LOBLOLLY PINE
SAGS SITE PREPARATION STUDY
AGE 12 RESULTS

Plantation Management Research Cooperative

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PMRC TECHNICAL REPORT 2000-1

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EXECUTIVE SUMMARY

A designed experimental study was installed at 25 locations throughout the Piedmont and Upper Coastal Plain regions of South Carolina, Georgia, and Alabama with the objective of evaluating the effects of different site preparation treatments, both chemical and mechanical, on growth and yield of cutover site-prepared loblolly pine (*Pinus taeda* L.) plantations. The following six site preparation treatments were randomly assigned to the treatment plots at each location: (1) burn, (2) chop and burn, (3) shear, pile and disk, (4) chop, herbicide & burn, (5) herbicide & burn, and (6) herbicide, burn & herbicide. A mixed model approach was used to analyze the age 12 measurements and the 3-yr periodic growth from ages 6 to 9, and 9 to 12 yr. Installation and the interaction of installation and treatment were treated as random factors and site preparation treatment was treated as a fixed factor.

Chopping before burning compared to burning only increased mean dbh and mean height. The herbicide and burn treatment significantly increased mean dbh and height over the burn only treatment. There were no significant differences between the chop and burn treatment and the chop, herbicide, and burn treatment with regards to dbh. The chop and burn treatment had a significantly smaller mean dbh than the herbicide and burn treatment. The chemical treatment increased dbh and height an average of 0.31 in. and 2.3 ft respectively, over the mechanical treatments. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in mean dbh over all other treatments. Chopping before burning significantly increased basal area per acre, and total and merchantable volume. Average basal area per acre for the herbicide and burn treatment was significantly greater than for the chop and burn treatment and the chop, herbicide and burn treatment. There was not a significant difference between the chop and burn treatment and the chop, herbicide and burn treatment. There was a steady progression of increasing yield with increasing site preparation intensity. There was not a significant difference in yield between the shear, pile and disk treatment and either the chop, herbicide, and burn treatment or the herbicide and burn treatment. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in yield over all other treatments with a gain of 676 ft^3/ac over the next best treatment at age 12. Results for merchantable volume were essentially the same as for total volume. The burn only and chop and burn treatments had significantly lower survival from age 1 than all other treatments.

There were no significant differences in mean dbh growth between the burn only treatment and the most intensive treatment, the herbicide and burn treatment with follow-up herbicide, during the period between 6 and 9 yr. Between 9 and 12 yr, the burn only treatment was growing significantly faster than the most intensive treatment and the complete control treatment had significantly lower 3-yr periodic growth between ages 9 to 12 than all other site preparation treatments in this study. There were slight differences in mean dbh growth between the other site preparation treatments. Mean height growth rates for the less intensive treatments are still increasing over time while the growth rates for the herbicide and burn with follow up herbicide, and the herbicide and burn treatments are beginning to decrease over time. The trend of increasing mean height growth with increasing site preparation intensity

still holds true for the period between ages 6 and 9 yr, but during the 3 yr period between 9 and 12 yr the trend is no longer present. In terms of mean basal area growth the most intensive treatments are still growing faster than the chop only treatment during both 3-yr periods. The 3-yr periodic growth of total and merchantable volume for both periods is still increasing with both site preparation intensity and age.

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INTRODUCTON

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

Mechanical site preparation methods gained popularity with forest managers in the late 1950's as an attempt to replicate old-field survival and growth of second and third rotation pine stands. It quickly became obvious that these mechanically site prepared, cutover plantations were not performing as well as old-field plantations. During the late 1970's, in response to the high cost of mechanical treatments and this inability to reproduce old-field survival and growth, many forest managers adopted chemical site preparation methods. More recently, combinations of chemical and mechanical site preparation treatments have gained popularity.

The objectives of site preparation are to reduce competing vegetation, dispose of logging debris, improve soil conditions, and to facilitate planting. The ultimate goal is improved survival and growth to the extent that the added production more than pays for the cost of treatment. In 1986 the PMRC initiated a study to evaluate the effects of different site preparation treatments, both chemical and mechanical, on growth and yield of cutover site-prepared loblolly pine (*Pinus taeda* L.) plantations.

STUDY DESIGN

A designed experimental study was installed at 25 locations throughout the Piedmont and Upper Coastal Pain regions of South Carolina, Georgia, and Alabama. The existing stand at each location was harvested in 1984 with the area scheduled for planting during the 1985-86 season. Site selection was completed in a way to avoid obvious site quality differences and to ensure reasonable uniformity of residual vegetation on the harvested site.

Each installation consists of seven square 1/2-acre treatment plots with an interior square 1/5-acre measurement plot. All treatment plots were at least 10 chains from adjacent stands to reduce the problems with wildlings seeding in and the spatial dispersion of plots within an installation was kept to a minimum. The following six site preparation treatments were randomly assigned to the treatment plots at each location.

1.Burn (B):	This minimal site preparation treatment was a broadcast burn in August 1985.
2.Chop & Burn (C&B):	This mechanical treatment was a single pass with a drum roller chopper in June 1985, followed by a broadcast burn in August.
3.Shear, Pile & Disk (S,P&D):	Plots that received this intensive mechanical treatment were sheared with a KG blade in June 1985. The debris was moved at least 2 chains away from the plot installation before the plots were flat-harrowed.
4.Chop, Herbicide & Burn (C,H,&B):	This combined mechanical and chemical treatment consisted of a single pass with a drum roller chopper in June 1985, followed by a broadcast herbicide treatment of 3% Roundup™ in August after some resprouting had occurred, and a broadcast burn one month later.
5.Herbicide & Burn (H&B):	This was a chemical site preparation treatment with 20 lbs of Tordon™ 10k and 20 lbs of Pronone™ per acre, applied in April 1985, followed by a broadcast burn in August. This treatment was an attempt to simulate an operational brown and burn treatment on small plots.
6.Herbicide, Burn & Herbicide (H,B&H):	This treatment was the same as treatment #5, but with annual spraying of Oust™ at 4 oz/ac to control herbaceous weeds for the first three yr and annual spot spraying with Roundup™ after planting to kill sprouting vegetation until crown closure. This treatment essentially eliminated all competing vegetation with only minimal effort after the second growing season.

Each installation also contained a replicate of one treatment. This treatment was randomly selected from treatments 2 through 6.

All experimental plots were hand-planted with improved stock during the 1985-86 planting season at a 10' by 8' spacing. Two seedlings were planted about 2 feet apart at each planting spot, and if both survived after the first growing season, one was eliminated to ensure reasonably uniform stocking of approximately 545 trees per acre across all treatments.

After the third growing season tree heights were measured, crown class was recorded and all trees were examined for the incidence of fusiform rust (*Cronartium quercum* f. sp. *fusiforme*) cankers. After the sixth, ninth and twelfth growing seasons all trees 4.5 feet tall or greater were measured for dbh to the nearest 0.1 inch, inspected for the incidence of fusiform cankers, and every other tree was measured for height with a clinometer. The tree height data were used to develop height-diameter regression equations for each plot to estimate the heights of the unmeasured trees. The following height-diameter relationship was fit to each plot at each measurement age:

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

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

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

ANALYSIS

Installations were treated as random factors of the experiment since region-wide recommendations were the objectives of the study. The replication within an installation represented an attempt to quantify the within location error. A mixed model approach was used because it allows for the mixed effects and unbalanced nature of this design. Installation and the interaction of installation and treatment were treated as random factors, and site preparation treatment was treated as a fixed factor. The analyses were completed on the following dependent variables: average dbh, range in dbh, skewness and kurtosis statistics of the dbh distribution, average height, surviving trees per acre, basal area per acre, total and merchantable stem volume and percent fusiform rust infection. An orthogonal contrast was used to test the following hypothesis on all dependent variables:

$$(u_2+u_3)/2=u_5$$

where u=mean of the dependent variable associated with the subscripted treatment number. This contrast was conducted to compare the operational mechanical treatments to the operational chemical site preparation treatment. Preplanned pairwise comparisons of least square means were conducted to detect differences between individual treatment level means. All statistical tests were conducted at the alpha=0.05 significance level. To obtain the correct degrees of freedom (df) the Satterthwaite option in SAS®'s PROC MIXED procedure was used. In the discussion of the results, gains due to differences in site preparation treatments were calculated as differences in least squares means.

AGE TWELVE RESULTS

Table 1 gives the Type III F value and resulting p value from the test of the fixed effect, site preparation treatment, for each dependent variable in the study at age 12.

Table 1. Type III test of the fixed effect, site preparation treatment, for each dependent variable in the study at age 12.

Dependent Variable	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Type III F	Pr > F
Average DBH (in.)	5	114	43.3	0.0001
Range in DBH Distribution (in.)	5	167	1.08	0.3747
Skewness of DBH Distribution	5	147	3.72	0.0034
Kurtosis of DBH Distribution	5	149	1.88	0.1017
Average Height (ft)	5	105	47.34	0.0001
Basal Area (ft^2/ac)	5	115	48.06	0.0001
Total Volume (ft^3/ac)	5	114	54.89	0.0001
Merch. Volume (3-in. top, ft^3/ac)	5	115	57.22	0.0001
Trees per Acre	5	110	9.65	0.0001
Percent Fusiform Infection	5	143	2.9	0.0159

Average DBH

Chopping before burning compared to burning only increased mean dbh 0.98 in. (Figure 1) through age 12. This large increase may be explained by the competition effect of the large residual hardwood overstory that survived the burn only site preparation treatment, overtopping the planted pine. The herbicide and burn treatment significantly increased mean dbh 1.39 in. over the burn only treatment, and 0.41 in. over the chop and burn treatment. No significant differences were detected between the chop and burn treatment, the shear, pile and disk treatment, and the chop, herbicide, and burn treatment. The orthogonal contrast analysis indicated a significant difference between the operational chemical and operational mechanical site preparation treatments. The chemical treatment increased dbh an average of 0.31 in. over the mechanical treatments. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in mean dbh over all other treatments. The difference between the herbicide and burn treatment and the herbicide, and burn with follow-up herbicide treatment is mostly due to control of herbaceous vegetation since almost all hardwoods were killed on both treatments by the chemical application. Table 2 gives the arithmetic means and coefficients of variation for each treatment at ages 6, 9, and 12 yr.

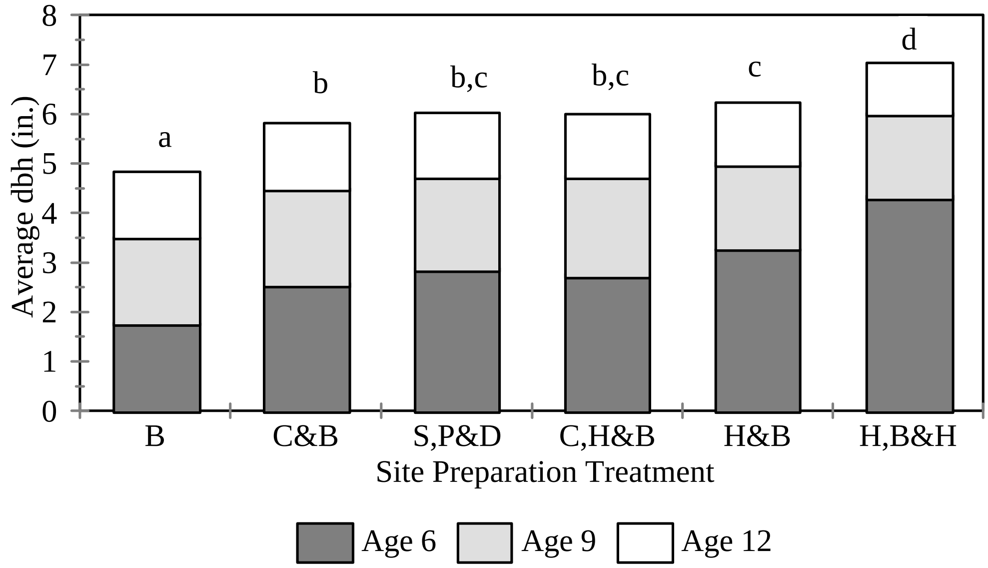

Figure 1. Least squares means for average dbh (in.) by age and treatment for loblolly pine. Different letters indicate significant differences between treatment means.

Table 2. Summary of arithmetic means and coefficients of variation by treatment and age for average dbh (in.).

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	1.8	35.78	3.5	28.2	4.8	23.8
C&B	2.5	23.5	4.5	13.3	5.8	9.6
S,P&D	2.7	27.1	4.8	16.8	6.0	12.1
C,H&B	2.8	21.6	4.7	12.8	6.0	8.6
H&B	3.2	17.1	5.0	11.1	6.3	8.9
H,B&H	4.2	12.7	6.0	10.8	7.0	9.8

DBH Distrubtions

There were no significant differences in the range of the dbh distributions due to site preparation treatment at age 12. The burn only treatment had a significantly higher mean skewness statistic over all other treatments. A smaller proportion of stems in the burn only dbh distribution are pushed toward the larger diameter classes indicating a more symmetric distribution. There were no significant differences between site preparation treatments with regards to the kurtosis statistic from the dbh distributions.

Average Height

Mean height increased with increasing site preparation treatment intensity (Figure 2). Chopping before burning significantly increased mean height an average of 5.0 ft, which again may be attributed to the residual hardwood overstory on the burn only treatment. As with mean dbh, there was not a significant difference in average height between the chop and burn treatment and the chop, herbicide, and burn treatment. The chop and burn treatment, the shear, pile and disk treatment, and the chop, herbicide and burn treatment had smaller mean heights than the herbicide and burn treatment. The contrast analysis indicated that the chemical treatment increased height an average of 2.3 ft over the mechanical treatments. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in mean height over all other treatments. These average heights include all trees, not just dominants and codominants. Nevertheless, average heights are not expected to vary with treatment as much as other variables such as dbh because it is less affected by density (pine or hardwood). Heights are affected by density when density is very high, however, and the differences here reflect primarily differences in interspecific competition density. The significant difference between age 12 heights for treatment 5 and treatment 6 emphasizes the residual effect of herbaceous weeds on average heights. Table 3 gives the arithmetic means and coefficients of variation for each treatment at ages 6, 9, and 12 yr.

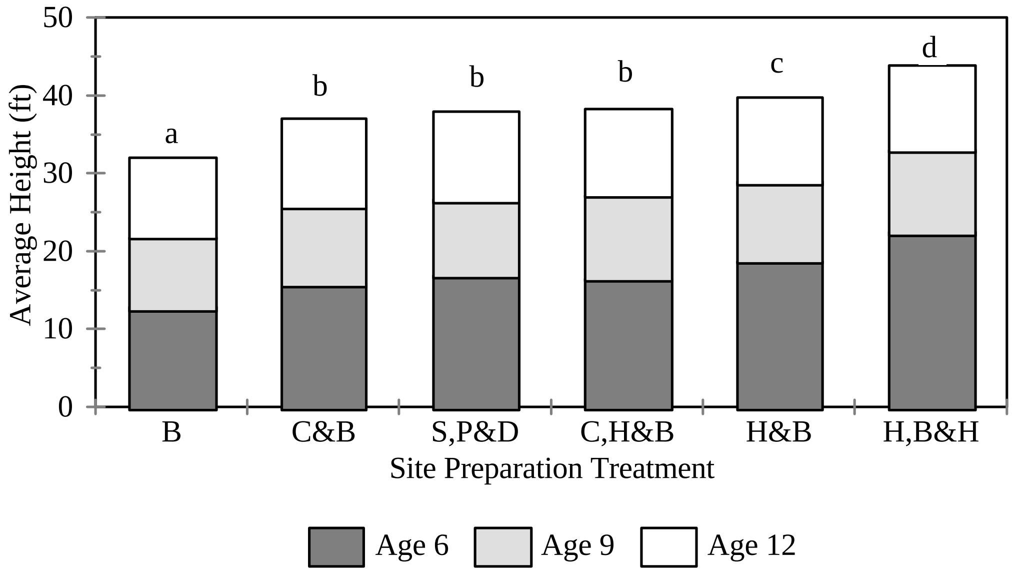

Figure 2. **Least squares means for average height (ft) by age and treatment for loblolly pine. Different letters indicate significant differences between treatments.**

Table 3. **Summary of arithmetic means and coefficients of variation by treatment and age for average height (ft).**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	12.6	23.8	21.7	22.7	32.0	21.6
C&B	15.2	19.6	25.8	16.0	36.9	13.9
S,P&D	16.1	22.3	26.7	17.8	37.8	15.1
C,H&B	16.5	18.3	27.2	15.1	38.3	12.6
H&B	18.1	16.2	29.2	12.8	40.0	11.6
H,B&H	21.6	14.2	33.0	11.6	43.7	10.5

Basal Area per Acre

Chopping before burning significantly increased basal area an average of 28.9 ft^2/ac (Figure 3). Average basal area per acre for the herbicide and burn treatment was significantly greater than for the chop and burn treatment and the chop, herbicide and burn treatment. The result of the orthogonal contrast was significant; the operational chemical treatment resulted in an average gain of 11.1 ft^2/ac over the operational mechanical treatments. There was not a significant difference between the chop and burn and the chop, herbicide and burn treatment. Although the chop, herbicide and burn treatment killed some hardwoods, the amount of time after chopping was not sufficient to allow vigorous sprouting and thus reduced the efficacy of the Roundup™ treatment. The result is that there are minimal differences in competition between the two treatments. The herbicide and burn treatment with follow-up herbicide resulted in an increase in average basal area over all other treatments with a gain of 25 ft^2/ac over the next best treatment at age 12. Basal area per acre is affected by number of trees per ac and by average tree dbh. The trends in basal area per acre across treatments mirror those in trees per ac (see section on trees per ac at age 12). The exception is the most intensive treatment where a larger average tree size resulted in more basal area even though trees per ac was not significantly different from less intensive treatments.

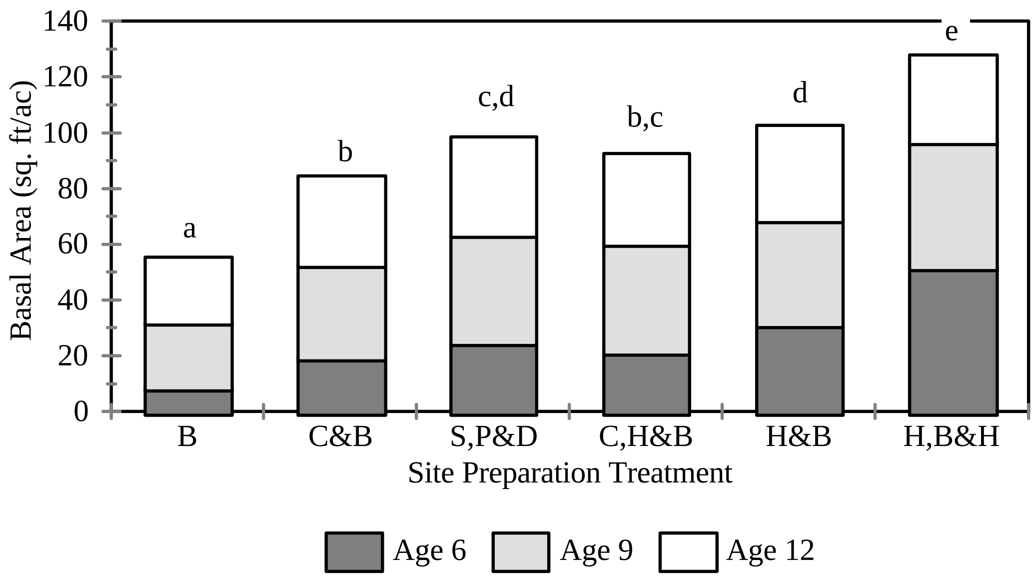

Figure 3. **Least squares means for basal area (ft^2/ac) by age and treatment for loblolly pine. Different letters indicate significant differences between treatments.**

Table 4. **Summary of arithmetic means and coefficients of variation by treatment and age for basal area (ft^2/ac).**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	9.9	72.8	31.9	53.3	55.4	48.3
C&B	17.7	52.6	52.6	35.1	84.2	26.4
S,P&D	22.7	53.2	63.6	36.2	98.3	27.4
C,H&B	22.9	49.4	61.1	34.7	93.3	26.8
H&B	29.8	38.5	70.4	25.8	103.8	19.7
H,B&H	48.6	29.8	96.4	22.6	127.0	19.7

Total Volume per Acre

There was a steady progression of increasing yield with increasing site preparation intensity. The chop and burn treatment significantly increased total volume 590.8 ft^3/ac over burn only. There was not a significant difference in yield between the shear, pile and disk treatment and either the chop, herbicide, and burn treatment or the herbicide and burn treatment. The operational chemical treatment resulted in an average gain of 287.5 ft^3/ac over the operational mechanical treatments. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in yield over all other treatments with a gain of 676 ft^3/ac over the next best treatment at age 12.

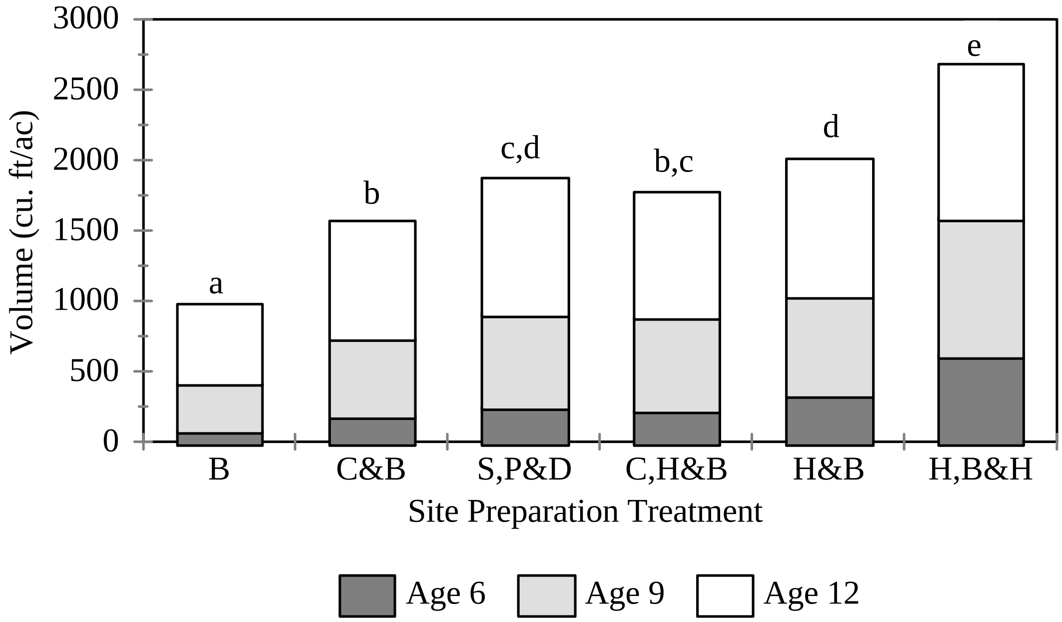

Figure 4. **Least squares means for total volume (ft^3/ac) by age and treatment for loblolly pine. Different letters indicate significant differences between treatments.**

Table 5. **Summary of arithmetic means and coefficients of variation by treatment and age for total volume (ft^3/ac).**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	88	81.2	416	63.9	976	57.7
C&B	172	62.6	739	45.3	1569	35.1
S,P&D	229	63.9	912	46.1	1864	36.8
C,H&B	232	61.5	891	44.7	1793	34.9
H&B	318	49.8	1070	34.4	2047	27.3
H,B&H	571	37.7	1576	28.6	2652	25.4

Merchantable Volume per Acre

Results for merchantable volume were essentially the same as for total volume. There was a steady progression of increasing merchantable volume with increasing site preparation intensity. There was not a significant difference in yield between the shear, pile and disk treatment and either the chop, herbicide and burn treatment or the herbicide and burn treatment. The operational chemical site preparation treatment resulted in an average gain of 283.1 ft^3/ac in merchantable volume over the operational mechanical treatments. The herbicide and burn treatment with follow-up herbicide for complete vegetation control resulted in a significant increase in yield over all other treatments. The gain for the complete control treatment over the herbicide and burn treatment has widened slightly at age 12 compared to the difference in the two treatments at age 9.

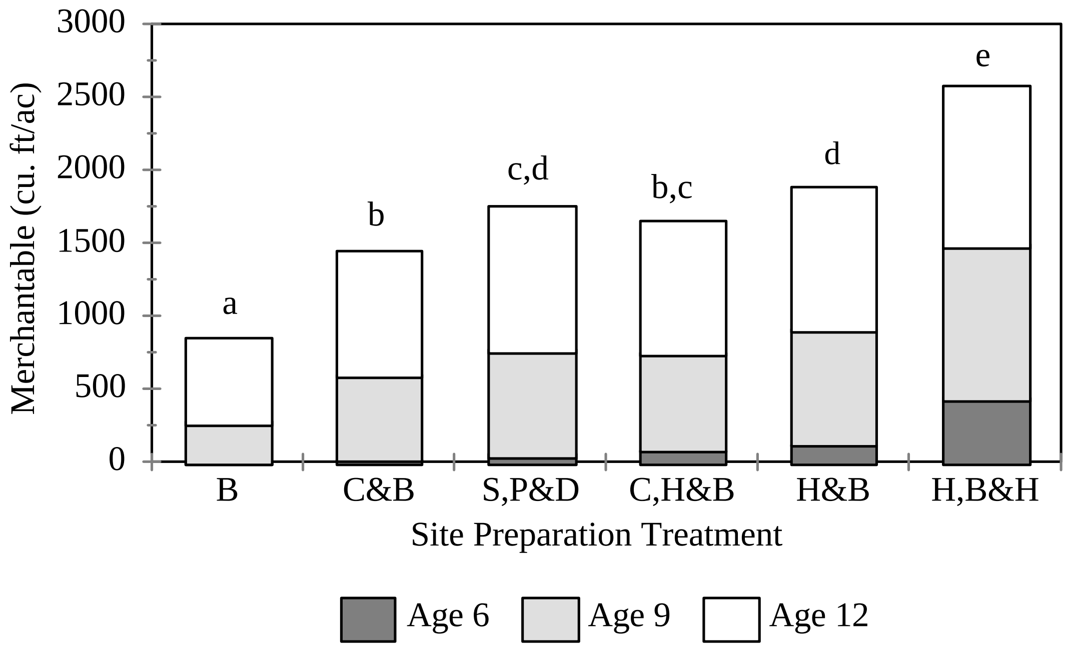

Figure 5. **Least squares means for merchantable volume (ft^3/ac) by age and treatment for loblolly pine. Different letters indicate significant differences between treatments.**

Table 6. **Summary of arithmetic means and coefficients of variation by treatment and age for merchantable volume (ft^3/ac).**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	30	132	276	88	846	65
C&B	48	108	593	56	1445	37
S,P&D	91	102	768	57	1740	39
C,H&B	80	134	751	53	1669	37
H&B	121	117	929	40	1919	29
H,B&H	429	48	1472	31	2546	26

Trees per Acre

Trees per ac indicates survival after age 1; double planting insured better survival for some treatments to age 1 than are reflected in the trees per acre values. The burn only treatment and chop and burn treatments had significantly lower survival than all other treatments (Figure 6) and the burn only treatment had an average of 61 trees per acre less than the chop and burn treatment. The large overtopping residual hardwoods not killed by the burn only site preparation treatment are probably responsible for much of this difference in survival. Treatments 4 through 6 were not significantly different from each other. This means that the larger basal area and volume of treatment 6 are a result of the larger average tree size rather than better survival after age 1. Since the major difference between treatments 5 and 6 is herbaceous weed control (HWC), this result emphasizes the importance of HWC. Table 7 gives the arithmetic means and coefficients of variation for each treatment at ages 6, 9, and 12 yr. In some cases there were slight discrepancies from age to age on trees per acre. Subsampling at younger ages is a likely cause of these discrepancies. The PMRC staff is currently in the process of retagging all plots to give each tree an identification to better monitor changes in trees per ac between measurements.

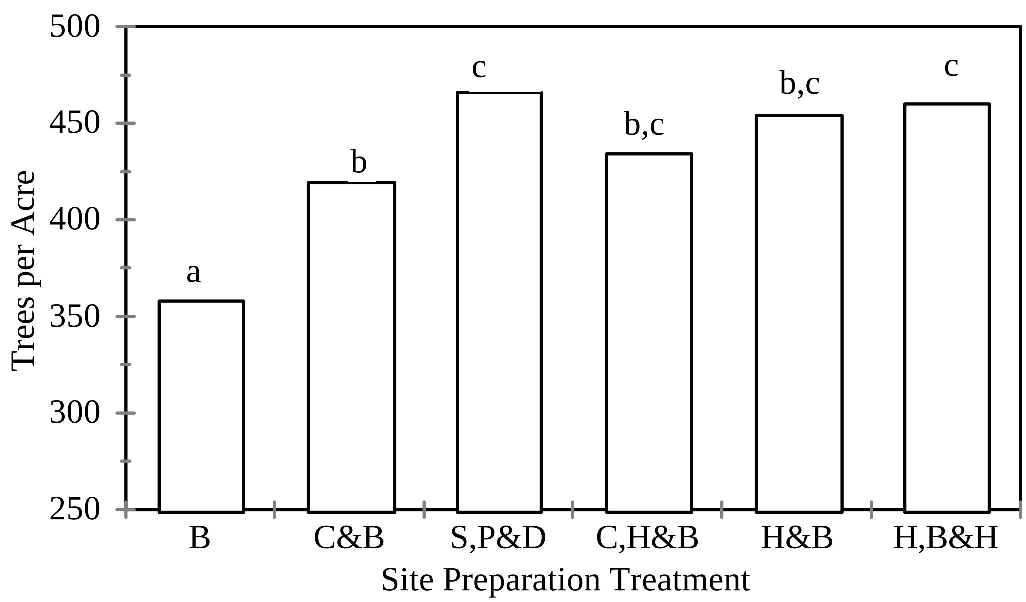

Figure 6. **Least squares means for trees per acre by treatment for 12 yr loblolly pine. Different letters indicate significant differences between treatments.**

Table 7. **Summary of arithmetic means and coefficients of variation by treatment and age for trees per acre.**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	368	29.1	370	27.3	358	30.7
C&B	434	18.8	426	17.5	421	17.8
S,P&D	471	16.0	471	15.4	467	15.2
C,H&B	452	18.9	444	19.4	438	19.6
H&B	473	13.4	463	14.1	455	15.7
H,B&H	470	15.3	467	15.2	455	15.1

Percent Fusiform Infection

Each tree in the study was examined for the incidence of fusiform stem cankers. These records were used to determine the percentage of infected trees on each plot. Figure 7 indicates which treatments were significantly different at age 12. The fluctuations between ages indicated in Table 8 are likely caused by fusiform induced mortality; once a tree dies it is no longer counted as a tree with a canker and thus reduces the infection percentage on the plot. There are no apparent trends in these means with regards to treatment.

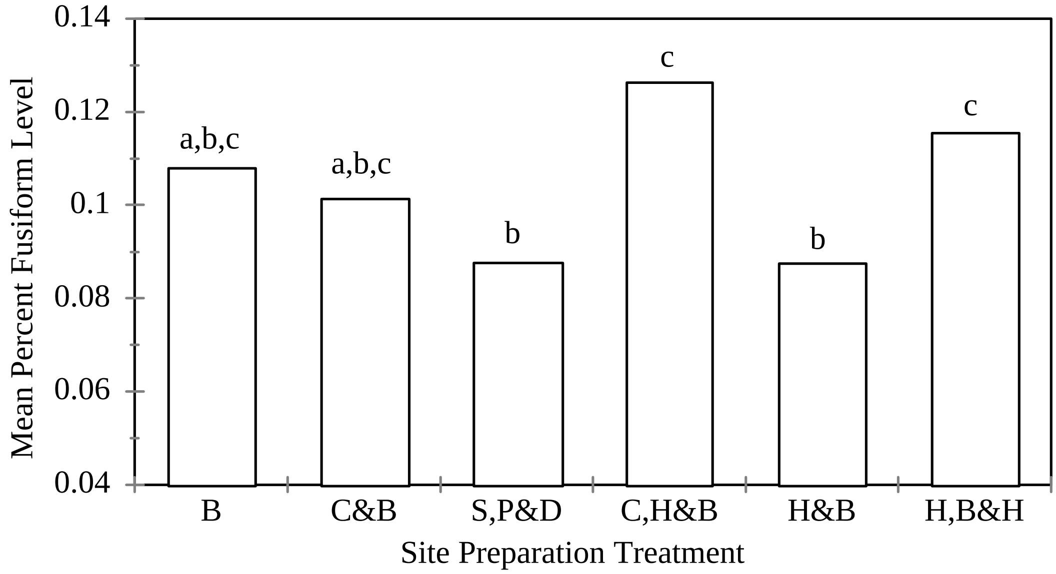

Figure 7. **Least squares means for fusiform infection level (%) by treatment for 12 yr loblolly pine. Different letters indicate significant differences between treatments.**

Table 8. **Summary of arithmetic means and coefficients of variation by treatment and age for fusiform infection level (%).**

	Age 6		Age 9		Age 12	
Treatment	Mean	CV%	Mean	CV%	Mean	CV%
B	8.7	80	6.5	90	10.8	94
C&B	6.4	123	5.0	102	9.4	105
S,P&D	6.1	114	4.8	142	8.4	120
C,H&B	6.9	147	6.9	137	12.7	94
H&B	4.0	96	4.2	101	8.7	108
H,B&H	5.9	133	5.7	130	12.4	102

THREE YEAR PERIODIC GROWTH

An analysis was conducted to examine the 3-yr periodic growth, between ages 6 and 9, and 9 and 12 yr, of the dependent variables. The objective was to determine whether the different site preparation treatments are converging or diverging over time with regard to the dependent variables.

Periodic Average DBH Growth

There were no significant differences in mean dbh growth between the burn only treatment and the most intensive treatment, the herbicide and burn treatment with follow-up herbicide, during the period between 6 and 9 yr. Between 9 and 12 yr, the burn only treatment was growing significantly faster than the most intensive treatment (Table 9) and the complete control treatment had significantly lower 3-yr periodic growth between ages 9 to 12 yr than all the other site preparation treatments in this study. These results indicate that the mean dbh for the least intensive and most intensive site preparation treatments are no longer diverging and in fact, have begun to converge (Figure 8). It is important to remember that these site preparation treatments are at different stages of stand development. The complete control treatment exhibited significantly greater dbh growth rates early in stand development and now, as the stand matures, the complete control is starting to exhibit slightly lower growth rates as intraspecific competition intensifies. This stage of development is characterized by a reduction in individual tree growth rates relative to their potential in the absence of competitive interaction (Long and Smith, 1984). It is important to note that while the 3-yr periodic growth rates are significantly higher for the chop only treatment, the absolute difference in dbh between the treatments at age 12 average 2.2 in. which is considerably larger than the differences in the periodic growth. There were slight differences in mean dbh growth between the other site preparation treatments (Table 9), and as expected, the dbh growth rates are declining over time.

Table 9. **Average mean dbh growth (in.) by treatment for the two 3-yr periods. Different letters indicate significant differences between site preparation treatments.**

3-yr period	B	C&B	S,P&D	C,H&B	H&B	H,B&H
6 to 9 yr	1.7 (a)	2.0 (b)	2.1 (b)	2.0 (b,d)	1.8 (c,d)	1.8 (a, c)
9 to 12 yr	1.3 (a)	1.3 (a)	1.3 (a,b)	1.3 (a,b)	1.2 (b)	1.0 (c)

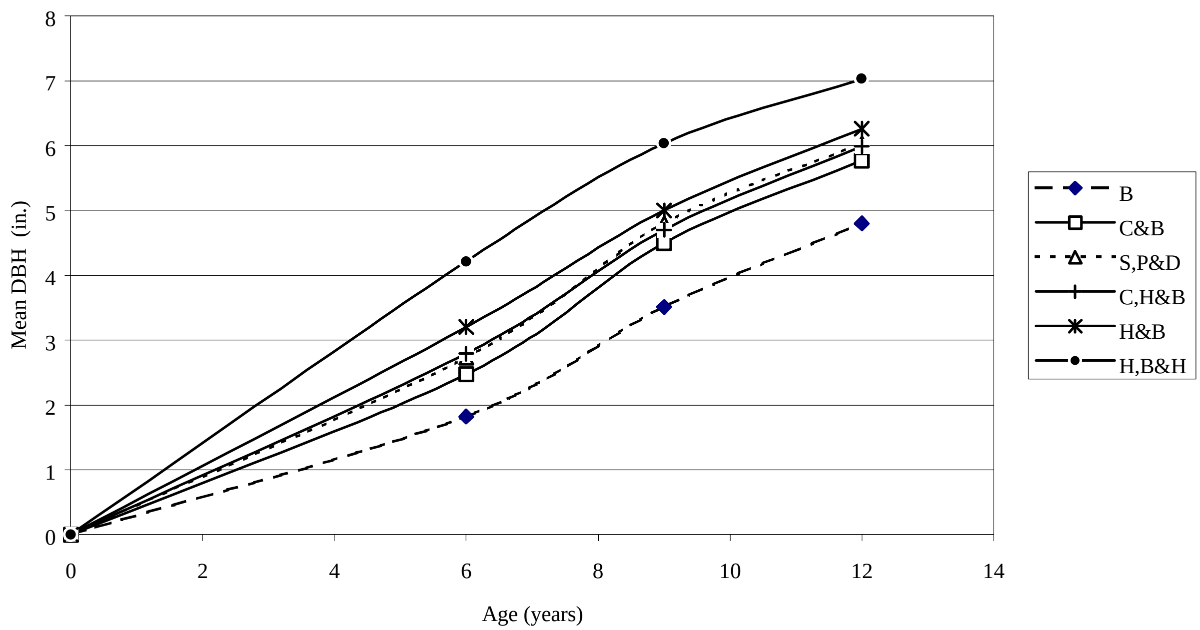

Figure 8. **Mean dbh for the different site preparation treatments over age.**

Periodic Average Height Growth

Examining Figure 9 and Table 10 reveals an interesting observation; the mean height growth rates for the less intensive treatments are still increasing over time while the growth rates for the herbicide and burn with follow up herbicide, and the herbicide and burn treatments have begun to decrease over time. The trend of increasing mean height growth with increasing site preparation intensity still holds for the period between ages 6 and 9 yr, but during the 3 yr period between 9 and 12 yr the trend is no longer present. Again, these trends must be evaluated in the context of stand development. Average heights for treatments 5 and 6 are 40.0 and 43.7 ft respectively, at age 12 compared to 32.0 to 38.3 ft for the less intensive treatments.

Table 10. Average mean height growth (ft) by treatment for the two 3-yr periods. Different letters indicate significant differences between site preparation treatments.

3-yr period	B	C&B	S,P&D	C,H&B	H&B	H,B&H
6 to 9 yr	9.1 (a)	10.6 (b)	10.6 (b)	10.7 (b)	10.9 (b,d)	11.3 (d)
9 to 12 yr	10.2 (a)	11.1 (b)	11.2 (b)	11.0 (b)	10.8 (a,b)	10.8 (a,b)

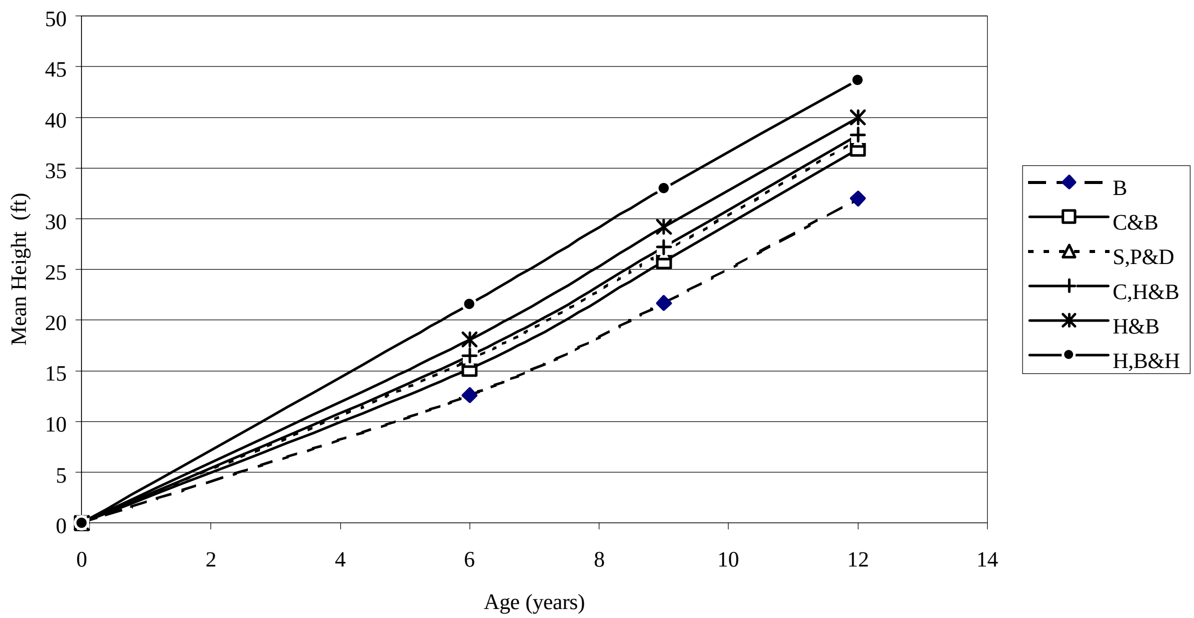

Figure 9. Mean height for the different site preparation treatments over age.

Periodic Average Basal Area per Acre Growth

In terms of mean basal area growth the most intensive treatments are still outgrowing the chop only treatment during both 3-yr periods (Table 11). These results differ from the dbh analysis and can be explained by the dynamics of dbh growth. A 1-in. increase in dbh on a 3-in. tree results in less basal area growth than a 1-in. increase on a 6-in. tree. Increasing the diameter of a larger cylinder will result in a larger cross sectional area, and therefore adding a smaller growth increment on a large dbh can result in more basal area growth than a larger diameter growth increment on a smaller dbh. It is also interesting to note that the most intensive treatment has reached its maximum mean annual increment (MAI) somewhere before age 12, while for the other treatments MAI at age 12 is still greater than MAI at age 6 (Figure 10).

Table 11. Average basal area growth (ft^2/ac) by treatment for the two 3-yr periods. Different letters indicate significant differences between site preparation treatments.

3-yr period	B	C&B	S,P&D	C,H&B	H&B	H,B&H
6 to 9 yr	22.0 (a)	35.1 (b)	41.1 (c)	37.9 (b,c)	40.0 (c)	48.1 (d)
9 to 12 yr	23.5 (a)	31.6 (b)	34.8 (c)	31.9 (b,c)	33.2 (b,c)	30.8 (b)

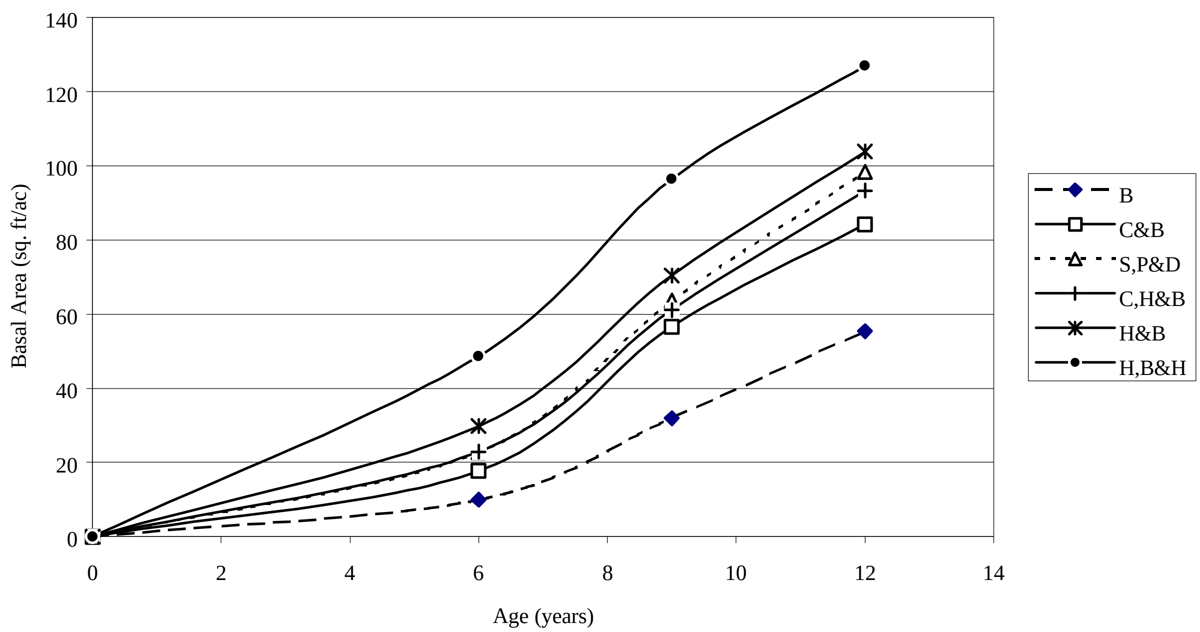

Figure 10. Mean basal area for the different site preparation treatments over age.

Periodic Average Total Volume per Acre Growth

The total volume growth for both 3-yr periods is still increasing with both site preparation intensity and age. It is obvious from these results that the volume growth curves for each treatment have not yet reached their inflection points. This is expected due in part to the fact that MAI for basal area is expected to peak several years prior to volume MAI. The periodic growth trends for merchantable volume were similar to those for total volume (Table 13 and Figure 12).

Table 12. Average total volume growth (ft^3/ac) by treatment for the two 3-yr periods. Different letters indicate significant differences between site preparation treatments.

3-yr period	B	C&B	S,P&D	C,H&B	H&B	H,B&H
6 to 9 yr	329 (a)	569 (b)	686 (c,d)	653 (c)	736 (d)	1017 (e)
9 to 12 yr	560 (a)	828 (b)	959 (c)	891 (b,c)	960 (c)	1089 (d)

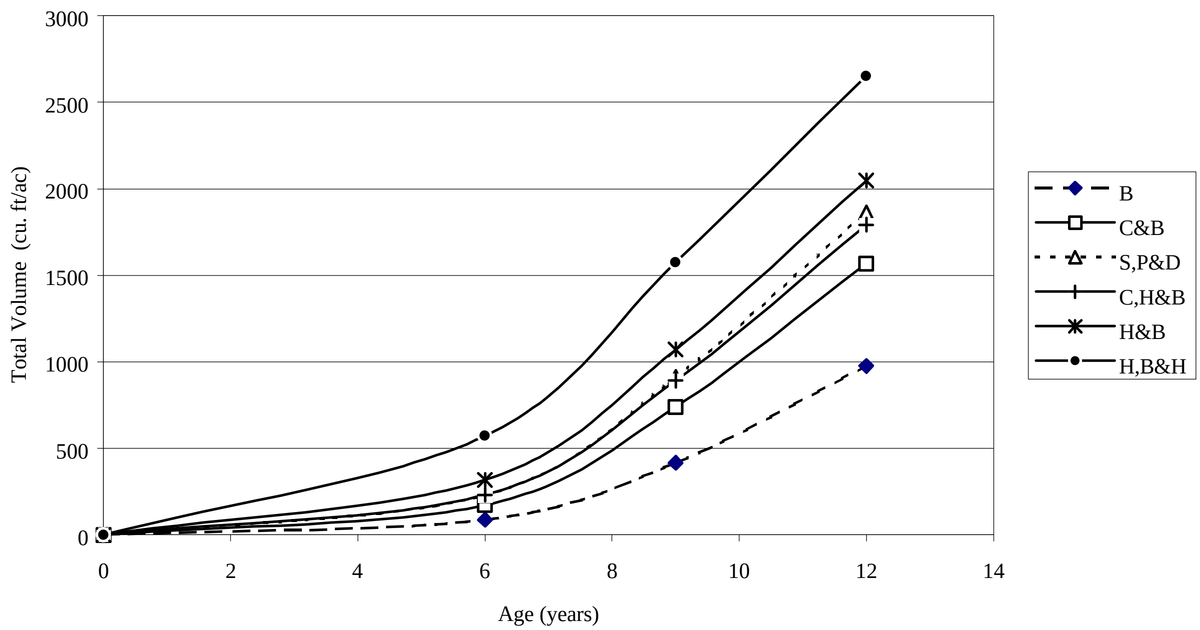

Figure 11. Mean total volume for the different site preparation treatments over age.

Table 13. **Average merchantable volume growth (ft^3/ac) by treatment for the two 3-yr periods. Different letters indicate significant differences between site preparation treatments.**

3-yr period	B	C&B	S,P&D	C,H&B	H&B	H,B&H
6 to 9 yr	368 (a)	659 (b)	864 (c)	743 (b,d)	790 (c,d)	1089 (e)
9 to 12 yr	570 (a)	850 (b)	979 (c)	906 (b,c)	973 (c)	1087 (d)

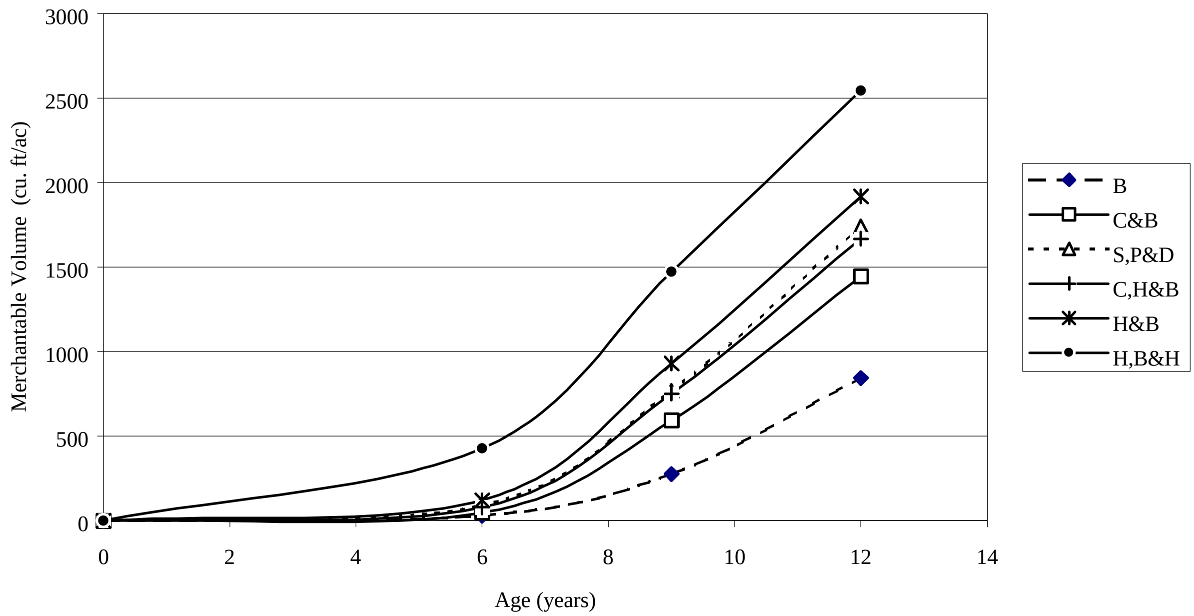

Figure 12. **Mean merchantable volume for the different site preparation treatments over age.**

DISCUSSION

The herbicide and burn, with follow-up herbicide treatment increased mean dbh, mean height, basal area per ac, and total and merchantable volume per ac of loblolly pine over all other treatments. This treatment results in complete control of all herbaceous and woody competition and enables the pine to grow free from interspecific competition. The significant differences between the herbicide and burn treatment and the complete control treatment are mainly attributed to herbaceous competition since the hardwoods were adequately removed from both treatments by the chemical applications. The lack of any significant differences between the chop and burn treatment and the chop, herbicide and burn treatment is noteworthy; although the chop, herbicide and burn treatment killed some hardwoods, the amount of time after chopping was not sufficient to allow vigorous sprouting and thus reduced the efficacy of the Roundup™ treatment. The burn only treatment consistently had very poor production. The considerable difference between the burn only and the chop and burn treatment can be explained by the competitive effect of the residual hardwood overstory that survived the burn only site preparation treatment overtopping the planted pine. There were significant differences in mean dbh, mean height, basal area per ac, and total and merchantable volume per ac between the operation chemical treatment and the two operational mechanical treatments. In all cases the chemical treatment performed significantly better than the mechanical treatments. Trends in survival after age 1 echo that of basal area per ac, except for the complete control treatment, where a larger average tree size resulted in more basal area even though the average trees per ac for the complete control treatment was not significantly different from the average of the less intensive treatments. There were no apparent trends in percent fusiform infection levels with regard to site preparation treatment intensity.

The results of the periodic growth analysis indicates that the mean dbh for the least intensive and most intensive site preparation treatments are no longer diverging and in fact, have begun to converge. While this is an interesting observation it is not one to cause alarm; even though the 3-yr periodic growth rates are significantly higher for the chop only treatment, the absolute difference in dbh between the treatments at age 12 are considerably larger than the differences in the periodic growth. These results reveal that the two treatments are at different stages of development. The mean height growth rates for the less intensive treatments are still increasing over time while the growth rates for the herbicide and burn with follow up herbicide, and the herbicide and burn treatments are decreasing over time. These differences in mean height are also an indication that the treatments are at different stages of development. In terms of basal area, and total and merchantable volume growth, the most intensive treatments are still outgrowing the chop only treatment. The 3-yr periodic growth of total and merchantable volume for both periods still increased with both site preparation intensity and age.

The following analyses remain to be completed on this data:

1. Evaluate whether there are correlations between competition classes, and between competing vegetation and the crop pine tree attributes,
2. Conduct tests on each stand attribute to determine if correlations exist between competition measurements and treatments,
3. Address the questions concerning the economic feasibility of these different site preparation treatments, and
4. Develop models with the intent of helping managers better estimate future gains from the different site preparation methods.

This study is scheduled to be remeasured again at age 15.

LITERATURE CITED

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