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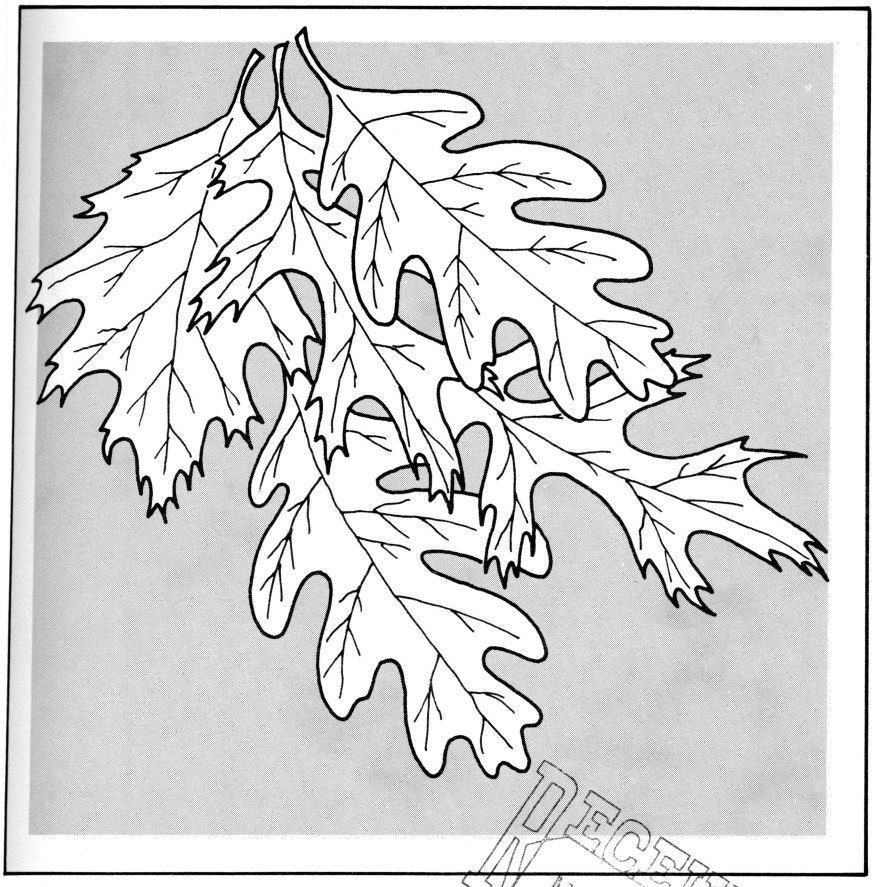

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Effects of Improvement Cuttings and Thinnings on the Development of Cove and Mixed Oak Stands

KENNETH L. CARVELL

General Background Information

A LARGE ACREAGE of the hardwood forests in West Virginia consists of evenaged second growth, which originated after heavy cuttings and wildfire in the early part of this century. Many problems encountered in managing these stands have their origin in the preference for certain species in these early cuttings, plus the effects of fire.

In the Appalachians, complex mixtures of species known as "cove hardwoods" occupy the moist sites. On drier slopes and ridges, oaks and their associates are the characteristic cover. The heavy, often complete, removal of the more valuable species, and the wildfires that followed, have resulted in an abnormally high component of scarlet oak,[1] sassafras, bigtooth aspen, and black locust, trees often left by the early loggers, or species which sprout vigorously after fire. Due to past logging preference, white and northern red oak, black walnut, black cherry, cucumbertree, sugar maple, basswood, and white ash have decreased in abundance.

Recognizing the need for more information on satisfactory methods of managing young hardwood stands to obtain the largest amount of quality sawtimber at the end of the rotation, foresters with the West Virginia University Agricultural Experiment Station established a series of research plots at the West Virginia University Forest in 1949. These forty plots have been managed under different thinning regimes. At five-year intervals measurements have been made to determine changes in composition, growth, form and condition. This bulletin presents a 15-year summary of the information obtained from these plots.

History of Experimental Area

Although heavy cuttings were made during the nineteenth century, the most recent and heaviest logging took place between 1915 and 1927. These cuttings

[1]Scientific names of trees referred to in this bulletin are given in Appendix Table 13.

This study was designed and carried on for many years by Allen W. Goodspeed, Professor of Forest Management at the West Virginia University Division of Forestry.

removed all merchantable stems, leaving only culls. After cutting, wildfire burned over this tract almost annually until 1936, when the area was acquired by the State for a state forest. Since 1936 almost no wildfire has occurred on this tract. Thus, most of the present stands originated from sprouts after the last wildfires in the mid-thirties.

Design of Experiment

Each summer between 1949 and 1953 one block of eight plots was established. Three of these blocks were located in oak types and two in cove hardwood types. Each half-acre plot was surrounded by an isolation strip. During the five years of plot establishment, one-half of the plots in each block received an improvement cutting (I_1). This cutting improved the character and condition of the stand by removing culls left in the previous logging, undesirable species, and trees with poor form. Plots which received no initial improvement cutting are designated I_0. Table 1 shows the treatment schedule followed during the 15-year period.

In low thinning (T_1) all merchantable lower-crown-class trees and weak codominants were cut. In crown thinning (T_2) those upper-crown-class trees were removed which interfered with the development of the most promising

TABLE 1. Outline of cuttings planned for the forty thinning-study plots, showing time of plot establishment, initial treatment and thinning type applied to each plot.

Year Established	Plot No.	Code Name*	Treatment			
			At time of Establishment	After 1st Five-year Measurement	After 2nd Five-year Measurement	After 3rd Five-year Measurement
1949 Oak	1	I_1T_0	Improvement	None	None	None
1949	2	I_1T_1	Improvement	None	None	Low
1949	3	I_1T_2	Improvement	None	None	Crown
1949	4	I_1T_3	Improvement	None	None	Selection
1949	5	I_0T_0	None	None	None	None
1949	6	I_0T_1	None	None	Low	None
1949	7	I_0T_2	None	None	Crown	None
1949	8	I_0T_3	None	None	Selection	None
1950 Oak	1	I_1T_0	Improvement	None	None	None
1950	2	I_1T_1	Improvement	None	None	Low
1950	3	I_1T_2	Improvement	None	None	Crown
1950	4	I_1T_3	Improvement	None	None	Selection
1950	5	I_0T_0	None	None	None	None
1950	6	I_0T_1	None	None	Low	None
1950	7	I_0T_2	None	None	Crown	None
1950	8	I_0T_3	None	None	Selection	None

TABLE 1 (Continued)

Year Established	Plot No.	Code Name*	Treatment At time of Establishment	After 1st Five-year Measurement	After 2nd Five-year Measurement	After 3rd Five-year Measurement
1951 Cove	1	I_1T_0	Improvement	None	None	None
1951	2	I_1T_1	Improvement	None	Low	None
1951	3	I_1T_2	Improvement	None	Crown	None
1951	4	I_1T_3	Improvement	None	Selection	None
1951	5	I_0T_0	None	None	None	None
1951	6	I_0T_1	None	None	Low	None
1951	7	I_0T_2	None	None	Crown	None
1951	8	I_0T_3	None	None	Selection	None
1952 Cove	1	I_1T_0	Improvement	None	None	None
1952	2	I_1T_1	Improvement	None	Low	None
1952	3	I_1T_2	Improvement	None	Crown	None
1952	4	I_1T_3	Improvement	None	Selection	None
1952	5	I_0T_0	None	None	None	None
1952	6	I_0T_1	None	None	Low	None
1952	7	I_0T_2	None	None	Crown	None
1952	8	I_0T_3	None	None	Selection	None
1953 Oak	1	I_1T_0	Improvement	None	None	None
1953	2	I_1T_1	Improvement	None	None	Low
1953	3	I_1T_2	Improvement	None	None	Crown
1953	4	I_1T_3	Improvement	None	None	Selection
1953	5	I_0T_0	None	None	None	None
1953	6	I_0T_1	None	None	Low	None
1953	7	I_0T_2	None	None	Crown	None
1953	8	I_0T_3	None	None	Selection	None

*I_0 means that there was no improvement cutting at the initiation of the experiment, and I_1 that there was an improvement cutting the year of establishment. T_2 no thinning; T_1, low thinning, T_2, crown thinning, T_3, selection thinning.

individuals. In selection thinning (T_3) dominant trees were removed, if they had large crowns and poor natural pruning. In all initial thinnings wolf trees were girdled or cut. In addition, all other merchantable stems were cut, if they would not live until the next thinning.

Analysis of Results

For the cove type, the five-year measurements for plots receiving the same treatment schedule were averaged. Appendix Tables 1 through 6 show changes in composition, number of trees per acre, basal area, and volume. The data for the three blocks located in oak types were averaged. Similar data for these plots is presented in Appendix Tables 7 through 12.

Discussion

Cove Sites. The composition of the 100 largest trees on the cove hardwood plots in the year of plot establishment included a diversity of species (Appendix Table 1). Through improvement cuttings and thinnings the less desirable species were removed, increasing the percentage of yellow-poplar and the more desirable oaks. Comparison of plots which had improvement cuttings immediately after establishment with those where cutting was delayed for a decade suggests little advantage in molding composition early. The change in the amount of yellow-poplar on the control (I_0T_0) from 53 to 67 per cent illustrates the natural ability of this species to outgrow other species and dominate stands on good sites.

Comparison of Appendix Tables 2, 3, and 6 suggests that a ten-year interval between cuttings may be too short and result in insufficient volume in the second cutting. Cove plots that received an initial improvement cutting produced between 3.1 and 4.7 cords per acre in the second cut. This small volume per acre would be unattractive to pulpwood contractors, suggesting that a 15-year interval between intermediate cuttings may be more desirable from an economic standpoint.

Appendix Tables 5 and 6 show the differences in utilizable wood between the treated plots and the control. Although the control had a high merchantable volume at the close of the 15-year period, when the volume removed in thinning and improvement cutting is added, the amount of merchantable wood lost by withholding cutting is apparent. Efficient use of wood fiber, demonstrated by the four plots which received and initial improvement cutting, stresses the importance of entering cove stands early, if markets for material of this size are available.

Appendix Table 4 suggests that the plots with the early improvement cuttings increased faster in average diameter. This can be attributed to the ability of young trees to respond rapidly when their crowns are released. This is one advantage of making intermediate cuttings early.

Oak Sites. Appendix Table 7 shows changes in species composition for the oak plots. The faster-growing species, northern red, black, chestnut, and scarlet oaks, tend to dominate the stand even without the aid of intermediate cuttings.

White oak, due to its slower growth, gradually loses crown class. In improvement cuttings and thinnings, white oak was removed when interfering with promising northern red and black oaks because of their faster growth rate and equivalent quality. Intermediate cuttings could have been used to increase the amount of white oak, if desired, but the slower growth rate would result in a longer rotation. In certain parts of West Virginia, primarily in limestone areas, white oak of exceptional quality is obtained. There, the forest manager may desire to increase the percentage of white oak in his stands through intermediate cuttings.

Scarlet oak grows rapidly, and made up a large portion of these stands prior to treatment. Although scarlet oak was removed in improvement cuttings and thinnings, the large amount originally present made it necessary to remove this species gradually through a series of cuttings. Only under unusual circumstances should scarlet oak be left as a final crop tree, since they prune poorly and develop heartwood rot. The prominence of scarlet oak, even on the treated plots, attests to its rapid diameter growth.

Chestnut oak was classed as a desirable species on the oak plots, but as an undesirable species on the cove sites. On average and below average sites many chestnut oak are comparable in form and condition to northern red and black oaks. Here, each chestnut oak should be evaluated for form and condition, and compared with adjacent oaks, before deciding to leave it or remove it from the stand. On cove sites, chestnut oak does not grow as rapidly as yellow-poplar, cucumbertree, or northern red and black oaks, and is rarely of comparable form or condition. Thus, it is considered an undesirable species.

Yellow-poplar is usually scarce on oak sites due to poor survival during the seedling stage. On these sites it grows rapidly in diameter, but develops taper and coarse branching. No effort should be made to eliminate poplar from oak sites, but each poplar should be evaluated for its potential as a crop tree.

The volume removed in thinning from plots which had an initial improvement cutting was extremely low, between 2.1 and 3.3 cords per acre (Appendix Table 12). Such low volumes would not be attractive to most pulpwood contractors. This suggests that a longer cutting interval than 15 years may be desirable for oak sites.

The total number of trees per acre on the oak sites is considerably higher than on the cove hardwood plots. The heavy mortality on the oak plots (Appendix Table 8) does not signify that the intermediate cuttings were too light. This loss was primarily in unmerchantable diameter classes that could not be removed at a profit during thinning. In spite of heavy mortality during the 15-year period, the number of trees on oak plots was still higher than on the cove sites.

Total cord production on the cove hardwood sites averaged nearly one cord per acre per year. Total cord production on oak sites was considerably less, generally between 0.6 and 0.7 cords per acre per year.

General. It appears that the importance of an initial improvement cutting depends largely on the condition of the stand and the availability of markets for small wood products. Although the initial improvement cutting may alter stand composition slightly, and favor trees with the straightest boles, the better species on cove sites, yellow-poplar and northern red oak, tend to outgrow the less desirable species. On oak sites, northern red, black, and chestnut oaks outgrow many less desirable associates. Scarlet oak, however, is often abundant on oak sites and grows as rapidly, or more rapidly, than the more desirable oaks. The amount of scarlet oak can be reduced effectively through early improvement

cuttings, but due to its abundance in many stands can only be eliminated through a series of partial cuttings.

If markets exist for material from 15-20-year-old stands, slight improvement in composition, spacing, and tree form results. However, if such cuttings must be made at a direct cost due to lack of markets, it appears that the slight improvement in the stand is not justified. When stand improvement was delayed until the stand was 25-30 years old, and carried out in the thinning operation, stands of nearly equivalent quality resulted. When early improvement cuttings cannot be made throughout the whole stand, early removal of scattered wolf trees, remnants from past logging, through herbicides will do the greatest good with little financial investment per acre.

Low thinnings appeared to be least effective in shaping composition (Appendix Table 7). Low thinning, however, left a stand of vigorous trees since the primary removal was in the low-vigor, lesser crown classes. Where total wood fiber production is the primary goal, low thinnings probably have a very important place in the silvicultural system.

Crown thinnings generally resulted in slightly less growth, but caused significant changes in stand composition (Appendix Tables 1 and 7), and spacing, since upper-crown-class trees were sorted over, and only the best stems of the best species left.

Selection thinning had the benefit of removing super-dominants and wolf trees, and is probably a good first thinning for many natural stands where culls and other remnants from the previous rotation exist. The possibility of using a series of selection thinnings is questionable, since once this undesirable element is eliminated, further cutting of the largest and most vigorous trees would result in extremely long rotations.

Summary

Between 1949 and 1953 forty long-term thinning plots were established in 15-20-year-old hardwood stands on cove and oak sites. One-half of these plots received an initial improvement cutting; the rest had no intermediate cutting until the time of the first thinning, 10-15 years later. Low, crown, and selection thinnings were included in this study. The treatment schedule is presented in Table 1.

Comparison of plots which had improvement cuttings with those where cutting was delayed for a decade or more, shows little advantage in molding stand composition early. On cove sites, yellow-poplar and northern red oak outgrew less desirable associates and dominated the stand. On oak sites, northern red, black, and chestnut oaks competed successfully with less desirable species. However, where scarlet oak was abundant, it crowded out desirable oaks unless removed gradually through intermediate cuttings.

For cove hardwood sites, a 10-year cutting interval was too short to yield sufficient volume in the second cutting. On oak sites, 15 years appears to close an interval between cuttings.

When an improvement cutting can be made at a break-even point or small profit, slight improvement in composition, spacing, and tree form results. If early cuttings must be done at a direct ost, it appears that improvement work can be delayed with little harm to the stand. When an early improvement cutting cannot be made through the whole stand, early removal of scattered wolf trees with herbicides will do much to improve spacing and form at small cost.

Low thinning appeared to be less effective than crown thinning in molding stand composition. Selection thinning has the benefit of removing coarse super-dominants, and is often an important first thinning, but once this undesirable element is eliminated, selection thinning would have little value and would lengthen the rotation.

Appendix

(follows)

TABLE 1. Change in species distribution of the 100 largest trees (d.b.h.) for the cove-site plots during the fifteen-year period covered by this study.

Species	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
	Per cent							
Yellow-poplar	79-87*	72-86	70-87	61-72	53-67	67-78	76-78	76-92
Black cherry	3-9	10-1	19-8	19-20	12-9	4-6	7-10	6-2
N. red and black oak	10-4	6-9	1-1	6-4	10-9	7-12	9-6	9-6
White oak	0-0	0-0	0-2	0-0	0-0	0-0	0-0	0-0
Desirable species	92-100	88-96	90-98	86-96	75-85	78-96	92-94	91-100
Chestnut oak	1-0	5-4	3-2	3-2	9-6	2-2	2-2	1-0
Red maple	4-0	2-0	0-0	6-0	0-1	6-2	1-3	2-0
Sassafras	1-0	0-0	1-0	0-0	6-4	1-0	0-0	0-0
Other hardwoods	2-0	5-0	6-0	5-2**	10-4	13-0	5-1	6-0
Less desirable species	8-0	12-4	10-2	14-4	25-15	22-4	8-6	9-0

*The first figure indicates the initial number of trees of this species included in those with the 100 largest diameters, breast height. The second figure indicates the number of this species at the close of the 15-year period.

**Black birch.

TABLE 2. A summary of changes in number of trees per acre for the cove hardwood types for the fifteen-year period.

Year	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
	Number of Trees per Acre							
1951-52								
No. of trees	811	715	676	731	827	808	677	661
No. removed	248	122	162	173	0	0	0	0
No. remaining	563	593	514	558	827	808	677	661
% removed	30.6	17.1	24.0	23.7	0	0	0	0
Change, 1951-52 through 1956-57	35	-18	-1	-56	-155	-288	-115	-143
1956-57								
No. of trees	598	575	513	502	672	520	562	518
Change, 1956-57 through 1961-62	-53	-102	37	22	-87	36	-62	-55
1961-62								
No. of trees	545	473	550	524	585	556	500	463
No. removed	0	41	79	55	0	135	107	70
No. remaining	545	432	471	469	585	421	393	393
% removed	0	8.7	14.4	10.5	0	24.3	21.4	15.1
Change, 1961-62 through 1966-67	-112	-18	-72	-126	-78	-82	-64	-103
1966-67								
No. of trees	433	414	399	343	507	339	329	290
Total number of trees removed 1951-67	248	163	241	228	0	135	107	70
Mortality	130	138	36	160	320	334	241	301

TABLE 3. Changes in basal area per acre for the cove hardwood type for the fifteen-year period.

Year	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
					Square Feet			
1951-52								
Before cutting	80.6	87.6	85.7	78.7	78.3	87.0	81.2	95.4
Amount removed	27.1	23.2	19.4	24.1	0.0	0.0	0.0	0.0
After cutting	53.5	64.4	66.3	54.6	78.3	87.0	81.2	95.4
% removed	33.6	26.5	22.6	30.6	0.0	0.0	0.0	0.0
Change, 1951-52 through 1956-57	25.1	24.0	22.3	18.2	15.5	15.6	12.9	20.4
1956-57								
Basal area	78.6	88.4	88.6	72.8	93.8	102.6	94.1	115.8
Change, 1956-57 through 1961-62	19.8	27.6	26.8	22.7	15.0	19.1	11.6	13.9
1961-62								
Before cutting	98.4	116.0	115.4	95.5	108.8	121.7	105.7	129.7
Amount removed	0.0	17.8	18.0	8.5	0.0	31.1	22.2	37.0
After cutting	98.4	98.2	97.4	87.0	108.8	90.6	83.5	92.7
% removed	0.0	15.4	15.6	8.9	0.0	25.6	21.0	28.5
Change, 1961-62 through 1966-67	18.0	12.5	9.8	7.1	9.9	10.2	13.0	10.5
1966-67								
Basal area	116.4	110.7	107.2	94.1	118.7	100.8	96.5	103.2
Total basal area removed in cuttings	27.1	41.0	37.4	32.6	0.0	31.1	22.2	37.0

TABLE 4. Average diameter of the 100 largest trees on cove hardwood plots at the time of plot establishment and after fifteen years of management.

	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
					Inches			
Average d.b.h. in 1951-52	9.3	10.0	10.6	9.8	8.6	11.5	9.1	11.5
Average d.b.h. in 1966-67	11.7	12.0	12.6	11.6	10.3	13.0	10.9	13.2
Increase	2.4	2.0	2.0	1.8	1.7	1.5	1.8	1.7

TABLE 5. Changes in merchantable cubic foot volume per acre for the cove hardwood plots during the period from 1951-52 through 1966-67.

Year	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
1951-52								
Original volume	1,327.6	1,516.3	1,552.0	1,371.2	1,237.0	1,489.2	1,433.1	1,862.3
Removed in thinning	449,0	370.8	299.6	443.7	0.0	0.0	0.0	0.0
Remaining volume	878.6	1,145.5	1.252.4	927.5	1,237.0	1,489.2	1,433.1	1,862.3
1956-57								
Volume	1,462.9	1,721.2	1,829.8	1,460.1	1,690.6	2,044.2	1,881.4	2,445.6
Growth since 1951-52	584.3	575.7	577.4	532.6	453.6	555.0	448.3	583.3
1961-62								
Volume	2,082.3	2,542.3	2,547.2	2,066.4	2,248.3	2,592.6	2,399.4	3,085.0
Growth since 1956-57	619.4	821.1	717.4	606.3	557.7	548.4	518.0	639.4
Removed in thinning	0.0	424.6	385.9	272.4	0.0	588.8	497.2	967.6
Remaining volume	2,082.3	2,117.7	2,161.3	1,794.0	2,248.3	2,003.8	1,902.2	2,117.4
1966-67								
Volume	2,680.3	2,568.7	2,496.7	2,186.0	2,528.1	2,375.1	2,236.8	2,573.5
Growth since 1961-62	598.0	451.0	335.4	392.0	279.8	371.3	334.6	456.1
Increase, 1951-52 through 1966-67	1,352.7	1,052.4	944.7	814.8	1,291.1	885.9	803.7	711.2
Total volume removed in cuttings	449.0	795.4	685.5	716.1	0.0	588.8	497.2	967.6
Total production (Increase, 1951-67 plus volume removed in cutting)	1,801.7	1,847.8	1,630.2	1,530.9	1,291.1	1,474.7	1,300.9	1,678.8

TABLE 6. Changes in merchantable cord volume per acre for the cove hardwood plots during the period from 1951-52 through 1966-67.

Year	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
	Cords							
1951-52								
Original volume	14.8	16.8	17.2	15.2	13.7	16.5	15.9	20.7
Removed in cutting	5.0	4.1	3.3	4.9	0.0	0.0	0.0	0.0
Remaining volume	9.8	12.7	13.9	10.3	13.7	16.5	15.9	20.7
1956-57								
Volume	16.2	19.1	20.3	16.2	18.8	22.7	20.9	27.2
Growth since 1951-52	6.4	6.4	6.4	5.9	5.1	6.2	5.0	6.5
1961-62								
Volume	23.1	28.2	28.3	23.0	25.0	28.8	26.7	34.3
Growth since 1956-57	6.9	9.1	8.0	6.8	6.2	6.1	5.8	7.1
Removed in thinning	0.0	4.7	4.3	3.1	0.0	6.5	5.6	10.1
Remaining volume	23.1	23.5	24.0	19.9	25.0	22.3	21.1	24.2
1966-67								
Volume	29.8	28.5	24.7	24.3	28.1	26.4	24.8	28.6
Growth since 1961-62	6.7	5.0	0.7	4.4	3.1	4.1	3.7	4.4
Total increase, 1951-52 through 1966-67	15.0	11.7	7.5	9.1	14.4	9.9	8.9	7.9
Total volume removed in cuttings	5.0	8.8	7.6	8.0	0.0	6.5	5.6	10.1
Total production (Increase, 1951-67 plus volume removed in cuttings)	20.0	20.5	15.1	17.1	14.4	16.4	14.5	18.0

TABLE 7. Change in species distribution of the 100 largest trees (d.b.h.) for the oak plots during the fifteen-year period covered by this study.

Species	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
	Per cent							
White oak	11-8*	17-13	24.22	17-13	16-13	36-26	18-17	11-10
N. red and black oak	28-36	21-21	9-15	12-18	18-38	16-17	9-18	10-18
Chestnut oak	19-32	34-32	17-24	31-26	12-9	4-15	30-35	33-50
Yellow-poplar	3-8	0-0	24-10	1-3	0-4	1-9	14-12	3-5
Black cherry	3-1	7-4	5-5	1-3	1-4	3-1	13-5	5-2
Desirable species	64-85	79-70	29-76	62-63	47-68	60-68	84-87	62-85
Scarlet oak	26-13	16-29	5-17	32-37	32-27	15-23	8-11	18-10
Red maple	3-1	1-0	3-7	1-0	0-3	8-9	5-1	11-5
Hickory	0-0	0-0	0-0	1-0	1-1	0-0	0-0	0-0
Other hardwoods	7-1	4-1	13-0	4-0	20-1	17-0	3-1	9-0
Less desirable species	36-15	21-30	21-24	38-37	53-32	40-32	16-13	38-15

*The first figure indicates the initial number of trees of this species included in those with the 100 largest diameters, breast height. The second figure indicates the number of this species at the close of the 15-year period.

TABLE 8. Changes in the number of trees per acre for the oak plots for the fifteen-year period covered by this study.

Species	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
1949-50-53								
No. of trees	1,047	1,111	993	961	989	882	851	883
No. removed	240	290	186	174	0	0	0	0
No. remaining	807	821	807	787	989	882	851	883
% removed	22.9	26.1	18.7	18.1	0.0	0.0	0.0	0.0
Change, first 5-year period	-72	-127	-86	-46	-144	-115	-239	-181
1954-55-58								
No. of trees	735	694	721	741	845	767	612	702
Change, second 5-year period	-70	-35	-78	-102	-156	-176	-115	-117
1959-60-63								
No. of trees	665	659	643	639	689	591	497	585
No. removed	0	0	0	0	0	180	153	161
No. remaining	665	659	643	639	689	411	344	424
% removed	0.0	0.0	0.0	0.0	0.0	31.0	30.1	27.5
Change, third 5-year period	-137	-135	-132	-142	-128	-2	-27	-50
1964-65-68								
No. of trees	528	524	511	497	561	409	317	374
No. removed	0	104	58	81	0	0	0	0
No. remaining	528	420	453	416	561	409	317	374
% removed	0.0	19.9	11.4	16.3	0.0	0.0	0.0	0.0
Total no. trees removed, 1949-68	240	394	244	255	0	180	153	161
Mortality, 1949-68	279	297	296	290	428	293	381	348

TABLE 9. Changes in basal area per acre for the oak plots for the fifteen-year period covered by this study.

Year	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
1949-50-53				Square Feet per Acre				
Before cutting	69.8	75.9	77.4	73.8	69.2	68.0	79.6	73.3
Amount removed	20.1	20.8	23.3	18.3	0	0	0	0
After cutting	49.7	55.1	54.1	55.5	69.2	68.0	79.6	73.3
% removed	28.8	27.4	30.1	24.8	0.0	0.0	0.0	0.0
Change, first 5-year period	18.5	14.9	16.6	16.4	16.2	17.0	9.5	15.9
1954-55-58 Basal area	68.2	70.0	70.7	71.9	85.4	85.0	89.1	89.2
Change, second 5-year period	17.3	17.6	18.4	16.0	9.4	10.4	7.2	2.1
1959-60-63								
Before cutting	85.5	87.6	89.1	87.9	94.8	95.4	96.3	91.3
Amount removed	0	0	0	0	0	28.1	30.2	24.9
After cutting	85.5	87.6	89.1	87.9	94.8	67.3	66.1	66.4
% removed	0.0	0.0	0.0	0.0	0.0	29.5	31.5	27.3
Change, third 5-year period	0.9	4.2	7.4	4.7	7.0	13.8	10.3	5.0
1964-65-68								
Before cutting	86.4	91.8	96.5	92.6	101.8	81.1	76.4	71.4
Amount removed	0	15.4	10.6	18.6	0	0	0	0
After cutting	86.4	76.4	85.9	74.0	101.8	81.1	76.4	71.4
% removed	0.0	16.8	11.0	20.1	0.0	0.0	0.0	0.0
Total amount of basal area removed in cutting	20.1	36.2	33.9	36.9	0	28.1	30.2	24.9

TABLE 10. Average diameter of the 100 largest trees on oak plots at the time of plot establishment and after fifteen years of management.

	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
Average d.b.h. in 1949-50-53	6.5	6.2	7.9	7.6	Inches 6.6	7.2	8.1	7.6
Average d.b.h. in 1964-65-68	8.7	9.0	8.9	9.5	9.3	9.6	11.5	8.8
Increase	2.2	2.8	1.0	1.9	2.7	2.4	3.4	1.2

TABLE 11. Changes in merchantable cubic foot volume per acre for the oak types for the period from 1949-50-53 through 1964-65-68.

Year	Plot Treatment I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
					Cubic Feet			
1949-50-53								
Original volume	784.98	844.05	1,072.13	958.69	817.03	865.38	1,198.01	1,016.46
Removed in cutting	259.99	238.56	414.62	290.37	0.00	0.00	0.00	0.00
Remaining volume	524.99	605.49	657.51	668.32	817.03	865.38	1,198.01	1,016.46
1954-55-58								
Volume	957.14	1,019.21	1,107.18	1,053.49	1,263.46	1,340.80	1,626.08	1,367.21
Growth, first 5-year period	432.15	413.72	449.67	384.87	446.43	475.42	428.07	350.75
1959-60-63								
Volume	1,367.88	1,371.41	1,696.27	1,380.67	1,574.42	1,722.32	1,881.30	1,675.15
Growth	410.74	352.20	589.09	327.18	310.96	381.51	255.22	307.94
Removed in cutting	0.00	0.00	0.00	0.00	0.00	499.04	613.33	513.25
Remaining volume	1,367.88	1,371.41	1,696.27	1,380.67	1,574.42	1,223.28	1,267.97	1,161.90
1964-65-68								
Volume	1,560.02	1,623.84	1,895.42	1,664.93	1,809.15	1,552.58	1,607.32	1,341.35
Growth	192.14	252.43	199.15	284.26	234.73	329.30	339.35	179.45
Removed in cutting	0.00	195.15	209.07	308.02	0.00	0.00	0.00	0.00
Remaining volume	1,560.02	1,428.67	1,686.35	1,356.91	1,809.15	1,552.58	1,607.32	1,341.35
Increase, 1949-68	775.04	584.64	614.22	398.22	992.12	687.20	409.31	324.89
Total volume removed in cutting	259.99	433.71	623.69	598.39	0.00	499.04	613.33	513.25
Total production (Increase, 1949-68, plus volume removed in cutting)	1,035.03	1,018.35	1,237.91	996.61	992.12	1,186.24	1,122.64	838.14

TABLE 12. Changes in merchantable cord volume per acre for the oak plots for the period from 1949-50-53 through 1964-65-68.

Year	Plot Treatment							
	I_1T_0	I_1T_1	I_1T_2	I_1T_3	I_0T_0 (Control)	I_0T_1	I_0T_2	I_0T_3
	Cords							
1949-50-53								
Original volume	8.7	9.4	11.9	10.6	9.1	9.6	13.3	11.3
Removed in cutting	2.9	2.7	4.6	3.2	0.0	0.0	0.0	0.0
Remaining volume	5.8	6.7	7.3	7.4	9.1	9.6	13.3	11.3
1954-55-58								
Volume	10.6	11.3	12.3	11.7	14.0	14.9	18.1	15.2
Growth, first 5-year period	4.8	4.6	5.0	4.3	4.9	5.3	4.8	3.9
1959-60-63								
Volume	15.2	15.2	17.8	15.3	17.5	19.1	20.9	18.6
Growth since 1954-55-58	4.6	3.9	5.5	3.6	3.5	4.2	2.8	3.4
Removed in cutting	0.0	0.0	0.0	0.0	0.0	5.5	6.8	5.7
Remaining volume	15.2	15.2	17.8	15.3	17.5	13.6	14.1	12.9
1964-65-68								
Volume	17.3	18.0	21.1	18.5	20.1	17.2	17.9	14.9
Growth since 1959-60-68	2.1	2.8	3.3	,3.2	2.6	3.6	3.8	2.0
Removed in cutting	0.0	2.1	2.3	3.4	0.0	0.0	0.0	0.0
Remaining volume	17.3	15.9	18.8	15.1	20.1	17.2	17.9	14.9
Increase, 1949-68	8.6	6.5	6.9	4.5	11.0	7.6	4.6	3.6
Total volume removed in cuttings	2.9	4.8	6.9	6.6	0.0	5.5	6.8	5.7
Total production (Increase, 1949-68 plus volume removed in cuttings)	11.5	11.3	13.8	11.1	11.0	13.1	11.4	9.3

TABLE 13. Scientific names of species referred to in this study.

Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Basswood	*Tilia americana* L.
Birch, black	*Betula lenta* L.
Cherry, black	*Prunus serotina* Ehrh.
Cucumbertree	*Magnolia acuminata* L.
Locust, black	*Robinia pseudoacacia* L.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, white	*Quercus alba* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Walnut, black	*Juglans nigra* L.
Yellow-poplar	*Liriodendron tulipifera* L.