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Response of Planted Loblolly Pine Following Various Conversion Methods

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Response of Planted Loblolly Pine Following Various Conversion Methods

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INTRODUCTION

THE upland soils of Alabama's Upper Coastal Plain frequently are stocked with low-grade hardwoods that do not produce financial returns comparable to those produced by pine on similar sites.

Various methods of converting hardwood stands to pine employed by progressive landowners in recent years have posed the question "What responses can be expected in survival and growth of planted loblolly pine (*Pinus taeda* L.) following various methods of conversion?"

Because of the absence of literature on the early growth and development of pine stands after hardwood control treatments, a study of this problem was begun in 1959 on the Fayette Experiment Forest of the Auburn University Agricultural Experiment Station, (12). The objective was to test effects of seven methods of conversion on survival and early growth of planted pine.

LITERATURE REVIEW

The literature is extensive concerning the initial success or failure of various hardwood control methods (1,5,6,9,10). Little information, however, can be found on early growth and development of pine following such hardwood control measures. Ferguson (2) indicated that planted loblolly pine increased in height for 2 or 3 years after release from competition with the increase proportional to the degree of release. His experimental design, however, precluded a rigorous analysis of the data. Miller (4) reported on the 9-year results of a study comparing 2 chemicals at 3 levels of concentration on the release of planted loblolly pine seedlings. He concluded that hardwood control was feasible as the data indicated that a moderately dense upland hardwood stand had been successfully converted to an established loblolly pine stand.

Study Area

The area involved in this study is situated in Fayette County near U.S. highway 43, 10 miles north of Fayette, Alabama in the Upper Coastal Plain soils region. It is an upland area on a gentle slope with a southern aspect. The soils are of the Ruston series and are deep, well-drained and moderately eroded. The profile is described as follows: 1 - 6 inches, brown, very friable fine sandy loam; 6 - 20 inches, yellowish-red, friable fine sandy clay loam; 20 - 49 inches, yellowish-red very friable fine sandy loam; and below 49 inches, strongly brown to red, sandy loam to light clay loam.

Ruston soils tend to be low in fertility and available moisture. Loblolly pine site index ranges from 66 to 80 as determined by the Soil Conservation Service and these figures can be used as an approximate guide to the productivity of the area.

Annual precipitation averages 53 inches per year, ranging from 40 to 75 inches. Mean annual temperature is 61.4° F. and the frost-free period averages 231 days.

The original forest, Table 1, produced 1.5 cords of merchantable pine pulpwood per acre, 1,330 board feet of pine sawtimber, and 925 board feet of hardwood sawtimber per acre (Inter. ¼-inch rule). Most hardwood sawtimber was of poor quality. Pine stocking and growth were low. Consequently, the full productive capacity of the area was not being realized. The upper canopy was sparse but the largely hardwood understory canopy, consisting of miscellaneous shrubs, seedlings and sprouts of oak (*Quercus spp.*, L.), hickory (*Carya spp.*, Nutt.), sweetgum (*Liquidambar styraciflua*, F.), black gum (*Nyssa sylvatica*, Marsh.), red maple (*Acer rubrum*, L.), dogwood (*Cornus florida*, L.), persimmon (*Diospyros virginiana*, L.), and sourwood (*Oxydendrum arboreum*, DC.), plus many muscadine grape vines (*Vitis rotundifolia*, Michx.) was dense. Pine in the understory was noticeably absent.

TABLE 1. CONDITIONS ON STUDY AREA PRIOR TO CUTTING OR TREATMENT[1 2 3]

Species	Stocking (per acre)				Basal Area (per acre)			Volume (per acre)	
	Sprouts and seedlings	Small saplings	Pulp-wood	Saw-timber	Small saplings	Pulp-wood	Saw-timber	Pulp-wood	Saw-timber
	Number	*Number*	*Number*	*Number*	*Sq.Ft.*	*Sq.Ft.*	*Sq.Ft.*	*Cords*	*Bd.Ft.*
Pine			31	19		6.09	13.27	1.5	1,330
Hardwoods									
shrubs	1,750	2	0	0	0	0	0	0	0
oak and hick.	2,643	351	122	13	9.88	17.03	11.60		902
Misc.[4]	2,042	62	28	1	2.17	8.62	0.38		23
Subtotal	6,435	415	150	14	12.05	25.65	11.98		925
Grand Total	6,435	4.5	181	33	12.05	31.74	25.25	1.5	2,255

[1] Based on 1958 statistics.
[2] Sprouts and seedlings—1′ high, 1″ d.b.h.
Small saplings—1.1″ d.b.h. to 3.5″ d.b.h.
Pulpwood—3.5″ d.b.h. and greater.
[3] Blanks in table indicate that data was not available.
[4] Miscellaneous species; sweetgum, blackgum, red maple, and semitrees such as dogwood, sourwood, and persimmon.

METHODS

A randomized block design, consisting of 7 treatments (including an untreated check) with 5 replications per treatment, was established under comparatively uniform stand conditions. Treatment plots were square, 132 feet on each side, with a 46.2 foot x 46.2 foot permanent sample plot located in the center of each treated plot. This left an isolation strip of 85.8 feet between sample plots. One year prior to hardwood control treatments a sale, averaging 2,255 board feet of sawtimber and 1.5 cords of pine pulpwood per acre, was made of all merchantable timber. The treatments were as follows:

1. Check – No hardwood control measures were applied.

2. Scarification by bulldozer – With the bulldozer blade at ground level, all stems were pushed over or uprooted and all slash windrowed.

3. Injector-applied herbicide[1] – Stems one inch d.b.h. and larger were injected around the base at one inch spacing except for hickory and maple that received a frill of injections. An herbicide was applied in a 1-to-12 ratio with diesel fuel.

4. Girdle without herbicide – Stems 1 to 3 inches d.b.h. were cut at waist height. Stems over 3 inches d.b.h. were axe girdled, chipping out a 3-inch strip of bark and cambium.

5. Axe frill and herbicide – Stems 1 to 3 inches d.b.h. were cut at waist height. Stems over 3 inches d.b.h. were single axe frilled with an axe. An herbicide in a 1-to-30 ratio with diesel fuel was applied to all cut surfaces with an oil can.

6. Chain girdle and herbicide – Stems 1 to 3 inches d.b.h were cut at waist height. Stems over 3 inches d.b.h. were girdled with a Brady Handy Girdler.[2] Herbicide in a 1-to-30 ratio with diesel fuel was applied to all cut surfaces with an oil can.

7. Foliage spraying plus axe frill and herbicide – Spray was applied from a tractor-mounted device through a three-nozzle,

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[1] The herbicide used in treatments 3, 5, 6, and 7 was a Dionoxol compound of half 2,4-D and half 2, 4,5-T at a concentration of 4 pounds of acid equivalent per gallon.

[2] Joe Brady and Associates, Birmingham, Alabama. Trade name and company are included for the benefit of the reader but do not imply any endorsement by the Auburn University Agricultural Experiment Station.

12-foot "A" frame. Approximately 60 gallons per acre were applied in a ratio of 1 part herbicide, 2 parts diesel fuel and 57 parts water. This was about twice the rate of application currently considered best for foliage spraying. Stems over 4 inches d.b.h. were axe frilled and herbicide in a 1-to-30 ratio with diesel fuel applied to cut surfaces with an oil can.

In January 1959, each treatment plot was planted with loblolly pine seedlings. These were 1-0 seedlings which averaged 1 foot in height. The spacing was 6 by 9 feet and resulted in 35 seedlings per sample plot. Treatment two was applied in January 1959 prior to planting and treatments 3 through 7 were applied after hardwood leaves had fully developed in the spring of 1959.

Total heights and numbers of surviving pine were determined and recorded after each growing season for 6 years after treatment. All hardwood reproduction was counted on 4 one-milacre subplots which were randomly[3] located in each sample plot replication. The sixth year after treatment the diameters breast high of all surviving pines with heights greater than 4½ feet were measured and recorded. Furthermore, all the surviving pines were tallied by the following vigor classes:

Excellent – Dominant, free to grow, well-formed trees with a minimum live crown ratio of 1:2.

Good – Dominant and codominant trees with a minimum live crown ratio of 1:3.

Fair – Intermediate trees partially suppressed by hardwoods.

Poor – Deformed and/or overtopped trees.

Standard statistical methods were used to analyze the data, (7).

RESULTS

Table 2 summarizes the mensurational data for the seven treatments.

Survival

Analysis of variance of the numbers of surviving pine indicated significant differences among the various treatments 6 years after they were established (Appendix Table 1). The order of signifi-

[3] The permanent sample plots encompassed 49 milacres and a table of random numbers was used to select 4 one-milacre subplots for measurements.

TABLE 2. MENSURATIONAL DATA SIX YEARS AFTER PLANTING, ON A PER ACRE BASIS

Treatment	Survival[1] data		Heights[1]				Diameters[2]		Basal[2] area
			Sum of[3] heights	Av.[4] height	Standard deviation	Annual[5] growth	Av. d.b.h.	Annual growth	
No. Description	*Number*	*Per cent*	*Feet*	*Feet*	*Feet*	*Feet*	*Inches*	*Inches*	*Sq.Ft.*
1. Check (no treatment)	498	69.7	2,834.9	5.7	±3.1	0.8	0.5	0.07	0.857
2. Bulldozer scarification	625	87.4	9,819.3	15.7	±3.1	2.4	2.5	0.38	24.410
3. Injected herbicide	600	84.0	8,023.2	13.4	±3.6	1.0	1.9	0.27	13.532
4. Girdle only (no herbicide)	535	74.9	6,594.5	12.3	±3.7	1.8	1.6	0.23	9.062
5. Axe frill with herbicide	608	85.1	8,911.0	14.7	±3.9	2.1	2.2	0.31	18.226
6. Chain frill with herbicide	584	81.7	8,339.5	14.3	±2.9	2.0	2.1	0.30	14.552
7. Foliage spray (plus treatment 5 on overstory)	384	53.7	4,573.9	11.9	±4.5	1.7	1.6	0.23	6.715

[1] Live, planted stems only.
[2] Live, planted stems over 4.5 feet in height.
[3] The sum of the total heights of all trees by treatment.
[4] Determined by dividing the sum of heights figure by survival number.
[5] Determined by dividing average heights per tree by 7 (growing years).

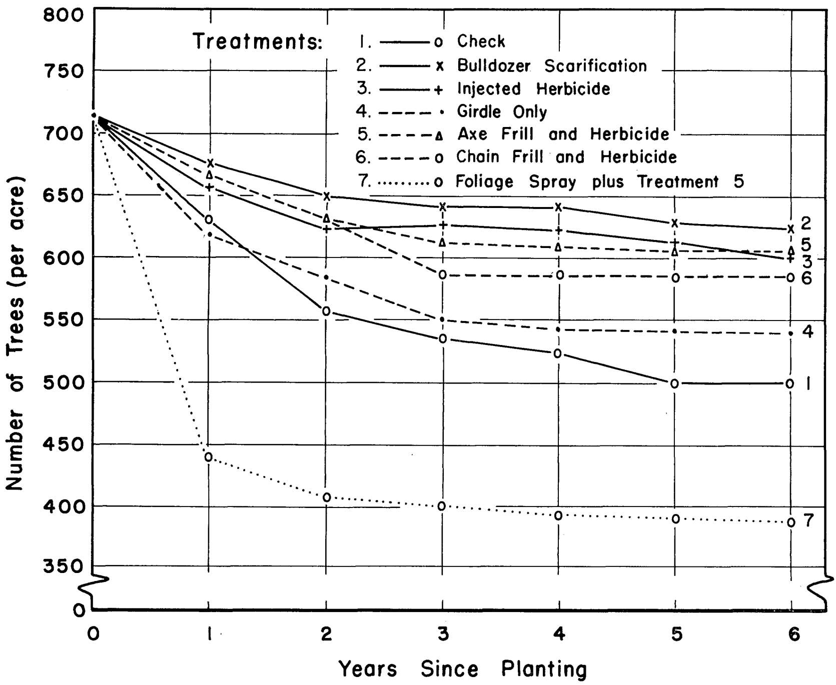

FIG. 1. Number of surviving loblolly pine seedlings for six years after planting.

cant differences (P < 0.01) as indicated by Hartley's sequential range test (7) was:[4]

Treatment:	2	5	3	6	4	1	7
Mean No. pines per acre:	625	608	600	584	535	498	384

Pine survival 6 years after hardwood control treatments were established ranged from a high of 87.4 per cent for treatment 2 to a low of 53.7 per cent for treatment 7.

The bulldozer scarification, injector-applied herbicide, axe frill and herbicide, and chain girdle and herbicide treatments resulted in 25.4, 20.5, 22.1, and 17.2 per cent, respectively, greater numbers of surviving planted pines 6 years after treatment than did the check treatment. Data of treatment 7, foliage spraying, indicated a significant decrease of 23.0 per cent (P < 0.01) in pine survival over the control. This latter difference is attributed to mortality

[4] In this report, all means and treatment numbers not underscored by the same line differ at the 0.01 level of significance.

of the pine in the first year after treatment, resulting from heavy dosage of herbicide spray applied to the area, Figure 1. The high rate of mortality could have been avoided had foliage spraying been done prior to planting. Data from other studies indicate that mist blower application of low volumes with high concentrations would have resulted in less pine mortality, (9).

Analysis of the data for numbers of surviving pine did not indicate a significant treatment and year interaction term following the first year's mortality. However, mortality was greatest the first year after planting, ranging from a low of 5.7 per cent under treatment 2 to a high of 38.3 per cent under treatment 7. In the following 5 years pine mortality on scarified plots and herbicide plots was very small. In the check plots and the "girdle only" plots pine mortality was appreciable, Figure 1.

Vigor Classes

Figure 2 indicates the number of pine seedlings per acre by vigor class for each of 7 treatments. Analysis of variance (Appendix Table 2) of the number of seedlings classified as excellent indicated significant differences ($P < 0.01$) between treatments. Hartley's range test indicated the order of significant differences to be:

Treatment:	2	5	6	3	4	7	1
Mean No. of stems:	502	392	367	286	139	127	20

The best treatment, scarification, resulted in 25.1 times as many excellent stems per acre as the control treatment. The other treatments, 3 through 7, varied from 19.6 to 6.3 times greater abundance over the control; all showed a significant increase as indicated.

Combining the number of excellent and good vigor stems on each treatment indicates stands of 93, 563, 453, 335, 523, 510, and 237 stems per acre for treatments 1 through 7, respectively, that are in a position for future development. Treatments 1, 3, and 4 all have substantially more trees in the fair and poor vigor classes as a result of no hardwood control (treatment 1) or increasing hardwood competition because of ineffective control (treatments 3 and 4).

For the first 2 years after treatment the pine seedlings on the bulldozer plots exhibited chlorotic yellowing of the foliage plus

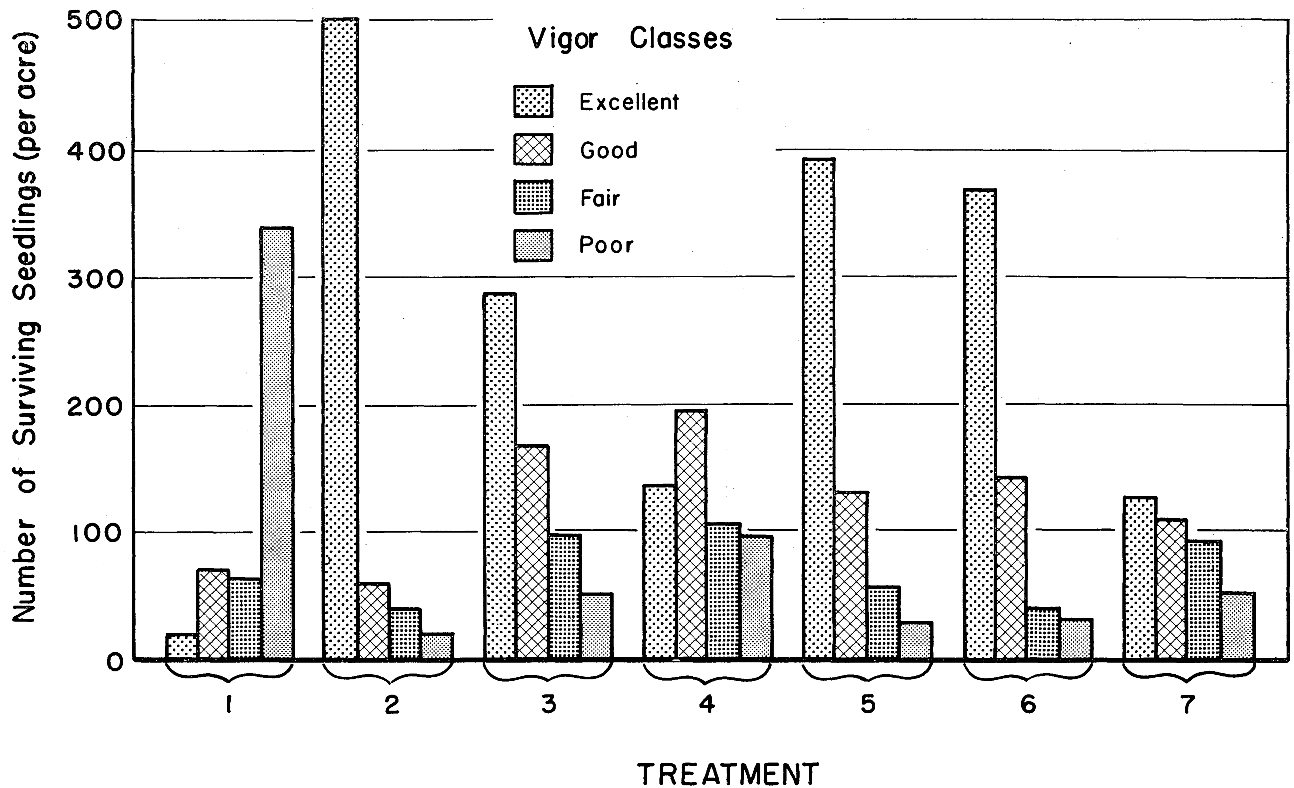

FIG. 2. Number of pine surviving after six years, by vigor class and treatment.

reduced height growth as compared to other treatments. The visual symptoms were typical of a nitrogen deficiency (11) and, although no chemical analyses were made, the condition was attributed to the loss of nitrogen and organic matter as a result of the scarification.

Height Growth

Average heights of pine stems on treated plots ranged from 2.0 (treatment 7) to 2.8 (treatment 2) times greater than on the untreated check plot (treatment 1). Analysis of variance of the mean height growth data (Appendix Table 3) with Hartley's range test indicated the following significant differences ($P < 0.01$) existed between treatments 6 years after hardwood control measures were begun:

Treatment:	2	5	6	3	4	7	1
Mean height (feet):	15.7	14.7	14.3	13.4	12.3	11.9	5.7

All hardwood control treatments resulted in significantly greater height growth than did the check (treatment 1).

The pine seedlings developing on treatment 2, scarification, showed more uniformity in height than did stems on the other treatment plots at the end of the 1964 growing season. This is illustrated by the coefficient of variation values, wherein standard deviation of height is expressed as a percentage of respective mean height. These values are 53, 20, 27, 30, 27, 21, and 37 per cent respectively for treatments 1 through 7. In proportion to their significantly larger size, pine stem height variation was considerably less under treatment 2 than under most other treatments. This difference can, in part, be attributed to ineffective hardwood control measures.

After the 1959 growing season, annual height growth increased on all treatments for 2 years, Figure 3, and then tended to remain stable or decrease for treatments 1, 3, 4, and 7 while increasing for treatments 2, 5, and 6. Figure 3 indicates that the average annual height growth of seedlings on the check plot was always 1 foot or less. On all other plots, after the initial year of establishment, seedlings averaged almost 2 feet and in some cases, i.e., treatment 2, 3 feet per year.

A significant treatment and year interaction was also indicated by the analysis of variance date ($P < 0.01$). This indicates that the treatment effects resulted in different patterns of height responses from year to year. Part of the significant treatment and year interaction is explained by the annual height growth decreasing on plots where hardwood control was ineffective or is diminishing. For example, treatment 4, girdling only, resulted in a quick release of the pine and early rapid height growth that was again suppressed by the numerous sprouts that developed from girdled stems, Figure 3. Analysis of variance (Appendix Table 4) along with the following multiple comparisons of the number of live hardwood stems 1 inch and greater d.b.h. on treatment plots, indicated that significantly greater numbers ($P > 0.01$) of hardwood stems were live on treatment 4, girdle only, than on the herbicide treated plots:

Treatment:	4	1	3	7	5	6	5
Mean No. per acre:	1150	1100	400	350	200	200	50

Observations indicated that herbicide treated stems did not sprout as profusely as did stems girdled only and therefore released pine were able to continue early rapid growth, Figure 3.

Another part of the interaction is explained by the relatively poor early height growth of the pine seedlings on the scarified plot caused by the loss of nitrogen and organic matter. These pines eventually surpassed other pines in growth. This same effect was observed on treatment 7 when the early height growth was suppressed by the heavy volume of herbicide applied. Both of these conditions were reflected in the growth patterns demonstrated by Figure 3.

Diameters and Basal Areas

Average diameters breast high of each treatment are summarized in Table 2. Analysis of variance (Appendix Table 5) and Hartley's range test indicated the following order of significant differences ($P < 0.01$) between the various treatments:

Treatment:	2	5	6	3	4	7	1
Mean d.b.h. (inches):	2.5	2.2	2.1	1.9	1.6	1.6	0.5

The order of response was identical to the order in height growth, Figure 3. All hardwood control treatments resulted in significantly greater diameters than did no hardwood control, ranging from a low of 3.2 (treatment 7) to a high of 5.0 times (treatment 2) greater.

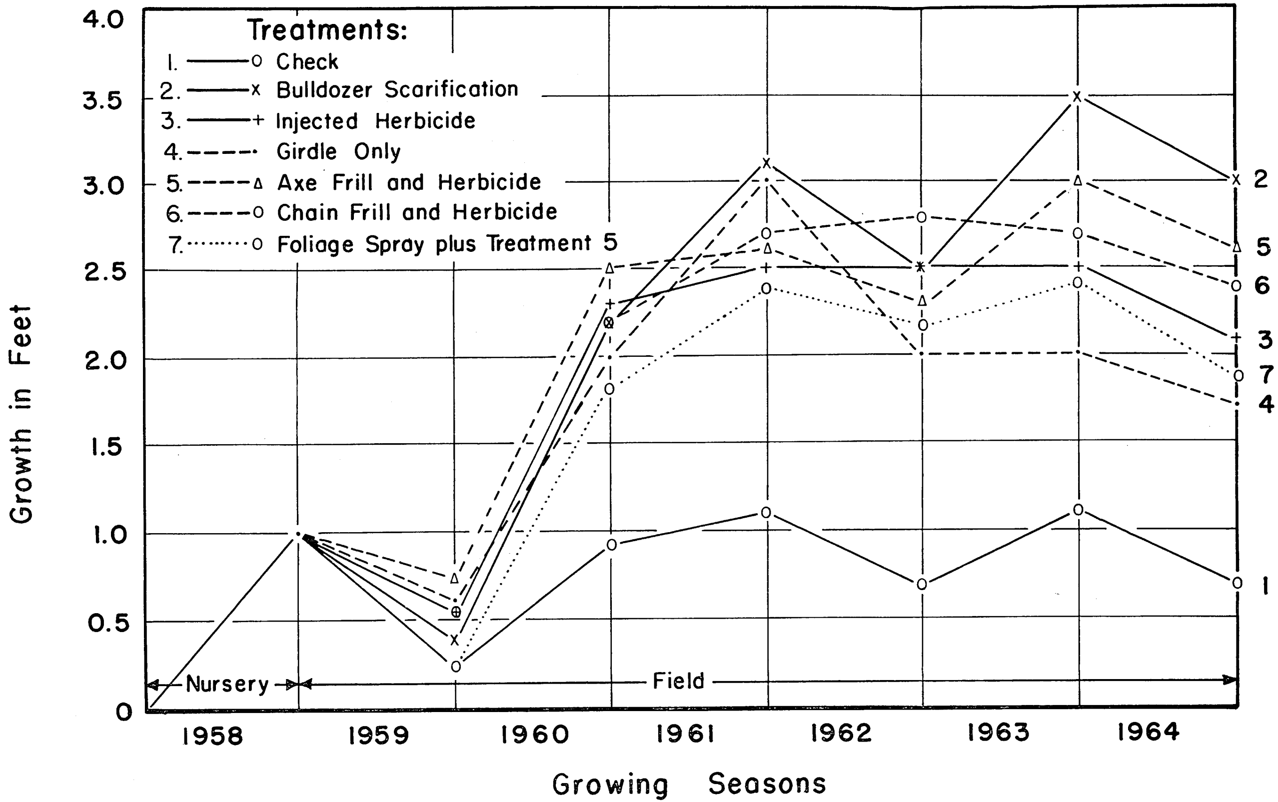

FIG. 3. Average annual height growth of planted loblolly pine by treatment.

Basal area per acre indicated large differences between treated plots and the control although the order of significant differences, as indicated by analysis of variance (Appendix Table 6) and multiple comparisons, was the same as the orders of differences observed for mean heights and mean diameters, i.e.:

Treatment:	2	5	6	3	4	7	1
Mean BA per acre (sq. ft.):	24.4	18.2	14.6	13.5	9.1	6.7	0.9

Six years after hardwood control treatments were applied treatment 7 had 7.4 times greater basal area than the control, while treatment 2 had 27.1 times greater.

Volume

Multiplying the basal area of each tree greater than 0.3 inches d.b.h. by the corresponding height and summing for each treatment plot to give an approximate index of volume, Table 2, indicated that the treated plots had a large superiority over the untreated check plot and also that large differences existed between treatments themselves. Analysis of variance of per acre volumes (Appendix Table 7) and Hartley's range test indicated the following order of significant differences ($P < 0.01$) between the various treatments:

Treatment:	2	5	6	3	4	7	1
Mean vol. per acre (cu. ft.):	421.5	308.0	230.6	207.8	131.0	108.4	10.4

Treatment 2 had approximately 1.5 to 40.5 times more cubic foot volume per acre than the other treatments. All hardwood control treatments resulted in volumes significantly greater than did no hardwood control treatment ranging from 10.4 times (treatment 7) to 40.5 times greater (treatment 2).

In an attempt to illustrate early stand development, the volume index data indicate the greatest differences between treated plots and the control although the order of differences was the same as the order observed for mean heights, mean diameter, and mean basal area. The number of significant differences, however, was greater with the volume data than with the other mensurational data. Only treatments 6 and 3, and treatments 4 and 7 were indicated as similar with the volume analysis while the other mensurational data analysis indicated that numerous treatments were similar. The above data indicate that although mean height, mean diameter, and mean basal area data are necessary and important in understanding early stand development, the best criterion from the present study for assessing early stand development is total cubic foot volume which encompasses all measurements into one.

Resurgence of Hardwoods

None of the hardwood control treatments applied in this study completely eradicated hardwoods. However, the number of hardwood stems competing with pine was significantly reduced by scarification and herbicide treatments. This was evident not only from number of hardwood stems remaining but by response of the pine in height, diameter, survival, volume, and basal area. Figure 4 shows the total number of hardwood stems by size classes present at the end of the fifth growing season. The greatest numbers occur on plots where the overstory stand was more completely killed, i.e., treatments 2, 3, 5, and 6. However, most of the stems, 60 to 80 per cent, were under 4 feet in height and offered little competition to the pine. The scarification plots had the greatest total resurgence of hardwood but 83 per cent of these were under 4 feet in height and 99.6 per cent were under 1 inch in d.b.h. Thus the data indicate that the understory hardwoods, as well as the pine, responded to a release from the competing overstory.

The girdle only treatment (treatment 4) resulted in an immediate kill of the treated stems but sprouting was so profuse that any advantage gained by the girdling was quickly overcome. Treatment 7, foliage spraying, actually had less hardwood stems after 5 growing seasons than did the check plot. However, the adverse effect of the spray on the young pine and the size of the existing hardwood stems[5] retarded the development of the pine.

The linear correlation coefficient (r) between numbers of hardwood stems greater than 1 inch d.b.h. and total cubic foot volumes was 0.88, significant at the one per cent level[6]. This correlation indicates that larger hardwood stems were the most serious competitors with the pine, as the fewer the number of hardwoods over 1 inch d.b.h., e.g., on treatment 1, the greater was the total volume of pine.

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[5] Many stems over 25 feet in height but less than 4 inches d.b.h. were unaffected by treatment.

[6] Data of treatment 7 are deleted from this analysis since height growth of pine had been so adversely affected by foliage spray.

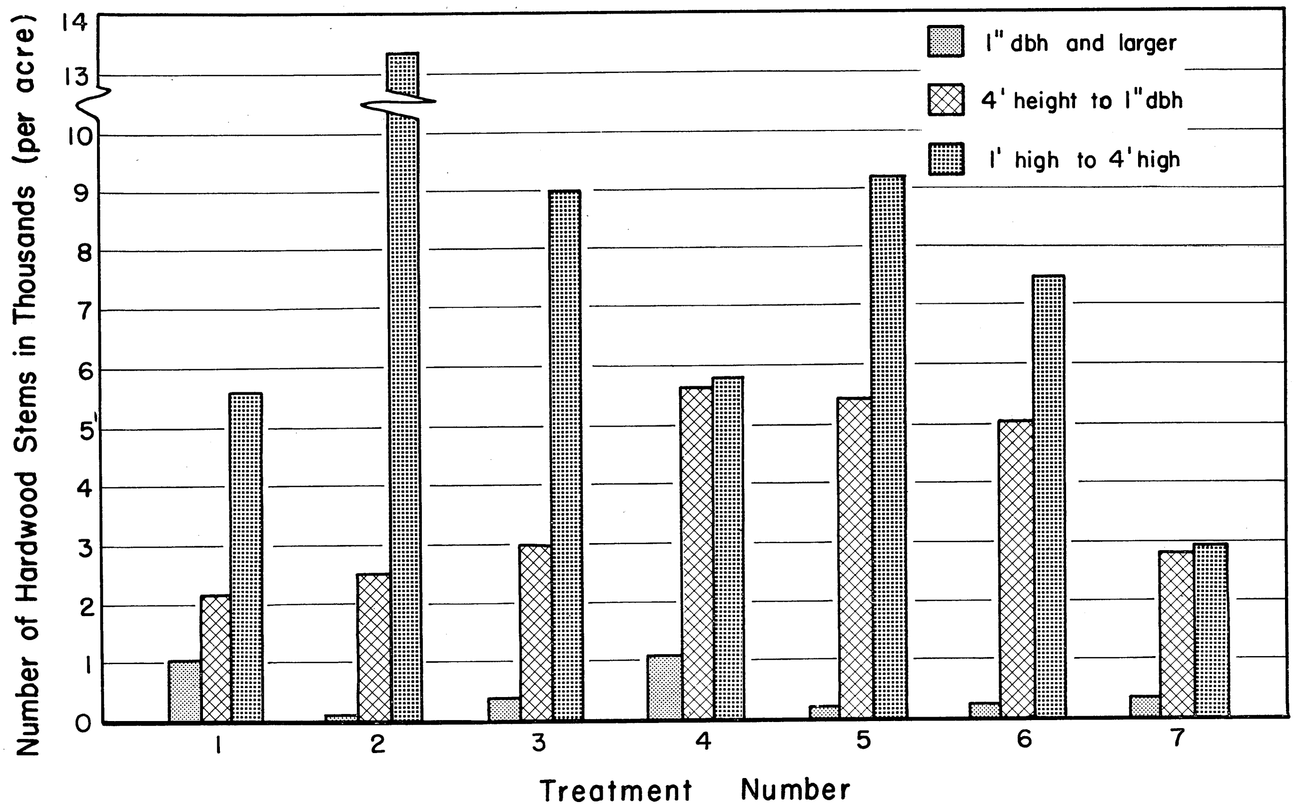

FIG. 4. Number of hardwood stems by treatment and size class five years after treatment.

An adverse effect of the hardwood control treatments was the influx of muscadine grape and other vines into the plots. The weight of these vines often resulted in deformed pine stems and even death of some trees.

Cost Estimates

Table 3 shows initial cost per acre for establishing each treatment. Planting costs, including the cost of both seedlings and planting, were $14 per acre for all treatments except scarification, which was $12 per acre because of the greater ease of planting on open ground. Total costs ranged from $14 per acre for the check to $25 per acre for the foliage spraying treatment.

The initial costs per acre are shown compounded for 6 years at 6 per cent interest in Table 3. Dividing this compound cost by the sum of all heights per plot and multiplying by a factor of 10 gives the cost per 10 feet of height growth. Expressed in this manner, costs per 10 feet of height growth were least for treatments 2, 3, and 5 and approximately twice as great for treatments 1 and 7 with other treatment costs falling between these extremes, Table 3. It was felt by the authors that an expression of compounded cost in terms of resulting growth would yield more realistic comparison figures than would costs alone.

Comparison to Old-Field Plantation

In an attempt to compare the development of plantations established under hardwood control treatments with development of an old-field plantation, 15 trees from a 15-year-old loblolly plantation, established on an old field, were sampled by standard stem analysis procedures. The old field was on the same soil type and had the same aspect as the hardwood control study area and consequently, was assumed to have comparable site conditions. Stems were sampled from a range of diameters and a height over age curve plotted. Linear regression lines of the form $Y = bX + a$, where Y = height, and X = age, were derived from these data and the data of the current study, Figure 5. The correlation coefficients (r) between age and average height for each of these situations, are reported to indicate the degree of relationship between height and age at this early age (Appendix Table 8).

These data imply that plantations developed under hardwood control treatments were not equal in development to an old-field

TABLE 3. TIME AND COST OF TREATMENT ON A PER ACRE BASIS

Treatment	Time				Cost				
					Materials		Total		Per 10 ft. of height growth
	Treat.	Plant.	Equip.	Labor and equip.	Chem.	Plants	Time and material	Comp. to 6 yrs.	
No. Description	*Hr.*	*Hr.*	*Hr.*	*Hr.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
1. Check (no treatment)	0.00[1]	10.0[1]	0.00[2]	10.00	0.00[3]	4.00	14.00	19.86[4]	0.070
2. Bulldozer scarification	3.85	8.0	2.61	19.67	0.00	4.00	23.67	42.48	0.043
3. Injected herbicide	3.16	10.0	0.00	13.16	2.56	4.00	19.72	35.39	0.044
4. Gridle only (no herbicide)	4.37	10.0	0.00	14.37	0.00	4.00	18.37	32.97	0.050
5. Axe frill with herbicide	5.41	10.0	0.00	15.41	0.94	4.00	20.35	36.53	0.041
6. Chain frill with herbicide	6.89	10.0	0.00	16.89	1.15	4.00	22.04	39.56	0.047
7. Foliage spray (plus treatment 5 on overstory)	2.36	10.0	0.19	12.94	8.57	4.00	25.51	45.79	0.100

[1] All labor charged at $1.00 per hour.
[2] Equipment involved the use of a caterpillar tractor (RH-4) and the operating cost was set at $3.00 per hour, not including operator.
[3] Chemical cost $6.09 per gallon and diesel fuel $0.12 per gallon.
[4] Compound interest rate of 6 per cent.

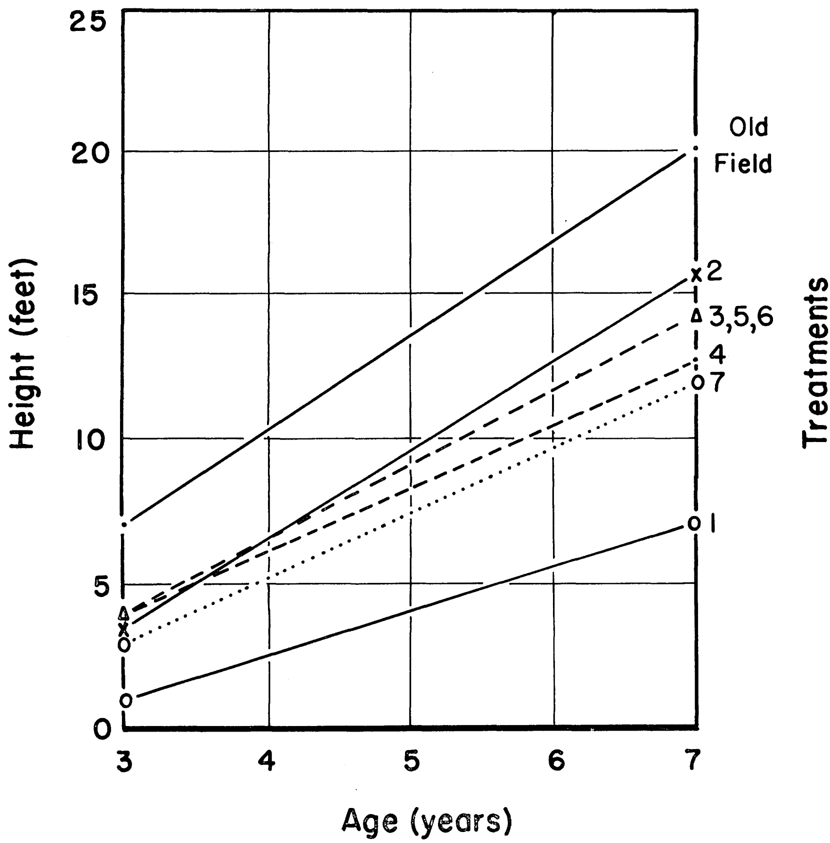

FIG. 5. Comparisons of early height growth between an old field plantation and the experiment plantation receiving hardwood control treatments.

plantation of the same age, species, and site. The average height of stems on the best hardwood control treatment, scarification, was only 78 per cent as tall as the average height of stems from the old-field plantation. The advantage of the old field can probably be attributed to residual fertility from past land-use practices and, because there were no competing hardwoods, more available moisture. The average heights of pine on the other hardwood control treatments ranged from 27 per cent to 71 per cent as tall as the average height of the stems of the old-field planting.

DISCUSSION

Much of the variation in survival and growth of the planted pine can probably be explained by variations in available soil moisture, soil nutrients, and light as influenced by the degree of hardwood control achieved by various conversion procedures. The best development of planted pine was on scarified plots (treatment 2) and, although it is not known whether or not the differences in development resulted from variations in light, nutrients, and moisture, it is not unreasonable to assume that all contributed to the development of pine. Other studies have indicated similar effects of hardwood competition on light and soil moisture availability, (3,13).

Data from the present study indicate that pine planted under treatments that were only partially effective in hardwood control, i.e., treatment 4, girdle only, are in need of release if the planted pines are to adequately survive and develop to produce a fully stocked stand. However, the preceding data and field observations indicate that treatment 2, scarification, treatment 3, injector-applied herbicide, treatment 5, axe frill and herbicide, and treatment 6, chain girdle and herbicide, have resulted in conditions that are now ready to support relatively well-stocked vigorous pine stands of much greater value than the pre-existing hardwood cover.

SUMMARY

Data presented indicate that various hardwood control techniques can be used to convert low-value hardwood stands to higher value pine stands on upland sites at costs not unreasonable. The data suggested that, although height, diameter, survival, and basal area data are necessary in depicting early development of plantations, they may be misleading and not entirely complete. Total cubic foot volume data gave the most accurate picture of early stand development in this study. Data on early growth and development of planted loblolly pine following various hardwood conversion procedures are presented. Bulldozer scarification, injector-applied herbicide, axe frill and herbicide, and chain girdle and herbicide show the most promise as methods of converting hardwood stands to vigorous pine stands. It is suggested that anything less than a complete removal of hardwoods (at least to one inch diameter at groundline) will result in the need for a hardwood cleaning to release the pine soon after the initial treatment.

Variations in survival and growth of the planted pines are attributed to variations in available soil moisture, nutrients, and light as influenced by the degree of hardwood control achieved by the various conversion procedures.

In comparing the development of the hardwood control treated stands with an old-field plantation it was found that the treated stands were not developing as rapidly as were nearby older plantings in an old field at an equivalent earlier time.

FIG. 6. Stand conditions six years after treatment of a check plot, upper left; bulldozer scarified plot, upper right; herbicide treated plot, lower left; and girdle only plot, lower right.

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APPENDIX

APPENDIX TABLE 1. ANALYSIS OF VARIANCE OF NUMBERS OF SURVIVING LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	209	5,175.524	
Replications (R)	4	275.048	67.762
Treatments (T)	6	2,957.791	492.965[1]
Error (a) R×T	24	1,321.351	55.056
Year (Y)	5	331.810	66.362[1]
T × Y	30	58.723	1.957
Error (b) R×Y+R×Y×T	140	230.801	1.649

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 2. ANALYSIS OF VARIANCE OF NUMBERS OF EXCELLENT VIGOR LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	34	2,621.543	
Replications	4	50.686	12.671
Treatments	6	2,158.743	359.790[1]
Error	24	412.114	

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 3. ANALYSIS OF VARIANCE OF MEAN HEIGHTS OF LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	209	4,062.730	
Replications (R)	4	4.530	1.130
Treatments (T)	6	496.230	78.200[1]
Error (a) R×T	24	139.890	5.830
Year (Y)	5	3,120.290	624.060[1]
T × Y	30	232.690	7.760[1]
Error (b) R×Y+R×Y×T	140	69.100	0.490

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 4. ANALYSIS OF VARIANCE OF THE NUMBER OF HARDWOOD STEMS 1.1 INCHES D.B.H.

Source of variation	D.F.	Sum of squares	Mean square
Total	34	207	
Replications	4	7	1.750
Treatments	6	96	16.000[1]
Error	24	104	4.333

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 5. ANALYSIS OF VARIANCE OF MEAN DIAMETERS BREAST HIGH OF LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	34	17.000	
Replications	4	0.410	0.102
Treatments	6	13.190	2.198[1]
Error	24	3.400	0.142

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 6. ANALYSIS OF VARIANCE OF MEAN BASAL AREA PER PLOT OF LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	34	5.703	
Replications	4	0.210	0.052
Treatments	6	4.333	0.722[1]
Error	24	1.160	0.048

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 7. ANALYSIS OF VARIANCE OF CUBIC FOOT VOLUMES OF LOBLOLLY PINE SIX YEARS AFTER PLANTING

Source of variation	D.F.	Sum of squares	Mean square
Total	34	1,859.366	
Replications	4	65.451	16.363
Treatments	6	1,337.890	222.982[1]
Error	24	456.025	19.001

[1] Denotes significance at the 0.01 level.

APPENDIX TABLE 8. REGRESSION COEFFICIENTS AND CONSTANTS FOR REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS (r) FOR DATA BETWEEN HEIGHT AND AGE OF LOBLOLLY PINE FROM AN OLD-FIELD PLANTATION AND HARDWOOD CONTROL TREATMENTS

Treatments	b	a	r
2	3.02	5.52	
3, 5, 6[1]	2.57	3.78	0.999
4	2.14	2.36	0.994
1	0.90	0.52	0.997
7	2.24	3.62	0.999
old field	3.25	—2.72	0.922

[1] Since average heights of pine were similar under herbicide treated plots, one regression was derived from the combined data of treatments 3, 5 and 6.