EFFECT OF CROWN RELEASE ON TREE GRADE AND DBH GROWTH OF WHITE OAK SAWTIMBER IN EASTERN KENTUCKY

Gary W. Miller and Jeffrey W. Stringer[†]

ABSTRACT.—Forest managers need information on the effect of stand density on residual tree growth and quality to prescribe effective thinning treatments in hardwood stands. Crop tree release treatments were applied in 70- to 75-year-old upland oak stands located in eastern Kentucky. Two treatment levels, applied as a complete crown release of 20 and 34 sawtimber-sized crop trees per acre, were compared to unreleased controls. Data were collected on 12 permanent 0.5-acre plots, with 4 plots randomly assigned to each of the two treatment levels and untreated controls. Tree quality and DBH growth were monitored for 17 years on 148 white oak crop trees. Average DBH growth of released trees in both release treatments was 27 percent greater than that observed for unreleased controls. After 17 years, 89 percent of selected crop trees were in grades 1 or 2, compared to 53 percent at the beginning of the study. No significant differences were found between tree grade distributions on the treated and control plots, indicating that a complete crown release did not adversely affect tree grade.

Numerous studies have shown that commercial thinning in hardwood stands 1) concentrates growth on the most desirable residual trees, 2) reduces the time required to yield products of a desired size, and 3) increases the total yield by harvesting and utilizing trees that would die in the absence of thinning (Miller 1997; Nowak 1996; Oliver and Larson 1996). Although thinning to an appropriate residual density clearly increases growth and yield, some observers caution that thinning too heavily or removing desirable crop trees during thinning can reduce the value yield of hardwood stands by adversely affecting the average quality of the residual trees (Dale 1972).

Current thinning guidelines for upland oaks recommend leaving a residual stand density of 60 to 70 percent of full stocking to maximize wood volume production (Roach and Gingrich 1968). The guidelines also recommend removing poorer quality trees and retaining better quality trees to allow value growth to accrue on trees with the highest potential rate of return. The traditional method of applying a thinning treatment involves removing less desirable trees throughout the stand on an area-wide basis to achieve the target level of average residual stand density. This study tested an alternative method of thinning by applying a crown-release treatment to individual crop trees with the potential for yielding high-quality, high-value sawtimber and veneer logs. The crown-release method of thinning involves removing only competing trees whose crowns are touching the crowns of selected residual crop trees.

Area-wide and crown-release treatments differ with respect to two important questions. 1) Is the focus on finding undesirable trees to cut or desirable trees to retain? 2) Is the focus on reducing competition throughout the stand or reducing competition around individual trees? In area-wide treatments, the emphasis is on searching for and removing trees of poor quality, poor form, or low vigor to achieve a recommended average residual stand density. Note that area-wide treatments distribute removals throughout the stand, thus reducing competition over a relatively large area. A disadvantage of the area-wide approach is that little direct effort is made to improve the microsite conditions around the best residual trees, thus some desirable trees may receive little or no benefit from the thinning operation. Alternatively, the emphasis in crown-release treatments is on identifying the most promising residual trees and then removing competing trees in their immediate vicinity. This approach assures that site resources (sunlight, water, and soil nutrients) freed by the thinning treatment are directly allocated to the designated

[†]Principal Research Silviculturist (GWM), Northeastern Research Station, USDA Forest Service, 180 Canfield Street, Morgantown, WV 26505; and Associate Extension Professor of Hardwood Silviculture, Department of Forestry, 223 Thomas Poe Cooper Building, University of Kentucky, Lexington, KY 40546. GWM is the corresponding author: to contact, call (304) 285-1521 or e-mail at gwmiller@fs.fed.us.

crop trees. An advantage of the crown-release approach is that the residual crop trees, selected because they best meet management objectives, fully benefit from the thinning operation.

In practice, control of average stand density can be used in conjunction with the crown-release approach by varying the number of crop trees released per acre (Perkey and others 1994), thus providing a means for managing the allocation of site resources at both the stand and individual-tree levels.

The objective of this study was to determine the effect of crown-release treatments on the growth and quality of desirable white oak crop trees. Preliminary results on DBH (diameter at breast height) growth and the cost of treatments were reported by Stringer and others (1988a).

Stand Description

The study was conducted at the University of Kentucky's Robinson Forest in eastern Kentucky. The 70- to 75-year-old stands were dominated by upland oaks. The initial basal area averaged 111 ft^2/ac (stems = 1.0 inch DBH), and white oak (*Quercus alba* L.) occupied 58 percent of the initial stand (fig. 1). Other stand components included black oak (*Q. velutina* Lam.), yellow-poplar (*Liriodendron tulipifera* L.), American beech (*Fagus grandifolia* Ehrh.), and hickories (*Carya* spp.). The overstory included an average of 67 dominant and codominant trees/ac that were either large pole or small sawtimber with an average DBH of 13 inches. White oak site index averaged 73 (base age 50 years). There was no evidence of recent disturbance and the stands were essentially 100 percent stocked before treatment (Roach and Gingrich 1968).

Figure 1.—White oak crop trees were monitored for 17 years in eastern Kentucky.

Study Methods

The long-term management goal for the study sites was to have a fully stocked stand in which codominant trees averaged 22 to 24 inches DBH at final harvest and occupied approximately 80 percent of full stand stocking (Gingrich 1967). Understory trees were expected to occupy the remaining 20 percent stocking. Equations developed by Gingrich (1967) indicated that the number of 24-inch trees needed to occupy 80 percent of full stand stocking varied from 20 to 35 trees per acre, depending on the degree of crowding and its effect on crown size. Two release treatments, defined as 20 and 34 crop trees per acre, and an untreated control were replicated 4 times each and randomly distributed among 12 experimental areas. Each area was two acres in size, and a square 0.5-acre measurement plot was centered in each area. All trees ≥ 1.0-inch DBH within the 0.5-acre measurement plot were tagged for long-term monitoring. Crop trees within each area were selected based on the following criteria:

1. Dominant or codominant crown class.
2. White oak.
3. Potential grade 1 or 2 butt log.
4. Even spacing within the stand.

Crop trees were released by felling competing trees with a chain saw. Competing trees were defined as adjacent trees whose crowns touched those of the selected crop trees. After release, crop trees were free to grow on all sides. Crop trees selected in control areas were monitored but not released. DBH, crown class, tree grade (Hanks 1976), and remarks were recorded for each crop tree before treatment and again after 17 years. Additional data on epicormic branches and length of clear sections on the 16-foot butt log also were recorded for each crop tree during the final inventory.

A one-factor repeated measures ANOVA was used to examine the effect of crown release treatments on DBH growth. The fixed effect model has the form:

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

where Y is DBH growth; μ is the overall mean; α is the effect of release treatment; β is the effect of time; and ε is the random error. The general linear models procedure in SAS was used for all statistical analyses (SAS Institute Inc. 1998). The Tukey-Kramer HSD mean separation test was used for all multiple comparisons. Treatment effects were considered to be statistically significant when $P<0.05$. For each analysis, the residuals were tested for normality using the Shapiro-Wilk test and for homogeneity of variance using the Levene test.

The counts of sawtimber trees (≥ 11.0 inches DBH) in each tree grade for released and control plots were compared before and 17 years after treatment using a Pearson Chi^2 test to determine if the grade distributions were not equal due to the release treatment.

Results and Discussion

The crown-release treatments reduced residual stand stocking to an average of 76 percent (table 1), which was a relatively light thinning treatment as defined by Roach and Gingrich (1968). As competing trees were felled to release selected crop trees, a relatively small amount of basal area was damaged (Stringer and others 1988b). The 34-and 20-crop-tree treatments removed an average of 75 trees/ac and 54 trees/ac, respectively. The 34-crop-tree treatment also removed more basal area, cubic volume, and relative density compared to the 20-crop-tree treatment (table1). Removals are usually positively related to the number of crop trees released per acre (Perkey and others 1994). In this case, however, the number of crop trees released per acre did not have a significant effect on residual stand stocking because plots in the 34-crop-tree treatment were slightly overstocked when the study began. The additional trees removed in the 34-crop-tree treatment were mostly smaller poletimber trees, thus releasing additional crop trees did not have a proportional effect on residual stand density. After treatment, all crop trees were free to grow on all sides.

The initial DBH of crop trees ranged from 8.3 to 18.9 inches. Released trees grew an average of 3.1 inches DBH, while unreleased trees grew 2.4 inches DBH over the 17-year study, an average increase of 27 percent due to crown release (table 2).

A total of 153 crop trees were selected at the beginning of this study, and 148 trees were still alive after 17 years. Of the 5 trees that died, 3 were in control plots and 2 were in treated plots. There was no indication that the release treatments affected mortality.

A summary of the changes in tree grade for the surviving 148 crop trees is presented in Table 3. DBH is a main factor that determines tree grade (Hanks 1976), so changes in tree grade were stratified into size classes that correspond to minimum DBH requirements for each tree grade: 9.6 inches DBH for grade 3, 12.6 inches DBH for grade 2, and 15.6 inches DBH for grade 1. Several strata had sample sizes large enough to extract some meaningful results. For example, 10 control trees and 26 treated trees were initially limited by DBH to grade 3 and then grew large enough to enter grade 2. Note that 7 of 10 control trees and 25 of 26 released trees improved in grade as they grew large enough to enter a higher grade. Similarly, the majority of trees in initial size class 2 that grew to ending size class 1 improved in grade for both control and released trees.

The release treatments did not reduce tree quality or prevent otherwise good trees from increasing in grade as they grew. Although the release treatments resulted in relatively small reductions in overall stand density, the full crown release resulted in maximum reductions in density in the immediate vicinity of selected crop trees. The data indicated that among desirable crop trees with excellent initial quality and vigor, a full crown release stimulated faster DBH growth but did not diminish the quality of the butt log, thus there was no adverse effect on tree grade.

Table 1.—Per acre stand data by thinning treatment for upland oaks in eastern Kentucky.

	Number of stems			Basal area			Volume		RD[3]
Inventory	≥1.0[1]	≥5.0	≥11.0	≥1.0	≥5.0	≥11.0	≥5.0	≥11.0[2]	≥1.0
		No./ac			ft^2/ac		ft^3/ac	bf/ac	%
				34 Crop Trees Per Acre (n=4 plots)					
Initial	782	180	42	109.0	93.4	48.2	1,982	6,274	107
Cut	74	57	18	35.3	34.8	20.2	776	2,489	30
Residual	708	123	24	73.7	58.6	28.0	1,206	3,785	77
17-year	753	155	39	104.6	83.5	51.0	1,790	7,287	104
				20 Crop Trees Per Acre (n=4 plots)					
Initial	732	160	47	103.4	90.5	51.6	1,975	6,679	100
Cut	55	39	15	29.6	29.0	18.3	677	2,578	25
Residual	677	121	32	73.8	61.5	33.3	1,298	4,101	75
17-year	657	123	40	95.4	76.6	51.4	1,711	7,462	94
				Control (n=4 plots)					
Initial	654	138	60	110.6	99.1	71.6	2,296	10,045	102
17-year	643	128	67	128.1	112.7	92.6	2,705	13,849	115

[1]Minimum DBH of trees included in total.
[2]Sawtimber volume, International 1/4-inch rule.
[3]Relative density, or stand stocking as measured by Gingrich (1967).

Table 2.— Average 17-year DBH growth of white oak crop trees in eastern Kentucky.

Initial Size Class	Treatment	N	Initial DBH	17-yr[1]DBH Growth[1]
			————inches————	
DBH < 9.6	Control	3	8.6	2.51 a
	20 Crop Trees/ac	2	8.8	2.49 a
	34 Crop Trees/ac	21	8.3	2.84 b
9.6 ≤ DBH < 12.6	Control	12	11.4	2.49 a
	20 Crop Trees/ac	17	11.3	3.51 b
	34 Crop Trees/ac	17	10.7	3.12 b
12.6 ≤ DBH < 15.6	Control	20	13.9	2.53 a
	20 Crop Trees/ac	11	13.9	3.26 b
	34 Crop Trees/ac	19	13.8	2.88 b
DBH ≥ 15.6	Control	15	17.2	2.27 a
	20 Crop Trees/ac	5	18.9	3.10 b
	34 Crop Trees/ac	6	17.3	3.20 b
All Crop Trees	Control	50	14.0	2.44 a
	20 Crop Trees/ac	35	13.1	3.32 b
	34 Crop Trees/ac	63	11.5	2.96 b

[1]Means followed by the same letter are not significantly different at the 5 % level of significance.

Table 3.—Change in tree grade for white oak crop trees after 17 years in eastern Kentucky.

Initial Size Class	Ending Size Class	Initial Tree Grade	Control				Thinned			
			N	Change in Grade Increase	Same	Decrease	N	Change in Grade Increase	Same	Decrease
						number of trees				
4	4	4	1	0	1	0	4	0	4	0
4	3	4	1	0	1	0	16	12	4	0
4	2	4	1	1	0	0	3	3	0	0
3	3	3	2	0	2	0	1	0	1	0
		4	0	—	—	—	1	1	0	0
3	2	3	10	7	3	0	26	25	1	0
3	1	3	0	—	—	—	5	5	0	0
2	2	2	3	0	3	0	3	0	3	0
		3	3	2	1	0	1	0	1	0
2	1	2	6	6	0	0	18	16	2	0
		3	8	6	2	0	9	7	2	0
1	1	1	3	0	3	0	6	0	6	0
		2	11	9	2	0	4	3	1	0
		3	1	1	0	0	1	0	1	0

[1]Size Class 4 (DBH < 9.6); Size Class 3 (9.6 ≤ DBH < 12.6); Size Class 2 (12.6 ≤ DBH < 15.6);Size Class 1 (DBH ≥ 15.6); Size classes represent DBH thresholds for tree grades 4,3,2,1, respectively. Grade 4 collectively represents trees below sawlog quality.

A total of 103 crop trees were sawtimber size (≥ 11.0 inch DBH) before treatment. The grade distributions of released versus control trees were compared before and after treatment. The percentage of crop trees in grades 1, 2, and 3 did not differ significantly before (P = 0.813) or 17 years after (P = 0.568) the crown release treatment (table 4). Due to size limitations, the percentage of trees in grade 1 did not exceed 10 percent when the study began. After 17 years of growth, the percentage of trees in grade 1 was nearly 50 percent for both control and released crop trees. The percentage of trees in grade 2 was slightly greater for released crop trees compared to controls, probably because more released trees reached the minimum size for grade 2 due to faster growth. The data suggested that faster growth following release reduced the time required for crop trees to reach the minimum DBH required to enter higher grades compared to controls.

In addition to DBH, surface characteristics of the 16-foot butt log of the tree are also important factors that affect grade. Epicormic branches that form on the butt log can diminish quality and value because they reduce the yield of defect-free wood. Logs with no branches or defects are much more valuable because they can yield high-quality lumber or even veneer, the highest value product. The formation of epicormic branches can occur when the quantity or distribution of auxins produced by the tree is altered by a change in light, moisture, nutrients, or temperature after a disturbance (Bowersox and Ward 1968). In this study, thinning did not increase the number of epicormic branches on white oak crop trees (table 5). Note that the crop trees observed in this study were the most vigorous and highest quality trees available when the release treatments were applied. Such trees usually do not lose quality after crown release treatments (Miller 1996; Ward 1966; Dale 1972).

The average number of epicormic branches on the butt log 17 years after thinning was related to the initial DBH of crop trees; small trees had more branches, while large trees had less. Trees that were ≥ 15.6 inches DBH before treatment averaged < 1 epicormic branch 17 years later (table 5). The proportion of crop trees with at least one 8-foot clear section (all four faces) on the butt log also increased as initial DBH increased. For trees ≥ 12.6 inches DBH at the beginning of the study, the percentage of trees with at least one 8-foot clear section on the butt log was 69 percent for control trees and 73 percent for released trees 17 years after release (table 5). This result supports the finding that crown release did not diminish the butt log quality of vigorous, desirable crop trees.

Table 4.—Pearson Chi-square comparison of tree grade distributions for white oak crop trees before and 17 years after thinning in eastern Kentucky.

Distribution	Treatment	Tree Grade 1	2	3	Total	Tree Grade 1	2	3	Total	X^2	Prob
		—Number of trees—				—Percents by row—					
Original	Control	3	20	20	43	7.0	46.5	46.5	100	0.414	0.813
	Thinned	6	25	29	60	10.0	41.7	41.7	100		
17-year	Control	21	16	6	43	48.8	37.2	14.0	100	1.130	0.568
	Thinned	28	27	5	60	46.7	45.0	8.3	100		

Table 5.—Characteristics of the 16-foot butt logs of white oak crop trees 17 years after crown release: average number of epicormic branches and number of trees with at least one clear 8-foot section.

Initial Size Class	Treatment	N	Mean number of epicormic branches/tree	Crop trees with 8-foot clear section
			—no. of branches—	—no. of trees—
DBH < 9.6	Control	3	6.7	1
	20 Crop Trees/ac	2	8.5	0
	34 Crop Trees/ac	21	5.4	3
9.6 ≤ DBH < 12.6	Control	12	3.7	5
	20 Crop Trees/ac	17	3.0	8
	34 Crop Trees/ac	17	2.0	12
12.6 ≤ DBH < 15.6	Control	20	3.1	14
	20 Crop Trees/ac	11	1.1	7
	34 Crop Trees/ac	19	2.8	14
DBH ≥ 15.6	Control	15	0.9	10
	20 Crop Trees/ac	5	0.0	4
	34 Crop Trees/ac	6	1.0	5
All Crop Trees	Control	50	2.8	30
	20 Crop Trees/ac	35	2.3	19
	34 Crop Trees/ac	63	3.3	35

Conclusions

This study shed some light on the effect of thinning on residual tree quality. Results indicated that full crown release of 70- to 75-year-old white oak sawtimber crop trees did not have an adverse effect on butt log quality and tree grade 17 years after the thinning treatments. One reason is that the thinning treatments reduced stand density to an average of 76 percent, thus the removals were relatively light (table 1). Although a slightly lower residual density is recommended (Roach and Gingrich 1968), each released crop tree was free to grow on all sides after release. As a result, the environment around each crop tree was characteristic of a much lower average stand density. Note that released crop trees responded to additional free growing space, and their DBH growth increased by an average of 27 percent compared to unreleased crop trees (table 2).

Although growth increased, no crop trees decreased in grade following release (table 3). The grade distribution for released trees was similar to that of unreleased trees (table 4), and surface characteristics on the butt logs were similar to that of unreleased trees (table 5). However, the data suggested that crop trees with smaller initial DBH had more epicormic branches and fewer clear 8-foot sections after 17 years. Initial vigor, as evidenced by relative DBH or relative crown position, is an important factor that determines the risk of developing epicormic branches (Miller 1996; Brinkman 1955; Smith 1965). It is logical to conclude that the results would have been dramatically worse if the larger, more vigorous trees had been removed during the thinning and smaller, less vigorous trees had been chosen as residual crop trees.

The results support two major recommendations of Roach and Gingrich (1968): 1) The best quality trees of desired species should be retained and trees of poor quality or undesirable species should be removed. 2) The residual stand density should be reduced to approximately 60 to 70 percent stocking as measured by the upland hardwood stocking guide (Gingrich 1967). They also recommended that an effort should be made while marking the cut trees to provide desirable residual crop trees with a full crown release. A general conclusion of this study is that releasing approximately 35 crop trees per acre in sawtimber white oak stands similar to the study area would result in a residual stand density consistent with current recommendations, provide a significant increase in DBH growth, and produce no adverse effect on butt-log quality or tree grade of the released crop trees.

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