OAK-HICKORY REGENERATION IN EASTERN KENTUCKY[1/]

Deborah B. Hill[2/]

Abstract.--A 1958 experiment designed to increase the oak-hickory component in previously high-graded mixed hardwood stands in Eastern Kentucky was remeasured in 1981 to determine its success. The experiment utilized three circular opening plot sizes (50,150 and 250 ft. diameter), and three herbicide treatments using 2,4,5-T in oil (control, remove all regeneration, leave only oak-hickory regeneration); each size-treatment combination was replicated three times. Density measurements taken in 1981 and compared with initial measurements demonstrated that oaks and hickories persisted in almost all plots, regardless of size or treatment. Basal area measurements from 1981 showed the oak-hickory complex to exhibit variable stand dominance at this time. Previous studies indicating that oaks may exhibit late ascendance justify continuing remeasurements of this Kentucky experiment to see if the oak-hickory complex will demonstrate greater stand dominance with increasing age.

Keywords: oak-hickory regeneration, stand dynamics, herbicides

INTRODUCTION

Foresters and other natural resource managers have expressed considerable concern about the problem of regenerating oak (Quercus spp.) in mixed stands after cutting. Oliver's (1978) work in New England implied that fairly small numbers of oak in the developing stand (e.g., 100 oaks/acre) were sufficient to create a stand of dominant oaks (~45 oaks/acre) at age 50 or greater. Studies in central and Appalachian hardwoods (McGee 1967, Sander et al. 1976, Smith 1981, Loftis 1982, Gottschalk 1983, Johnson and Krinard 1983, Loftis 1983a, 1983b Sander 1983, Lorimer 1984, O'Hara 1986, Ross et al. 1986) indicate that a somewhat larger number of stems of large oak advance reproduction, supplemented by stump sprouts, is necessary to establish a new oak stand in competition with early dominant species such as yellow-poplar in these regions. Some authors (Loftis 1978, Smith 1981) have also tested the efficacy of herbicide treatment prior to or following harvest to control regeneration of species other than the desired oaks.

Oliver (1978) also determined, from stem analysis, that red oak exhibits late ascendance in New England. It remains in the mid-canopy or lower canopy for two to three decades while faster-growing species overtop it. However, at age 25 or older, oak will gradually overtop its competitors (red maple and black birch (Oliver 1978)) to dominate the stand. Whether a similar growth pattern is evident with white oaks in the Appalachian or central hardwood complex is not yet clear.

[1/] Paper presented at the Sixth Central Hardwood Forest Conference, Knoxville, TN, February 24-26, 1987.

[2/] Assistant Professor, Department of Forestry, University of Kentucky, Lexington, KY 40546-0073.

In 1958, a cooperative agreement between the Kentucky Agricultural Experiment Station and the Berea Forest Research Center (USFS) initiated an experiment to determine appropriate size of opening for group selection cutting and subsequent cultural treatment in oak-hickory stands in eastern Kentucky. The purpose of the experiment was to upgrade previously high-graded stands by increasing the relatively more economically valuable oak-hickory component of the stand. The study was carried out on Robinson Forest, the research forest for the University of Kentucky, which had been cut heavily in the early 1920's. By the late 1950's there was not only some good quality young timber on the land, but also older residuals, often of poor quality or less desirable species, left from the earlier cut.

Robinson Forest is located in southeastern Kentucky and is situated on the Rugged Eastern Area of the Cumberland Plateau as defined by Braun (1950), and is characterized by deep, narrow valleys and winding pointed ridges (McFarlan 1943). Elevations range from 800 to 1600 ft m.s.l. Soils are primarily deep and well-drained loams. Climate is temperate humid continental with warm summers and cool winters. Vegetation is the mixed mesophytic forest association (Braun 1950) and is the most complex association of the eastern deciduous forest, dominated by red and white oak, yellow-poplar, sugar maple, and beech, among others. Harvesting practices in this century, largely highgrading, have resulted in a second growth forest that is not as rich as the original forest, particularly following the loss of American chestnut (Castanea dentata) (Overstreet 1984).

METHODS

Experimental plots were established on the south side of a main ridge between two watersheds on Robinson Forest in eastern Kentucky (fig. 1). Aspects varied over almost 180 degrees, but were predominantly south-easterly and therefore fairly dry. Slopes on the forest are characteristically steep; the plots varied in slope from 33% to 66%, most commonly about 50%. Site index for oaks and mixed hardwoods ranges between 55 and 65, but on these dry midslope plots probably is in the lower part of that range.

Circular plots of three sizes (D = 50, 150, and 250 ft) were established. All species of commercial value greater than 12" in diameter were cut and removed. Unmerchantable

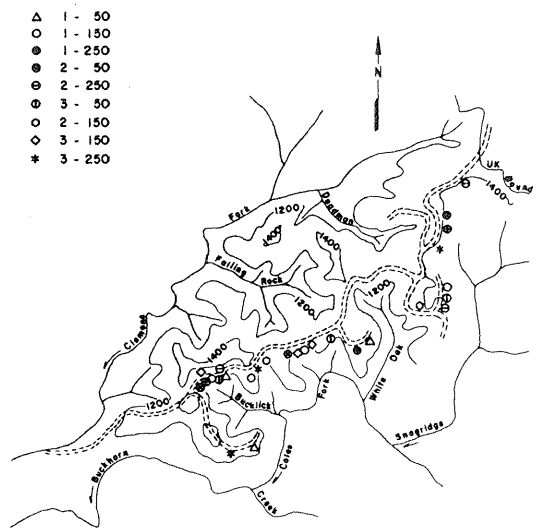


Figure 1.—Plot Locations, Oak-Hickory Study Robinson Forest, Breathitt/Knott Counties

trees greater than 12" dbh were girdled uniformly to a subcambial depth[3/] and trees of all species 3-12" dbh were frilled and poisoned with a 2,4,5-T oil emulsion (24:1 herbicide to #2 fuel oil - 100 gallon mix). Following cutting, three cultural treatments ((1) no further treatment (control); (2) basal spray of all regenerating stems less than 3" dbh with 2,4,5-T oil emulsion saturating root collar and lower 4" of stem; and (3) basal spray with 2,4,5-T oil emulsion all regenerating stems less than 3" dbh except those of oaks and hickories) were established on the plots. Each size-treatment combination was replicated three times, for a total of 27 plots. Milacre plots were also established for later evaluation. The smallest plots had 10 milacre subplots, the 150 ft plots had 20 and the 250 ft plots, 30. Measurement of regeneration in terms of species and numbers were taken in 1960, but no height or diameters were recorded at that time.

[3/]Trees were girdled with a Little Beaver, a gasoline-powered piece of equipment used at that time to make an even, deep cut around the tree with a blade like a router.

In 1981, these plots were relocated, with the exception of one 50 ft plot that had inadvertently been clearcut in the process of a logging operation in the area. Most of the original milacre plots were also eventually located, but yielded virtually no usable information. Species and diameter measurements were taken in 1981 for all trees greater than 1" dbh. These data were compared with the 1960 data to determine changes in relative density (% of total stems/plot). Basal area data were calculated from the diameter measurements. Frequency of occurrence, density and basal area, calculated as percentages, were then used to determine the importance value of each species. Yellow-poplar and red maple were the major competitors for the oaks and hickories; species other than these were simply grouped as "other". Statistical analysis of the 1981 data consisted of analysis of variance and Duncan's multiple range test within plot size by treatment. There was considerable variability within each size-treatment combination, so none of the results were statistically significant.

RESULTS

In 1981, the most common species in the experimental plots were red maple (*Acer rubrum*), yellow-poplar (*Liriodendron tulipifera*), and 5 species each of oaks and hickories: white oak (*Quercus alba*), chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), black oak (*Q. velutina*), northern red oak (*Q. rubra*), bitternut hickory (*Carya cordiformis*), mockernut hickory (*C. tomentosa*), pignut hickory (*C. glabra*), shagbark hickory (*C. ovata*), and red hickory (*C. ovalis*). Data for all oaks and all hickories are grouped together for comparison with yellow-poplar, red maple and all other species.

Frequency of Occurrence

Table 1 illustrates the frequency of occurrence, relative density and relative basal area for these four species or species groups as well as their importance value. The low frequency of oaks and hickories in the smallest plots was due more to the absence of hickories than of oaks. The 1960 data indicated that oaks occurred on all plots but one of the 250 ft plots, and hickories were missing from one 150 and two 50 ft plots. By 1981, both oaks and hickories appeared on the plots where they had originally been missing, but disappeared (oaks) in one of the 50 ft plots and (hickories) in one plot of each size in which oaks and hickories had been favored.

Yellow-poplar did not occur at all in the 50 ft plots of the first two treatments, and in only one plot where oaks and hickories had been favored. They apparently seeded in on plots of larger size, regardless of treatment, but appeared in greatest numbers on plots where all regeneration (and therefore competition) had been removed.

Red maple occurred on all plots in 1960 with the exception of one of each treatment in the 250 ft plots. By 1981, it appeared on all the plots where it had originally been lacking but disappeared in two control plots (50 ft and 250 ft).

Table 1.—Frequency of occurrence, density, basal area (%s), and importance value of oak-hickory, yellow-poplar, red maple, and other species by plot size and treatment

Plot Size (ft.)	Treatment	Plots (No.)	% Frequency (# plots/total plots)				% Density (# trees/plot)				% Basal Area (BA/total BA)				Importance Value (F+D+BA÷100)			
			O-H	Y-P	RM	OTH	O-H	Y-P	RM	OTH	O-H	Y-P	RM	OTH	O-H	Y-P	RM	OTH
50	Control	3	83	0	67	100	12	0	22	66	50.48	0.00	10.64	38.91	1.45	0.00	1.00	2.05
50	Remove All	2[1/]	50	0	100	100	14	0	34	52	21.35	0.00	19.38	59.27	0.85	0.00	1.53	2.11
50	Leave O-H	3	50	33	100	100	8	1	31	60	15.19	0.18	17.94	66.69	0.73	0.34	1.49	2.27
150	Control	3	100	100	100	100	42	12	11	35	67.63	7.96	14.48	9.93	2.10	1.20	1.25	1.45
150	Remove All	3	100	67	100	100	58	12	13	17	75.80	5.69	10.28	8.22	2.34	0.85	1.23	1.25
150	Leave O-H	3	83	100	100	100	35	9	27	29	62.42	9.40	14.44	13.75	1.80	1.18	1.41	1.43
250	Control	3	100	100	67	100	49	3	22	26	70.27	2.20	11.50	16.04	2.19	1.05	1.00	1.42
250	Remove All	3	100	100	100	100	53	20	4	23	79.39	4.33	6.62	9.65	2.32	1.24	1.11	1.33
250	Leave O-H	3	83	100	100	100	55	13	11	21	77.58	7.69	6.37	8.36	2.16	1.21	1.17	1.29

[1/] The third plot of this size was inadvertently destroyed in a logging operation after 1965.

Other species varied from plot to plot, but the most consistent species were the intermediate species, blackgum (Nyssa sylvatica) and sourwood (Oxydendrum arboreum), and understory species, flowering dogwood (Cornus florida) and eastern redbud (Cercis canadensis). White ash (Fraxinus americana), sugar maple (Acer saccharum), black cherry (Prunus serotina), and black locust (Robinia pseudoacacia) each occurred in about one third of the plots, primarily in plots where all regeneration had been removed.

Density is the one measure that could be compared between 1960 and 1981 data. Figures 2, 3 and 4 illustrate the changes in dynamics among the four species groups over this 21-year time span. Within each plot size, the species densities are compared by treatment.

"Other" species clearly dominate the smallest plots in all treatments and maintain approximately one third of the density in control treatments of larger plot sizes. Red maple also dominates the oak-hickory complex in the 50 ft plots; yellow-poplar is virtually nonexistent. Red maple is also the only species that consistently demonstrates an increase in relative density under all treatments. Oaks and hickories consistently decrease.

In the intermediate sized plots, the oaks and hickories clearly have the greatest relative density. They were subordinate only to "other" species in 1960, but by 1981, their relative density had increased substantially, especially in the treatment where all regeneration had been eliminated. The oak-hickory complex did not respond as effectively in the plots where oaks and hickories were supposedly favored. Both yellow-poplar and red maple showed increases from 1960 to 1981 and achieved similar levels under the first two treatments. Only where oaks and hickories were favored did red maple substantially exceed yellow-poplar.

In the largest plots, "other" species comprised the largest portion of density in 1960. Oaks and hickories represented less than 20% of the total density and were fairly consistent among treatments at that time. Red maple was comparable to the oaks and hickories in the control plots, but was only half their density in the plots under other treatments. Red maple actually decreased over time in the plots where all regeneration had been removed.

Figure 2.—

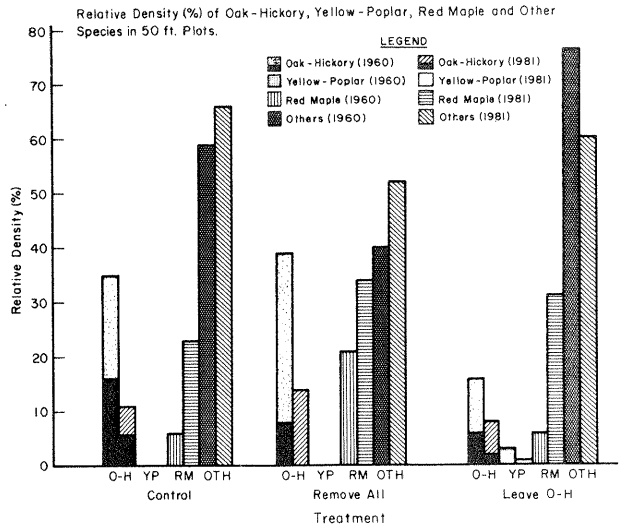


Figure 3.—

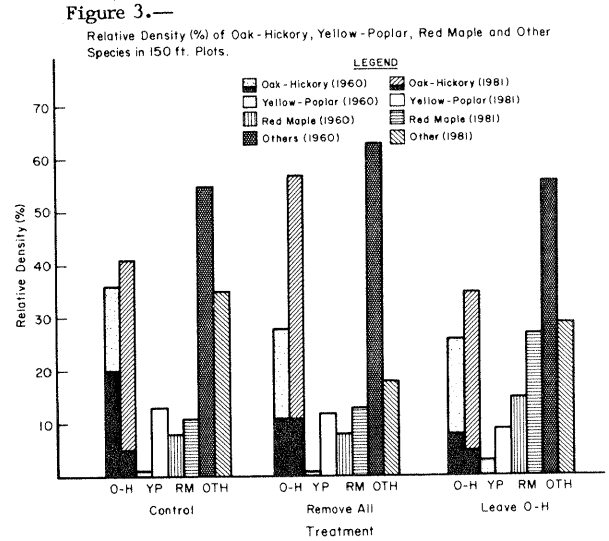
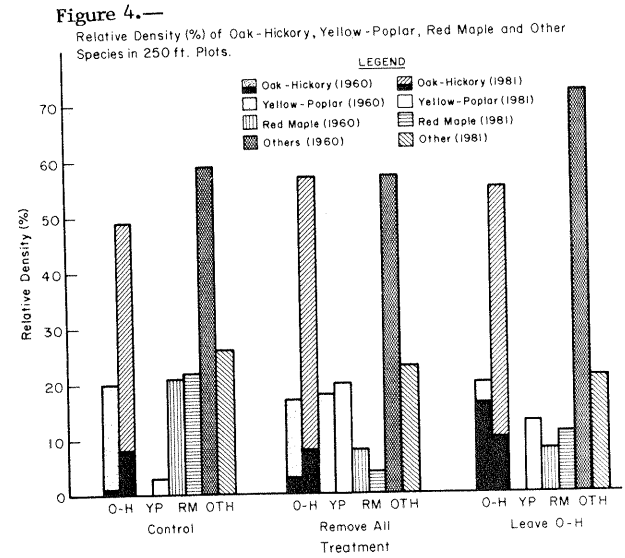


Figure 4.—



Yellow-poplar increased substantially over time in the non-control plots. Oaks and hickories increased markedly in relative density under all treatments, but, as in the 150 ft plots, they still did best in the plots where all regeneration had been removed. Oaks increased consistently under all treatments, but hickories decreased in the leave oak-hickory treatment.

Basal Area

In terms of the success of the original experiment, the basal area data are perhaps the most valuable. Figures 5, 6, and 7 illustrate comparative basal areas among the four species groups within plot size and between treatments. Combined oaks and hickories dominate on the control plots of smallest size, but are dominated by the combination of red maple and other species under the two experimental treatments. In the two larger sized plots, however, the oak-hickory complex clearly dominates plot basal area, regardless of treatment. In two instances (150 ft - remove all; 250 ft - leave oak-hickory) the basal area of hickories alone equalled or exceeded the basal area of all species other than the oak-hickory complex.

Figure 5.—
Basal Area (ft^2) of Oak-Hickory, Yellow-Poplar, Red Maple and Other Species in 50 ft Diameter Plots by Treatment.

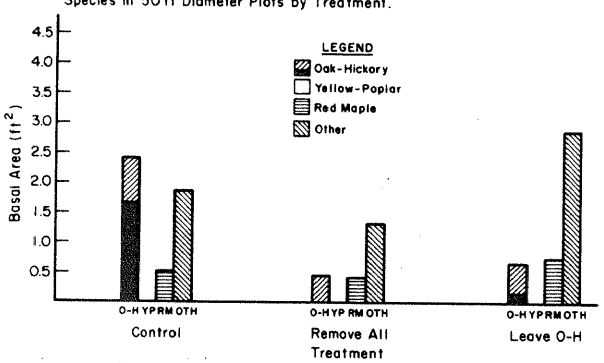


Figure 6.—
Basal Area (ft^2) of Oak Hickory Yellow-Poplar, Red Maple and Other Species in 150 ft. Diameter Plots by Treatment.

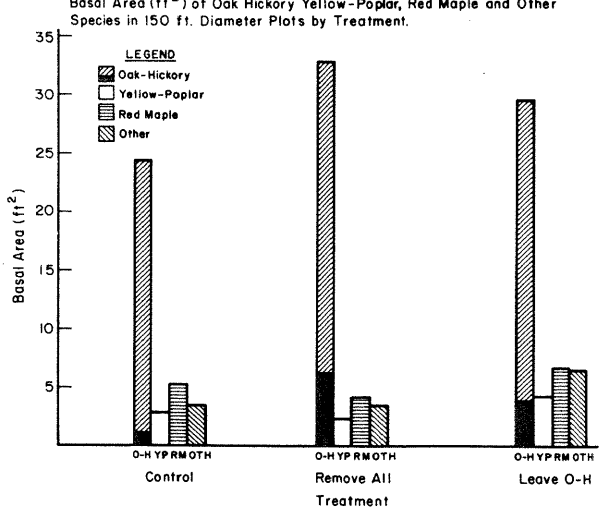
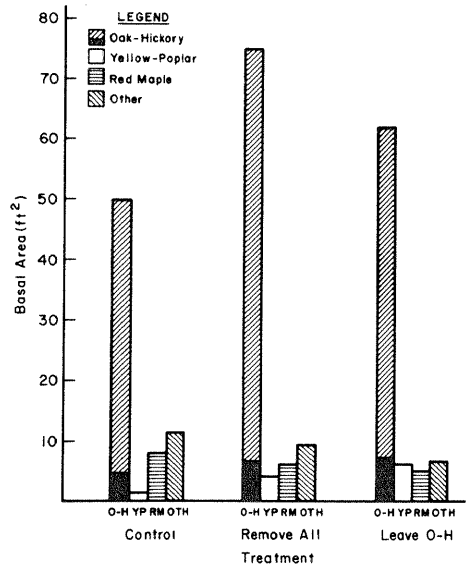


Figure 7.—
Basal Area (ft^2) of Oak-Hickory, Yellow-Poplar, Red Maple and Other Species in 250 ft. Diameter Plots by Treatment.



Importance Value

Importance value gives a useful comparison of the behavior of each species on the experimental plots in the absence of height data and crown position information. Figures 8, 9, and 10 illustrate comparative importance values among the four species groups within plot size and between treatments.

In the two larger plot sizes, the oak-hickory complex exhibits greater importance values than all other species or species groups. In all plot sizes, the importance value for oaks and hickories is greater where all regeneration was removed than where oak-hickory regeneration was favored. Yellow-poplar has its greatest overall importance values in the largest plots and performs only slightly better where all regeneration was removed than where oaks and hickories were left. Red maple's importance value is greatest in the smallest plots where it is not competing with the oaks and hickories. Its importance value decreases with increasing plot size. "Other" species clearly have their greatest importance value in the smallest plots, but have fairly consistent importance values in the larger plots, regardless of treatment.

Figure 8.—
Importance Value of Oak-Hickory, Yellow-Poplar, Red Maple and Other Species in 50 ft. Plots by Treatment.

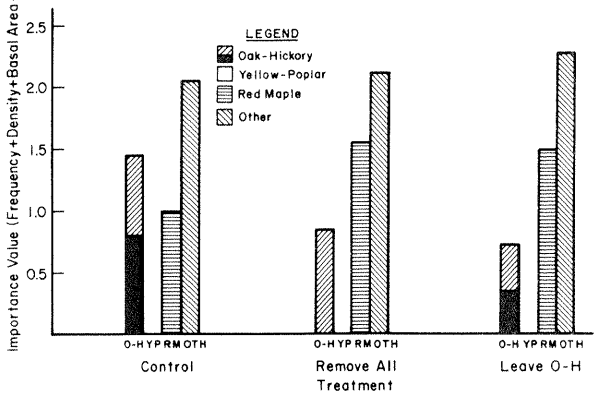


Figure 9.—
Importance Value of Oak-Hickory, Yellow-Poplar, Red Maple and Other Species in 150 ft Plots by Treatment.

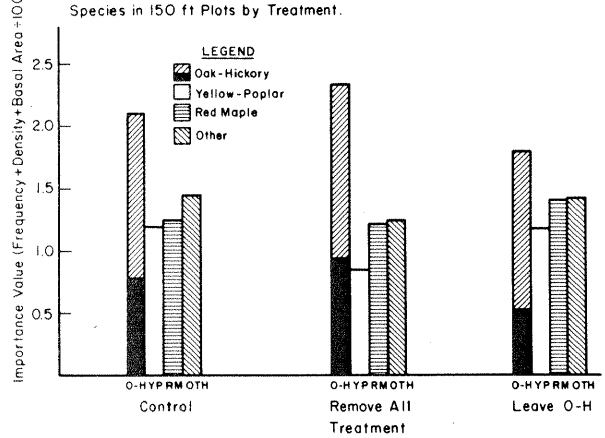
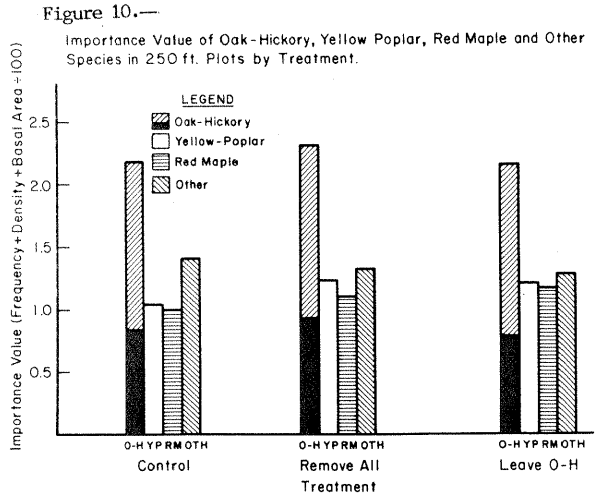


Figure 10.—
Importance Value of Oak-Hickory, Yellow Poplar, Red Maple and Other Species in 250 ft. Plots by Treatment.



DISCUSSION

In the design of the original experiment, it was hypothesized that oaks and hickories would be most successful under the "control" and "leave oak-hickory regeneration" experimental plots. Success was expected on control plots because of the ability of the oak-hickory complex to sprout vigorously after cutting and to dominate in existing stands of mixed hardwoods. In plots where only oak-hickory regeneration had been left success was expected because of the competitive edge thereby given to those species. The data for relative density indicate that this was not the case. Of all size and treatment combinations, the oak-hickory complex was most successful on the intermediate plots where all regeneration had been removed. There were oaks and hickories represented in all size and treatment combinations, which was not necessarily true of other species, especially yellow-poplar, and the oak-hickory complex did persist in the mixed hardwood stands to the present. Basal area data indicate that the oaks and hickories dominate the larger plots, comprising 60% or better of total basal area, even when their relative density was only 35%.

Of all the species that came into the experimental openings after treatment, yellow-poplar was most likely to have grown from seed rather than from rootstocks or stump sprouts. Yellow-poplar will become established and achieve early rapid height growth in plots large enough to provide ample sunlight (>50 ft diameter). Basal areas were greatest where oaks and hickories had been favored rather than where all regeneration had been removed.

Red maple regeneration, like that of most maples, is shade tolerant and persists in the understory. It will, however, respond aggressively to sudden release and exhibits indeterminate growth characteristics. Since basal area tended to decrease as plot size increased, red maple may have been outcompeted by other species, primarily the oak-hickory complex.

Removing all regeneration other than oaks and hickories paradoxically did not favor those species. It is postulated that when shade-grown oak and hickory saplings were suddenly exposed to full sunlight, especially in the larger plots, they may have died back to their rootstocks in the first few years following cutting. In this case, when the rootstocks resprouted, yellow-poplar seedlings may already have achieved height growth sufficient to compete actively with the oaks and hickories and thus slow their emergence into the upper canopy.

Smith (1981) reported on a study in West Virginia that was very similar to this one. The same plot sizes and chemical were used; site indexes and forest types were similar. Table 2 illustrates a comparison of the two studies. Smith's study found large quantities of red maple, but found yellow-poplar only on sites with site index greater than 60. Both red maple and the oaks sprouted from cut stumps, even after treatment with herbicide.

On the basis of these two studies, it does appear that the combination of moderate sized group selection or patch clearcutting and post-logging herbicide treatment is successful in regenerating an Appalachian upland hardwood forest with a major oak-hickory component.

SUMMARY

An experiment designed in the late 1950's to encourage regeneration of oaks and hickories in a previously cutover mixed mesophytic forest was successful in preserving a substantial oak-hickory component in the reulting stand. Since earlier research in oaks in mixed stands (Oliver 1978) implied that oaks demonstrate late ascendance and may not dominate a stand initially because of competition with more rapidly growing associates, a similar pattern was expected to emerge in this study.

After 21 years, species of oaks and hickories described in measurements taken immediately after the experiment was established still occur in the stands. Although the relative density of oaks and hickories have changed over time in almost all size-treatment combinations, the oak-hickory complex remains a substantial component of the stands and comprises 15% or more of the basal area of all size-treatment combinations, and 60% or more of the larger sized plots, regardless of treatment.

The combination of cutting practice and herbicide applicaton resulted in stands where the oaks and hickories which were desired have indeed emerged and dominated. These stands can be expected to produce good quality oaks and hickories, plus some red maple and yellow-poplar, by the time they reach harvestable size.

Table 2.—Response of Appalachian hardwoods to group selection cutting followed by herbicide treatment

		West Virginia 10 year results		Kentucky 21 year results	
Plot Size (Diam-Ft)	Treatment	$\bar{x}$ DBH (in)	$\bar{x}$ Dominant Trees/AC	$\bar{x}$ DBH (in)	$\bar{x}$ Dominant Trees/AC
50	Control[1/]	2.2	220	2.9	1780
50	Moderate[2/]	1.4	325	1.5	2580
50	Intensive[3/]	1.5	290	1.5	1000
150	Control	3.2	340	3.7	914
150	Moderate	2.6	375	4.5	906
150	Intensive	1.9	470	4.1	962
250	Control	3.0	460	5.1	335
250	Moderate	2.4	510	4.3	462
250	Intensive	2.0	480	5.3	484

[1/] Control – WV used no herbicide treatment; KY used 2,4,5-T to kill all trees 3–12 dbh

[2/] Moderate – WV basal sprayed standing trees with 2,4,5-T; KY basal sprayed all species < 3" dbh except oaks and hickories with 2,4,5-T

[3/] Intensive – WV basal sprayed all standing trees and stumps with 2,4,5-T; KY basal sprayed all species < 3" dbh

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