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Fire Effects in Northeastern Forests: Oak

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PREFACE

This is the second in a series of papers dealing with fire effects in northeastern forests. The 21-State region incorporates many diverse ecosystems—the northern hardwoods of New England, the boreal forests of Minnesota, the oak-hickory forests of Missouri, and fine hardwoods in the Central States. In spite of the fact that all forests have some things in common, each responds somewhat differently to fire. Although less is known about fire ecology in the Northeast than in any other region of the country, some information is scattered throughout the literature. The purpose of this series is to compile what we know today and make it readily available to managers. Each paper in the series will summarize the literature; detailed information on specific topics can be obtained from the accompanying references. When the series is complete in several years, the individual papers will be updated and republished as a single, bound volume. Other papers in the series to date include: aspen.

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FIRE EFFECTS IN NORTHEASTERN FORESTS: OAK

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". . . almost every forest climax of North America displays a fire subclimax . . ." (7).

Fire is Important

Fire has played a major role in the forest ecosystems of the Northeastern and North Central United States (23). Although fire's role in destroying and renewing eastern hardwood forests has diminished greatly during this century, wildland fires, and their absence, can have a profound effect on both overstory and understory vegetation. Oaks, for instance, are commonly assumed to be favored over other hardwood species, by occasional fire. Our purpose here is to bring together some of the existing information about the effects of fire on some of the major upland oak species in eastern North America.

Origin of Existing Stands

Many upland oak stands of today originated under the severe conditions of human-caused intentional broadcast burning, destructive logging practices, and severe fires that consumed heavy slash. In some cases, the combination of these factors reduced the viability of previously dominant seeds of other species that remained in the duff.

MORTALITY

Heat

Fire can injure or kill any living tissue; the cambium and leaves of an oak tree are not exceptions. When living tissue reaches 147°F, it dies almost instantaneously (2). But the death of plant tissue is a function of both temperature and time. For example, a cambium layer exposed to 120°F for over an hour will die (2). To produce such temperatures at the cambium layer, there must be more heat or a longer heating time at outer bark surfaces.

Factors

Several factors determine direct fire-caused mortality in oak: season of year; bark characteristics, size, vigor, and form of tree; fire intensity; and stocking level.

Season and Bark

During the dormant season, trees are generally less susceptible to injury by fire because of their physiological state (6). In addition, ambient air temperature tends to be lower than during the growing season, necessitating higher energy release to raise the internal temperature of the tree to the lethal point (20). Bark characteristics are determined by the species and age of a tree. The easiest bark characteristic to measure is bark thickness although this is not always a true indicator of resistance to fire. For oaks, bark thickness decreases in the following order: chestnut, black, red, and white oak. Based on bark thickness alone, red oaks should be more resistant to damage than white oaks. This is not true in Missouri where the red oak group is much more susceptible to fire damage than the white oak group (22), but it may be accurate elsewhere. In addition to bark thickness, other differences among oak species such as bark configuration and chemical constituents contribute to fire resistence but have not been fully explained (35, 3, 20, 8, 30).

Size and Vigor

Larger trees are able to survive more intense fires than smaller trees (15, 28, 30) not only because they have thicker bark but also because they have a larger area of cambium that can continue to function if a portion is killed. Trees of low vigor do not sprout well and may not be able to heal as quickly as more vigorous trees (16). Intense summer burns can reduce the vigor of oak trees (5).

Form

The form of an oak tree is also a factor in determining severity of fire damage. If a tree is crooked or leaning, flames may be directly below the stem, increasing heat at the bark surface (28).

Fire Intensity and Stocking

Fire intensity is markedly different from fire to fire and even within a fire.[1] The greater the fire intensity the more energy is directed at the tree the greater the likelihood of death or injury (9). Scorch height can be used as a rough approximation of fire intensity (20).[2] Because stems in an overstocked stand tend to be smaller in diameter and less vigorous than those in an adequately stocked stand, they are more likely to be fire-damaged.

Other Damage

The loss due directly to a fire may be but a small percentage of the total damage of trees lost later to pathogens (1). Basal fire wounds provide a threshold for insects and decay that may degrade and eventually kill trees prematurely (20). The propensity of oaks to frost crack also increases due to injuries (14), including those from fire.

REPRODUCTION AND STAND ESTABLISHMENT

Oak regeneration and establishment can be divided into several categories including: (1) acorn production, (2) seedling establishment, and (3) sprouting.

Acorn Production

Although acorn production appears little affected by fire, a dying tree will often produce a massive seed crop (27). Acorns themselves can be killed by a fire before they have germinated because they have a high moisture content (29). The moisture inside the acorn can heat up and burst open the acorn.

Seedling Establishment

Seedling establishment depends upon sound acorns escaping predation, surviving overwintering conditions (for those in the red oak group), the successful penetration of the cotyledons through the leaf litter, and penetration of the roots to the

[1] *To compare fires, we must know fire intensity (the product of the available fuel energy and the rate of spread) (4). The intensity of a flaming front can be determined from the flame length. Flame length, as well as rate of spread, can give an approximation of heat released. Rothermel and Deeming have given methods to estimate both rate of spread and flame length in the field without instruments (24).*

[2] *Simard, Albert J.; Baumgartner, David C. Predicting hardwood mortality following wildfires in the Lake States. Presented to: 89th Annual Meeting Michigan Academy of Science, Arts and Letters, March 22-23, 1985. Michigan State University. East Lansing, MI.*

mineral soil (13). These requirements are influenced by several factors including litter depth. Litter depth is readily reduced by fire. For example, an area that had been repeatedly burned then kept fire free for 10 years had twice as many oak seedlings as a comparable unburned area (3).

Roots

In northeastern hardwood forests, surface fires are most common (3). Aerial portions of trees may be injured or killed but roots are generally left viable (18, 11). Although root tissue is more susceptible to heat-induced injury than above-ground tree tissues (12), the insulating quality of the soil and the heat-release charateristics of most fires allow roots to remain viable.

Sprouting

Oak trees often resprout when top-killed by fire, thus re-establishing a stand. This ability is due in part to initial seedling morphology. Many oak seedlings develop an "S" shaped crook at the soil surface that allows dormant buds to be protected from the heat of a fire.[3] With repeated fires, these stems form "stools" (callus tissue filled with dormant buds) (17). The new sprouts grow vigorously, using the existing older root stock after the above-ground stem is killed. Numbers of sprouts are often increased by fires (25). Sprouts may be the most desirable form of reproduction (25). Many sprouts can rapidly attain the height needed (4.5 ft) to make them effective members of a regenerating stand (26). Southern red, post, and scarlet oaks produced more sprouts on annually and periodically burned areas than on unburned areas (33). Also, white oak sprouts were found to increase from 500 to 2,000 stems per acre after two spring burns of "moderate" to "high" intensity (35). Black and scarlet oaks sprouts also increased but not as dramatically as the white oaks.

Other Competition

Fire can reduce the stocking of other species relative to oak, thereby decreasing interspecies competition. For instance, in Rhode Island, scarlet, white, and black oak overstory trees accounted for 94 percent of the total basal area on repeatedly burned plots compared with only 53 percent on unburned plots (3).

Best Germination

The best oak acorn germination occurs on mineral soil under a light covering of leaves (25). Fire can help provide this condition by reducing excess litter. In addition to providing desirable seed bed conditions, fire can help induce more vigorous sprouting from older root stocks, which may produce a desirable form of reproduction.

ESTABLISHED STANDS

Secondary Effects

Fire can injure, kill, stimulate, or have no effect on the components of an established oak stand. Fire injury occurs in established oak trees when the cambium is killed. Such wounds provide a threshold for insects and diseases. Ambrosia beetles may begin to bore fire-damaged scarlet oak within 6 months after a fire.

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[3]*McQuilkin, Robert A. The possible role of fire in the oak regeneration process. Columbia, MO: North Central Forest Experiment Station; 1982. 29 p. Unpublished paper.*

It appears that the beetles prefer working in more severely damaged trees. In a New York study, 45 percent of fire-injured, but living oak trees became infected with fungi (31). These fungi, with one exception, appeared after fires, but were not present in undamaged trees. In another study, abundant fungi caused superficial decay of oak sapwood during the first summer after a fire. By the second season the fungi had migrated deeper into the sapwood; and by the third season, heartrot had developed (1). Insects attacked mainly in the first year after a fire; the total number of fungi peaked in the third year. Rot in lowland red oak develops up the bole of a damaged tree at an estimated 1.25 feet per decade (34). Oaks can minimize losses due to damaged cambium by rerouting the functions of fire-killed portions within weeks after a fire (10).

Estimating Damage

Estimating stem damage and subsequent mortality of fire-injured trees is difficult. Equations have been devised to predict mortality based on degree of basal scorch. For example, we may expect that 50 percent of post oak trees 5 inches in diameter at breast height (d.b.h.) will die if the scorch height reaches 5 feet during the growing season. During the dormant season, scorch height must reach 7 feet to cause the same amount of mortality. White, black, and scarlet oaks are not able to withstand as high a scorch height as post oak. In addition to scorch height, circumference scorched can aid in predicting fire-related mortality. Large white, black, northern red, and chestnut oaks can withstand bark scorch up to two-thirds of their circumferences (19).

No Effect

Often, no change in the growth of surviving trees is noticed after a fire. For example, in New Jersey on poor sites, diameter growth remained the same on basally fire wounded trees as on trees with no wounds (28). Also, in the southern Appalachian Mountains, Jemison reported that basal wounding of 8- to 20-inch-diameter vigorous white and black oaks did not affect diameter growth for 2 to 7 years after the fires (10).

Stimulation

In some instances, fire may stimulate the growth of oak trees, as reflected by incremental increases in height and/or diameter. Jemison discovered that if a wound on an 8- to 10-inch-d.b.h. white oak is less than 27 percent of its circumference, the tree grows faster the first year after a fire than before the fire.

SUMMARY

Fire in Oak

Many of today's oak stands have evolved as part of a community subjected to recurring fires (32). Recent management difficulties in establishing natural oak regeneration may be due, in part, to a changed forest floor brought about by an absence of fire. Existing forest floors on some oak sites provide a more favorable seed bed for more tolerant tree species but a poor seed bed for acorns. Controlled fire may play a critical role in the natural perpetuation of the upland oaks types. For instance, seedling establishment may be increased by burning due to a decrease in litter depth and exposure of mineral soil. Also, competition from other species might be reduced and the proportion of oaks in advanced reproduction might be increased with fire. And, after stand establishment, fire might be used to keep less desirable species from encroaching under oak.

Prediction Difficult

Fire is still undeveloped as a a silvicultural tool in upland oak management. The range of effects from fire to fire and even within a single fire is great, making predictions of effects difficult. The best available specific guidelines on fire application can be found in *A Guide for Prescribed Fire in Southern Forests* (21) and in handbook and manual supplements for specific national forests.

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Effects of fire on the oak timber type are reviewed. Many oak stands of today originated under severe fire regimes. Fire can kill or injure oak trees. Factors determining direct injury or mortality from fire include: season of year; bark characteristics, size, vigor and form of tree; fire characteristics and stocking level.

KEY WORDS: Fire ecology, fire management, silviculture.

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