REGENERATING OAK STANDS WITH PRESCRIBED FIRE: PRELIMINARY RESULTS OF THE SHELTERWOOD-BURN TECHNIQUE

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ABSTRACT

Growing-season prescribed fires were tested as a means to promote oak (*Quercus spp.*) regeneration after an initial shelterwood harvest. Two oak stands on sites in the Virginia Piedmont were reduced in basal area to 8 square meters per hectare in the first stage of a two-step shelterwood system. Three years later, a portion of each shelterwood stand was burned during August to improve the competitive position of oak regeneration. A year later, density of oak stems in burned areas was not different than in unburned areas. However, the principal competitors of oak, i.e., red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and yellow-poplar (*Liriodendron tulipifera*), had dramatically lower densities in burned areas than in unburned areas. Heights of oak stems were not different between burned and unburned areas while heights of competing species were markedly reduced by burning. Because of the reduction in density and height of competitors, the competitive position of oak was enhanced by prescribed burning. If these favorable effects remain through the establishment period, this approach could become a valuable tool for resource managers desiring to regenerate oak-dominated stands on productive sites.

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INTRODUCTION

Oak (*Quercus spp.*) forests of eastern North America present resource managers with a perplexing puzzle. Why is this suite of species so common in mature stands, yet so difficult to regenerate, especially on productive sites? Historically, oaks have been regarded as a major component for much of the eastern hardwood forest (Braun 1950). For the past few decades, a compositional shift from oak to more shade-tolerant species, i.e., American beech (*Fagus grandifolia*) and red maple (*Acer rubrum*), has been occurring in the absence of disturbance on the more productive sites (McGee 1984, Abrams and Downs 1990). Disturbance of such sites shifts composition towards fast-growing intolerant species, such as sweet birch (*Betula lenta*), sweetgum (*Liquidambar styraciflua*), and yellow-poplar (*Liriodendron tulipifera*) (Loftis 1983, Schuler and Miller 1995). This shift is often undesirable because of the many ecological and economic values of oak. Controlling competition while encouraging oaks to regenerate and grow is a major challenge for resource managers. Such a challenge must be faced if oaks are to remain a major component of forest stands on productive sites.

The shelterwood system is often recommended and used to regenerate oak stands on productive sites where competition from faster-growing species is a problem (Sander et al. 1983, Hannah 1987). The initial shelterwood harvest encourages oak regeneration by reducing the tree canopy so more light, nutrients, and water reach the understory while maintaining an acorn source for future oak seedling establishment. In theory, once oak regeneration is established and becomes a vigorous major component of the advanced regeneration pool, the residual overstory can be removed. Sometimes this technique works (Wolf 1988) but sometimes it fails, leaving too few oaks among the regeneration to create a new oak-dominated forest (Loftis 1983, Schuler and Miller 1995).

Prescribed fire has been suggested as a means of favoring oak regeneration on productive sites (Lorimer 1992, Van Lear and Watt 1992) by reducing acorn insect pests (Martin and Mitchell 1981), preparing seedbeds (Galford et al. 1988), and reducing competing vegetation (Maslen 1989). However, past research on fire effects in mature hardwood forests has produced inconsistent results (Lorimer et al. 1994) due, in part, to inadequate experimental design, implementation, and monitoring. Also, most studies have involved only single fires. A study of repeated prescribed fires as a preharvest treatment (Barnes and Van Lear 1998) indicates that fire will favor oaks but the benefits are slow to manifest themselves, thus limiting its applicability.

Shelterwood harvesting followed several years later by prescribed burning has not been tested for improving the competitive position of oak in the advanced regeneration pool of species. Such an approach may benefit oak because of natural differences in growth strategies between oak and other hardwoods. Oaks have a conservative growth strategy of emphasizing root development over shoot growth while many of their competitors do the opposite (Kelty 1988, Kolb et al. 1990).

This article reports on a pilot study done by the Virginia Department of Game and Inland Fisheries to improve the competitive position of oak advanced regeneration in three-year-old shelterwood stands by prescribe burning them during the summer.

METHODS

The study was conducted at the Powhatan Wildlife Management Area in the Piedmont of central Virginia. This area consists of broad gently-rolling hills underlain by Cecil sandy loam soil (Typic Hapludults) (Reber 1988). Climate is warm continental with 105 centimeters of annual precipitation distributed evenly throughout the year and an average growing season of 190 days. Elevation is approximately 90 meters above sea level.

Two mature hardwood stands, 75–95 years old and undisturbed for at least 30 years, were selected for the study. Site index for oak_{50} was measured at 23 meters and basal area was 25–28 square meters per hectare. White oak (*Quercus alba*) and scarlet oak (*Q. coccinea*) dominated the canopy. Other overstory species included yellow-poplar, sweetgum, hickories (*Carya spp.*), red maple, American beech, southern red oak (*Q. falcata*) and black oak (*Q. velutina*). Midstory and advanced regeneration species included red maple, beech, flowering dogwood (*Cornus florida*), and blackgum (*Nyssa sylvatica*). Advanced regeneration density was approximately 5000 stems per hectare with oak reproduction comprising about 10% of the total.

Two 15 hectare oak-dominated stands were treated with the first stage of a two-step shelterwood harvest during summer 1990. Both stands were marked to remove poor-quality oaks and low-value species with a target of 50% canopy opening after harvesting. Actual post-harvest basal area was 8 square meters per hectare.

Following harvest, ten 0.004 hectare plots were systematically located in each shelterwood stand to monitor development of the advanced regeneration pool. By 1993, advanced regeneration was abundant (≈ 30,000 stems per hectare) and was dominated by yellow-poplar. The shelterwood harvest enhanced oak regeneration (≈ 4000 stems per hectare) but these stems were outnumbered and overtopped by hardwood competitors. It was felt that these stands were not regenerating to oak and prescribed fire was chosen as a follow-up treatment.

Each shelterwood stand was divided into burn (2–3 hectare each) and no-burn (12–13 hectare each) treatment areas. This division separated the advanced regeneration monitoring plots into three burn and seven no-burn plots in each stand. Two additional plots were systematically located in the burn areas of each stand to increase sample size. There were no differences in species composition and density between burn and no-burn areas in either stand prior to burning.

Table 1. Density (stems per hectare) ± one standard error of regeneration[1] for the treatment areas.

Species	Unburned[2]	Burned[2]
Oak	4029 ± 804b[3]B[4]	3582 ± 805bA
Hickory	633 ± 121aC	642 ± 188aB
Red maple	2331 ± 1100bB	420 ± 148aB
Sweetgum	1775 ± 509bB	74 ± 38aB
Yellow-poplar	14635 ± 2195bA	444 ± 115aB
Miscellaneous[5]	6200 ± 1048bB	6397 ± 998bA

[1] Regeneration is defined as greater than 30 centimeters tall and less than 10 centimeters diameter at breast height.
[2] n = 14 and 10 for shelterwood-unburned and shelterwood-burned, respectively.
[3] Means followed by the same lowercase letter within a row are not significantly different (α = 0.05) between treatments.
[4] Means followed by the same uppercase letters within a column are not significantly different (α = 0.05) among species.
[5] Includes American beech, blackgum, and flowering dogwood.

Prescribed fires were conducted in both stands during the afternoon of August 24, 1993 using strip-head fires. Weather conditions were: air temperature 30–32 C, relative humidity 40–50%, and south–southwest winds at 8–16 kilometers per hour. Both areas readily burned and flame lengths were generally 0.6–1.2 meters.

One year after prescribed burning, all monitoring plots were inventoried for density and height of advanced regeneration. All seedlings and sprouts between 30 centimeters tall and 10 centimeters diameter at breast height in each plot were identified to species. Multiple stump sprouts were tallied as a single stem and the tallest stem of each species was measured to the nearest 5 centimeters.

Treatment effects were compared for three species (red maple, sweetgum, and yellow-poplar) and three species groups (oak, hickory, and miscellaneous) in two separate stands. This study was designed as a randomized complete block with two blocks (stands) and two treatments (shelterwood-no burn, and shelterwood-burn) per block. Density and height differences among species and species groups were detected among and within treatments using analysis of variance and Duncan's multiple range test (α = 0.05). When needed, data were rank-transformed to correct for unequal variances and non-normality (SAS 1985).

RESULTS

No block effect was noted, so data were pooled to decrease variance and for ease of presentation (Table 1). Unburned shelterwood areas had abundant advanced regeneration totaling 29,603 stems per hectare (Table 1). Yellow-poplar density was more common than all other groups and species within the unburned shelterwood plots. The densities of oak, sweetgum, and red maple did not differ from each other but were significantly greater than the density of hickory.

The burned shelterwood treatment differed dramatically from the unburned shelterwood treatment in stem density (Table 1). Top-kill of advanced regeneration was nearly 100% and 2–5 dominant overstory

Table 2. Mean height (centimeters) ± one standard error of regeneration[1] for the treatment areas.

Species	Unburned[2]	Burned[2]
Oak	85 ± 14a[3]B[4]	62 ± 8aA
Hickory	—[5]	—
Red maple	294 ± 96aA	100 ± 18bA
Sweetgum	279 ± 37aA	88 ± 11bA
Yellow-poplar	328 ± 63aA	76 ± 23bA

[1] Regeneration is defined as greater than 30 centimeters tall and less than 10 centimeters diameter at breast height.
[2] n = 14 and 10 for shelterwood-unburned and shelterwood-burned, respectively.
[3] Means followed by the same lowercase letter within a row are not significantly different ($\alpha = 0.05$) between treatments.
[4] Means followed by the same uppercase letter within a column are not significantly different ($\alpha = 0.05$) among species.
[5] Data not collected for this species.

trees per hectare were killed. Densities of red maple, sweetgum, and yellow-poplar were markedly lower than in the unburned shelterwood plots. Conversely, densities of oak, hickory, and miscellaneous midstory species did not differ between burned and unburned shelterwood treatments.

Oak regeneration was shorter than the regeneration of its competitors in the unburned shelterwood plots but not in the burned shelterwood plots (Table 2). There were no differences in height among species in the burned treatment. Red maple, sweetgum, and yellow-poplar were shorter in the burned treatment than in the unburned treatment, but there were no height differences for oak between treatments.

DISCUSSION

Although these results must be viewed as preliminary, they suggest that the competitive position of upland oaks in the advanced regeneration pool can be enhanced by prescribed burning in shelterwood stands for at least the first year after burning. Density and height of oak advanced regeneration were not adversely affected by fire while density and height of its principal competitors were markedly reduced.

The differences among species in response to fire may be due to different growth strategies, the types of disturbance and the sequence and/or timing of disturbance. The initial shelterwood harvest disturbs the canopy, increasing the amount of nutrients, sunlight, and water available to understory vegetation. The increase of sunlight is especially important because oak regeneration is adversely affected by dense shade (Lorimer et al. 1994).

Oak reproduction probably responds to this release by developing their root systems (conservative growth strategy) while their competitors emphasize shoot growth (Kelty 1988, Kolb et al. 1990). The subsequent prescribed fire disturbs the forest floor, top-killing the advanced regeneration but causing little overstory mortality. It forces the rootstocks to sprout. Oak advanced regeneration, because of its root development, is a vigorous sprouter, suffering less mortality and less height reduction than other hardwood reproduction that does not have well-developed root systems. Thus, fire apparently promotes oak regeneration at the expense of other species.

Results of this study are preliminary. The trends shown by our data may change as more data are collected. Single fires in other hardwood environments have produced mixed results with some burns benefitting oak regeneration while others have had a negative impact on oak reproduction (Lorimer et al. 1994), so these stands need to be monitored for several years. Oak regeneration is already starting to lag behind its competition in height growth, there are still plenty of red maple, sweetgum, and yellow-poplar seedlings present, and new seedling establishment is possible. Additional prescribed fires may be needed to maintain oak domination of the advanced regeneration pool during the establishment phase of these stands.

CONCLUSIONS

The reduction in densities and heights of red maple, sweetgum, and yellow-poplar by burning, without adversely impacting oak regeneration nor causing excessive overstory mortality, has important implications for landowners and resource managers interested in maintaining oaks on productive sites. The initial shelterwood harvest is a commercial entry. Some of the profits are used to manipulate regeneration via prescribed fire and costs can be minimized by planning for prescribed fire during the initial logging operation. Once adequate oak regeneration is achieved, 1074 stems per hectare that are at least 1.4 meters tall (Sander 1971), residual trees are harvested and fire is withheld from the stand.

This shelterwood-burn approach for regenerating oak stands has important ramifications for wildlife management. The method creates quality early-successional habitat for popular upland game species, i.e., white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*) and bobwhite quail (*Colinus virginianus*), as well as many nongame species (Wood 1981). The residual overstory oaks and hickories provide habitat for songbirds and squirrels, vertical cover, and hard mast crops (Drake 1991). Burning stimulates production of berries, grasses, and legumes on the forest floor (Stransky and Roese 1984). Resprouting hardwood regeneration has nutrient-rich foliage and serves as horizontal cover (DeWitt and Derby 1955). The occasional death of overstory trees creates snags for raptors and beetle-foraging sites for woodpeckers. Once fallen, these snags provide cover for small mammals and substrate for many important elements in the faunal food web (McMinn and Crossley 1995).

Frequent burning (annual or biennial) in a shelterwood would create a savannah-like understory (Thor and Nichols 1973), a habitat type once common but now rare in the eastern United States (Lindestrom 1656, Buckner 1983). Such habitat may be valuable for a wide variety of wildlife, such as those migrant songbirds dependent on grasslands. Occasional burning, once or twice a decade, would create a two-layered stand with an open hardwood overstory and a well-developed understory. This is a potentially important habitat for biodiversity in mixed hardwood ecosystems.

The shelterwood-burn method should be tested in various physiographic regions and sites. Research is also needed on the method's effects on stand dynamics, wildlife, and herbaceous plant communities. Toward this end, a long-term replicated study has been initiated in the central Piedmont of Virginia to more fully document effects of this regeneration method on advanced reproduction and how it may favor oak regeneration (Brose and Van Lear 1996). Early results of this long-term project support the findings of this pilot study.

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