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Regeneration After Shear Felling and Chipping of Upland Hardwoods

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SUMMARY

Low-quality hardwood stands on the Cumberland Plateau and the Western Highland Rim were harvested by shear felling and on-site chipping. Methods for introducing loblolly pine (*Pinus taeda* L.), white pine (*P. strobus* L.), shortleaf pine (*P. echinata* Mill.), and yellow-poplar (*Liriodendron tulipifera* L.) seedlings into these stands with minimum or no site preparation were explored. The effect of limited site preparation on natural regeneration was also evaluated. The desirability of intentional development of planted pine-natural hardwood mixtures was studied. Intensive harvest was found to be a key to reduced site preparation needs.

ACKNOWLEDGEMENT

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INTRODUCTION

A great acreage of low-quality forest has developed in the Cumberland Plateau region because of fire, poor cutting practices, insects, disease, and poor site quality (McGee 1982). A key to improved management of these low-quality stands, many of which need to be regenerated, is intensive utilization of the low-quality products generally found on the area.

Intensive utilization, in concept, accomplishes several goals. First, it implies that most of the timber on an area will be used by the purchaser and therefore stumpage returns will be greater than would be the case with less intensive utilization. Second, intensive utilization removes most of the low-quality trees and reduces the effort needed to prepare the area for the next crop of trees. Intensive utilization can range from traditional pulpwood and sawlog removal with firewood cutting to shear felling and on-site chipping as discussed in this paper.

The process of shear felling and whole-tree chipping has many silvicultural advantages in the Cumberland Plateau region, but there can also be problems. The practicality of felling trees by shearing and then chipping whole trees on the site depends to a great extent on the lay of the land and access. The rolling slopes of the plateau tops and much of the Eastern and Western Highland Rim are conducive to shearing. However, the steepness of some of the slopes on the Western Rim, the Ridge and Valley, and the Plateau Escarpment precludes the use of mechanized shearing. Efficiency of operation also requires sizable acreages in order for a harvesting operation to be worthwhile to a logging contractor. If the chipping is to be done on site, as reported here, the chip vans require good roads.

Problems can be caused by very large trees and/or many very small trees. The intensity of the problems caused by large and small trees depends to a great extent on the kind of equipment used. Some workers have observed that sheared hardwoods tend to sprout less than those cut with chain saws (Miller and Phillips 1984). A problem to guard against is a tendency to shear and chip trees that could be used for higher value products. This wasteful practice can be avoided by logging high-quality trees in advance of the shearing or by collecting the high-quality logs separately as part of the skidding and shearing process.

This paper documents regeneration response 5 years after shear felling on the Cumberland Plateau and 3 years after shear felling on the Western Highland Rim. Both natural and artificial regeneration are evaluated on these areas. Since the harvesting and regeneration procedures reported here involve minimal or no site preparation, attention has been given to the development of natural hardwoods in planted stands. The pros and cons of the resulting mixed stands are discussed, with particular emphasis on the loblolly pine-hardwood mixture. Earlier results have been reported in previous papers (McGee 1980, Sims and others 1981).

THE CUMBERLAND PLATEAU

Objectives

This study compared the growth and development of planted loblolly pine, white pine, and yellow-poplar (see Appendix for scientific names) to natural regeneration on sites where all standing vegetation >4 inches d.b.h. has been sheared and chipped. Evaluations were made of what effects herbicide injection of residual trees had on stand development.

Study Area

The study area, on land belonging to the University of the South near Sewanee, TN, was typical of Cumberland Plateau land that has been logged and burned at irregular intervals. The 37-acre area, classified as landtype 1 (Smalley 1982), has broad undulating ridges with occasional outcroppings of rock. The soil is mostly Hartsells sandy loam. Site indexes ranged from 55 to 75 feet for oak at 50 years. Accurate site-quality appraisals were impossible to obtain because suitable overstory index trees were lacking, but the site is capable of producing better timber than was harvested at the time the study began.

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Before harvest, the study area supported a sparse overstory, many intermediate trees, and a variety of plants in the understory (table 1). The overstory contained about 135 trees per acre, mostly scarlet oak and white oak. Almost all of the overstory trees over 12 inches d.b.h. were culls from previous harvests. Only about 30 trees on the area were of sawtimber size and quality. Some intermediate trees, over 4.5 feet tall but less than 5 inches d.b.h., had invaded the area following irregular cutting, but many intermediate trees, particularly white oak, were 60 to 80 years old.

There were 7,050 stems per acre less than 4.5 feet tall. Most were very small, and distribution was variable. Because of large relicts and many small stems, this tract was less than optimal for shearing and chipping, but it was typical for the Cumberland Plateau.

Harvest

The harvest began in September 1976 and was completed by November. Trees sheared by a tracked feller-buncher were skidded to a central site and fed into the chipper. Chips were stored on the ground and hauled to the pulpmill. The 30 sawtimber trees scattered throughout the stand were cut with chain saws.

The 37 acres yielded about 1,200 green tons of chips (32.4 tons/acre). In the shearing operation, almost all stems ≥4 inches d.b.h. were felled. However, from 50 to 500 stems per acre (mostly 2 to 3 inches d.b.h.) remained on the site (figs. 1 & 2).

The major impact of logging on soil occurred at the central chipping location. The skidding, piling of chips, and hauling shown in figures 3 and 4 affected 1.5 acres, of which 0.75 acre was seriously compacted. Little soil movement resulted from logging disturbance, and no soil deposition was observed in Jackson Lake a few hundred feet away.

Design

Twenty-four 1-acre plots were established away from the central area of compaction, and within each 1-acre plot a central area slightly larger than 0.25 acre was delineated for measurements. Six plots each were randomly designated for: (1) planting 1.0 loblolly pine, (2) planting 2.0 white pine, (3) planting 1.0 yellow-poplar, and (4) natural regeneration. All residual trees >4.5 feet tall on three randomly selected plots in each of the four categories were injected with herbicide (picloram plus 2,4-D) during the winter following harvest. Plots receiving this treatment are referred to as "injected plots." Plots not receiving the herbicide treatment are referred to as "uninjected."

Seedlings were planted in March 1977 at 8- by 10-foot spacings. Survival, height, and relationship to competition were determined on the central measurement areas; these measurement areas contained 143 seedlings, with each planting space representing an 8- by 10-foot subplot. So that comparisons could be made between natural regeneration and planted trees, 143 8- by 10-foot subplots were established in each of the 6 plots assigned to natural regeneration. Heights of planted seedlings were compared to the heights of the tallest desirable tree on each natural regeneration subplot.

Results

Survival.—After five growing seasons, survival of planted loblolly pine, white pine, and yellow-poplar was ≥90 percent (table 2). The small amount of mortality between the second and fifth year was quite surprising because growing conditions were less than ideal due to several droughts and a severe ice storm. In natural regeneration areas after five growing sea-

Table 1.—*Preshearing inventory of a Cumberland Plateau forest*

Species	Stem Size: Height <4.5 feet	Height >4.5 feet; d.b.h. <5 inches	d.b.h. ≥5 inches	Stems per acre (average)
	Number Per Acre			
Blackgum	1050	350	1	1401
Red maple	575	140	2	717
Dogwood	2400	220	5	2625
Sassafras	1450	170	...	1620
Hickory	275	278	16	569
White oak	600	462	45	1107
Post oak	....	10	12	22
Black oak	250	155	12	417
Scarlet oak	150	58	41	249
Sourwood	175	355	1	531
Yellow-poplar	25	....	...	25
Other species	100	38	...	138
Total	7050	2236	135	9421

Figure 1.—*A low-quality hardwood stand on the Cumberland Plateau following harvest by shearing with a tracked feller-buncher to a 4-inch diameter limit.*

Figure 2.—*Trees harvested by shear-felling waiting to be chipped.*

Figure 3.—*Tree being fed into chipper; chips are being piled before loading.*

Figure 4.—*Chips being loaded into a van; vans require roads that are in relatively good condition.*

Table 2.—*Survival of planted seedlings and natural regeneration on the Cumberland Plateau*

Species	Survival at 2 years		Survival at 5 years	
	Injected[1]	Not injected	Injected	Not injected
	Percent			
Loblolly pine	94	96	91	92
Yellow-poplar	98	99	96	97
White pine	95	96	90	93
Natural regeneration[2]	92	83	87	73

[1]Injected = plots where hardwoods >4.5 inches d.b.h. were injected with picloram 2,4-D; not injected = plots where hardwoods were not injected.

[2]Numbers in this row indicate percentage of subplots that contain at least one white oak, scarlet oak, black oak, yellow-poplar, black cherry, hickory spp., or other desirable species.

sons, 80 percent of the 8- by 10-foot subplots contained one or more white oak, scarlet oak, black oak, yellow-poplar, hickory spp., black cherry, or other desirable species. The number of subplots containing desirable trees dropped by about 7 percent between the second and fifth year (table 2).

Height Growth.—Two years after study initiation there was little difference among average heights or heights of the tallest trees among planted loblolly pine, planted yellow-poplar, and desirable natural regeneration, but all were taller than planted white pine (table 3).

After 5 years, loblolly pines were substantially taller than yellow-poplar, white pine, or desirable natural regeneration. However, due to a great deal of within-plot variation, analyses of variance were not significant. Desirable natural trees growing on plots that had not received the injection treatment were taller than those growing on injected plots. Height ranges for the 200 tallest planted trees per acre/over the 6 plots after 5 years were: loblolly pine, 12.7 to 14.6 feet; white pine, 6.5 to 7.0 feet; yellow-poplar, 8.2 to 10.7 feet; and desirable natural saplings, from 7.8 to 11.7 feet.

Within-plot variation for average heights after 5 years was substantial for all species except white pine. However, calculated variances are greately reduced when only the 400 and 200 tallest trees per acre are included. Loblolly pines planted in injected plots (fig. 5) are much more uniform in height than those planted in plots where residuals had not been injected (fig. 6). Variances in height for the average, 400 tallest, and 200 tallest loblolly stems per acre were (respectively) 4.54, 1.70, and 0.76 for injected plots compared to 7.69, 3.14, and 1.26 on plots not receiving the injection treatment. Variances in height for the desirable natural stems in injected plots were 7.66, 4.92, and 2.41 for average, 400 tallest, and 200 tallest stems per acre, respectively, compared to 13.18, 11.81, and 3.80 for plots not receiving the injection treatment.

Competition.—Shearing to a 4-inch d.b.h. limit had left occasional dense clumps of red maple, sourwood,

Figure 5.—*Three-year-old loblolly pines planted on sheared area where residual hardwoods had been injected with herbicide.*

Figure 6.—*Three-year-old loblolly pines planted on sheared area with no additional site preparation. Many of the residual hardwoods have increased substantially in size and provide serious competition to individual planted loblolly.*

Table 3.—*Average heights of planted seedlings and natural regeneration two and five growing seasons after shear felling on the Cumberland Plateau*

Species	Treatment of residuals	After 2 years			After 5 years		
		Stand average	Tallest 400 per acre	Tallest 200 per acre	Stand average	Tallest 400 per acre	Tallest 200 per acre
		Feet					
Loblolly pine	Injected	3.7	4.1	4.6	11.7	12.5	13.6
	Not injected	3.7	4.0	4.5	10.5	11.8	13.2
Yellow-poplar	Injected	3.0	3.4	4.0	6.3	7.2	8.7
	Not injected	3.2	3.6	4.2	7.2	8.2	9.5
White pine	Injected	1.5	1.7	2.0	5.1	5.8	6.7
	Not injected	1.6	1.8	2.0	5.0	5.7	6.7
Natural regeneration[1]	Injected	2.7	3.3	4.3	6.3	7.2	9.0
	Not injected	3.6	4.2	5.7	7.9	8.3	11.0

[1]Natural regeneration includes white oak, scarlet oak, yellow-poplar, black oak, hickory spp., black cherry, and others.

Table 4.—*Competitive position of planted trees in relation to hardwood residuals 5 years after shear felling on the Cumberland Plateau*

Species	Residuals injected[1]			Residuals not injected		
	Free to grow	Not free to grow	Dead	Free to grow	Not free to grow	Dead
	Percent					
Loblolly pine	62	28	9	32	61	7
Yellow-poplar	5	91	3	6	92	2
White pine	31	88	10	20	72	8

[1]Residual hardwoods >4.5 inches d.b.h. were injected with picloram 2,4-D prior to planting of seedlings.

dogwood, sassafras, blackgum, oaks, and other species, while sizable patches had little or no vegetation. Herbicide injection had reduced the number of live residuals over 4.5 feet tall from about 400 to 32 per acre on the 12 plots receiving this treatment.

Height growth of planted trees did not show much variation between injected and uninjected plots after either 2 or 5 years. However, seedlings planted on injected plots had a stronger crown position; loblolly seedlings in particular had a very high percentage of free-to-grow seedlings on the injected plots (table 4). Only 8 percent of the loblolly planted on injected plots were judged to be seriously affected by competition while 36 percent were seriously affected in uninjected plots. About one-half of the yellow-poplar and one-third of the white pine were seriously affected by the hardwood competition on injected plots (fig. 7).

Distribution of Natural Regeneration.—The distribution of desirable natural regeneration had not changed much between the second and fifth growing seasons. White oak, scarlet oak, black oak, and hickory continued to be the tallest and best distributed of the desirable species (table 5) (fig. 8). The subplots lacking desirable stems increased from 12 to 15 percent. About 35 to 40 percent of the desirable stems described in table 5 were free to grow. Some of the desirable stems received competition from residual trees in the uninjected plots, and some of the competition was from stems of other desirable species. How-

Figure 7.—*Five-year-old planted white pine on sheared area where residuals were injected with herbicide.*

Table 5.—*Distribution of desirable natural regeneration in unplanted plots on the Cumberland Plateau by number of subplots occupied by a particular species*

Tallest desirable species	After 2 years	After 5 years
	Subplots Per Acre[1]	
White oak	216	192
Scarlet oak	132	124
Black oak	72	64
Yellow-poplar	24	20
Hickory spp.	28	64
Black cherry	16	12
Other species	12	12
No desirable species present	72	84

[1]Numbers are based upon the tallest desirable stem in each of the 8- by 10-foot subplots. For example, white oak was the tallest desirable tree on 216 subplots per acre after 2 years.

ever, most of the competition to desirable natural regeneration was from the several hundred sourwood, dogwood, blackgum, and other stems per acre that had resprouted.

Loblolly Pine-Hardwood Mixture.—It now appears that even on the injected plots, where 62 percent of the planted loblolly were free-to-grow, the subsequent stand will be a pine-hardwood mixture. On the uninjected plots, where 32 percent of the loblolly were free-to-grow and 36 percent were judged to be seriously affected by the competition, hardwoods will be a more important factor. While freedom to grow is an important consideration in evaluating a tree's future prospects, the actual height of the tree in relation to competition is also of interest. All of the free-to-grow trees were taller than the competition, but not all of the loblolly taller than the competition, were judged completely free-to-grow. When the heights of the loblolly pine on each subplot are compared to the heights of competing hardwoods (fig. 9), the considerable influence of the injection treatment is apparent.

After 2 years, only 26 percent of the loblolly on injected plots was as tall or taller than all other vegetation on each subplot. This percentage increased markedly each year so that after 5 years, 84 percent of the loblolly pines matched or exceeded the height of the hardwoods. If desirable hardwoods are included where either a pine is dead or where a taller competing hardwood is a desirable species, the percentage of planted pine plus desirable hardwoods that are taller than the competition increases to 37 and 90 percent after 2 and 5 years.

On the uninjected plots only 11 percent of the planted loblolly were as tall or taller than the competition after 2 years, and after 5 years the percentage increased to 52 percent. Including desirable hardwoods where pines have died or where a desirable hardwood is tallest on the subplot increases the percentage to 26 percent and 58 percent after 2 and 5 years.

While it is risky to forecast what will be the ultimate outcome in the struggle between the pines and the desirable and undesirable hardwoods, some short-term predictions can be made. The steady increase in dominance of pine and pine plus desirable hardwoods on the injected plots from 2 through 4 years and a slight decrease in the rate of increase between years 4 and 5 suggest that by age 10, at least 80 percent of the subplots will be occupied by a dominant pine or desirable hardwood (fig. 9). However, it is sheer speculation as to how long the increase in pine dominance

Figure 8.—*Five-year-old natural oak regeneration following shearing and injection of residuals.*

will continue on the untreated plots. A guess is that the percentage of the pines that are as tall or taller than the competition will not increase much more. Thus, at age 10, a 60 percent stocking of subplots with a dominant pine or desirable hardwood on the untreated areas may be a good estimate.

THE WESTERN HIGHLAND RIM

Objectives

Study objectives were to compare the growth and development of planted loblolly pine, shortleaf pine, and yellow-poplar to natural regeneration in stands where all stems >1 inch d.b.h. had been sheared and chipped and to evaluate the effect of no additional site preparation on stand development.

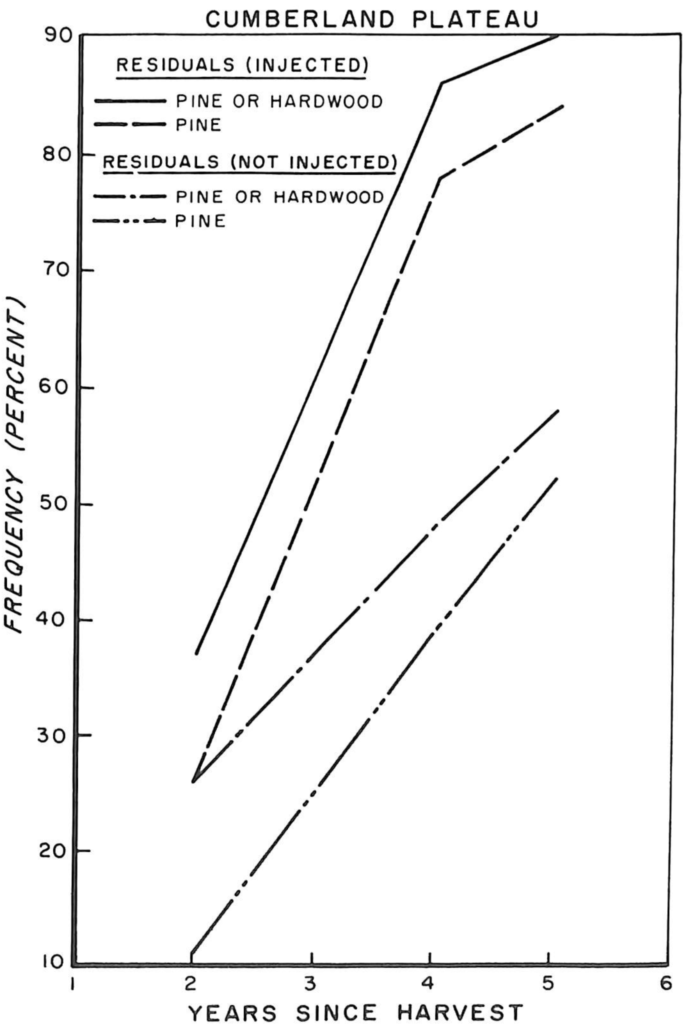

Figure 9.—*Frequency of pine or desirable hardwood being the tallest tree on an 8- by 10-foot subplot.*

Study Area

The 40-acre study area is typical of much of the hardwood forest of the Western Highland Rim. It is located in Humphreys County on the Duck River tract of land owned by Koppers Co. near Buffalo, TN. The area is characterized by narrow ridges containing Dickson silt loam shallow phase soil along the ridgetops. Soils along the slopes are mainly cherty Bodine. The hollows contain Humphreys silt loam soils. Site index, as roughly determined by on-site measurements, ranged from 57 to 74 feet for oak at 50 years.

Vegetation on the area was characterized by a moderate overstory, many intermediate stems, and an understory containing a wide variety of plants. The overstory contained about 190 stems per acre. Basal area averaged approximately 75 square feet per acre and included numerous culls and residuals left from logging 20 years earlier. White oak, hickory spp., post oak, and scarlet oak were the major overstory species. Black oak and sourwood were also present in the overstory. Blackgum, white oak, dogwood, the hickories, post oak, and sourwood were the chief components of the midstory. Scarlet oak, white ash, and sassafras were also part of the midstory, along with a few yellow-poplar. The understory contained 3,431 trees and 2,243 shrubs per acre.

The Harvest

Harvesting began in September 1980 and was completed in October. Trees were sheared by a rubber-tired feller-buncher (fig. 10) to a 1-inch d.b.h. limit. Most of the remaining stems were pushed over or broken during skidding. The trees were skidded to one of several chipping areas and decked until they could be fed into the chipper. The chips were fed directly into waiting vans.

After the skidding, the ridges and gentle slopes had a clean-swept look (fig. 11). In the narrow, steep hollows a few trees could not be reached by the feller-buncher, and about 20 trees were too large for the shear. These trees were felled by chain saw.

Study Design

The study contains thirty two 1-acre plots in 4 blocks in a completely randomized block design. Each block contains two plots each of planted loblolly pine, planted yellow-poplar, and planted shortleaf pine, and two plots designated for natural regeneration. One plot of each planted species and one plot of natural regeneration in each block was designated to receive competition control. At the time of this report no competition control beyond the initial harvest had been imposed on any of the plots. Each of the 32 plots contains a central measurement area slightly larger than 0.25 acre.

Figure 10.—*Hydro-Ax shearing low-quality white oak on Western Highland Rim.*

The loblolly, shortleaf, and yellow-poplar were planted in March 1981 at a 10- by 10-foot spacing. Comparisons between the planted seedlings and natural regeneration were made possible by identifying 121 10- by 10-foot subplots in each of the measurement plots selected for natural regeneration.

Survival and height measurements for loblolly, yellow-poplar, and natural regeneration were made 2 and 3 years after the study began. Unfortunately, almost all the planted shortleaf died shortly after the initial planting and were replanted a year later. Therefore, shortleaf pines are 1 year younger than other species.

Results

Survival.— After 2 growing seasons, survival ranged from acceptable to excellent (table 6). Only 3 of 968 planted yellow-poplars had died on the 8 measurement plots. Loblolly survival also was very good. In the unplanted natural stands, 80 percent of the subplots contained a desirable tree. The replanted shortleaf had a relatively low but acceptable 78 percent survival.

Following a drought during the third growing season and intensified attacks on loblolly pine by tip moths and sawflies, overall mortality increased along with the likelihood of future seedling loss (table 7). After 3 years, the survival of yellow-poplar was holding at 99 percent. However, 273 of the yellow-poplar suffered severe top dieback toward the end of the third growing season, and it is likely that many of these will not survive (table 8). Loblolly survival dropped to 89 percent. Survival on one plot of loblolly that had intensive sawfly infestation dropped from 93 to 80 percent. Survival of shortleaf decreased to 68 percent. Natural regeneration stocking after 3 years was holding at 80 percent.

Table 6.—*Survival of planted and natural regeneration after 2 and 3 growing seasons on the Western Highland Rim*

Species	Survival at 2 years	Survival at 3 years
	Percent	
Loblolly pine	94	89
Yellow-poplar	100	99
Shortleaf pine[1]	78	68
Natural mixture[2]	88	80

[1]Shortleaf were replanted; measurements are for survival at 1 and 2 years.

[2]Numbers indicate percentage of subplots that contain a white oak, scarlet oak, black oak, yellow-poplar, black cherry, hickory spp. or other desirable species.

Because planting of loblolly pine is widespread throughout the Western Highland Rim, mortality and damage to loblolly is worthy of careful study. After 2 years, 159 of the 913 loblolly pines had been damaged by sawflies (table 7). In addition, 91 seedlings had been damaged by tip moth and 38 had been browsed by deer. One year later, 641 loblolly pines (74 percent) had heavy tip moth damage, but only 6 showed any evidence of sawfly damage. Of the 50 loblolly pines that had died between the second and third growing seasons, most had been completely stripped by sawflies during the second (1982) growing season.

Height Growth.— Height growth for natural regeneration, planted loblolly (fig. 12), and yellow-poplar after the second growing season was generally acceptable, but height growth was disappointing following an exceedingly hot and dry 1983 growing season (table 9). Between years 2 and 3 the average height growth of yellow-poplar was only 1.2 feet and that of the tallest 200 trees averaged 1.7 feet. Consequently, only 121 (12 percent) of the yellow-poplar were as tall, or taller than their hardwood competitors.

The average loblolly grew from 3.8 feet to 5.3 feet between years 2 and 3; the tallest 200 per acre grew from 4.6 feet to 6.4 feet. About one-third of the loblolly were as tall or taller than adjacent hardwood competitors.

Desirable natural hardwood regeneration also showed the effects of the drought. Between years 2 and 3, average height increased only 1.7 feet for all

Figure 11.—*Two sites on the Western Highland Rim where low-quality hardwood stands had been sheared to a 1-inch d.b.h.*

Table 7.—*Insect damage to planted loblolly pines on the Western Highland Rim*

Year	No damage	Sawfly damage		Tip moth damage		Total number of trees
		Moderate	Heavy[1]	Moderate	Heavy	
	Number of Trees[2]					
1982 (2nd)	663	109	50[3]	91	....	913
1983 (3rd)	4	6	0	212	641	863

[1]Heavy = needles completely stripped from tree.
[2]Number includes loblolly planted on the eight 1/4-acre measurement plots.
[3]The 50 trees stripped by sawfly larvae made up the total loblolly pine mortality between 1982 and 1983.

Table 8.—*Dieback of planted yellow-poplar on the Western Highland Rim following the 1983 (third) growing season*

Living trees[1]	Amount of dieback		
	None	Partial	Complete
	Number		
962	574	115	273

[1]Trees living at end of 1983 growing season on the eight 1/4-acre measurement plots.

trees and 1.8 feet for the 200 tallest trees per acre.

The replanted shortleaf, 1 year behind the other planted species and the natural competition, did not grow much during the first growing season, and height growth between the first and second growing seasons was almost nil. The 1-year loss in growth, the drought, and deer browsing made it unlikely that the shortleaf could compete with the natural hardwood competition unless released.

Competition.—Residual standing vegetation following the shearing to a 1-inch d.b.h. limit was almost nonexistent. Only a few trees taller than 4.5 feet were left standing, and these were usually on the lower slopes where shearing and skidding were restricted. Thus all planted trees, desirable natural regeneration, and undesirable hardwoods began growth with complete freedom from overhead shade. The exception was the replanted shortleaf, which was shaded by competitors at the time of planting.

Distribution of Natural Regeneration.—White oak, hickory, yellow-poplar, and white ash made up over half the component of tallest desirable stems on the eight natural regeneration plots after 2 years (table 10). Due to the extremely hot and dry growing season the following year (1983), yellow-poplar and white oak dropped in frequency of occurrence. Yellow-poplar, in particular, declined, dropping from being the tallest desirable stem on 45 subplots per acre to being the tallest desirable on only 28 subplots per acre. Oaks will likely dominate the new stand, since they are the tallest desirable tree on about 200 of the 435 subplots per acre. After 3 years, about 62 percent of the tallest desirable trees on each plot were taller than the other competing hardwoods.

The Loblolly Pine-Hardwood Mixture.—Two years after planting, 21 percent of the loblolly was at least as tall as the competing hardwoods (fig. 13). However, if subplots are included where a desirable hardwood was the tallest hardwood, the stocking of dominant pine plus dominant desirable hardwoods becomes 50 percent. One year later, the percentage of subplots with a dominant pine had increased to 36 percent, and the percentage of subplots with a dominant pine or a dominant desirable hardwood had increased to 65 percent.

As part of the original study design, release was planned for four of the eight loblolly plots. At this time it appears that selective release could substantially improve the competitive position of about 60 percent of the loblolly. However, between years 2 and 3, about 16 percent of the loblolly improved their competitive position, and the trend appears to be for more pine to express dominance in the future. It appears that 50 to 60 percent of the loblolly will be dominant by age 5. Therefore, no release will be performed until the rate of recruitment into the dominant category drops significantly.

Figure 12.—*Two-year-old loblolly planted on area that had been sheared to a 1-inch d.b.h. on the Western Highland Rim.*

DISCUSSION

Low-quality hardwood stands often constitute major problems for forest managers who wish to increase the productivity of their forests. Intensive harvesting of low-quality stands as described in the above two studies provides numerous regeneration options. It is clear that intensive harvest can lead to relatively inexpensive natural or artificial regeneration. It is also clear that while certain levels of artificial regeneration successes can be achieved at very low cost, the level of success will increase with increased effort in site preparation. Another important point is that the sites described on the Cumberland Plateau and on the Western Highland Rim are at best only moderate sites for hardwood growth. Thus, the favorable results obtained from limited site preparation described here will not be reproduced on better sites where the competition from hardwoods would be more intense.

The results reported suggest three pathways for regeneration. These pathways are natural regeneration, artificial regeneration, and the deliberate development of planted pine-natural hardwood mixtures. Each method has advantages and disadvantages, the importance of which depends largely on the owner's or manager's objectives.

The natural hardwood regeneration that has developed following shearing to either a 4-inch or 1-inch d.b.h. limit has been very encouraging. The overall distribution of desirable trees has been good, and the relative dominance of desirable hardwoods over undesirable hardwoods is generally acceptable for all natural regeneration plots in both study locations. Thus it appears that if a low-quality stand is sheared, particularly to the 1-inch d.b.h. limit, no additional treatment is needed to insure the development of an acceptable stand of desirable hardwoods. One must recognize, however, that on these mediocre to moderate sites the volume of high-quality hardwood material produced will be limited. Nevertheless, these new

Table 9.—*Average height and competitive position of planted trees and natural regeneration on the Western Highland Rim following shear-felling*

Species	After 2 years: Average height	After 2 years: Height of tallest 200 trees per acre	After 2 years: Tree tallest[3] planted or desirable	After 3 years: Average height	After 3 years: Height of tallest 200 trees per acre	After 3 years: Tree tallest planted or desirable
	Feet	*Feet*	*Percent*	*Feet*	*Feet*	*Percent*
Loblolly pine	3.8	4.6	21.00	5.3	6.4	36
Yellow-poplar	2.8	3.6	7.00	4.0	5.3	12
Shortleaf pine[1]	0.9	1.1	0.24	. . .	. . .	. .
Natural regeneration[2]	3.9	5.6	50.00	5.6	7.4	62

[1]Shortleaf heights are for seedlings outplanted 1 year; there was very little growth the second year, so no data is listed for second-year growth.
[2]Heights of natural regeneration are based upon the tallest desirable tree in each of the 10- by 10-foot subplots.
[3]Percent of plots where the tallest tree was either a planted tree or a desirable hardwood.

stands will be far better than the low-quality stands that were harvested. The new stands will also be of considerable value for wildlife, as dominant oaks are plentiful in both areas. If natural regeneration is the goal, and only trees over 4 inches d.b.h are sheared, leaving large groups of residuals, chain saw felling of these residuals will provide release and a source of vigorous sprouts. A herbicide should *not* be used on oaks and other desirable species as was done in this study.

The effectiveness and advantages of artificial regeneration following shearing depend on the species planted and the needs of management. White pine offers tremendous opportunities for some landowners on the Cumberland Plateau. Large volumes of white pine can be grown on relatively poor sites in 40 to 60 years. Planting white pine following shearing is a good procedure. However, the slow early growth of white pine may make release in 4 to 6 years necessary in order to maintain a substantial number of dominant white pines in the stand. Actually, the herbicide injection applied at the time of shearing has not greatly favored the growth of white pine. A less expensive, more reasonable approach would be to plant white pine with no herbicide treatment following shearing, and then use release as needed at a later date.

Yellow-poplar survival was very high on both the Cumberland Plateau and the Western Highland Rim. However, height growth was less than spectacular at both locations. Because of poor height growth, only a small percentage of the yellow-poplar was free to grow, even on herbicide-injected plots on the Plateau. Thus the component of yellow-poplar that will ultimately prevail in these stands is highly speculative. Release would improve the chances of yellow-poplar becoming dominant, but site quality at both locations would preclude the production of large volumes of high-quality material.

Loblolly pine has been widely planted on the Plateau and Rim, usually following intensive site preparation. However, in recent years the high cost of site preparation has discouraged some owners from planting. The results of this study show that loblolly can be introduced into low-quality stands with little or no site preparation. However, the viability of this approach depends on the intensity of the harvest and the willingness of the owner to accept variable distribution of pines with a hardwood component.

The performance of the 5-year-old loblolly on the Cumberland Plateau study area is very encouraging in both injected and uninjected plots. The herbicide injection that reduced the number of residual stems from over 400 to about 30 per acre was considered reasonably effective. In plots where residual stems had been injected, 62 percent of the loblolly were judged completely free-to-grow and 84 percent were as tall as the competing hardwoods. In uninjected plots, only 32 percent of the loblolly were free-to-grow and 52 percent were as tall as the competition. Somewhat surprisingly, the percentage of dominant pines on the uninjected plots has continued to increase; an additional 13 percent outgrew the hardwood competition between years 4 and 5 (fig. 9).

While herbicide injection of residual hardwoods at the time of harvest was effective in increasing loblolly pine dominance on the Plateau, it is interesting that average heights of pine on injected plots vs. uninjected plots do not significantly differ after 5 years. However, there is greater uniformity in the loblolly pines in the injected plots, and eventually pine yields should be greater on these plots.

On the Western Highland Rim study area the planted loblolly received no release following the harvest of all trees whose d.b.h. was larger than 1 inch, and 36 percent were as tall or taller than the competing hardwoods after 3 years. Only 21 percent had been as tall as the competition after 2 years (fig. 13). Without further treatment many of the planted pines will never be dominant or codominant, but these pines have been introduced into the stand at no expense to the landowner except for planting costs. If the competing hardwoods were lopped after 3 years, loblolly would probably be dominant on 90 percent of the subplots after 5 years.

The selection of the best species to plant, the decision to accept natural regeneration, the determination of subsequent site preparation needs, and, certainly, the advisability of pine-hardwood mixtures are definitely subjects open to conjecture—depending on the objectives of management and specific conditions. However, it is very clear that, regardless of the pathway to regeneration, an intensive harvest of low-quality stands will make the pathway easier and less

Table 10.—*Distribution of desirable natural regeneration on unplanted plots on the Western Highland Rim by number of subplots occupied by a particular species*[1]

Tallest desirable species	After 2 years	After 3 years
	Subplots per acre[1]	
White oak	99	89
Hickory	56	53
Yellow-poplar	45	28
White ash	46	54
Post oak	35	34
Chestnut oak	22	19
Scarlet oak	23	22
Black cherry	18	12
Northern red oak	10	5
Black oak	11	14
Southern red oak	12	13
Blackjack oak	4	4
No desirable tree species present	54	88

[1]Numbers are based upon the tallest desirable stem in each of the 10- by 10-foot subplots. For example, white oak was the tallest desirable tree on 99 subplots per acre after 2 years.

expensive. Every tree that is used is one less tree that must be controlled or that will interfere with future stand development.

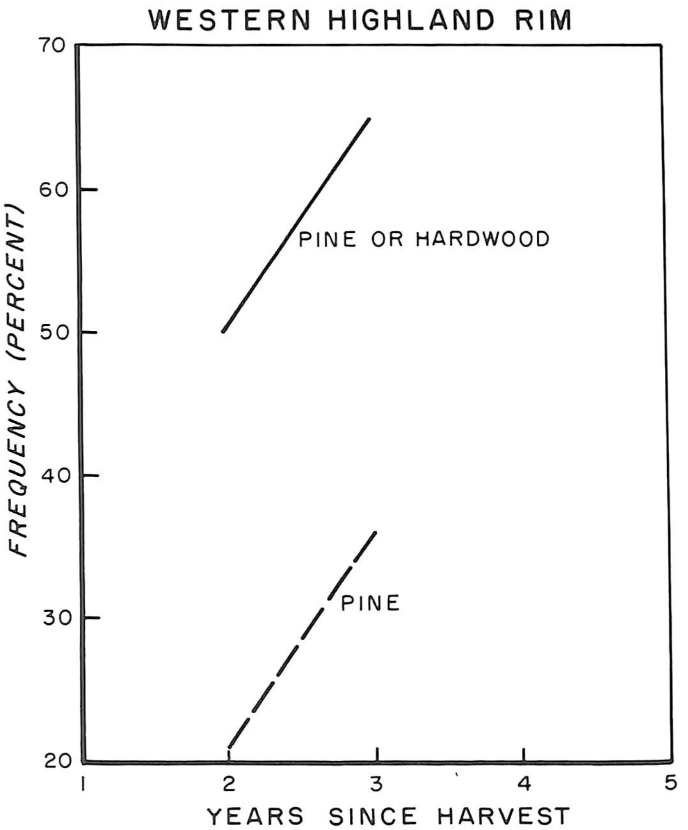

Figure 13.—*Frequency of pine or desirable hardwoods being the tallest tree on a 10- by 10-foot subplot.*

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APPENDIX

Common Names	Scientific Names
Ash, white	*Fraxinus americana* L.
Blackgum	*Nyssa sylvatica* Marsh.
Cherry, black	*Prunus serotina* Ehrh.
Dogwood	*Cornus florida* L.
Hickory	*Carya* spp.
Maple, red	*Acer rubrum* L.
Oak	*Quercus* spp.
black	*Q. velutina* Lam.
blackjack	*Q. marilandica* Muenchh.
chestnut	*Q. prinus* L.
northern red	*Q. rubra* L.
post	*Q. stellata* Wangenh.
scarlet	*Q. coccinea* Muenchh.
southern red	*Q. falcata* Michx.
white	*Q. alba* L.
Pine	*Pinus* spp.
loblolly	*P. taeda* L.
shortleaf	*P. echinata* Mill.
eastern white	*P. strobus* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) DC
Yellow-poplar	*Liriodendron tulipifera* L.

Discussion of chemicals in this paper does not constitute a recommendation for their use or imply that uses discussed here are registered. If herbicides are handled, applied, or disposed of improperly, they can harm humans, domestic animals, desirable plants, pollinating insects, and fish or other wildlife. Water supplies can be contaminated. Herbicides should be used only when needed and handled with care. Directions on the container label should be followed and precautions heeded.

McGee, Charles E. Regeneration after shear felling and chipping of upland hardwoods. Res. Paper SO-224. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1986. 13 p.

Intensive utilization of low-quality hardwood stands is suggested as a way to reduce site preparation requirements and improve regeneration. The benefits and problems associated with limited site preparation and pine-hardwood mixture are discussed.

Additional keywords: Natural regeneration, planted pines, pine-hardwood mixture, intensive harvest, Cumberland Plateau, Western Highland Rim.