How Much Older are Appalachian Oaks Below-Ground than Above-Ground?

Daniel J. Heggenstaller, Eric K. Zenner, Patrick H. Brose, and Jerilynn E. Peck

ABSTRACT

Young oaks (Quercus spp.) are known to invest more in early root growth than shoot growth, enabling seedlings to tolerate stem die-back and resprouting. The resulting disparity in age between above- and below-ground tissues has been previously demonstrated for seedling-sized stems, but not for successful canopy-ascending trees. We compared the age of stem cross sections taken at 1.0 ft above the ground and those taken at the rootcollar of northern red (Q. rubra) and chestnut oaks (Q. montana) and measured growth rates over the first five years of development. Of 51 sampled stumps, 88% had root systems that were an average of 2.3 to 3.6 yrs older than the aboveground stem. The early height growth rate averaged 19 in./yr supported the supposition that most sampled oaks had been advance regeneration that resprouted following harvest. These results indicate that at least a single topkill does not necessarily pose an impediment to oak regeneration success and may, in fact, provide a competitive advantage and reiterate long-standing assertions that oak reproduction must be well-established before the final harvest.

Keywords: northern red oak, chestnut oak, root age, seedling sprout

Young oaks develop an extensive root system at the expense of early height growth, enabling them to die back and sprout repeatedly as long as light levels are greater than about 5% full sunlight (Larsen and Johnson 1998, Dey et al. 2007, Brose 2011). A logical consequence of this strategy is that the below-ground root systems are older than the aboveground stems. This disparity between root and stem ages in young oak seedlings has been documented in several studies. A 1944 report from Missouri observed an average root age of 24 years for seedling-sized stool sprouts (Liming and Johnston 1944) and a 1956 report from Ohio found that 74% of 100 oak "seedlings" were 3 to 31 years older below-ground (at the rootcollar) than aboveground (Merz and Boyce 1956). A report from central Pennsylvania indicated that oak, maple, and black cherry seedling sprouts ($<$0.5 in. diameter) averaged 5 years (range 1 to 18, $N = 120$) older just below the rootcollar than just above it (Ward 1966). Extensive sampling in West Virginia resulted in an observed average age of 5 to 17 years (range 1 to 50, $N = 520$) for below-ground tissue (1 to 1.5 in. below the rootcollar) of seedling-sized sprouts (with rootcollar diameters $\leq$ 2 in.) of various oak species (Tryon and Powell 1984).

These studies considered only seedling-sized reproduction—most of which would not have survived to become canopy dominants. However, common oak management guides evaluate regeneration success based on canopy closure or third decade stocking (Brose et al. 2008, Steiner et al. 2008). We therefore wanted to know if this strategy has been employed by 20 to 30 year old oaks in Pennsylvania and, if so, how great the age disparity may be. Our approach was to compare the ages of below- and aboveground tissue, and the growth rate over the first five years of development, in two predominant oak species in stands of known and comparable stand initiation.

Methods

Sampling took place in six young unmanaged mixed hardwood stands originating after clearcut harvests of the previous mature oak stands between 1969 and 1984; three in the Appalachian Plateaus (AP) province of northwestern Pennsylvania and three in the Ridge and Valley (RV) province of central Pennsylvania. The predominant oak species was northern red oak (*Quercus rubra* L.) in the AP and chestnut oak (*Quercus montana* L.) in the RV. The primary direct competitors of these oaks were red maple (*Acer rubrum* L.), sweet birch (*Betula lenta* L.), and black cherry (*Prunus serotina* Ehrh.). In each stand, all potential oaks were identified as those bearing characteristics typical of trees thought to be of seed origin (i.e., straight, single stemmed, no scars or knots near the base). From these, a stratified random sample was taken of ten dominant or co-dominant oaks and ten intermediate or suppressed oaks. Each tree was marked at 0, 12, 24, and 54 in. in height and felled above this point. A cross-section was cut at each of the marked points, which was air dried and sanded to facilitate ring detection. True rings were counted under a stereo dissecting microscope. To determine the height of each tree at ages 0 and 5, we set the age of each tree at the 0 in. height to 0 yrs. The age at each subsequent height for which a cross-section was taken was calculated as the difference between the number of growth rings at that height and the number of rings associated with the age of 0 yrs. To determine the height of each tree at age 5 when no cross-section was taken that corresponded

Manuscript received March 13, 2012; accepted June 12, 2012. http://dx.doi.org/10.5849/njaf.12-008.

Daniel J. Heggenstaller (djheggenstaller@gmail.com), Penn State School of Forest Resources. Eric K. Zenner (eric.zenner@psu.edu), Penn State University, School of Forest Resources, 305 Forest Resources Building, University Park, PA 16802, Phone: (814) 865-4574; Fax: (814) 865-3725. Patrick H. Brose (pbrose@fs.fed.us), Northern Research Station, USDA Forest Service. Jerilynn E. Peck (peckj@psu.edu), Penn State School of Forest Resources. *The authors thank Greg Sanford, Eric Baxter, Bob Brown, Dave Cole, Josh Hanson, Lance Meyer, John Schwartzer, Kevin Cook, and Derek Larson for their dedicated field and lab work. The authors especially thank Kim Steiner for his contributions to the design of the umbrella project and assistance with site selection. The autors also thank the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry and Pennsylvania Agricultural Experiment Station Project PEN04225 for funding support.*

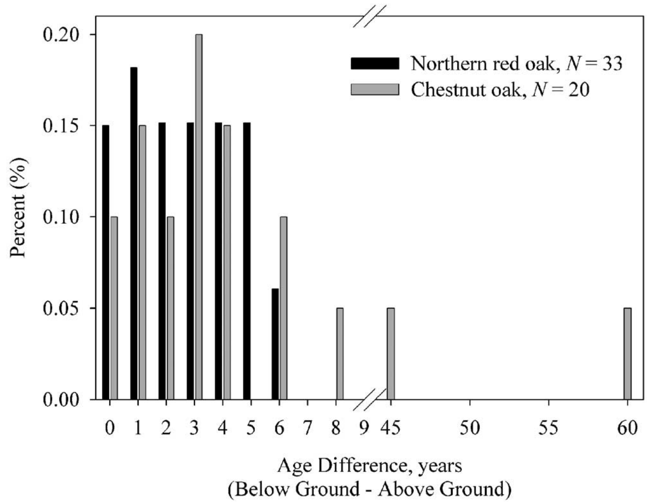

Figure 1. Distribution of age differences (below-ground tissue minus aboveground tissue). Differences are shown for each species separately, although they were not statistically significantly different after excluding the two extreme outliers.

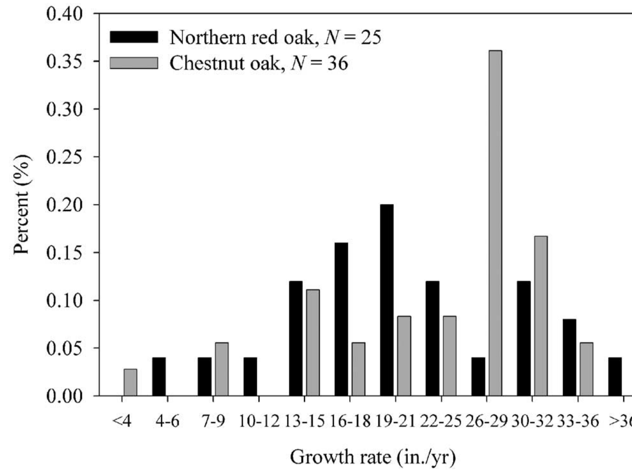

Figure 2. Height growth rates during the first five years of development. Rates are shown for each species separately, although their means were not statistically significantly different.

to that age, we divided the change in height between the ages of 0 and the age of the next closest cross-section by the number of years passed and added this average height increment to the recorded heights at ages 0 to 5.

These stumps were also excavated and cut again just at the rootcollar (~2 to 4 in. below ground level) to determine the number of growth rings at this height. In addition to the 35 hollow trees that lacked their pith due to stem decay, about an equal number was discarded because the stump was cut too low and the rootcollar was missed. The final subset of stumps for which rootcollar age was determined thus included 33 northern red oaks in the AP and 18 chestnut oaks in the RV. The disparity in age between the aboveground tissue (at 12 in. height) and the below-ground tissue (at the rootcollar) of the same tree was determined as the difference in the number of growth rings at each height. In addition, for another random subset of 25 northern red oaks and 36 chestnut oaks the mean growth rate over the first 5 years of development was calculated as the difference in height between ages 0 and 5 divided by 5 years. The statistical significance of the disparity in age between below-ground and aboveground tissue from the same tree was assessed, by region and crown class, using paired *t*-tests in SAS Version 9.1. Analysis of variance (ANOVA) was used to assess differences among provinces and crown classes in age disparity and height growth rates over the first 5 years of development.

Results

Of the 51 stumps sampled at the rootcollar, 88% had below-ground tissue that was older than the aboveground tissue (Figure 1), which tended to date back to the time of harvest. Although two chestnut oak outliers (excluded from subsequent analyses) were 45 and 60 years older than their respective stems, on average below-ground tissue was 2.3 to 3.6 yr (95th CI: 1.3 to 2.9 yrs) older than aboveground tissue ($P < 0.05$), which did not differ between provinces or crown classes ($P > 0.27$).

In addition, the average height growth rate for the first five years of development was 19 in./yr (95th CI: 14 to 24 in./yr), which did not differ between crown classes or species/provinces ($P > 0.48$). Only 10% of sampled oaks had height growth rates in the 4 to 12 in./yr range and only one chestnut oak grew at a rate of less than 4 in./yr (Figure 2).

Management Implications

Oaks follow a developmental pattern that differs from their competitors (Gottschalk 1985, Kolb et al. 1990, Brose 2011), favoring early root growth over shoot development. As a consequence, oaks often become overtopped by their competitors, but are better prepared to respond to disturbances such as the periodic surface fires thought to have once perpetuated oak forests throughout the East (Abrams and Nowacki 1992, Brose et al. 2001). Oaks readily sprout following such disturbances, but so too do their competitors: seedling sprouts of oak, black cherry, red maple, and sugar maple (*A. saccahrum*) have all been observed to have root systems upwards of a decade older than the aboveground stem (Tryon and Powell 1984). The extra root development of oak seedlings, however, is thought to provide the support necessary to survive repeated cycles of stem die back—providing an edge over competing species whose reserves become exhausted after fewer cycles of disturbance. Seedling-sized oak stems have often been found with root systems more than 10 to 30 years older than the aboveground stems (Liming and Johnston 1944, Merz and Boyce 1956, Tryon and Powell 1984), with some root systems having supported 4+ generations of stems after repeated aboveground die back (Liming and Johnston 1944). We also documented some oaks (the outliers) that were many decades older than their contemporaries. Further, it is not unreasonable to assume that at least some of the hollow trees we were unable to age at the rootcollar, which were predominantly chestnut oaks, may also have died back repeatedly and been closer in age to the outliers than to the subset we were able to age.

Our data demonstrate that the majority of these surviving oaks were present prior to the harvest, many as advanced regeneration (cf. Phares 1971) most likely having sprouted following damage during harvest. In addition to having root systems several years older than their stems, only one chestnut oak had a growth rate low enough (<4 in./yr) to be considered a new germinant (Phares 1971, Crow 1992, Brose 2011). The early growth rates of most stems were considerably higher than the common range for undamaged advanced regeneration (4 to 12 in./yr; Brose and Van Lear 1998, Brose 2011), and more in keeping with results from Virginia and Ohio demonstrating that oak sprouts originating from advanced root systems have the potential to grow several feet per year during the first few years of stand development (Sander 1971, Brose and Van Lear 1998). These data are thus consistent with the widely held notion that oaks present before the harvest as advanced reproduction compete more successfully than acorn-origin oak seedlings in young stands (Sander 1971, Loftis 1990). Canopy ascending (dominant and co-dominant) oaks showed no difference in below-ground age disparity or initial 5-year height growth rate from intermediate and suppressed oaks, indicating that the resprouting strategy is both widespread and not sufficient to ensure success (i.e., canopy dominance).

However, the results of this study do indicate that successfully canopy-ascending oaks can originate from relatively small seedling sprouts and true seedlings. Of the subset of oaks that could be aged at the rootcollar, nearly all chestnut oak, and all northern red oak, root systems were less than 7 years older than the aboveground stems and 13% were the same age above- and below-ground and thus, presumably, true seedlings. This indicates that it is not always necessary for an oak to have accumulated a 10- to 30-year-old root stock to successfully compete following a catastrophic disturbance. Rather, even on comparable intermediate to high quality sites, one or two cycles of stem dieback over a period of less than a decade may suffice for adequate root development, provided dense understory shade and excessive browsing by white-tail deer (*Odocoileus virginianus*) are not serious limiting factors to the regeneration process. These findings support the sequential silvicultural strategies of SILVAH (Silviculture of Allegheny Hardwoods) for managing oak on good quality sites, in which shelterwood harvests are combined with the use of herbicides or prescribed fires to repeatedly kill off aboveground tissues until the root reserves of competitor species are exhausted during the oak regeneration process (Brose et al. 2001, 2008).

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