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Effects of a Prescribed Fire in a Central Appalachian Oak-Hickory Stand

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Abstract

Five years after a single prescribed fire in a second-growth central Appalachian oak-hickory stand, many overstory trees died or declined in vigor. A major reduction in butt-log quality on the residual trees was observed. Fire scars were prevalent on a large number of trees and scars showed various stages of decay. Advanced seedling and sprout reproduction increased for red maple, northern red oak, and hickory. Overall stocking of advance reproduction of red maple, black locust, and hickory increased during the 5 years; red and chestnut oak were poorly distributed and accounted for only 3 percent of the stocking. Striped maple was the most abundant and widespread noncommercial species before and after burning. The large amount of damage to the overstory stand and failure to control the large number of noncommercial understory stems with a single prescribed fire indicate that more research is needed before fire can be recommended for use as a regeneration tool in central Appalachian hardwood stands.

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Introduction

It is difficult to maintain a component of northern red oak (*Quercus rubra* L.) in regenerating Appalachian hardwood stands. This problem is more acute on high-quality sites where fast-growing species such as yellow-poplar (*Liriodendron tulipifera* L.) often dominate after clearcutting. Past research indicates that advance reproduction of large oak (more than 4.5 feet tall) is essential in maintaining an oak component in the new stand after overstory removal (Sander 1972). Loftis (1979) suggested shelterwood cutting with control of understory vegetation as one way to promote large oak advance reproduction.

Fire in hardwood forests has long been shown to be beneficial for improving the wildlife habitat, but the silvicultural benefits of fire are uncertain—particularly with regard to oaks. Prescribed fires in southern hardwood forests have increased browse and total herbaceous and vine coverage (Huntley and McGee 1982; Loomis 1977). In West Virginia hardwood forests, experimental fires resulted in increases in herbaceous vegetation and a more open understory structure which appeared to favor young turkey and grouse (Rogers 1984). However, the beneficial effect of burning for habitat and improvement begins to decline in the third year, indicating that frequent intervals of burning may be required to maintain the desired habitat.

In this paper we compare stand conditions before and 5 years after a fire to improve wildlife habitat that was carried out by the West Virginia Department of Natural Resources on the Road Run drainage of the George Washington National Forest near Brandywine, West Virginia.

The Study

The study area consists of 21 acres and was burned in the spring of 1980 (Fig. 1). Four adjacent acres were not burned and provide a basis for comparison.

Stand Condition

Before burning, the stand contained 115 trees per acre larger than 5 inches in diameter at breast height (d.b.h.). Red maple (*Acer rubrum* L.), chestnut oak (*Q. prinus* L.), red oak, hickory (*Carya* sp.), and black locust (*Robinia pseudoacacia* L.) were the major species (Table 1). On an adjacent unburned area there were 87 trees per acre larger than 5 inches in d.b.h. Chestnut oak, hickory, red maple, and red oak were the most abundant species. Basal area on the burned area before treatment was 90 ft^2 per acre and 90 ft^2 per acre on the unburned area (Table 2). Volume in trees larger than 11 inches in d.b.h. on the burned area was about 8,300 board feet per acre and about 12,000 board feet per acre on the unburned area. Effects of the fire were evaluated on the overstory trees (Table 3). A year before the area was burned, most of the unmerchantable trees 2.0 to 6.0 inches in d.b.h. plus a few of the larger cull trees were felled on the burned area. Although some of the stand parameters differ between the two areas, species composition, topography, and climate are similar. The understory advance reproduction on the burned area consisted of seedling- and sprout-origin red maple, chestnut oak, red oak, black locust, and hickory (Table 4). Understory advance reproduction on the unburned area was similar except that no black locust was present (Table 4). Both areas had heavy understory concentrations of striped maple (*A. pensylvanicum* L.), dogwood (*Cornus florida* L.), and witch-hazel (*Hamamelis virginiana* L.).

Table 1.—Species composition as percent of total number of trees more than 5.0 inches in d.b.h. on burned and adjacent unburned areas before and 5 years after burning

Species	Burned area 1980	Burned area 1984	Unburned area 1980	Unburned area 1984
	Percent			
Red maple	31	26	12	21
Chestnut oak	22	23	54	45
Red oak	18	21	8	14
Hickory	10	14	15	7
Black locust	9	7	0	7
Other	10	9	12	7

Table 2.—Per-acre stand data before and 5 years after the fire

Year	No. stems[a]	Basal area (ft^2)	Volume: Cubic feet	Volume: Board feet[b]
	Per acre			
	BURNED AREA			
1980	115	90	1,979	8,347
1984	93	73	1,596	6,541
	UNBURNED AREA			
1980	87	90	2,249	12,025
1984	96	96	2,391	12,711

[a]5.0 inches in d.b.h. and larger.
[b]11.0 inches in d.b.h. and larger.

Figure 1.—General view of the fire.

Table 3.—Severity of decay observed in overstory fire-scarred trees after 5 years

Species	Decay class[a]		
	1	2	3
	------- Percent -------		
Red maple	10	28	62
Blak gum	29	0	71
Black oak	67	0	33
Red oak	13	22	65
Chestnut oak	34	6	60
Hickory	31	8	61
Black locust	27	40	33
All species	22	17	61

[a]1 = Incipient decay: discoloration no fruiting bodies present; 2 = Moderate: few fruiting bodies, discoloration small amount of punky wood; 3 = Heavy: many fruiting bodies, associated with soft punky wood.

Soils and Climate

The study area is a shallow cove with associated ridges and slopes of 25 to 30 percent. Soil is classified as Berks-Rushtown-Weickert Association. Precipitation averages about 40 inches annually, and the growing season is about 150 days from about mid-April to early October.

Vegetation Sampling

Thirty-eight sampling points on a 1- by 2-chain grid were established on the burned area, and seven sampling points were established on the unburned area. Overstory trees larger than 5 inches in d.b.h. were tallied on 1/10-acre plots at odd-numbered sampling points. Large reproduction, trees 1.0 to 4.9 inches in d.b.h., were tallied on 1/100-acre plots at each sampling point. Trees were measured to the nearest 0.1 inch and tallied by species, stem quality, crown class, and whether they were of seedling or sprout origin. Overstory trees were evaluated for fire damage at the end of 5 years. Advance reproduction, 1.0 foot high to 0.99 inch in d.b.h., was tallied on a milacre plot at each sampling point.

Fuel Sampling

Forest fuels included the forest litter down to the beginning of the humus layer and all dead twigs, branches, and living vegetation smaller than 1.0 inch in d.b.h. Fuels were designated as woody or litter and were kept separate for determining the combined fuel weight. Fuels were sampled on predetermined 1/4-milacre square plots adjacent to odd-numbered sampling points before burning and adjacent to even-numbered sampling points after burning. The two fuel components were subsampled and weighed separately to determine moisture content so that oven-dry weight per acre for each component and the total could be determined.

Fire Behavior

Weather in the fire area was monitored before and during the fire. Wet- and dry-bulb temperatures, wind speed and direction, rates of fire spread, and flame heights were recorded during the fire when sustained changes in these parameters were observed. Flame heights and rates of spread were not recorded for flare-ups of relatively short duration. A small test fire was ignited to indicate the intensity of fire that could be expected.

Fireline intensity was calculated by the following method (Davis 1959):

$$I = Hwr$$

where

I = fire intensity in Btu/foot-second of fire line,

H = heat yield in Btu/pound of fuel (used 6,500 Btu/lb),

w = weight of available fuel (amount of fuel actually consumed by the fire) in lb/ft^2, and

r = rate of fire spread in feet/second.

Burning Procedures

The main fire was started at 2:30 p.m. on April 21, 1980. The relative humidity was about 25 percent and winds were 3 to 5 m.p.h. from the northwest. Relative humidity remained at 25 percent for the first hour and increased slowly to 42 percent at 4 p.m. It ranged from 42 to 48 percent until burning was completed at 5 p.m. Wind remained from the northwest during the afternoon but became more brisk with gusts to 12 m.p.h.

The main downwind firelines were fired first. After the backfire had burned in 30 to 40 feet, the upper two-thirds of the area was strip-fired parallel to the backfired lines at intervals of about 20 feet. Firing continued along the perimeter so that the strip head fires always burned out in a burned area inside of the perimeter. After all of the perimeter had been fired, the lower one-third of the area was fired. Total elapsed time for the fire was about 2-1/2 hours. Except for a small breakover, the fire was carried out according to plan.

Table 4.—Advance reproduction 1.0 foot tall to 0.9 inch in d.b.h. before and 5 years after burning.

Species	Time	Seedlings per acre	Sprouts per acre	Total	Stocking
		------ *Number*	------		*Percent*
			COMMERCIAL		
Red maple	Before burn	132	1,368	1,500	21
	After 5 years	368	1,395	1,763	50
Chestnut oak	Before burn	26	947	973	8
	After 5 years	0	316	316	5
Red oak	Before burn	0	658	658	3
	After 5 years	26	0	26	3
Black locust	Before burn	526	0	526	21
	After 5 years	500	658	1,158	58
Hickory	Before burn	0	0	0	0
	After 5 years	79	79	158	11
Other	Before burn	157	0	157	13
	After 5 years	79	0	79	13
Total	Before burn	841	2,973	3,814	47
	After 5 years	1,052	2,448	3,500	82
			NONCOMMERCIAL		
Striped maple	Before burn	3,921	342	4,263	76
	After 5 years	2,158	1,658	3,816	66
Dogwood	Before burn	605	1,158	1,763	26
	After 5 years	737	1,553	2,290	34
Witch-hazel	Before burn	290	395	685	16
	After 5 years	365	184	552	34
Other	Before burn	52	316	368	11
	After 5 years	184	0	184	11
Total	Before burn	4,868	2,211	7,079	84
	After 5 years	3,444	3,395	6,839	89

Fire Behavior

During the early phase of the fire when relatively narrow strip head fires were used, the rate of fire spread averaged about 2 feet per minute. Higher rates of spread, 3 to 35 feet per minute, were observed in deeper hollows on associated steep slopes where there was a heavy accumulation of litter and other fuels. Later in the day, winds became more gusty, further influencing the rate of spread.

Fuel consumption was variable. Before the fire, litter fuel averaged 4.39 $\pm$0.74 tons of oven-dried material per acre, *and woody fuel was estimated at 12.6 $\pm$6.33 tons per acre.* Sampling after the fire showed that litter fuel averaged 1.93 $\pm$0.46 tons of oven-dried material per acre, and woody fuel averaged 10.36 $\pm$6.39 tons of oven-dried material. The fire consumed about 56 percent of the litter fuel and 18 percent of the woody fuel. Combined, about 28 percent of the total oven-dried fuel was consumed. Small twigs less than 1.0 inch in d.b.h. were consumed over the area. Consumption of larger material was spotty except in areas where it was concentrated and in areas where fire intensity was highest.

Fireline intensity ranged from 47 to 425 Btu per foot-second of fireline. In general, the lower fire intensities were associated with the narrower strip head fires. As the perimeter of "safe" area increased, wider strips were used; this in combination with heavier fuel loading in the hollows contributed to an increase in fire intensity.

Results

Effects on Overstory Vegetation

During the 5 years after the fire, 22 trees per acre larger than 5 inches in d.b.h. died on the burned area compared to a net gain of 9 trees per acre on an adjacent unburned area (Table 2). Similarly, basal area decreased by 17 ft^2 per acre on the burned area compared to an increase of 6 ft^2 per acre on the unburned area. There also were decreases in cubic- and board-foot volumes on the burned area.

Sixty-six percent of the overstory trees in the burned area were damaged by the fire; 5 percent were killed; 28 percent showed no damage; and 1 percent died from other causes. The length of fire scars ranged from less than 1 foot to more than 30 feet and averaged 5.3 $\pm$0.9 feet on all damaged trees. After 5 years, the area of exposed wood on scarred trees ranged from 25 in^2 to 2,900 in^2 and averaged 651 $\pm$154 in^2 per tree for all species. Length of scar and area of scar were not correlated with tree d.b.h. In most cases, callous tissue along the edge of scars was well formed. Heavy decay—large numbers of conks and punky soft wood—was observed on 61 percent of the scarred trees; 17 percent were classed as having moderate decay and 22 percent were classed as having incipient decay—discoloration mostly with none or very few conks (Fig. 2). By species, black oak and black locust had the lowest incidence of heavy decay (Table 3).

Saplings

Most of the trees in the 1.0- to 4.9-inch class on the burned area were cut 2 years before burning, leaving an average of 37 red maple and hickory saplings per acre. There were 34 red maple and 3 hickories per acre with a milacre stocking of 21 and 3 percent, respectively. Hickory was sparse. Five years after the fire, the sapling stand contained 3 red maple and 82 black locust sprout-origin stems per acre. The hickories were killed. Stocking of black locust was 32 percent. Of the 37 noncommercial 1.0- to 4.9-inch stems per acre present before the fire, only 3 striped maple sprouts were present 5 years later.

By contrast, sapling stems on an adjacent unburned area increased from 128 to 186 stems per acre during the 5 years. Noncommercial species, dogwood, striped maple, and witch-hazel, increased from 43 to 158 stems per acre.

Advance Reproduction

Before burning, advance reproduction 1.0 foot high to 0.9 inch in d.b.h. totaled 3,814 stems per acre; 5 years after the fire there were 3,500 stems per acre (Table 4). Seedling-origin stems increased by 211 per acre and sprout-origin stems decreased by more than 500 per acre.

Figure 2.—Example of tree wounding from the prescribed burn and fruiting bodies of decay organisms.

A tally made 3 years after the fire showed that chestnut oak seedling-origin stems had increased from 26 to 53 per acre, but all died before the 5-year tally was taken. No red oak seedlings were recorded before the fire but 3 years later there were 53 per acre; at the end of 5 years, one-half of these were dead. There was a surge in the number of black locust seedlings during the first 3 years after the fire. However, three-fourths or about 1,500 of these seedlings died by the time the 5-year measurement was made.

Sprout stems less than 0.9 inch in d.b.h. totaled 2,973 per acre before burning and 2,448 per acre after 5 years. Red maple was the most common sprout and changed little in number during the 5 years after burning. There were no black locust sprouts before the fire but there were 658 stems per acre 5 years later. Basswood (*Tilia americana* L.), white pine (*Pinus strobus* L.), sweet birch (*Betula lenta* L.), and black gum (*Nyssa sylvatica* Marsh.) seedlings that were observed before the fire or 3 years later were dead 5 years after the burn.

Seedlings of noncommercial species totaled about 7,000 stems per acre before and 5 years after burning. Striped maple seedlings and sprouts dominated with 4,263 stems per acre and 76 percent milacre stocking before the fire. Five years after the fire, there were 3,816 striped maple stems per acre and 66 percent of the plots were stocked with at least 1 stem. Dogwood and witch-hazel seedlings and sprouts accounted for 2,843 stems per acre and 34 percent stocking 5 years after the fire.

On the unburned area, the number of commerical species of seedlings and sprouts increased over the 5-year period (Table 5). Red oak and chestnut oak seedlings increased both in numbers and distribution, indicating that some acorns had been produced and had germinated during the 5-year period. The increase was greatest during the first 3 years. A similar response on the burned area suggests that the surge and decline of oak on the burned area was not fire related. The numbers and distribution of noncommerical species on the unburned area also increased during the 5-year period.

Management Implications

Compared to the unburned area, we expected the burned area to have at least the same number or more seedlings, but this did not occur. We assume that a fair to good acorn crop occurred in the general area during the 5-year period because of the increase of red oak and chestnut oak seedlings on the unburned area. Milacre stocking is adequate on the burned area for species other than oak. Red maple and black locust dominate the advance reproduction and would be major components in the new stand if the overstory were removed in the near future.

Burning for regeneration of oak on Road Run has not enhanced the establishment of oak. It appears that we have a much better chance of establishing oak if we do nothing, as has been shown on the adjacent unburned area. On oak site indexes 70 and below, oak seedlings seem to become established and will survive for a number of years until they are released. Established oaks are regarded as more fire resistant, mainly because of their sprouting ability. Also, light fires when the seedlings are 5 to 10 years old might kill some of the shrubs and less desirable species, giving the oak sprouts and seedlings a growth advantage (Little 1973, 1974). Even though some of the oak tops will be killed by the fire, vigorous sprouts often regain their preburn height in a single growing season.

Another difficulty in using prescribed fire is controlling fire intensity so that damage to the overstory is minimal. Damage to the overstory was considerable during the Road Run fire. If trees are to be removed soon after burning, fire-damaged trees can be salvaged. However, if overstory removal is delayed too long, severe decay can develop and more trees will die. For example, average scar length was 5.3 feet; for a 6-inch-diameter tree, mortality probability would be about 65 percent (Loomis 1973).

For success in regenerating oaks, Sander (1979) recommended that there should be at least 435 advance oak seedlings per acre that are 5 feet tall before overstory removal. The problem occurs in establishing and managing the oaks to grow to this threshold size. Acorns are subject to predation by insects, birds, and mammals—55 to 70 percent of mature acorns may be consumed. Oak seed crops are unpredictable and good seed crops may occur at 2- to 5-year intervals (Olson 1974), so it may take 15 to 25 years to build up an abundance of red oak advance reproduction during poor to fair seed years.

In stands with high density overstories and understories, light may be the limiting factor in the establishment and growth of oaks. Sander (1979) reported that 30 percent of full sunlight is needed to maximize photosynthesis in oak seedlings. In Missouri forests, this condition is achieved by maintaining 40 percent overstory stocking and eliminating understory vegetation (Sander 1979). Herbicides and/or fire has been suggested as a means of reducing understory competition. With herbicides, basal spraying achieves a semblance of selectivity; with fire, all stems—desirable or undesirable—are affected.

Table 5.—Advance reproduction 1.0 foot tall to 0.9 inch in d.b.h. on the unburned area before and 5 years later

Species	Time	Seedlings per acre	Sprouts per acre	Total	Stocking
		------ *Number* ------			*Percent*
		COMMERCIAL			
Hickory	Initial	0	1,429	1,429	14
	5 years	0	1,143	1,143	14
E. hophornbeam	Initial	1,143	0	1,143	57
	5 years	1,143	0	1,143	71
Red maple	Initial	571	143	714	57
	5 years	286	1,285	1,571	43
Red oak	Initial	143	0	143	14
	5 years	286	286	572	29
Chestnut oak	Initial	0	0	0	0
	5 years	286	0	286	29
Black locust	Initial	0	0	0	0
	5 years	0	286	286	0
Total	Initial	1,857	1,572	3,429	86
	5 years	2,001	3,000	5,001	86
		NONCOMMERCIAL			
Striped maple	Initial	3,286	714	4,000	86
	5 years	4,571	0	4,571	86
Dogwood	Initial	1,286	1,000	2,286	57
	5 years	5,571	1,286	6,857	86
Serviceberry	Initial	857	0	857	29
	5 years	143	857	1,000	29
Witch-hazel	Initial	429	0	429	29
	5 years	714	3,000	3,714	57
Total	Initial	5,858	1,714	7,572	100
	5 years	10,999	5,143	16,142	100

The data obtained on the Road Run fire indicate that the fire was poorly timed. Although there were a few stems of advanced oak reproduction on the area, they were too few on the area before burning to warrant burning. Perhaps a better procedure would have been to open up the overstory and reduce the understory in anticipation of a good seed crop. This would allow for oak establishment and growth. Where competition is a problem, burning can be used to control unwanted vegetation. Several light burns might be sufficient to allow the advanced oak reproduction to reach a height of 5 feet or more. When the oaks attain that height and are abundant and well distributed, the overstory should be removed. Sander (1979) indicated that this process may take 15 to 25 years.

Burning for silvicultural purposes in the central Appalachian hardwood forest is still unknown, so additional research will be needed to determine whether fire has a place in the management scheme. The high rainfall and relatively few "dry" days when fire can be used and the variation in sites and species composition present a challenge to using fire silviculturally in this region.

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A prescribed fire in a central Appalachian mixed hardwood stand caused considerable damage to the butt logs of many overstory trees. Although there were increases in the abundance and distribution of several species of hardwoods, advanced red and chestnut oaks were poorly distributed 5-years after burning. An abundance of striped maple and other shrubs in the understory poses a threat to the development of desirable tree species. More research is needed on timing of fire in relation to oak seed crops and on reducing competition before fire can be recommended as a regeneration tool in central Appalachian hardwood stands.

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