RELEASE OF SUPPRESSED OAK ADVANCE REGENERATION

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Abstract—Oaks are not consistently regenerating on intermediate- and high-quality sites due to the lack of well-developed advance regeneration. Studies of northern red oak (*Quercus rubra* L.) seedling cohorts have shown that when grown under well-developed canopies and mid-stories, height growth is suppressed, and seedling mortality increases with time resulting in a sparsely populated bank of low-vigor advance regeneration. A mid-story removal treatment has been shown to improve vigor of northern red oak and cherrybark oak (*Q. pagoda* Raf.) regeneration in advance of a harvest. However, this treatment has not been widely tested, and indicators of advance regeneration vigor, such as height/age relationships, have not been defined for a number of important oak species. This study profiled the developmental characteristics of white and black oak (*Q. alba* L. and *Q. velutina* Lam.) seedlings growing under dense over-stories and mid-stories in central Kentucky and reports the initial growth response of these seedlings to a mid-story removal.

INTRODUCTION

Advance regeneration is defined as regeneration that is present prior to a regeneration event. For oaks (*Quercus* spp.), this encompasses a range of tree sizes and ages, from first-year seedlings to saplings that possess a wide range of vigor and growth potentials. Characterizing and managing this diverse pool of advance regeneration is difficult.

Advance regeneration is required to successfully regenerate oak. The intermediate- to shade-intolerance of oaks (Hodges and Gardiner 1992) and the dieback and resprouting nature of oaks (Johnson 1992) helps develop cohorts of advance regeneration. However, intermediate treatments are required to improve the competitive vigor of oak advance regeneration (Loftis 1983). Seedling sprouts and true seedlings perform differently under a wide range of light levels at the time of release (Lockhart and others 1999). We hypothesize that as the length of suppression in dense shade progresses, seedlings have less associated vigor and will not respond to a release treatment as well as seedlings that have been suppressed for shorter periods. This could have direct implications on when intermediate treatments, such as mid-story removal, should be performed relative to the establishment of oak cohorts.

Loftis (1992) has shown that a cohort of northern red oak (*Q. rubra* L.) seedlings at 12 years attained a height of > 1 foot. It was also shown that this cohort of seedlings exhibited a 90 percent mortality rate by year 12. However, little is known about the demographics of other oak seedling populations. It is critical to have seedlings with a height of > 4.5 feet at the time of a regeneration treatment in order for these seedlings to be competitive (Sander 1972). Treatments have been proposed that allow seedlings to achieve this stature without stimulating the growth of competing species (Johnson 1980, Loftis 1983). However, the optimum timing of this treatment relative to cohort age is unknown.

Describing populations of advance regeneration requires an understanding of the growth habits of oak seedlings. Oak seedlings have a conservative growth strategy, favoring root growth over shoot growth even when presented with improved growing conditions (Abrams 1998, Hodges and Gardiner 1992). Often seedlings die back and resprout and have been shown to perform differently when exposed to silvicultural treatments (Lockhart and others 1999). Understanding the nature of advance regeneration root systems and predicting below-ground biomass may be important to understanding the nature of their response. Many above ground features of a seedling can provide estimates of the condition and developmental stage of a root system (Johnson 1992). Due to the conservative growth strategy of oak seedlings, their well-developed root system may provide for a more timely response to release (Hodges and Gardiner 1992). Larger root systems may also have larger carbohydrate reserves for a seedling to tap upon release (Hodges and Gardiner 1992). This paper will outline some of the characteristics of white oak (*Q. alba* L.) and black oak (*Q. velutina* Lam.) seedling populations in upland oak stands in central Kentucky that have direct implications toward assessing advance regeneration vigor and will also provide some first-year growth response information on released advance regeneration.

STUDY SITES

Study sites were located on Berea College Forest in Madison County, KY, in the Knobs physiographic region located on the western edge of the Cumberland Plateau. Four stands containing a range of cohorts of black oak and white oak advance regeneration were selected for study. All stands have a mixed oak over-story with a significant white oak component. Site indices for these stands range from 73 to 82, with a mean of 78. Before treatment, basal area ranged from 100 to 115 square feet. The mid-story and under-story of these stands were dominated by red maple (*Acer rubrum* L.), sugar maple (*A. saccharum* Marshall), beech (*Fagus sylvatica* L.), and minor components of other species. In each stand, two 0.5 acre tracts were delineated for study (treatment and control).

METHODS

In January, 2004, 30 black oak and 120 white oak seedlings were excavated from the study sites. Seedlings were bagged, labeled, and immediately put on ice. In the lab, all seedling

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roots were rinsed in a water bath, photographed, and measured. Seedling tops were separated from the root system at the root collar. Measurements taken on the seedling top include: root collar diameter, length of all growth flushes or nodes, total height, and number of flushes (top age).

Root ages of white oak were measured 1 inch below the root collar by counting annual rings. It was not possible to accomplish this with black oak roots, and no root ages were obtained for this species. Length, root diameter (diameter 1 inch below root collar), wet mass, and dry weight were measured on all root systems. Two sections of root (root collar to 1 inch below root collar, and 1 inch below root collar to 2 inches below root collar) were sectioned, flash frozen in liquid nitrogen, and put in a –80 °C freezer. These were then analyzed for carbohydrate levels (data not presented in this paper).

Seedlings were classified into two groups: true seedlings and seedling sprouts. This was accomplished using comparisons of the top age (number of nodes or growth flushes) and the root age (number of growth rings 1 inch below the root collar). Seedlings that had the same top age and root age were classified as a true seedling, and seedlings that expressed a discrepancy between top age and root age (root age>top age) were classified as seedling sprouts.

All seedlings sampled were growing in an intact canopy setting. After this initial excavation of seedlings, a mid-story removal was implemented. This was accomplished by removing approximately 20 percent of the total stand basal area with a chainsaw and immediately spraying the stumps with 100 percent Roundup Pro®. Stems were removed starting with the 1 inch size class and moving up through diameter classes until the 20 percent target was achieved. A 25-foot buffer was installed around the treated growth and yield plot. In addition to the excavated seedlings, 400 seedlings of white oak, black oak, northern red oak, and red maple were tagged and measured (basal diameter, height, number of nodes, and length of last internode).

STATISTICAL ANALYSES

Analysis of variance (ANOVA) was used to test for significant differences between the seedling sprout characteristics and the true seedling characteristics. These variables include root mass, root diameter, root length, root age, seedling height, root collar diameter, and number of nodes (top age). ANOVA was also used to detect growth differences between treatments and among species. All comparisons were analyzed at $\alpha = 0.05$.

RESULTS

In the four stands that were profiled for this study, 55 percent of the seedlings sampled were true seedlings and 45 percent were seedling sprouts. Both seedlings and seedling sprouts encompassed a wide range of age. True seedlings averaged 6 years for both top age and root age (fig. 1). The average root age of seedling sprouts was approximately 9 years, while the average top age was 6 years (fig. 2). While root ages differed between seedlings and seedling sprouts, ages of tops were similar.

The mean height of seedling sprouts and true seedlings rarely surpass 1 foot in intact canopy settings in central Kentucky (fig. 3). While internode length was similar for true seedlings

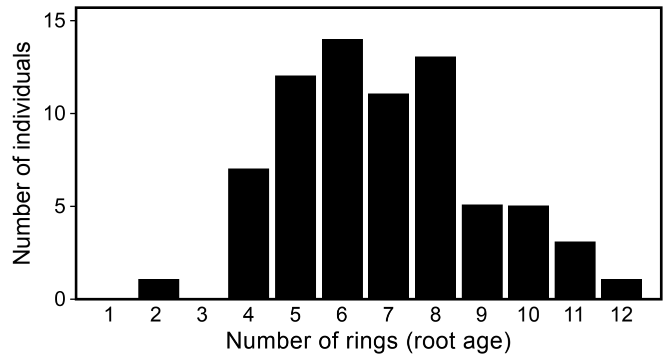

Figure 1—Age distribution of true white oak seedlings grown under intact canopies.

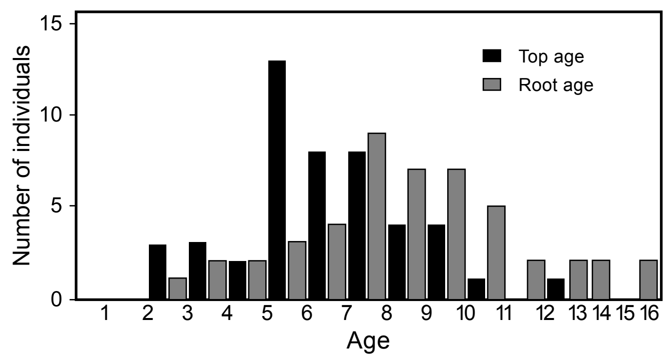

Figure 2—Age distribution of white oak seedling sprouts (top age and root age) grown under intact canopies.

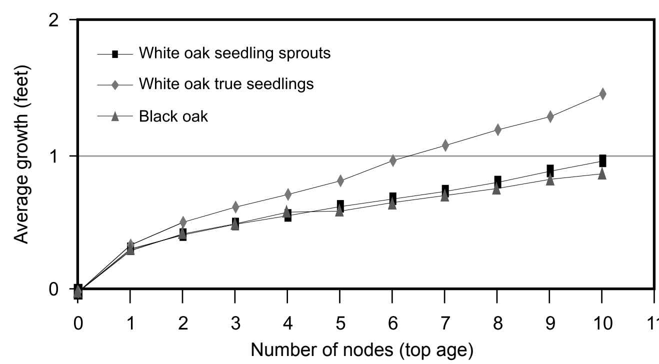

Figure 3—Average height growth of white oak seedling and seedling sprouts and black oak advance regeneration over time under intact canopies as indicated by internode length.

of white oak and black oak seedlings, white oak seedling sprouts had a significantly greater height at node 10. Due to the inability to obtain a root age from the black oak seedlings, we were unable to further classify the black oak into seedling sprouts and true seedlings. The performance of the black oak seedlings and the white oak true seedlings, under an intact canopy, is similar to the results reported by Loftis (1992) for northern red oak in the southern Appalachians.

Although we could not distinguish between one flush and multiple-flush years, it is rare for oak seedlings to have multiple flushes in a growing season in central Kentucky. From field observations, over-story oaks in central Kentucky tend to exhibit a multiple flush every 3 to 5 years as a result of above-average rainfall. However, this multiple flush phenomenon occurs less often in suppressed seedlings growing in intact canopy settings. During the experimental period, higher-than-average rainfall resulted in 2 to 3 growth flushes of canopy oak trees. However, monitored oak seedlings only flushed once. This lends credibility to the age estimation from node counts. Regardless, the seedlings and seedling sprouts monitored in this study fell short of the minimum height requirements needed to successfully compete after a regeneration harvest, and improvement in oak seedling height through the application of a mid-story removal is warranted.

INITIAL GROWTH RESPONSE

Seedlings and seedling sprouts of white oak, black oak, northern red oak, and red maple were monitored in order to assess the initial growth response to a mid-story removal. Initial response varied by species. All species of oak advance regeneration showed no height growth response to a mid-story removal. However, northern red oak and black oak had significantly better height growth in intact canopy conditions and also in a mid-story removal setting than white oak (fig. 4). There was no height growth difference between northern red oak and black oak. White oak had significantly less height growth in the mid-story removal setting that that of the control. This initial response to increased light levels is not unexpected due to oak's conservative growth strategy. There was a significant increase in basal diameter in the mid-story removal treatment over that of the control plot at all sites and across all species of oak seedlings (fig. 5). This suggests that as these oak seedlings are exposed to higher light intensities, they shift the allocation of photosynthate to root growth while maintaining height growth at pre-treatment levels. This trend also is not unexpected due to oak's conservative growth strategy. There was no significant difference in basal diameter growth among oak species.

RED MAPLE RESPONSE

Red maple seedlings did respond to increased light levels in both height and basal diameter growth. Red maple height growth in the mid-story removal areas was significantly greater than that of the control seedlings. Red maple seedlings also grew significantly more than white oak seedlings in both an intact canopy setting and in the mid-story removal plots. Figure 6 shows increased height growth of red maple compared to that of white oak.

These data indicate that red maple is out-growing white oak in height under intact canopies and in response to a mid-story removal. Red maple also exhibited the same significant increase in basal diameter growth as the oak seedlings when exposed to a mid-story removal. Basal diameter growth was significantly greater in the mid-story removal plots than the control plots (fig. 7).

CONCLUSIONS

Black oak seedlings and true white oak seedlings in central Kentucky upland oak stands follow a similar trend reported for northern red oak in North Carolina (Loftis 1992). Advance

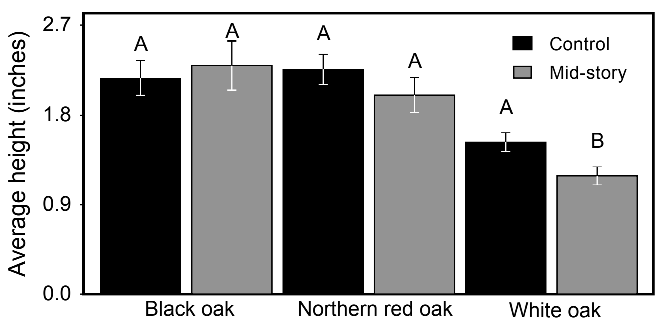

Figure 4—Advance regeneration height growth in 2004 by treatment and species. Letters represent significant differences between treatments (p<0.05) using ANOVA.

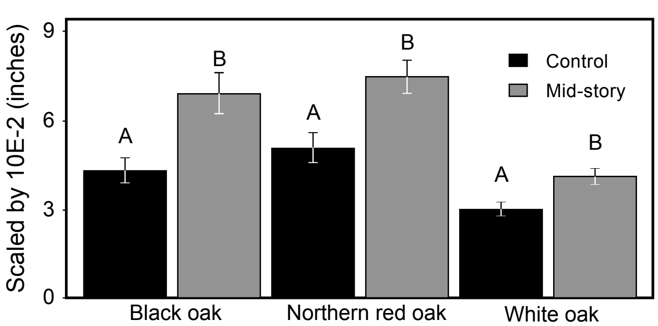

Figure 5—Basal diameter growth of advance oak regeneration by species and treatment. Letters represent significant differences between treatments (p<0.05) using ANOVA.

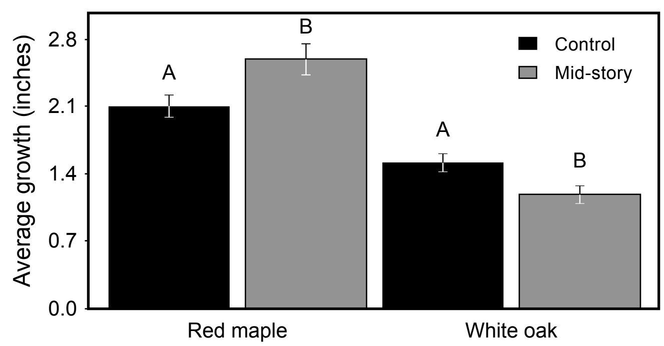

Figure 6—Red maple vs. white oak height growth response by treatment. Letters represent significant differences between treatments (p<0.05) using ANOVA.

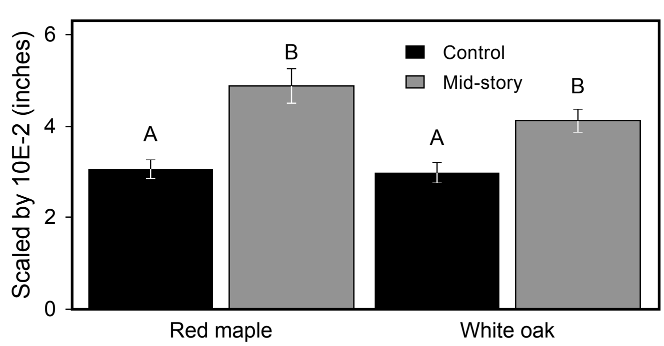

Figure 7—Red maple and white oak basal diameter growth by treatment. Letters represent significant differences between treatments (p<0.05) using ANOVA.

regeneration growing under intact canopies rarely attain a height > 1 foot. Results show that application of a mid-story removal significantly increases basal diameters of all oak species investigated. This indicates a positive response in tree vigor to this treatment that will ultimately result in a seedling or seedling sprout that has greater potential for rapid height growth when challenged with a full canopy release. However, red maple was also able to capitalize in both height and basal diameter growth in the first season following treatment implementation. This may pose problems over the life of this treatment making multiple under-story cleanings a necessity.

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