TEN-YEAR GROWTH RESPONSE OF RED AND WHITE OAK CROP TREES TO INTENSITY OF CROWN RELEASE

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Abstract—A thinning study of 60-year-old northern red oak (*Quercus rubra* L.), black oak (*Q. velutina* Lam.), and white oak (*Q. alba* L.) was superimposed on an existing crown-release study in the Boston Mountains of Arkansas during the summer of 1985. In the new study, individual crop trees were released to achieve relative stocking densities of 40 percent, 60 percent, or 80 percent, and control. The rule thinning method, which defines a thinning radius based on d.b.h., was employed. Ten-year diameter-growth response was influenced by the previous crown release treatment, species, and relative stocking density. Rule thinning can be used to effectively release potential red and white oak crop trees in intermediate-aged mixed oak stands. However, some competing trees—such as leaning trees, and large-diameter trees up-slope from the crop tree—may reduce growth benefits. These situations have to be considered for successful application of rule thinning.

INTRODUCTION

Several hundred thousand acres of forest land in northern Arkansas support overstocked, even-aged stands of pole- to small sawtimber-size oaks. Although many stands are on medium to good sites (site index of 60 to 70 feet at 50 years), diameter growth averages only about 1 inch in 10 years. Growth in these stands can be increased by areawide thinning to target stocking densities (Dale and Hilt 1986, Graney and Murphy 1994), which reallocates site resources to fewer trees, shortens time required to grow products to a given size, and allows utilization of low-vigor and poor-quality stems that would ordinarily die. However, this type of thinning does not guarantee effective release of all high-quality, potentially high-value stems (Lamson and others 1990, Smith and others 1994). Although there are markets for small hardwood roundwood in northern Arkansas, the value of the product is often too low to make these thinnings profitable.

Crop-tree release could provide an alternative means of increasing or maintaining growth of high-quality stems. The crown-touching method of crop-tree release (Smith and Lamson 1986, Lamson and others 1990) is a simple, straightforward, and effective method of releasing selected crop trees by removing the competing trees whose crowns touch the crown of the selected crop tree. Rogers and Johnson (1985) have suggested a crop-tree release technique they call rule thinning. In this method, diameter at breast height (d.b.h.) and a specified relative stocking are used to determine the thinning radius around the crop tree.

This paper summarizes 10-year diameter-growth response of red oaks [northern red (*Quercus rubra* L.) and black (*Q. velutina* Lam.)] and white oak (*Q. alba* L.) to crown release achieved by rule thinning. It describes the effects of first and second crown-release treatments on diameter growth of red and white oak crop trees and describes the effect of relative stocking density on crop-tree growth.

METHODS

Study Region

The Boston Mountains are the highest and most southern member of the Ozark Plateau's physiographic province. They form a band 30 to 40 miles wide and 200 miles long from north-central Arkansas westward into eastern Oklahoma. Elevations range from about 900 feet in the valley bottoms to 2,500 feet at the highest point. The plateau is sharply dissected, and most ridges are flat to gently rolling and are generally less than 0.5 mile wide. Mountainsides consist of alternating steep simple slopes and gently sloping benches.

Annual precipitation averages 46 to 48 inches, and March, April, and May are the wettest months. Extended summer dry periods are common, and autumn is usually dry. The frost-free period is normally 180 to 200 days long.

Study Description

Original study treatments—This study utilized 272 individual red and white oak crop trees that had been part of the crown-release and fertilization study established on Ozark National Forest land in 1974 (Graney 1987). The study was installed in three overstocked 50-year-old mixed oak poletimber stands on south- or west-facing mountain benches. In each stand, 40 to 48 red oak and 40 to 48 white oak crop trees were selected for the crown-release and fertilization treatments. All study trees were tightly grown, small-crowned codominants that required release. For each species group, one-half of the trees were randomly assigned crown release or no release, and each tree was randomly assigned one of three N-P fertilizer treatments. Crowns were released by removing two major competitors and only remaining smaller trees until the basal area based on a 10-factor prism count around each crop tree was reduced to about 70 ft^2 to approximate B-level stocking. Before treatment, mean d.b.h. for red oak sample trees was 8.33 inches, mean d.b.h. for white oak sample trees was 8.08 inches, and stand basal area averaged 122 ft^2 per acre. Sample-tree d.b.h. was

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measured to the nearest 0.01 inch annually from 1974 through 1985. The diameter measurement point for each tree was identified by a painted band.

Present study treatments and analysis—For each species, there were two sequences of thinning (one-release and two-release) and four relative stocking densities (40 percent, 60 percent, 80 percent, and no control of density), for a total of eight treatments (table 1).

Sample trees were released using the rule thinning method (Rogers and Johnson 1985). It is a two-step procedure:

1. Find the thinning radius in feet for a given stocking target and crop-tree d.b.h. Remove all trees within the boundary defined by the thinning radius.
2. Survey the area outside the thinning radius of the crop tree to determine if a tree larger than the crop tree is nearby. If such a tree is present, determine its d.b.h. and thinning radius. If the crop tree falls within the thinning radius of the larger tree, then the larger tree is removed.

Thinning-radius values for a range of tree diameters are presented in Rogers and Johnson (1985) (table 2). Thinning-radius values representative of those employed in the present study are:

Crop-tree d.b.h.	Relative stocking (%) 40	60	80
Inches	- - - - -*Thinning radius (ft)* - - - - -		
8	11.8	8.1	5.3
10	14.2	9.7	6.4
12	16.6	11.4	7.5
14	18.9	13.0	8.5

Crop trees receiving the 40 percent treatment were released from crown-touching competition on at least three sides but usually on four sides, while the 60 percent treatment resulted in release on three sides but

Table 1—Mean stand and tree characteristics after treatment and 10 years of growth by species (n=17 for each species x treatment combination)

Treatments		After treatment		10-year change	
		D.b.h.	Basal area	D.b.h.	Basal area
Release	Stocking	Mean (range)	Mean (range)	Mean (range)	Mean (range)
	Percent	----*Inches*-----	----*Ft²/acre*----	-----*Inches*-----	----*Ft²/acre*---
Red oaks (age = 61; site index = 62)					
First	40	10.3 (8.4-13.2)	40 (30-50)	12.3 (9.7-16.0)	47 (40-60)
	60	10.5 (9.9-14.7)	57 (50-70)	12.4 (10.6-16.7)	66 (50-80)
	80	10.3 (8.2-14.6)	80 (70-90)	11.7 (9.2-16.3)	89 (70-100)
	Control[a]	10.4 (8.0-15.1)	126 (100-150)	11.4 (8.9-16.3)	121 (110-140)
Second	40	10.9 (8.1-13.3)	42 (30-50)	13.1 (9.5-15.5)	55 (30-70)
	60	10.9 (8.2-13.3)	56 (50-70)	12.9 (10.3-15.5)	66 (50-80)
	80	10.8 (8.0-14.0)	75 (60-90)	12.4 (9.4-15.4)	84 (70-100)
	Control[b]	10.5 (7.9-14.6)	92 (80-110)	11.9 (8.5-16.7)	97 (70-120)
White oak (age = 63; site index = 59)					
First	40	9.5 (8.0-14.5)	43 (30-50)	11.4 (9.5-16.0)	52 (40-70)
	60	9.3 (7.6-11.6)	56 (40-70)	11.1 (9.6-14.4)	61 (50-70)
	80	9.4 (7.4-12.1)	84 (80-100)	10.6 (7.9-13.8)	95 (80-110)
	Control[a]	9.3 (7.2-11.0)	131 (80-170)	10.4 (8.3-12.3)	128 (100-150)
Second	40	10.8 (8.2-13.4)	43 (40-50)	13.2 (9.8-15.4)	54 (40-70)
	60	10.9 (7.4-13.4)	56 (50-60)	12.9 (8.9-15.8)	66 (50-90)
	80	10.9 (7.9-13.1)	75 (70-80)	12.5 (9.2-14.6)	84 (70-100)
	Control[b]	10.7 (8.0-12.2)	90 (80-110)	12.1 (9.3-13.6)	99 (90-120)

[a] Control trees not released in 1974 or 1985.
[b] Control trees partially released in 1974 but not released in 1985.

Table 2—Analysis of variance probabilities of greater F-value and Error II Mean Squares for red and white oak periodic annual diameter growth for 1986-1990, 1991-1995, and 1986-1995

		Red oaks			White oak		
		Periodic annual growth			Periodic annual growth		
Source of variation	DF	1986-90	1991-95	1986-95	1986-90	1991-95	1986-95
		----Pr > F----					
Rep	16	0.8502	0.2019	0.5257	0.4668	0.2044	0.3010
Release	1	0.0001	0.1071	0.0002	0.0001	0.0143	0.0001
Release x rep [Error I]	16	0.3612	0.2917	0.3933	0.7521	0.6786	0.6630
Stocking	3	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Release x stocking	3	0.3273	0.4318	0.5968	0.1380	0.5733	0.3396
		----Mean square x 100 (*inches*^{2})----					
Error II	96	0.1434	0.1915	0.1633	0.1087	0.1561	0.1216
Total	135						

occasionally in release on two sides. The 80 percent treatment released trees on one side at best and often effected no release from crown-touching competition. Control trees that were not released either in 1974 or in 1985 had crown-touching competitors on four sides, while controls released only in 1974 were often still free of crown competition on one side.

Crown-release and stocking-density treatments were applied in June and July 1985. Sample-tree d.b.h. was measured in the fall of 1985 following treatment and annually thereafter through 1995. Average tree and stand characteristics following treatment in 1985 and 10-year change in d.b.h. and basal area values are shown in table 1.

The study had a completely randomized split-plot design with one-release or two-release representing the whole plot, and relative stocking densities (40 percent, 60 percent, 80 percent, and no control of density) representing the subplots. Data were analyzed by analysis of variance with treatment effects tested at the 0.01 level of significance. Differences among treatment means were tested using the LSMEANS option of the General Linear Model procedure in SAS (SAS Institute 1989).

RESULTS

Over the 10-year measurement period, red and white oak crop trees receiving two release treatments produced significantly greater diameter growth than trees receiving the single crown release. However, this response was pronounced for only the first 5 years following treatment. While response to a second release was slightly greater over the second 5-year period, the difference in diameter growth was not significant at the 0.01 level (table 2).

Response to intensity of crown release (stocking level) was highly significant for each 5-year period. There was no significant interaction between number of release and stocking level for either species group (table 2).

Response to a First or Second Crown Release

When red and white oak crop trees received a second crown release, the second release treatment usually enabled the trees to maintain their previous rate of diameter growth. However, trees that had received no previous crown release responded to the release with increased diameter growth, and by the sixth through tenth years after release these trees were growing at about the same rate as the previously released trees (fig. 1).

Diameter growth of red and white oak trees that received only a single crown release generally declined throughout the 10-year measurement period but was still greater than diameter growth of the controls that received no release (0.15 in. vs. 0.10 for red oaks and 0.14 in. vs. 0.11 for white oak). Thus, some response to a single crown release can be expected to persist for about 20 years following release. This finding is consistent with the 20-year response reported for white oak poles in southern Illinois (Schlesinger 1978), but overall response in the present study is less than reported by Schlesinger (1978). To maintain growth rates observed for red and white oak crop trees at the end of the previous study, another effective crown release would be required within 10 years after the first release (fig. 1).

Response to Stocking Density

Response of red and white oak crop trees to stocking density varied somewhat by species and the previous

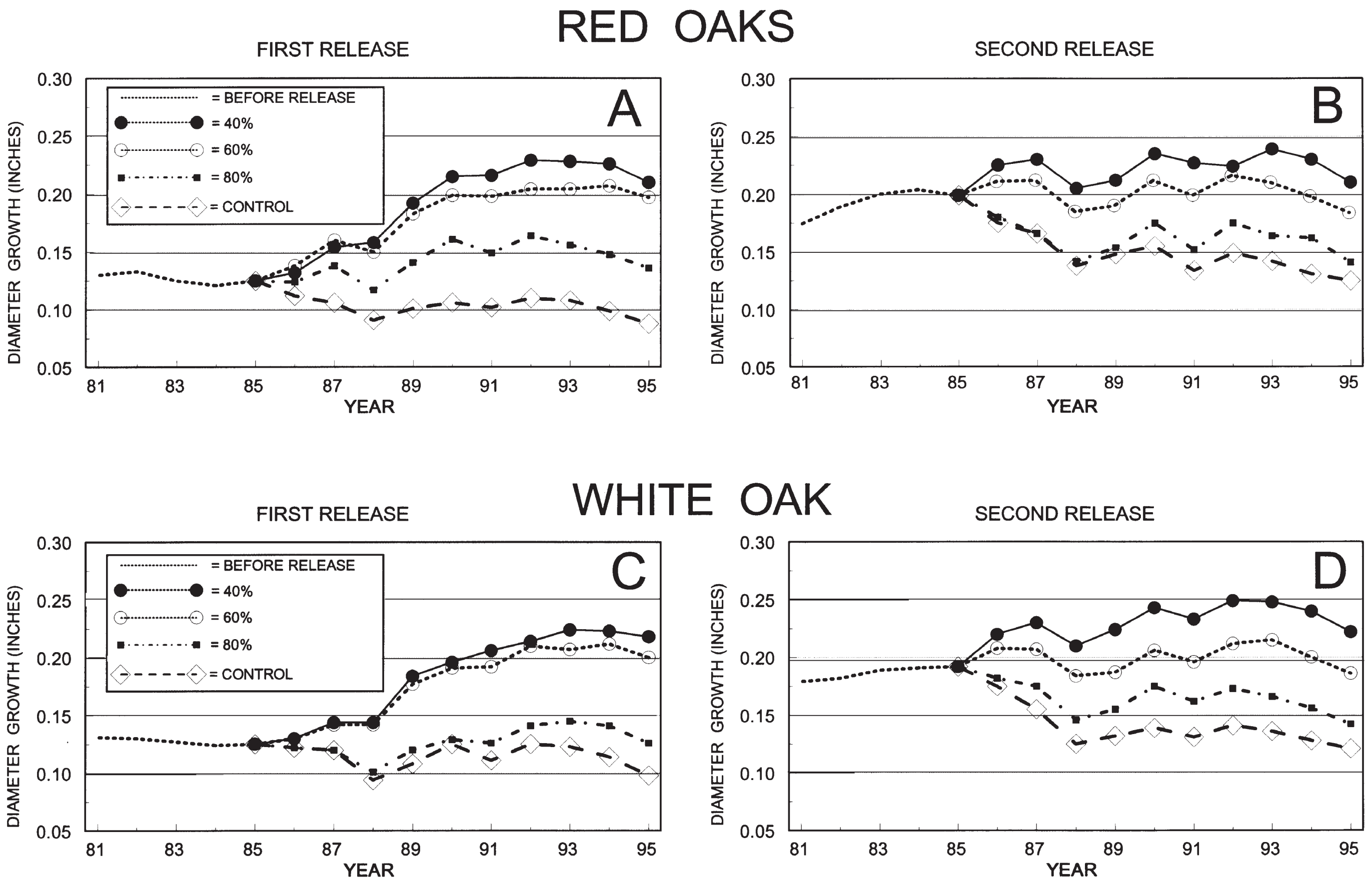

Figure 1—Mean annual growth of red and white oaks following first or second crown release treatments and at four relative stocking densities.

release treatment. However, the 60 percent and 40 percent relative stocking treatments produced the greatest responses in both red oaks and white oak.

Red oaks receiving the first crown release in 1985 did not have a significant growth response the first year after treatment, although growth of the released trees was greater than that of the nonreleased controls. After the first year, all red oaks that received only one release grew significantly better than the controls. Diameter growth of the once-released red oaks that were released to 40 percent and 60 percent increased rapidly by the fourth year and reached a maximum at 7 to 9 years after treatment. Once-released red oaks released to 40 percent stocking exhibited the greatest overall growth, the difference was not significantly greater than red oaks released to 60 percent stocking. Trees released to 80 percent stocking grew better than controls but significantly less than trees that received the 40 or 60 percent stocking treatments (table 3).

Red oaks that had received a previous crown release exhibited an immediate and significant diameter-growth response to a second crown release to 40 percent or 60 percent relative stocking density. Diameter growth of trees released to 80 percent stocking density was about the same as that of the control trees over the 10-year period. Although annual diameter growth of red oaks released to 40 percent stocking was consistently greater than that of those related to 60 percent stocking over the 10-year measurement period, differences between growth for the 40 percent treatment and growth for the 60 percent treatment were not significant. Diameter growth of red oaks receiving the control and 80 percent treatments generally declined over the 10-year period, but growth of the trees released to 80 percent stocking declined at a slower rate (table 3).

Diameter growth of white oak sample trees that received only one crown release did not respond to that release immediately. In white oaks, significant response to crown release began the third year after treatment. Response was significant only for the 40 percent and 60 percent stocking treatments. Unlike once-released red oaks that were released to an 80 percent stocking density, once-released white oaks receiving the 80 percent stocking treatment did not grow significantly more than controls. Once-released white oaks, like once-released red oaks, responded similarly to the 40 percent and 60 percent density treatments, and maximum diameter growth occurred about 7 to 9 years after release (table 3).

Table 3—Least square means comparisons for mean annual diameter growth response of red and white oaks to a first or second crown release and four relative stocking densities

	First release				Second release			
	Relative stocking (percent)				Relative stocking (percent)			
Species/year	Control[a]	80	60	40	Control[b]	80	60	40
Red oak								
1986	.112a	.124a	.138a	.132a[c]	.175a	.180a	.211b	.225b[c]
1987	.106a	.138b	.160b	.154b	.166a	.166a	.212b	.230b
1988	.091a	.117b	.150b	.158b	.128a	.142a	.185b	.205b
1989	.101a	.141b	.183c	.192c	.138a	.154a	.190b	.212b
1990	.106a	.161b	.199bc	.215bc	.155a	.175a	.212b	.235b
1991	.102a	.149b	.198c	.216c	.134a	.152a	.199b	.227b
1992	.110a	.164b	.204c	.229c	.149a	.175a	.216b	.244b
1993	.108a	.156b	.204c	.228c	.142a	.164a	.210b	.239b
1994	.099a	.148b	.207c	.226c	.131a	.162a	.198b	.230b
1995	.088a	.136b	.197c	.210c	.125a	.141a	.184b	.210b
Mean	.102a	.143b	.184c	.196c	.144a	.161a	.202b	.226b
White oak								
1986	.122a	.122a	.130a	.130a[c]	.175a	.182a	.208b	.220b[c]
1987	.120a	.120a	.142a	.144a	.155a	.175a	.207b	.230b
1988	.094a	.101a	.142b	.144b	.125a	.146a	.184b	.210b
1989	.108a	.120a	.177b	.184b	.132a	.155a	.187b	.224c
1990	.125a	.129a	.191b	.196b	.139a	.175b	.206c	.243d
1991	.111a	.126a	.192b	.206c	.131a	.162a	.196c	.233d
1992	.125a	.141a	.210b	.214b	.141a	.173a	.212b	.249c
1993	.123a	.145a	.207b	.224b	.136a	.166a	.215b	.248c
1994	.114a	.141a	.212b	.223b	.128a	.156a	.200b	.240c
1995	.098a	.126b	.200c	.218c	.121a	.142a	.186b	.222c
Mean	.114a	.127a	.180b	.188b	.138a	.163a	.200b	.232c

[a] Control trees not released in 1974 or 1985.
[b] Control trees partially released in 1974 but not released in 1985.
[c] Values in rows followed by the same letter are not significantly different at the 0.01 level.

White oak crop trees also responded immediately and significantly to a second crown release, but only for the more intensive release treatments. Diameter-growth responses to the 40 percent and 60 percent treatments were about the same for the first 3 years after release, but diameter growth of trees released to 40 percent stocking was significantly greater than that of trees released to 60 percent stocking for the remainder of the study. White oaks released to 80 percent stocking generally grew better than controls, but differences were not significant over the 10- year period. Diameter growth for both control and 80 percent stocking treatments generally declined over the 10- year period (table 3).

DISCUSSION

If applied as recommended, rule thinning gives a selected crop tree the growing space at a prescribed target stocking density. However, the method does require measurement of crop-tree diameter and corresponding thinning radius to identify competing trees to be removed. The method also requires consideration of noncrop trees larger than the crop tree that are outside of the crop tree's thinning radius but large enough to compete with the crop tree. This requirement could confuse marking crews initially. Strict application of the rule thinning method does not provide for removal of competing trees that are not within the crop tree's thinning radius or the larger noncrop trees' thinning radius but lean toward the crop tree and touch or even overtop the crop tree's crown. This situation occurred in each stand and usually involved large-diameter residual stems located on steep interbench slopes above the crop trees. Although our Boston Mountain oak stands are essentially even-aged, they usually include five or more trees per acre that were not removed in the previous harvest because of their quality, species, or size. These stems are usually cull or very low quality with large crowns and often have significant lean. When located on steep interbench slopes, these large-crowned, leaning stems often influence a much larger area than their diameter would suggest. Such trees must be considered when the rule thinning method is applied. In the present study, leaning trees that were in competition with the crop tree but that were not designated for removal by application of the method were removed in most instances.

Response to partial crown release may persist for as long as 20 years, but to produce acceptable rates of diameter growth and to maintain these growth rates, release treatments will have to be more intensive than the partial release applied in the previous study and may have to be repeated on a 10- or 15-year cycle.

The rule thinning crown release to 40 percent residual stocking density would be roughly equivalent to the crown-touching release procedure recommended for stands of pole- and small sawtimber-sized mixed hardwoods in the Appalachians (Lamson and others 1990, Smith and others 1994).

CONCLUSIONS

Crown release can be an effective method for increasing growth of red and white oaks in heavily stocked stands of intermediate-aged, pole- and small sawtimber-size mixed oaks in the Boston Mountains. Annual diameter growth of tightly grown codominant red and white oak crop trees can be increased from current levels of about 0.1 inch to 0.2 to 0.25 inch with effective crown release. However, to maintain the higher rates of diameter growth, additional crown release would be required after a 10- to 15-year interval.

The rule thinning method has important advantages. It is based on established and accepted oak stocking guides which define growing space requirements, and it was developed for upland mixed oak stands in the Missouri Ozarks. The method is straightforward and provides a system for providing consistent release of oak crop trees to a prescribed stocking. However, the method does require measurement of crop-tree diameter and thinning radius, and the evaluation of competing trees that are not within the defined thinning radius of the designated crop tree. The method also does not make provision for leaning trees that compete with the sample tree's crown but are not within thinning radii.

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