

THINNING RESULTS FROM A MIXED UPLAND HARDWOOD STAND AFTER 35 YEARS

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Abstract.—A long-term study of precommercial thinning was installed in a 6-year-old oak-dominated stand regenerated by clearcutting in the southern Appalachian Mountains of North Carolina. Three levels of residual stand density were tested: control (no thinning), and 200, and 400 residual trees per acre (TPA). Objectives of the study were to determine the response of an upland hardwood stand to thinning based on diameter at breast height (d.b.h.) and basal area increment. Analyses indicated that mean d.b.h. for the 200 TPA thinning treatment was significantly larger at 11, 24, and 35 years after thinning. There were no significant differences in mean total basal area per acre between all treatments in any period, with the exception of 11 years after thinning, when control plots had significantly lower basal area. The 200 TPA thinning treatment did increase total basal area of the drier-site oaks that remained competitive. Results of this study suggest that young mixed-oak stands on low to intermediate quality sites respond in diameter growth to a single precommercial thinning treatment early in the stem exclusion stage of stand development where stand density is reduced to 200 or fewer trees per acre.

INTRODUCTION

Many mixed upland hardwood forest stands on low quality sites in the southern Appalachians have been cut over and are understocked, but well stocked stands have originated from one or more clearcuttings (Schnur 1937). A number of options are available for management of such fully stocked young stands (Gingrich 1971a), particularly thinning treatments (Dale 1968, Hilt 1979, Hilt 1982). Management decisions for the enhancement of timber production and wildlife habitat are important for landowners with low to moderate quality forest sites in the southern Appalachians. Marginal productivity and low quality of timber products cause forest managers to consider early stand treatments that will reduce competition for site resources and concentrate growth on potential crop trees.

OBJECTIVES

A study of precommercial thinning was initiated in the spring of 1971. Boyette and Brenneman (1978) reported results after 5 years. At the time this study was initiated, very little information on precommercial thinning effects in upland hardwood stands that are predominately oak was available. Guidelines for appropriate thinning treatments were difficult to establish for early stand development because of several factors that can influence release responses, such as species, thinning density, type of release, spacing, and species-site interactions (Hilt and Dale 1987).

The primary objective of the study was to examine response to precommercial thinning treatments in a recently regenerated oak-dominated stand on a low to intermediate quality site. This report presents results of that study based on data collected at 16, 30, and 41 years after harvest.

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STUDY AREA

The study site is in the Bent Creek Experimental Forest, about 10 miles south of Asheville, NC. Situated in the Blue Ridge Physiographic Province, Bent Creek is a 6,000-acre drainage basin that receives about 45 inches of precipitation annually. The study site is in the lower end of the basin, on an intermountain area of low relief and Piedmont-like terrain. Elevation at the study site is 2,200 feet. The area occupies the mid to lower portion of a long, south-facing slope. Soils are mostly a complex of eroded Evard-Cowee loams, a common series on broad ridges and relatively level areas of intermountain basins. The complex Typic Hapludults with solum depths greater than 40 inches, is relatively low in productivity with a site index (SI_{50}) of 65-70 feet base age 50 for upland oaks.

METHODS

This study was installed in a 6-year-old stand of stump sprouts and advance regeneration that originated from clearcutting a predominantly shortleaf pine (*Pinus echinata* Mill.) stand with a midstory of mixed hardwoods. The hardwood component consisted mainly of oaks (*Quercus* spp): scarlet (*Q. coccinea* Muenchh.), black (*Q. velutina* Lam.), white (*Q. alba* L.), chestnut (*Q. prinus* L.), southern red (*Q. falcata* Michx.), northern red (*Q. rubra* L.), and post (*Q. stellata* Wangenh.). Other hardwoods included red maple (*Acer rubrum* L.), yellow-poplar (*Liriodendron tulipifera* L.), and sourwood (*Oxydendrum arboreum* (L.) DC.). Scattered groups of white pine (*Pinus strobus* L.) had been planted before the previous timber stand was harvested. Site preparation consisted of clean felling residual stems greater than 4.5 feet in height. The young stand of natural regeneration was severely overstocked for optimum timber production.

Four replicates of two precommercial thinning treatments were installed and compared to a no thinning control. Study treatments consisted of: 1) thinning to 400 trees per acre (TPA); 2) thinning to 800 TPA; and 3) a control plot in which no thinning was done. Treatment plots were 0.25-acre in area with a 0.10-acre center measurement plot. Crop trees were selected based on criterion of species, uniformity of spacing, tree quality, and the potential to develop into sawtimber. The preferred crop tree species selected for release were drier-site oaks, then mesic-site oaks, and yellow-poplar. This procedure resulted in the selection of some intermediate and suppressed trees being selected as crop trees, especially in the 800-TPA treatment and the control plots.

Measurement trees in each plot were identified by tree number and followed over several measurement periods, which allowed for survival and growth of individual trees to be followed. The initial stem height measurements were made in early spring 1972, immediately following the installation of the precommercial thinning treatments. All crop trees were measured in the treated plots. Repeat measurements of height and d.b.h. of the selected crop trees were made in the spring of 1977, 1982, 1996, and 2007, at stand ages 11, 16, 30, and 41 respectively.

In 1977, 5 years following the initial precommercial thinning treatments, the 800 TPA treatment was modified. It was determined that thinning to 800-TPA was not severe enough to provide adequate growth response in comparison with the control or 400-TPA treatment. To determine if heavier thinnings were beneficial, the 800-TPA treatment was thinned to 200 TPA. The final thinning treatments were: 1) thinning to 400 TPA at age 6; (2) thinning to 800 TPA at age 6 and 5 years later thinning to 200 TPA; and (3) a control plot in which no thinning was done.

Table 1.—Stand density (TPA), total basal area (ft²/acre), mean d.b.h. (inches), and percent stocking levels by thinning treatment, stand age, and assessment year

	1982 Stand Age 16			1996 Stand Age 30			2007 Stand Age 41		
	Control	200	400	Control	200	400	Control	200	400
Trees per acre	417	209	415	242	179	223	233	177	205
Total basal area	18	24	34	92	64	71	130	95	100
Mean d.b.h.	2.5	4.5	3.5	7.9	8.5	7.4	8.9	10.5	8.4
Percent stocking level	<30	<30	40	85	58	68	110	80	90

Analysis of variance was used to identify significant differences (probability level $P < 0.05$) among thinning treatments. Response variables included mean d.b.h. (inches), basal area (feet² per acre), and TPA for each precommercial thinning treatment at the time of each measurement. SAS 9.1.3 Service Pack 3 General Linear Models Procedure was used for all statistical analyses (SAS Institute Inc. 2004).

RESULTS

Stand Density and Development

Between 1982 and 1996, the natural mortality in the unthinned control treatment was 42 percent, with stand density decreasing from 417 to 242 TPA (Table 1). The mortality in the 400 TPA thinning treatment was similar at 47 percent, decreasing from 415 to 223 TPA. During this same period, natural mortality in the 200 TPA thinning treatment was 14 percent, decreasing from 209 to 179 TPA.

On average the TPA remained constant for the three treatments during the period 1996 to 2007, while the mean d.b.h. growth has slowed down considerably from the previous period. Stand conditions were moving into fully stocked conditions with stocking levels of 58, 68, and 85 percent for the 200 TPA, 400 TPA, and unthinned control treatments, respectively, at stand age 30.

By the 2007 assessment (age 41 years), stand conditions have reached stocking levels of 80, 91, and 110 percent for the 200-TPA, 400-TPA, and unthinned control treatments, respectively (Table 1). The unthinned control treatment was at the overstocked stocking level prior to mid rotation and trees reaching small sawtimber size.

Mean d.b.h. Development

Mean d.b.h. for the 200-TPA thinning treatment was significantly larger than the 400-TPA thinning treatment and the unthinned control at each sample period (Table 2). Despite different mean diameters at age 16 between the 400-TPA thinning treatment and the unthinned control, there were no differences in mean d.b.h. between these two treatments as the stand matured between age 30 and age 41.

Differences were not detected when only dominant and codominant crop trees were assessed (data not shown). The mean d.b.h. growth increases were largest for the period between 1982 and 1996. Trends indicate that white pine grew to the largest mean diameters across all thinning treatments, followed by scarlet oak, yellow-poplar, chestnut oak, and white oak. Except for chestnut oak, mean d.b.h. for all other species was largest in the 200-TPA thinning treatment when compared to the 400-TPA and the unthinned control (Table 3).

Table 2.—Mean d.b.h.(inches) by thinning treatment and assessment year

Thinning Treatment	1982	1996	2007
	Stand age 16	Stand age 30	Stand age 41
Unthinned control	2.5 c	7.9 b	8.9 b
200 TPA thin	4.5 a	8.5 a	10.5 a
400 TPA thin	3.5 b	7.4 b	8.4 b
R ²	92	95	95

*Values with the same letter within the same measurement period are not significantly different at the P <0.05

Table 3.—Mean d.b.h. (inches) for selected species by thinning treatment, stand age, and assessment year

Species	1982			1996			2007		
	Stand age 16			Stand age 30			Stand age 41		
	Control	200	400	Control	200	400	Control	200	400
Yellow-poplar	3.1	4.5	3.9	7.9	8.0	7.5	9.7	10.5	9.1
Scarlet oak	2.1	4.7	3.6	6.5	8.4	8.0	7.9	10.9	9.8
Black oak	2.0	3.9	2.5	5.2	7.2	5.9	6.9	8.7	7.0
White oak	2.7	4.7	4.1	6.0	7.7	7.1	6.6	8.7	8.2
Chestnut oak	3.7	4.8	4.6	7.6	7.8	8.1	9.9	9.9	10.1
White pine	3.6	8.0	7.6	13.0	19.6*	14.3	15.4	23.2*	17.8

* d.b.h. from a single tree in thinning treatment

Table 4.—Mean annual basal area growth rate (ft²) and mean annual d.b.h. growth rate (inches) by thinning treatment from 1996-2007 (age 30 to 41 years)

Thinning Treatment	Mean annual basal area growth rate from 1996-2007 (age 30 to 41)	Mean annual d.b.h. growth rate from 1996-2007 (age 30 to 41)
Unthinned control	3.6 a	0.14 b
200 TPA thin	2.9 a	0.16 a
400 TPA thin	2.9 a	0.13 b
R ²	85	86

*Values with the same letter within the same measurement period are not significantly different at the P <0.05.

The mean annual d.b.h. growth rate for the 400-TPA thinning treatment was not significantly different from the unthinned control treatment (Table 4). The mean d.b.h. growth rate for the 200-TPA thinning treatment was significantly larger than the unthinned control and the 400 TPA treatment. This range of mean annual d.b.h. growth rate (0.13 to 0.16 inches) for these thinning treatments was similar to other thinned even-aged upland oak stands between ages 30 and 40 years with stocking levels between 45 and 65 percent (Gingrich 1971b).

Total Basal Area Development

In 1982, the thinning treatments resulted in significantly higher total basal area than the unthinned control treatment (Table 5). The total basal area per acre in the 400-TPA thinning treatment was almost double

Table 5.—Total basal area (ft²/acre) by thinning treatment, stand age, and assessment year

Thinning Treatment	1982 Stand Age 16	1996 Stand Age 30	2007 Stand Age 41
Unthinned Control	18 b	92 a	130 a
200 TPA Thin	24 a	64 a	95 a
400 TPA Thin	34 a	71 a	100 a
R ²	86	88	87

*Values with the same letter within the same measurement period are not significantly different at the P <0.05

that of the control. By stand age 30 and through age 41, no significant differences in total basal area per acre for any of the treatments remained. This finding was also true when only dominant and codominant crop trees were assessed.

No significant differences in mean annual basal area growth rate were found between any of the thinning treatments and the unthinned control for the period between stand ages 30 and 41 years old (Table 4). The 2.9 mean annual basal area growth rate for both thinning treatments is similar to other even-aged upland oak stands at stand age 30 years with 50 to 60 percent stocking (Gingrich 1971b). The larger mean annual growth rate for the unthinned control was due to a larger number of trees of a smaller average diameter.

As the stand developed following thinning treatments, the drier-site upland oak species, including white oak, scarlet oak, and black oak, comprised more of the total basal area per acre in both the 200 TPA and 400 TPA treatments, when compared to the unthinned control (Table 6). Chestnut oak also comprised a large part of the total basal area per acre in both the 400 TPA and unthinned control treatments. The 200-TPA thinning treatment did increase the amount of total basal area of white oak, black oak, and scarlet oak that remained competitive at stand ages 30 and 41. Species such as black cherry, northern red oak, southern red oak, and post oak responded poorly during this stage and were overtopped by the drier-site oaks, yellow-poplar, and white pine. By stand age 30, the northern red oak and post oak had dropped out of all the treatments (Table 6). Red maple ingrowth has also increased in the unthinned control and 400-TPA thinning treatment.

By stand age 30, white pine trees that were present or seeded in naturally underneath the open hardwood canopies following disturbance comprised a greater percent of the total basal area per acre in the unthinned control treatments because they were not thinned out (Table 7). In the unthinned control white pine increased from 3 to 45 percent of the total basal area between stand ages 16 and age 30 at the expense of drier-site oak species and yellow-poplar. The percent of total basal area per acre for these drier site oak species during this period was greater in the 200 -PA and 400-TPA thinning treatments when compared to the unthinned control (Table 7).

DISCUSSION

Five years following the precommercial thinning treatments (1977 assessment; stand age 11), mean d.b.h. was significantly larger for the 400-TPA thinning treatment when compared to the other treatments while the mean d.b.h. for the 800-TPA thinning treatment was not significantly different from the unthinned control (Boyette and Brenneman 1978). Thinning to 800 TPA did not provide a sufficient tree growth response to justify future recommendations in young upland hardwood stands.

Table 6.—Total basal area (ft²/acre) by species, thinning treatment, and assessment year

Species	1982 Stand Age 16			1996 Stand Age 30			2007 Stand Age 41		
	Control	200	400	Control	200	400	Control	200	400
Yellow-poplar	4.7	2.9	4.6	14.6	6.6	7.0	22.2	11.2	10.4
Scarlet oak	2.4	4.8	4.8	6.2	14.1	13.0	8.3	22.2	17.1
Black oak	2.2	3.0	4.9	4.1	8.7	7.6	6.9	13.2	8.2
White oak	3.5	7.9	5.8	5.6	20.1	9.5	6.6	26.3	12.8
Chestnut oak	2.5	3.0	7.6	13.3	9.5	18.6	21.2	15.1	28.0
White pine	0.6	0.9	3.1	42.0	5.2*	11.2	58.1	7.3*	17.4
Hickory	0.5	0.1	1.1			0.1			0.2
Red maple				2.3		2.8	3.0		4.3
S. red oak	0.3	0.3	0.6			1.0			1.6
Black cherry	1.0	0.3	0.3	1.2			1.2		
N. red oak	0.2	0.2	0.7						
Post oak		0.2	0.2						
Other	0.2	0.1	<0.1	2.4			2.7		
Total basal area per acre	18	24	34	92	64	71	130	95	100

*Basal area from a single tree in thinning treatment

Table 7.—Percent of total basal area per acre for drier site oaks, yellow-poplar, and white pine by thinning treatment and assessment year

Species	1982 Stand age 16			1996 Stand age 30			2007 Stand age 41		
	Control	200	400	Control	200	400	Control	200	400
Drier site oaks	59	78	67	32	82	68	33	80	66
Yellow-poplar	26	12	14	16	10	10	17	12	10
White pine	3	4	9	45	8	16	45	8	17

Results from this study show that any increase in tree growth for the 400-TPA thinning treatment became less significant with later stand development. Another follow-up thinning may have been beneficial before stand age 30, although the stocking level was 68 percent and still considered adequate for stand growth. Gingrich (1971b) found that a single thinning, unless followed by a series of thinnings at 10- to 15-year intervals, is of doubtful value. A 400-TPA precommercial thinning level may be more appropriate if applied later in the stem exclusion stage of stand development and followed up with subsequent thinnings.

On this site, precommercial thinning to the lower 200-TPA density levels at stand age 11 resulted in increased diameter growth that was maintained after 35 years. The 200-TPA thinning treatment was at the 58 percent stocking level at stand age 30. The 200-TPA thinning treatment was at the B-line stocking level considered to be optimal stocking for additional stand growth (Gingrich 1971a).

Precommercial thinning did help to remove unmerchantable stems which upgraded the quality and growth potential of the residual stand while improving species composition. Results indicate that the species mixture of more desirable oak species was improved by precommercial thinning and increased the

percentage of total basal area per acre in thinned treatments when compared to the unthinned control. Thinning also helped to reduce the density of white pine trees that were present in the species mixture, allowing for more hardwood development. In the unthinned control, white pine ingrowth has created more of a conifer-hardwood mixed stand dominated by pines. This ingrowth of white pine trees in the unthinned control may have also contributed to reduced treatment differences between hardwood trees that were precommercially thinned.

Without some type of thinning on these drier sites, natural white pine stems may inhibit the early growth and development of desired oak species. On these drier sites in the southern Appalachian mountain region, previous researchers have found that white pine will out-compete most other species regardless of site quality, except yellow-poplar on $SI_{50} > 95$ feet (Doolittle 1958).

Where landowners want to produce both timber value and wildlife benefits, white pine can be an acceptable species to grow in mixtures on these drier sites. However, careful consideration should be given to how many white pine and yellow-poplar trees to leave when grown in mixtures on dry sites naturally regenerating to oak. These species, if not reduced to lower densities, can overwhelm young oak stands at higher stocking levels (Beck and Hooper 1986). Although yellow-poplar grew well from stump sprouts, management of this species is generally not recommended on sites of low to intermediate quality (Beck and Della-Bianca 1981).

For this study, the initial thinning treatment at age 6 was applied too early in the stem initiation stage of stand development. Other researchers have found that growth responses have been inconsistent for released crop trees in young stands less than 10 years after clearcutting (Hilt and Dale 1982, Trimble 1971). On these drier sites, precommercial thinning should be delayed until the stand reaches between 15 and 20 years old. Younger hardwood trees would respond better following more time for crown development. By waiting for the stand to develop further, foresters can better select the highest quality dominant trees of the preferred species. Landowners and foresters should plan their selection of crop trees and species composition based on which species are best adapted to their sites for the length of the rotation. A mixed species stand is very suitable for sites with SI_{50} less than 70 feet for upland oak where both timber and wildlife values are desirable.

ACKNOWLEDGMENTS

The study was designed and installed by Warren G. Boyette and Dwight L. Brenneman, foresters with the North Carolina Division of Forest Resources as part of the North Carolina State University Hardwood Cooperative Study No. 2, in the Pisgah National Forest at Bent Creek Experimental Forest near Asheville, NC. We thank Virginia McDaniel, forestry technician, Bent Creek Experimental Forest, for her assistance in relocating study plots and data collection.

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