SILVICULTURAL CUTTINGS IN AN OAK-HICKORY STAND IN MICHIGAN: 21-YEAR RESULTS [1]

Victor J. Rudolph

Michigan State University
East Lansing, Michigan

and

Walter A. Lemmien

W. K. Kellogg Forest
Augusta, Michigan

ABSTRACT

Single tree selection, group selection and shelterwood cuttings were applied to an 80-year-old oak-hickory stand in the Kellogg Forest, and the results compared with those on uncut control areas. Overstory black oak (Quercus velutina Lam.) decreased on the selection areas, because of periodic removals by cutting; other species increased. Growth per acre per year over a 20-year period was 196 board feet for the single tree selection treatment, 221 board feet for the group selection, and 191 board feet for the control areas. Development of the reproduction on each treatment area was followed for the 21-year period, and showed that the best development of the more desirable species, oak and black cherry (Prunus serotina Ehrh.), was on the shelterwood areas, but even here, the former oak-hickory stand is being replaced by a stand which will have more mixed hardwoods in it than the previous stand.

INTRODUCTION

Oak-hickory stands form most of the forested area in the southern portions of the three Lake States--Minnesota, Wisconsin and Michigan. For example, in the southern half of lower Michigan, there are 929,000 acres of oak-hickory, more than one-third of the total forested area in that portion of the state. In these stands, oak predominates, and accounts for over one-third of the total timber volume harvested annually in this area (Chase et al. 1970).

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Oak-hickory stands occupy a wide range of sites, from rich, fairly moist bottomlands, to dry, sandy and gravelly ridges of low fertility. Obtaining adequate desirable hardwood reproduction on the majority of sites is widely recognized as a difficult silvicultural problem, particularly on better sites, where natural reproduction tends towards less desirable species composition than that of the stand being harvested.

Most past cuttings in such stands have not followed specific silvicultural methods. Thus, little is known of the effects which silvicultural cutting methods have on the quantity and quality of reproduction obtained, and its subsequent development. More is known about growth made by residual stands following various partial cuttings, but even here, data related to specific cutting methods are sketchy.

This study evaluated the effectiveness of single tree selection, group selection, and shelterwood cutting methods in obtaining adequate reproduction of desirable species in an oak-hickory stand in southern Lower Michigan. Population change and development of reproduction, by species, were evaluated in relation to cutting treatments. Changes in the residual stand after cutting were also analyzed to determine effects of cutting treatments on residual stand growth and mortality. Results obtained indicated the suitability of these cutting methods for managing and regenerating similar stands.

REVIEW OF LITERATURE

Oak is more difficult to regenerate on good than on poor sites. In uncut oak stands on very poor sites in southern Michigan, Arend and Gysel (1952) found that 50 percent of the reproduction was black oak (*Quercus velutina* Lam.) and white oak (*Q. alba* L.), and was well distributed; on good sites, only four percent of the reproduction was oak, and was poorly distributed. Weitzman and Trimble (1957) also pointed out that medium and poor sites are the easiest places to obtain natural oak reproduction. When it does occur on better sites, oak reproduction must compete with faster-growing species.

Oak and mixed hardwood reproduction was adequate on a 2-acre clear-cut area in east-central Wisconsin. However, American elm (*Ulmus americana* L.), sugar maple (*Acer saccharum* Marsh.), and black cherry (*Prunus serotina* Ehrh.) outnumbered and outgrew the northern red oak (*Q. rubra* L.) in the 5-year period after clear-cutting (Scholz and DeVriend 1957).

Scarification of the soil by disking and hand hoeing coincident with a good acorn crop more than tripled the amount of red oak reproduction over that on untreated areas in southern Wisconsin (Scholz 1955). From one-third to one-fourth of the stand was cut at the time of scarification. Five years later, however, most of the initial oak stocking had been lost, and regeneration was about equal on disked and undisked areas (Scholz 1959).

Very light cuttings do not favor oak reproduction. For example, in Ohio, Meteer and Anderson (1953) found that oak reproduction was practically absent following two light cuts five years apart in an old-growth stand, which was one-third oak and two-thirds mixed hardwoods. Merz and Boyce (1958) studied reproduction following the reduction of basal area from 76 to 52 square feet per acre on one area, from 86 to 32 square feet per acre on a second area, and clearcutting on a third area. They concluded that the objectives of selection cutting and clearcutting can be realized by using the group selection system for managing oak-hickory stands in southeastern Ohio. They found more oak reproduction where the 52 square feet of basal area was left than where the cut was heavier or where the area was clearcut. In contrast, Roach and Gingrich (1968) indicated that even-aged upland central hardwoods can best be regenerated by clearcutting.

Animal influences also make oak regeneration more difficult. Gysel (1957) found that in only one year out of five were there enough sound acorns remaining after animal consumption to provide a partial stocking of seedlings in a heavily-cut stand. In other years, the few sound acorns produced only a few scattered oak seedlings per acre.

On a good site in southern Michigan, Gammon *et al.* (1960) followed development of the reproduction for seven years after the predominantly oak overstory was clearcut during a bumper acorn crop. Adequate reproduction to form a fully-stocked new stand consisted of white ash (*Fraxinus americana* L.), sugar maple, American elm, black cherry, red maple (*Acer rubrum* L.), and a small number of oaks. Most of the oaks were of stump sprout origin. Severe rabbit browsing of red oak seedlings had practically halted their height growth during the previous four years.

In a statewide survey of unmanaged well-stocked oak stands in Missouri, Nash (1959) reported average annual growth of 92 board feet per acre for five years. Plass and Greth (1959) reported 8-year growth averaged 213 board feet per acre per year in an oak hickory stand in southern Illinois that had been given a "rehabilitation cut." Minckler (1957) reported a rapid and immediate diameter growth increase of released trees following a harvest and improvement cut in a pole-sized oak stand. Best growth response was by codominant and intermediate trees.

Arend and Scholz (1969) summarized management recommendations for oak forests in the Lake States. They stressed the importance of identifying site quality to apply appropriate silvicultural treatments. They also pointed out that advanced reproduction is essential to obtaining adequate oak restocking following harvest of mature stands. Sander (1972) also stressed the importance of advanced reproduction in regenerating oak stands.

METHODS

The Study Area

The stand studied was in the W. K. Kellogg Forest, in Kalamazoo County, near Augusta, Michigan. This area has a relatively mild, humid climate, strongly influenced by the surrounding Great Lakes. Spring-summer-fall air temperature (May-October) averages 65°F. The frost-free growing season is approximately 160 days. Precipitation averages 31.5 inches per year.

The 26-acre stand was even-aged and predominantly of black oak. When initial cuttings were made in 1954, the stand was approximately 80 years old. It occupied a rolling, well-drained site, with soils developed from stony glacial drift. Soils were predominantly sandy loams of the Hillsdale, Fox, Spinks, and Osthemo series. Site quality for oak ranged from poor on upper slopes and ridges to medium on middle and lower slopes (Gysel and Arend 1953).

The area may have been grazed previous to 1930, but not since. A light improvement cut was made in the stand in 1931, during which some of the defective and poorly-formed trees were removed for fuelwood. Litter accumulation averaged two inches. Common understory species were flowering dogwood (*Cornus florida* L.) and sassafras (*Sassafras albidum* L.).

Black oak formed 66 percent of the stand volume, northern red oak 20 percent, and hickory (*Carya ovata* (Mill.) K. Koch and *C. glabra* (Mill.) Sweet, 8 percent. Associated species in decreasing order were red maple and black cherry.

The average gross and net volumes per acre were 9,742 and 9,030 board feet respectively. Basal area for trees 7.5 inches d.b.h. and larger averaged 86 square feet per acre.

Experimental Design

The area was subdivided into four randomized blocks, each having four 1.65-acre plots. The exterior half-chain (33 feet) of each plot formed an isolation area, so that data for each plot were obtained from an interior .93-acre area.

Initial measurements were made of each tree 7.5 inches d.b.h. and larger and the following information was recorded:

1. Tree number.
2. Species.
3. D.b.h., to the nearest tenth-inch.
4. Merchantable height in 16-foot logs, to the nearest half-log.

5. Crown class, by the four standard crown classes (dominant, co-dominant, intermediate, and suppressed).
6. Vigor class, according to the four vigor classes used for northern hardwoods (Goetzen, et al. 1943).
7. Tree class, based on the grade of the butt log, by the four log grades for northern hardwood logs (U.S. Forest Service 1949).
8. Cull defect class, based on the six cull defect classes developed by Zillgitt and Gevorkiantz (1946).

During the winter of 1954-55, the randomly assigned cutting treatments were applied to the plots. The treatments were:

1. Single tree selection, which left 75 square feet of basal area per acre in trees 7.5 inches d.b.h. and larger.
2. Group selection, which removed groups of trees occupying an area of approximately one-tenth acre. From the rest of the plot, only a few very defective trees were cut, so that the residual basal area per acre was approximately 75 square feet.
3. Shelterwood, which left approximately 40 square feet of basal area per acre in vigorous trees of desirable species (Fig 1).
4. Control, on which no cutting was made.

Small crawler tractors were used to ground-skid the logs to landings off the experimental area and all truck loading took place at these landings. There was no skidding across control plots. Logging commenced in November, and was completed in April. Most of the logging took place without appreciable snow cover on the ground. All tops of sawlog trees and trees below sawlog size which were cut were used for fuelwood. Where slash was concentrated, it was lopped and scattered after skidding was completed.

Cuttings in the single tree selection and group selection treatments were continued at 5-year intervals, using the same guidelines as in the initial cuttings. In the shelterwood treatment, the removal cutting was made 10 years after the seed cutting.

In October 1964, ten years after the initial cuttings, the seedling and sapling stems of sassafras, dogwood, viburnum (*Viburnum dentatum* L. and *V. acerifolium* L.), and similar undesirable species were basal sprayed with 2,4,5-T on half of each cutting plot in an attempt to reduce competition from these unwanted stems.

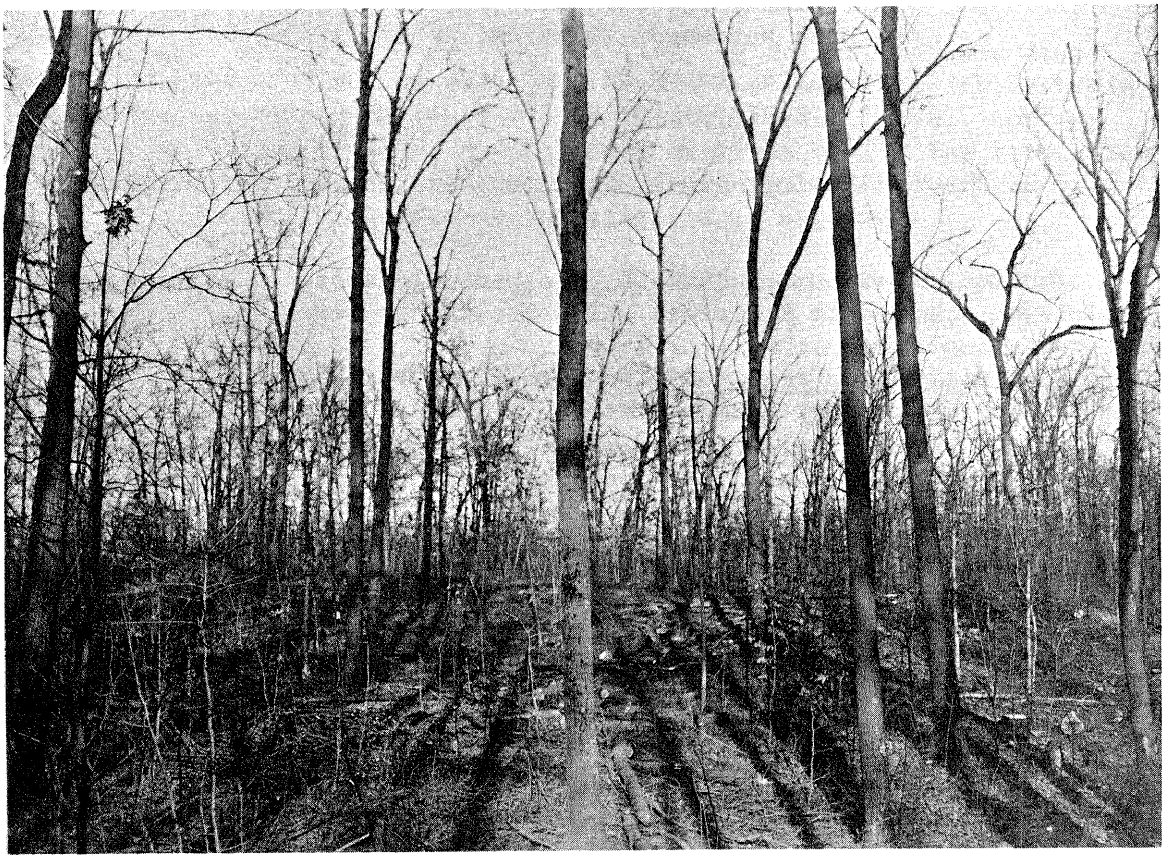

Figure 1. A shelterwood cutting plot in December 1954. The cutting has been completed, but the logs have not been removed yet. This was the most drastic of the treatments applied to this stand.

Stand Inventories

Before each 5-year cut on the selection cutting plots, a reinventory of the residual stand was made on the same basis as the initial inventory. On the shelterwood plots, a reinventory was made before the removal cut. Mortality and ingrowth were included in all reinventory data.

Reproduction inventories were made annually for five years after cutting. Tallies were made on 16 randomly but permanently located mil-acre quadrats within each plot. In the group selection plots, quadrats were located within cut groups. Reproduction counts by species were made for the first four inventories, and the fifth-year tally included tree

reproduction heights. Periodic reinventories of reproduction were made preceding each 5-year cut. The reproduction inventory in 1975, 21 years after the initial cuttings, was taken on 4-milacre plots using the original milacre plot centers as the centers for the larger plots. Plot size for this inventory was increased to obtain a more representative sample of all stems in the stands less than 8 inches d.b.h. Diameter and height measurements were made on each stem.

RESULTS AND DISCUSSION

Residual Stand Development and Growth

The most noticeable changes in stand characteristics over the 20-year management period occurred in the number of trees per acre and their diameters on the single tree selection and group selection areas (Table 1). As a result of the periodic cuttings, the number of black oak stems was reduced to half the initial level. On the uncut control plots, the number of black oak stems remained practically constant. The other species numbers changed little on the single tree selection plots, decreased in the group selection plots, and increased on the control plots.

The diameter of black oak had the greatest increase in the single tree selection plots, averaging approximately 3 inches during the 20 years. Red oak grew almost that well on both group and single tree selection plots. Diameter increases for the other species were considerably lower in the cutting treatments and the control plots.

Because the cuttings in both selection methods removed mostly black oak, the basal area of this species was reduced by about 50 percent during the management period. The other species generally showed some gains in basal area. Annual basal area growth on the selection plots and the control plots did not differ appreciably, averaging about 1.5 square feet per acre per year.

Significant improvement in stand quality occurred during the 20-year management period based on the proportion of stand volume that shifted from tree classes 3 and 4 into classes 1 and 2 (Table 2). The largest improvements occurred in red oak. Changes among other species did not differ greatly.

Stand quality improved only slightly in the two selection cutting treatments in comparison to control plots. In stands such as the one used in this study, potential butt log quality is usually apparent by the time stems reach large pole or small sawlog size; thereafter, improvement in grade of butt logs is dependent on diameter increment. The

Table 1. Stand characteristics in 1954 and 1974, by treatment and species, for stems 7.5 inches d.b.h. and larger--per acre basis.

Treatment	Species	Number of trees 1954	Number of trees 1974	Avg. D.B.H. (inches) 1954	Avg. D.B.H. (inches) 1974	Basal area (sq. ft.) 1954	Basal area (sq. ft.) 1974	Stocking percent[1] 1954	Stocking percent[1] 1974
Single tree selection	Black oak	52.8	24.2	13.6	16.6	53.0	36.5		
	Red oak	13.8	14.5	13.5	16.2	13.7	20.8		
	Hickory	19.9	17.0	10.2	11.4	11.4	12.0		
	Misc.[2]	17.7	16.2	10.4	11.7	10.5	12.1		
	All species	104.2	72.0	12.5	14.4	88.6	81.4	73	66
Group selection	Black oak	50.4	24.5	14.1	15.4	54.4	39.2		
	Red oak	15.8	11.2	14.7	17.6	18.6	19.0		
	Hickory	16.2	13.8	10.7	11.5	10.2	9.9		
	Misc.[2]	18.5	16.5	10.3	12.0	10.7	12.9		
	All species	100.9	66.0	13.1	15.0	93.9	81.0	76	64
Control	Black oak	42.2	40.7	13.2	15.4	39.9	52.6		
	Red oak	13.2	15.0	13.6	15.9	13.3	20.7		
	Hickory	18.2	21.0	10.7	11.9	11.4	16.1		
	Misc.[2]	21.8	25.0	11.0	11.5	14.3	18.0		
	All species	95.4	101.7	12.3	13.9	78.9	107.4	67	86
Shelterwood	Black oak	52.1	--	13.8	--	54.2	--		
	Red oak	13.6	--	14.6	--	15.8	--		
	Hickory	18.5	--	10.9	--	12.1	--		
	Misc.[2]	13.3	--	10.6	--	8.1	--		
	All species	97.5	--	13.1	--	90.2	--	72	--

[1] From Roach and Gingrich (1968).

[2] White oak, red maple, black cherry, sassafras.

removal of lower quality trees in the selection cuttings did not improve stand quality appreciably over that which occurred on control plots. But, because this stand was 80 years old when the study began, its structure and composition were already well defined. Development of tree quality probably would be different in stands with an uneven-aged structure.

Table 2. Stand quality in 1954 and 1974, by treatment and species.

Treatment	Species	Percentage of species volume by tree class 1954					1974				
		1	2	3	4	Total	1	2	3	4	Total
Single tree selection	Black oak	10	24	57	9	100	12	31	54	3	100
	Red oak	31	23	35	11	100	24	35	37	4	100
	Hickory	--	6	62	31	100	--	6	66	28	100
	Misc.[1]	9	--	50	41	100	--	18	60	22	100
	All species	13	21	53	13	100	14	28	51	7	100
Group selection	Black oak	13	19	61	7	100	15	45	38	2	100
	Red oak	32	31	34	3	100	43	44	11	2	100
	Hickory	--	--	76	24	100	--	26	46	28	100
	Misc.[1]	--	13	54	33	100	8	39	36	17	100
	All species	16	20	55	9	100	21	43	31	5	100
Control	Black oak	10	19	60	11	100	7	31	57	5	100
	Red oak	13	40	40	7	100	36	32	27	5	100
	Hickory	--	14	53	33	100	5	24	53	18	100
	Misc.[1]	--	16	51	33	100	--	40	38	22	100
	All species	8	22	55	15	100	13	32	47	8	100

[1] White oak, red maple, black cherry, sassafras.

Because of initial variation in the density and composition of the stand, the initial stand volumes and species distribution differed by cutting treatments (Table 3). Per acre volumes ranged from 9,945 board feet on the group selection areas to 7,403 board feet on the control areas. The volume ranged from 60 to 70 percent black oak, with smaller differences among the other species. The initial cutting treatments in 1954 reduced the range in volume considerably, but changed the volume distribution by species only slightly. Most of the volume removed in the initial and subsequent periodic cuttings was black oak.

For single tree selection and group selection treatments, reduction in the percentage of cull over the 20-year management period amounted to one percent, from an average of 8.5 to 7.5 percent. In black oak, which constituted more than half the original stand volume, the percentage of cull on the control plots remained constant, whereas it decreased on the cutting treatment plots.

Table 3. Initial and residual stand net volumes and subsequent growth rates by treatment and species - per acre basis.

Treatment	Species	Initial stand volume 1954	Residual stand volume 1954	Volume removed 1954-74	Stand volume 1974	20-year growth	Average annual growth
		board feet					
Single tree selection	Black oak	6,086	5,183	3,113	4,885	1,912	96
	Red oak	1,546	1,525	141	2,531	1,126	56
	Hickory	548	462	146	780	378	19
	Misc.[1]	520	427	191	825	496	25
	All species	8,700	7,597	3,591	9,021	3,912	196
Group selection	Black oak	6,467	5,341	3,454	5,515	2,502	125
	Red oak	2,322	1,970	827	2,632	1,137	57
	Hickory	583	457	173	705	295	15
	Misc.[1]	573	475	148	911	486	24
	All species	9,945	8,243	4,602	9,763	4,420	221
Control	Black oak	4,456	4,456	-	6,152	1,696	85
	Red oak	1,446	1,446	-	2,534	1,088	54
	Hickory	742	742	-	1,358	616	31
	Misc.[1]	759	759	-	1,181	422	21
	All species	7,403	7,403	-	11,225	3,822	191
				Volume removed 1954	Stand volume 1964	10-year growth	
Shelterwood	Black oak	6,413	3,368	3,045	4,449	1,081	108
	Red oak	1,986	1,536	450	1,894	358	36
	Hickory	858	152	706	301	149	15
	Misc.[1]	503	199	304	206	7	1
	All species	9,760	5,255	4,505	6,850	1,595	160

[1] White oak, red maple, black cherry, sassafras

Volumes of species other than black oak contributed more to total stand volumes in 1974 than they did in the 1954 stand. The largest gains were made by red oak, especially in the single tree selection method, where red oak was favored over the black oak in the periodic cuttings.

Growth of residual stands did not differ greatly among treatments for the 20-year period, ranging from 191 board feet per acre per year on the control plots to 221 board feet per acre per year on the group selection plots. The slight advantage of the group selection treatment is a result of a higher growing stock volume base, even though the basal areas were maintained at the same level by periodic cuttings. The residual stand in the shelterwood treatment grew quite rapidly, even though on a reduced growing stock base. Growth on control plots occurred on an increasing growing stock base, whereas the growing stock for the selection plots was held relatively constant by the periodic five-year cuttings.

On treatment plots, mortality was insignificant because of the periodic cuttings. On the control plots, mortality for the 20-year period was 702 board feet per acre, or about 35 board feet per acre per year.

Results from this study can be converted into monetary terms to give some indication of the financial results that may be expected from managing similar stands by similar silvicultural methods. At an average stumpage price of $25.00 per M board feet (1/4-inch International Rule) the gross income from the single tree selection areas which grew at the rate of 196 board feet would be approximately $4.90 per acre per year. If a selection cutting were made every five years, the periodic five-year gross income would be $24.50 per acre. For the group selection method, with a growth of 221 board feet per acre per year, the gross income every five years would be $27.63 per acre. These incomes are very modest at best, but it should be realized that they represent the productivity from an area with rather unproductive and unsuitable soils and sites for other uses.

Reproduction Establishment and Development

Years 1-5 -- For the first five years after initial cutting there were high numbers of reproduction stems of most species in all treatments (Table 4). Although red maple numbers were highest, there were large fluctuations from year to year for all treatments. Many red maple seedlings were transitory, and did not persist more than a year or two. By the fifth year, the group selection and shelterwood plots had larger and more than twice as much red maple reproduction over one foot in height as the control and single tree selection plots. However, because of variation within treatments, differences were not significant. Some red maple reproduction was 7 feet in height.

Oak was the second most numerous in the reproduction stratum for five years after initial cutting. During this period, their numbers declined gradually in all treatments except group selection. Only on the group selection and shelterwood plots did significant numbers of oak reach more than one foot in height in five years. Seedling height growth of oak reproduction on the group selection plots was significantly better than on other treatments, with some stems reaching 10 feet.

Table 4. Reproduction of major species for five years after initial cutting, by treatment, per acre basis.

Species	Treatment	Years after cutting: 1 Total No.	2 Total No.	3 Total No.	4 Total No.	5 Less than 1 ft. height No.	5 More than 1 ft. height No.	5 More than 1 ft. height Avg. height (feet)
Oak	Single tree selection	2,450	2,454	1,734	1,750	1,484	484	1.8
	Group selection	3,406	3,050	2,969[2/]	3,000[2/]	1,906	2,312[2/]	2.5[2/]
	Shelterwood	3,358	3,484	2,937[2/]	2,672	1,688	1,062[2/]	1.8
	Control	1,844	1,593	1,219	1,172	750	312	1.0
Red maple	Single tree selection	3,890	2,376	3,438	2,344	1,563	516	1.2
	Group selection	2,156	875	3,469	2,219	1,812	1,125	2.6
	Shelterwood	6,922	2,453	5,859	4,828	2,672	1,109	2.0
	Control	3,234	1,922	3,594	3,047	1,484	297	.9
Black cherry	Single tree selection	1,547	1,094	1,891	1,344	500	484	2.8
	Group selection	1,906	1,344	1,406	1,219	1,844	1,812[2/]	4.6[2/]
	Shelterwood	1,438	1,172	1,828	1,328	484	562	1.9
	Control	1,156	906	1,375	1,484	828	328	1.5
Hickory	Single tree selection	266	1,453	2,031	1,468	1,656	312	1.4
	Group selection	312	750	1,281	1,062	1,531	781[2/]	1.9
	Shelterwood	219	1,391	1,547	1,484	844	719[2/]	1.5
	Control	329	1,454	1,484	1,844	1,610	234	1.2
Misc.[1/]	Single tree selection	1,390	1,281	1,984[2/]	1,062	203	719	2.8
	Group selection	3,438[2/]	2,031	2,656[2/]	1,688	219	1,906[2/]	4.6[2/]
	Shelterwood	3,359[2/]	2,906	4,906[2/]	2,890	266	1,391	3.3
	Control	468	578	719	828	234	344	1.6

[1/] Includes sassafras, elm, white ash and aspen.

[2/] Significantly greater than the control at the 5% level.

There were between 1,000 and 2,000 black cherry seedlings per acre in all treatments for the first five-year period, except on group selection plots, where there were significantly larger numbers. For both black cherry and miscellaneous species such as sassafras, elm, ash and aspen (Populus tremuloides Michx.), height growth was best on the group selection plots and was greater than that for any other species.

For most treatments, the number of hickory seedlings showed some increase during the five years after cutting. Again, the group selection treatment produced the best results in seedling numbers and height growth, with the shelterwood treatment next best.

The miscellaneous species showed significantly higher numbers of stems in group selection and shelterwood treatments than in single tree selection or control treatments. Approximately 80 percent of these trees were sassafras, many of them originating as sprouts from small stems broken off or destroyed during logging.

A summary of results five years after cutting indicated that the group selection treatment had the highest numbers of reproduction stems over one foot in height, and that these had made significantly greater height growth than stems in other treatments. The next best results occurred on shelterwood plots for all species except black cherry, which had greater height growth on the single tree selection areas. Seedling numbers and their height growth were higher on the single tree selection areas than on the control areas, but not significantly so.

Years 7-15 -- Beginning with the reproduction inventory in the seventh year after cutting, individual oak species were identified (Table 5). Black oak emerged as the most numerous of the three oaks, through the fifteenth year after cutting, but white oak showed somewhat greater height growth. The eighth year after cutting there was a heavy acorn crop which resulted in a temporary increase in oak numbers in the tenth-year inventory. By the fifteenth year, oak numbers varied considerably among the four treatments, with group selection and shelterwood plots having the highest numbers; however, the differences were not significant. Also, a gradual shift in height growth occurred in the period between the seventh and fifteenth years in favor of the shelterwood treatment, so that the ranking of height growth for all three oaks was: shelterwood, group selection, single tree selection and control. Among the oaks, black oak was the tallest with some stems attaining 15 feet.

Red maple seedlings continued to fluctuate in numbers, but the group selection and shelterwood plots still had the highest numbers. As with the oaks, the tallest red maple by the fifteenth year occurred on the shelterwood plots, but they were not significantly taller on the average than on group selection plots. The tallest red maples were 17 feet.

Table 5. Reproduction of major species 7, 10 and 15 years after initial cutting, by treatment, per acre basis.

		Years after cutting								
		7			10			15		
		Less than 1 ft. height	More than 1 ft. height		Less than 1 ft. height	More than 1 ft. height		Less than 1 ft. height	More than 1 ft. height	
Species	Treatment	No.	No.	Avg. ht.ft.	No.	No.	Avg. ht.ft.	No.	No.	Avg. ht.ft.
White oak	Single tree sel.	16	233	2.0	31	453	2.2	16	156	2.0
	Group selection	0	109	3.0	31	531	4.0	0	219	4.1
	Shelterwood	31	218	1.7	0	514	5.0 2/	0	124	4.9
	Control	6	109	.5	78	281	1.9	62	94	.6
Red oak	Single tree sel.	265	140	1.0	266 2/	984 2/	1.4	16	375	1.2
	Group selection	62	186	2.0 2/	0	781	1.6	31	500	2.6
	Shelterwood	171	295 2/	1.8	16	703	2.0 2/	0	405	2.9 2/
	Control	109	78	1.0	62	203	.9	47	94	1.0
Black oak	Single tree sel.	700	249	1.4	625	1,031	1.4	94	437	1.6
	Group selection	217	326	2.1	438	2,250 2/	3.0 2/	62	281	4.0
	Shelterwood	434	420	1.8	266	1,546	2.8 2/	78	405	4.2
	Control	297	78	.8	344	532	1.1	234	78	.8
Red maple	Single tree sel.	1,135	747	2.3	922	2,593	2.2	453	984	2.7
	Group selection	310	590	3.3	62	2,844	4.5 2/	72	1,312	4.5 2/
	Shelterwood	1,286	1,320	2.3	344	3,639	4.1 2/	78	1,514	5.0 2/
	Control	2,187 3/	531	1.3	1,078 3/	2,812	1.8	1,078 3/	781	1.8
Black cherry	Single tree sel.	281	561	2.0	156	1,687	2.8	78	545	3.8 2/
	Group selection	46	498	5.8 2/	0	3,094 2/	7.7 2/	0	656	4.5 2/
	Shelterwood	480	683 2/	2.9	47	1,484	4.7 2/	16	842 2/	3.4 2/
	Control	1,750	271	1.4	359	688	1.8	259	328	1.9
Hickory	Single tree sel.	1,104	405	1.2	1,078	1,094	1.5	391 2/	921 2/	1.6
	Group selection	295	265	1.8	438	1,594 2/	3.0 2/	62	1,062 2/	2.5 2/
	Shelterwood	574	870	2.1 2/	250	1,624 2/	2.1	62	1,343 2/	2.9 2/
	Control	1,328 3/	297	1.1	1,359	484	1.6	281	452	1.3
Misc. 1/	Single tree sel.	233	702	2.2	125	1,936	3.8 2/	31	1,186	3.2
	Group selection	31	482	5.1 2/	0	2,969	7.2 2/	0	3,250 2/	3.4
	Shelterwood	93	1,072	4.4 2/	16	2,482	6.2 2/	16	1,795 2/	5.4 2/
	Control	156	359	1.6	422 3/	1,342	2.2	62	500	2.4

1/ Includes sassafras, elm, white ash and aspen.
2/ Significantly greater than the control at the 5% level.
3/ Significantly greater than the other treatments at the 5% level.

Black cherry reproduction showed much the same pattern of abundance as the other species, but height growth was significantly better for group selection than other treatments. A few black cherry stems were 12 feet in height after 15 years.

Hickory reproduction numbers fluctuated moderately from one inventory to the next, with group selection and shelterwood treatments having significantly more reproduction than other treatments. The fifteenth-year tally also showed that the reproduction on the shelterwood plots was taller than on the group selection plots.

Reproduction of miscellaneous species, mostly sassafras, maintained high numbers in successive inventories. The silvicide applied by basal spraying to half of each cutting plot reduced the average height of sassafras taller than one foot in the fifteenth-year inventory. Numbers of sassafras did not change appreciably because most treated stems sprouted the following year. However, height of the new sprouts was less than that of the stems that were killed by basal spraying. No impact of the herbicide on the numbers or height growth of other treated species could be detected.

Year 21 -- The inventory taken in 1975, 21 years after initial cutting, best demonstrated the development of the new stands, particularly on the shelterwood and group selection plots (Table 6). A representative view of each treatment in 1975 is presented in figures 2, 3, 4 and 5.

Twenty-one years after the initial cuttings, red maple was the most abundant reproduction in all height classes and was also the leader in height growth. The best growth occurred on the shelterwood plots but development was also good on other treatment plots. It is evident that the future stand will have more red maple in it than the previous stand.

Red oak seedlings were the most numerous of the three oaks in the smaller height classes on all treatment areas except shelterwood. The shelterwood plots also had the largest numbers of oaks in the larger height classes, especially white oak. The group selection plots ranked next, followed by single tree selection plots. Black oak reproduction grew well only in shelterwood plots.

In all treatments, black cherry was well represented. Stem numbers and their heights were about the same for group selection and shelterwood treatments, although numbers were much lower in control and single tree selection treatments. Even though the study area is not a good site for black cherry development, there were more stems entering the new stand than were present in the past.

Hickory developed equally well on group selection and shelterwood plots. It was less abundant than red oak, equal to black oak, and greater than white oak, and height growth was about equal to that of white oak.

Table 6. Reproduction and residual stand components less than 8 inches d.b.h. 21 years after cutting, by height class, species and treatment - per acre basis.

Species	Treatment	Number of stems by height class - ft.									
		<1	1	2-5	6-10	11-15	15-20	21-30	31-40	41-50	51+
White oak	Single tree sel.	64	64	80	16	11	4	4	8	4	
	Group selection	112	96	48	36	28	20	8	8	4	
	Shelterwood	160	48	16			12	16	16	12	
	Control	128	32								
Red oak	Single tree sel.	864	160	144	4	8	4	8		8	
	Group selection	960	80	48		4	8	20	4		
	Shelterwood	96	16	32	16			8			
	Control	448									
Black oak	Single tree sel.	192	96	160							
	Group selection	368	128	64	44	8		4			
	Shelterwood	64		80	4	24	12	24	24		
	Control	368	112	48							
Red maple	Single tree sel.	560	384	400	172	44	24	32		4	4
	Group selection	784	208	352	144	56	48	44	16		
	Shelterwood	928	240	240	92	36	44	68	76	28	8
	Control	1,536	304	448	76	28	12	20	8	8	4
Black cherry	Single tree sel.	432	304	352	172	20	4	4		8	
	Group selection	800	256	496	140	40	36	32	8	16	
	Shelterwood	800	384	416	136	28	12	32	24	4	4
	Control	432	144	208	88	8	4	8		8	4
Hickory	Single tree sel.	512	256	256	52	16			4	4	
	Group selection	272	112	256	56	16	4	12	12		4
	Shelterwood	192	144	144	124	40	12	8		4	4
	Control	496	144	128				4		4	4
Dogwood	Single tree sel.			4	76	72	20	28	4		
	Group selection				24	68	32	16			
	Shelterwood				48	136	60	116	8		
	Control			16	140	172	152	60	4		
Misc.1/	Single tree sel.	240	144	496	132	92	28	48	8		
	Group selection	256	368	464	252	128	56	60	36	8	4
	Shelterwood	224	160	144	68	96	60	112	36	4	4
	Control	240	176	192	112	40	40	28	8		

1/Includes sassafras, elm, ash and aspen.

Figure 2. A control plot in 1975. No cuttings have taken place here.

Figure 3. A single tree selection plot in 1975. Cuttings were made here in 1954, 1959, 1964 and 1969.

Figure 4. A shelterwood plot in 1975. The removal cut was made in 1964.

Figure 5. A group selection plot in 1975. The group cutting removing the trees from the area in the foreground was made in 1954.

Sassafras, which made up more than 95 percent of the miscellaneous species group, continued to be numerous and aggressive, even on the control plots. Although a weed species, it was a strong competitor with more desirable species. There were no noticeable differences in numbers or heights of sassafras between portions of the plots that had been treated with basal spraying in 1964 and those that had not been treated.

Flowering dogwood was included in the 1975 inventory because it had become noticeably more numerous and developed as the study progressed. Like sassafras, it was important as a competitor for growing space. The dogwood showed some residual effect of the 1964 basal spraying, because its numbers and heights on the control plots were slightly greater than those on cut plots.

The diameter distribution of stand components less than 8 inches d.b.h. indicated that red maple, dogwood and sassafras predominated on control plots (Table 7). The single tree selection plots were similar, but had more oak and black cherry; however most stems of these species had not reached breast height after 21 years. Species composition by diameter classes on group selection and shelterwood plots was similar, but more evenly distributed among the several species on the shelterwood plots. The group selection plots had more smaller-sized stems and fewer larger-sized stems than the shelterwood plots. This was attributed to the edge effect of the residual stand which increased proportionately more over time on the group selection plots than in other treatments.

SUMMARY

Single tree selection, group selection and shelterwood cuttings were applied to 12 randomly located 1.65-acre plots in an even-aged 80-year-old oak-hickory stand on a medium to poor site in southern Lower Michigan. The selection cuttings were continued for 20 years at five-year intervals, retaining a residual basal area of 75 square feet per acre. The removal cut in the shelterwood treatment was made 10 years after the seed cut reduced the stand to 38 square feet of basal area per acre. Uncut control plots were left for comparison.

In the selection cuttings, black oak, which formed two-thirds of the initial stand, was reduced by 50 percent during the 20-year period by cutting removals. Black oak decreased slightly on the control areas, while the other species showed small gains in numbers. Black oak diameters increased three inches on the single tree selection areas, and much less on the other treatments. Stand quality changes accompanied the increases in tree diameters; many trees with a grade 3 butt log became trees with a grade 2 butt log. These quality changes did not differ between the various treatments. The amount of defect decreased about one percent, from 8.5 to 7.5 percent, with the cutting treatments, and remained fairly constant on the control areas.

Table 7. Stems less than 8 inches d.b.h. 21 years after cutting, by diameter class, treatment and species - per acre basis.

Treatment	D.B.H. inches	Number of stems, by species						
		Oaks	Red maple	Black cherry	Hickory	Sassa-fras	Dog-wood	Misc.[1]
Single tree selection	0[2]	1,782	1,516	1,250	1,078	641		282
	1	32	78	24	20	113	152	16
	2	16	27	4		54	24	
	3	4	8			28	12	4
	4	8	4	4			12	
	5	8	4					
	6			4	8		4	
	7	4		4				
Group selection	0	981	1,453	1,192	903	1,139		186
	1	69	109	86	55	303	52	74
	2	46	34	74	12	38	14	39
	3	20	7	14		13	7	21
	4	20		14	7			21
	5	14		7				14
	6			14				
	7							
Shelterwood	0	469	1,406	1,656	640	312		41
	1	47	113	51	59	152	183	20
	2	16	58	28	4	109	70	8
	3	32	43	8		20	47	4
	4	4	24	8		4	27	4
	5	8	16	8	4	16	8	4
	6	16	12	4	4	4	4	4
	7	4	16	4	4			
Control	0	1,187	2,281	844	812	422		203
	1		51	20		31	316	47
	2		12	4		28	117	8
	3		12		8	28	55	
	4		12	4		4	8	
	5		4				4	
	6	4		12	8		4	
	7		4					

1/Includes elm, ash and aspen.

2/Stems less than breast height (4.5 feet).

Mortality on the cutting treatment areas was insignificant, but averaged 35 board feet per acre per year on the uncut control areas. Growth on the single tree selection areas was 196 board feet per acre per year over the 20-year period. On the group selection areas it was 221 board feet, and 191 board feet on the control areas. The shelterwood plots produced 160 board feet per acre per year for the 10 years before the removal cut was made.

The growth and development of these stands over the 20-year period indicates results to be expected from managing similar stands by these silvicultural methods. Results obtained in this study are similar to those reported by Plass and Greth (1959), and Minckler (1957), but growth obtained was more than twice that reported by Nash (1959).

Reproduction was very abundant on all treatments for the first five years after cutting. Red maple was the most numerous, with oak reproduction second in importance. Group selection produced the most and the tallest reproduction after five years; shelterwood was next best.

Inventories in the seventh, tenth, fifteenth and twenty-first years after cutting showed increasingly that the shelterwood plots had the most numerous new stems, and the best height growth. Red maple predominated in numbers and height in all treatments. Black cherry and hickory reproduction was well represented in both group and single tree selection treatments. Among the oaks, red oak was the most numerous in the smaller height classes. White oaks on the shelterwood areas were tallest, although a few black oaks also grew to about the same height there.

Sassafras and dogwood were abundant in all treatments, especially on control plots. These two undesirable species predominated over considerable growing space at the end of the 21-year management period. Basal spraying with a silvicide half-way through the management period on one-half of each cutting plot had no appreciable effect on sassafras, and only slightly decreased dogwood numbers.

Twenty-one years after initial treatment, red maple, dogwood and sassafras reproduction dominated that portion of the stand less than eight inches d.b.h. on the control plots. On the single tree selection plots, composition and development were similar, but there was more oak and black cherry; however, most oak and cherry stems were still below breast height.

Among trees less than 8 inches d.b.h., group selection and shelterwood treatments showed a relatively equal distribution of oaks, black cherry, red maple, hickory, sassafras and dogwood. The reproduction on shelterwood plots showed the best height growth, but even on these areas, growth of the desired species in the reproduction was slow, due in large part to strong competition from sassafras and dogwood. The former oak-hickory stand is being replaced by a stand which will have more mixed hardwoods in it than the previous stand.

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ABOUT THE AUTHORS

Victor J. Rudolph received a B.S. in forestry from Utah State University in 1941, and M.F. and D. For. degrees from the Duke University School of Forestry in 1943 and 1950, respectively. After naval service 1943-46, he was research associate, 1946-48, and assistant professor and assistant director of the Duke Forest, 1948-52, Duke University School of Forestry. Since 1952, he has been on the staff of the Forestry Department at Michigan State University, teaching and conducting research in forest management. He is the author or coauthor of more than 60 publications in the field of forest management.

Walter A. Lemmien received B.S. and M.S. degrees in forestry from Michigan State University in 1940 and 1953, respectively. After service in the army 1940-45, he became the resident forester at the W. K. Kellogg Forest, owned and operated by Michigan State University, where he supervises on-the-ground activities in some 30 research projects. He is the author or coauthor of 56 publications in various fields of forestry.

For reprints write: Dr. Victor J. Rudolph
Department of Forestry
Michigan State University
East Lansing, Michigan 48824