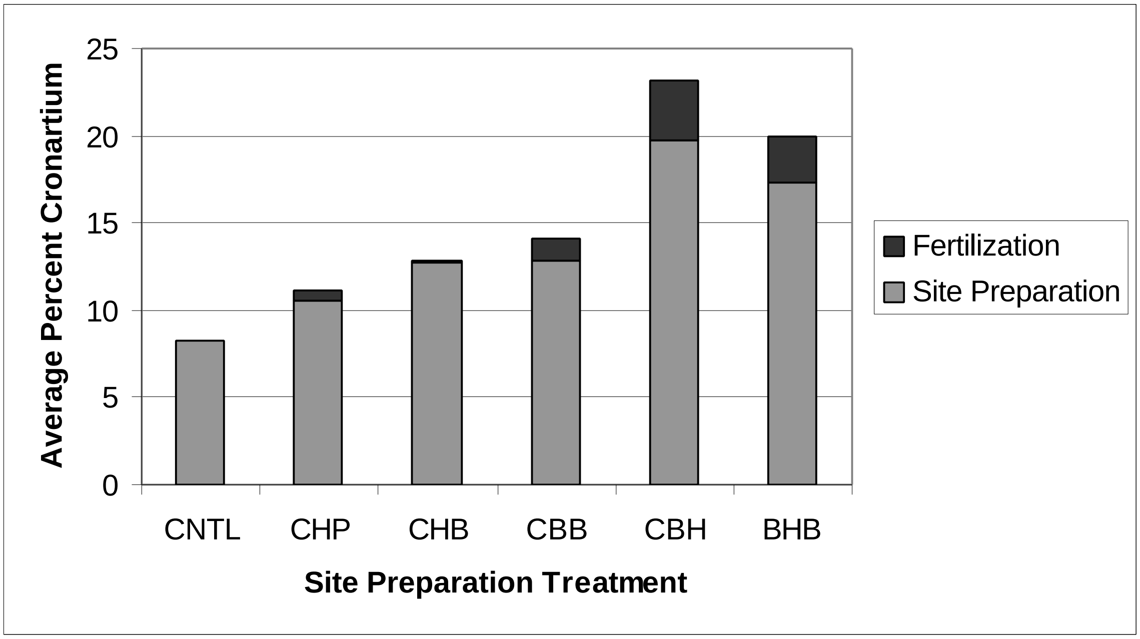

Figure 5. Average percent cronartium infection by treatment for all installations at age 20.

establish this study came from orchards of the late 1970's that had not been rogued of disease-susceptible clones. The improved planting stock/vegetation control study results at age 12 indicate that increased growth without increased fusiform infection is possible with genetically-improved stock.

Contrast analysis identified vegetation control as the only significant treatment, increasing the average infection rate by 8.05% (Table 4). As intensity increased, bedding was the only treatment to reduce the average infection rate although not significantly.

2.2 Per Acre Stand Characteristics

Unlike the individual tree characteristics, basal area per acre and per acre volumes directly involve the number of trees per acre and the distribution of diameters. The same split plot analysis of variance was used for these characteristics as for the individual tree variables. Treatment significantly affected each of these whole-stand characteristics. In addition, significant interactions between treatment and soil group were found for all whole stand characteristics except total, per-acre volume. In other words, the treatments had different effects on whole-stand performance on the different soil groups.

Table 3. Average percent cronartium infection by treatment.

Treatment	Treatment Code	Percent Cronartium
1	CNTL	9.2
2	UCHP	10.4
3	FCHP	11.8
4	UCHB	11.9
5	FCHB	11.7
6	UCBB	12.2
7	FCBB	12.5
8	UCBH	19.5
9	FCBH	22.3
10	UBHB	16.9
11	FBHB	21.8

Table 4. Gain from chopping, burning, bedding, fertilization and vegetation control on average percent cronartium infection after 20 growing seasons.

Treatment	Cronartium Percent Gain
Chopping	1.20
Burning	0.70
Bedding	-0.50
Vegetation Control	8.05*
Fertilization	1.84

2.2.1 Basal area per acre

The mean basal areas by treatment and soil group shown in Table 5 and Figure 6 illustrate the soil group x treatment interaction. An understanding of this interaction should allow forest managers to make more appropriate site-specific treatment prescriptions. In general, without fertilization and vegetation control, nonspodosols are the more productive sites, but with vegetation control, spodic soils are superior. Without vegetation control, spodosols responded better to fertilization than nonspodosols, but with vegetation control, nonspodosols responded better to the fertilization treatment. Spodosols, which make up a large percentage of flatwoods soils and are generally considered inferior sites, can be made highly productive with vegetation control and fertilization treatments. With vegetation control and fertilization, the two soil groups exhibited similar productivity. Across all sites, average basal area per acre ranged from 84.7 ft^2 /ac to 152.5 ft^2 /ac at age 20 for the different treatments.

As with the average height of individual trees, the fertilized, chop, burn and bed treatment (FCBB) had equal to more per-acre basal area than the unfertilized vegetation control plots at age 20 on nonspodosols. This was not true at earlier ages and indicates that there is a limit to the added growth that can be accomplished by controlling vegetation without supplemental nutrition on nonspodosols.

Table 5. Average per acre basal area (ft^2) by soil group and treatment.

Treatment	Treatment Code	Nonspodosols	Spodosols	All Soils
1	CNTL	84.70	85.38	85.06
2	UCHP	94.73	87.52	90.91
3	FCHP	104.04	119.18	112.45
4	UCHB	103.18	91.96	96.94
5	FCHB	128.27	122.76	125.03
6	UCBB	115.37	103.72	108.63
7	FCBB	130.54	127.45	128.80
8	UCBH	117.49	134.23	126.90
9	FCBH	135.84	139.68	138.00
10	UBHB	129.79	137.52	133.43
11	FBHB	145.74	152.49	148.89

Contrast analysis for basal area per acre was carried out by soil group and for the combined soil groups. Of the different treatments, vegetation control, bedding and fertilization significantly increased basal area on both soil groups. In addition, burning was significant on the nonspodosols. Gains from the various treatments are listed in Table 6 and illustrated in Figure 6.

Even though chopping averaged over 10 ft^2/acre gain in basal area for the nonspodosols, it was not statistically significant due to extreme variation in response to this treatment. On some sites, response to chopping was dramatically negative while on others it was the opposite.

It is interesting that bedding was significant for per-acre basal area even though there was no significant response in average tree dbh. The explanation may be found in Table 7 that shows age 20 survival for the different treatment groups. On nonspodosols, bedded treatment plots had, on the average, 44 more trees per acre than the treatment plots that were not bedded. The difference was far less on spodosols, amounting to only 9 more trees per acre on the bedded treatment plots.

Table 6. Gains in average per acre basal area from chopping, burning, bedding, fertilization and vegetation control by soil group.

Treatment	Nonspodosols	Spodosols	All Soils
Chopping	10.02	2.14	5.85
Burning	16.34*	4.01	9.31*
Bedding	9.16*	8.14*	8.22*
Vegetation Control	12.87*	29.51*	21.95*
Fertilization	16.78*	21.32*	19.27*

Table 7. Trees per acre at age 20 by treatment type and soil group.

Treatment	Nonspodosols	Spodosols	All Soils
Fert	389	459	427
No Fert	401	461	434
Herb	385	452	420
No Herb	413	468	444
Bed	421	465	443
No Bed	377	456	422
Burn	392	468	435
No Burn	380	460	424
Control	402	462	434
Unfertilized Chop	420	462	442

2.2.2 Volume per acre

Merchantable volume outside bark to a 3-inch top (o.b.) was calculated for all trees with a dbh greater than 4 inches. Total outside bark stem volume was computed for all trees. These values were summed by plot and expanded to a per-acre basis. Average values for merchantable volume are presented in Table 8 and for total volume in Table 9. The analysis of variance and contrast results for per-acre merchantable volume revealed the same trends as the basal area analysis. Treatments and the treatment x soil group interaction significantly impact merchantable volume per acre. There was not a significant treatment x soil group interaction for total volume, but the total volumes are displayed by soil group in Table 9.

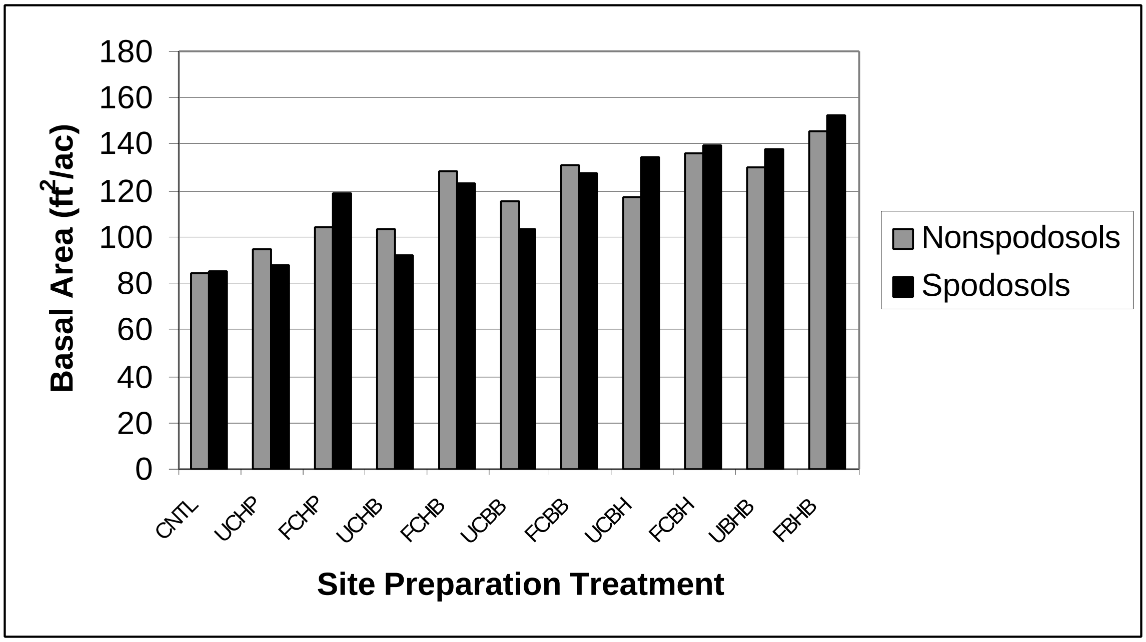

Figure 6. Per acre basal area by treatment and soil group.

Table 8. Average merchantable volume (ft^3) by soil group and treatment.

Treatment	Treatment Code	Nonspodosols	Spodosols	All Soils
1	CNTL	1786	1718	1750
2	UCHP	2082	1865	1967
3	FCHP	2581	2895	2756
4	UCHB	2507	1914	2177
5	FCHB	3357	2994	3143
6	UCBB	2811	2341	2539
7	FCBB	3448	3219	3319
8	UCBH	3017	3371	3216
9	FCBH	3692	3818	3763
10	UBHB	3305	3582	3435
11	FBHB	3989	4141	4060

Table 9. Average total volume (ft^3) by soil group and treatment.

Treatment	Treatment Code	Nonspodosols	Spodosols	All Soils
1	CNTL	1981	1928	1953
2	UCHP	2244	2076	2155
3	FCHP	2695	3051	2893
4	UCHB	2629	2103	2337
5	FCHB	3497	3152	3294
6	UCBB	2962	2508	2699
7	FCBB	3586	3376	3468
8	UCBH	3122	3504	3337
9	FCBH	3787	3932	3868
10	UBHB	3420	3706	3555
11	FBHB	4097	4271	4178

For nonspodosols, burning had a significant impact on volume but not for spodosols. Fertilization and bedding treatments appeared to produce approximately additive responses. At earlier ages, responses of spodosols to fertilization and bedding on sites with weed control were not additive, but at age 20 they appear to be very nearly additive. This may be an indication of the increasing importance of nutrition in stands as they age. Figures 7 and 8 show merchantable and total volume per acre by treatment and soil group.

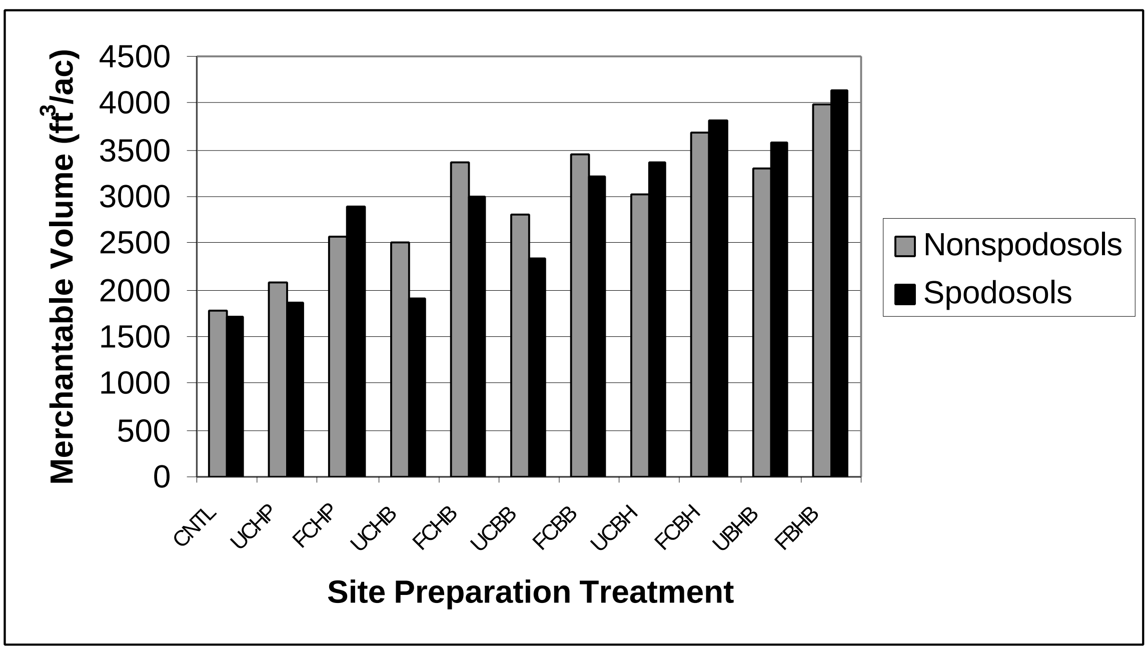

Figure 7. Per acre merchantable volume by treatment and soil group.

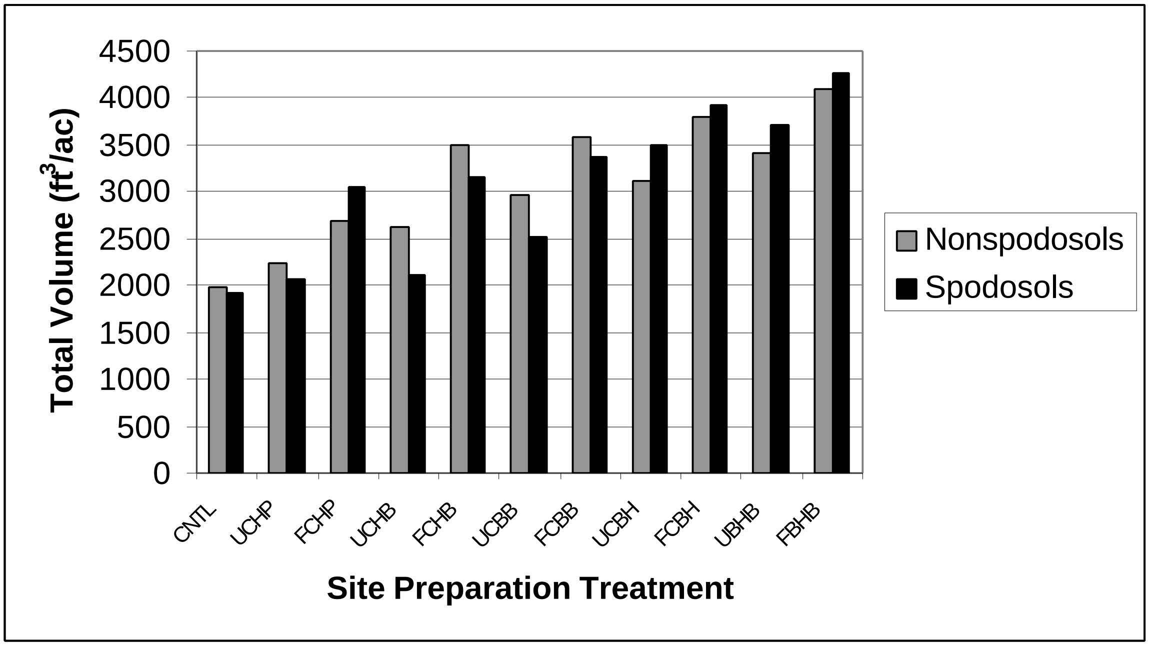

Figure 8. Per acre total volume by treatment and soil group.

The gains in average merchantable and total volumes per acre for the different treatments also follow the same trends as for basal area per acre (Tables 10 and 11). While the amounts differ, vegetation control, bedding and fertilization consistently resulted in significant gains regardless of soil group. Burning was significant only for nonspodosols. Even though chopping was not a significant treatment due to extreme variability, there were big differences on both soil groups due to this treatment. The gains indicate that fertilization is the most important single treatment for nonspodosols while vegetation control is the most important single treatment for spodosols. On both soil groups, the best gains came from using both treatments.

Table 10. Gains in per acre merchantable volume from chopping, burning, bedding, fertilization and vegetation control by soil group.

Treatment	Nonspodosols	Spodosols	All Soils
Chopping	296	147	218
Burning	601*	74	299*
Bedding	245*	297*	264*
Vegetation Control	470*	1111*	824*
Fertilization	669*	799*	741*

Table 11. Gains in per acre total volume from chopping, burning, bedding, fertilization and vegetation control by soil group.

Treatment	Nonspodosols	Spodosols	All Soils
Chopping	263	148	202
Burning	593*	64	291*
Bedding	258*	292*	266*
Vegetation Control	438*	1069*	785*
Fertilization	657*	777*	724*

3 CONCLUSIONS

The slash pine site preparation study was established in 1979 to evaluate the effects of different site preparation treatments on the growth and yield of slash pine. The study was one of the first in the Southeast to demonstrate the potential effects of complete vegetation control on the growth of pine plantations. It has, therefore, been followed with great interest throughout its life.

The age 20 data were used to carry out an analysis of variance to evaluate the effects of chopping, burning, bedding, fertilization and vegetation control on individual tree and whole stand characteristics. A mixed model approach was used so that the results can be applied with confidence across the range of slash pine sites represented by this study.

Chopping and burning had no significant effect on any of the average, individual tree characteristics. Bedding significantly increased average height but was not a significant factor for dbh or crown length. Bedding resulted in a significant decrease in crown ratio for nonspodosols. The practical significance is questionable, however, with a difference of only 0.04. Vegetation control and fertilization significantly increased average tree height and dbh. Treatment had no significant effect on average crown length. Unlike younger ages, some of the least intensively managed plots had crown lengths at age 20 comparable to the most intensively managed plots. In general, treatments that promoted rapid height growth tended to result in higher levels of cronartium infection. Vegetation control had the only significant effect, increasing the infection rate by 8%.

In order to indirectly examine the effect of treatment on survival patterns and diameter distributions, analysis of variance was carried out on per-acre stand characteristics including basal area, merchantable and total volume. Site preparation treatment significantly affected each of these measures. In addition, there was an interaction between treatment and soil type for per-acre basal area and merchantable volume.

On nonspodosols, burning, bedding, fertilization and vegetation control significantly increased per-acre basal area and volume. Similar results were found for spodosols with the exception of burning that had no significant impact. In general, without fertilization and vegetation control, nonspodosols were the more productive sites, but with vegetation control, spodic soils were superior. Without vegetation control, spodosols responded better to fertilization than nonspodosols. With vegetation control, nonspodosols responded better to the fertilization treatment. With vegetation control and fertilization, the two soil groups were found to be equally productive.

It is interesting that bedding significantly improved per-acre basal area but had no significant effect on average tree dbh. The explanation must lie in the survival trends. Over both soil groups, bedded treatment plots averaged 22 more trees per acre than plots that were not bedded.

These 20-year data show the increasing importance of nutrition as stands age. For the first time, the fertilized chop, burn and bed treatment (FCBB) had similar average tree height and crown length compared to the unfertilized vegetation control treatments. The FCBB treatment plots had equal or greater per-acre basal area, merchantable and total volumes. The results indicate that there is a limit to the added gains from vegetation control without additional nutrients.

The age 17 analysis of the slash pine site preparation study included growth and yield modeling and an economic analysis of the various treatments. Work on these aspects of the study is ongoing and results will be available in the near future.

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