THIRTY-ONE YEARS OF STAND DEVELOPMENT IN A NORTHERN RED OAK (*QUERCUS RUBRA* L.) PLANTATION, NORTH-CENTRAL OHIO, USA

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ABSTRACT.—Northern red oak stand development was monitored in a plantation at the Ohio Agricultural Research and Development Center (OARDC), Wooster, OH. By comparing stand development in this plantation with other stands (including those naturally regenerated), we attempt to evaluate the potential for ecosystem restoration of northern red oak forests. Approximately 4,000 seedlings were planted on this 1.9 ha site in November 1962 as a provenance test. Mortality rates were monitored during the autumns of 1962, 1963, and 1965, and were initially relatively high. Stem density (921.2 ± 40.3 stems ha^{-1} in 1968), basal area, and diameter were also periodically sampled until 1993, and these parameters exhibited expected patterns over the thirty-one year observation period. Examining long-term trends in plantations can provide insights into stand development patterns, expected growth rates and stand structures, and the potential for successful forest restoration.

Introduction

Across the Central Hardwoods Region, stands currently dominated by oaks are becoming less common due to regeneration failures. Long-term fire suppression and the increased mortality of oaks caused by gypsy moth (*Lymantria dispar* L.) defoliation and oak wilt [*Ceratocystis sogacearum* (Bretz) Hunt.], have resulted in many oak species being displaced by more shade-tolerant species (Hix and Lorimer 1991; Abrams and Nowacki 1992; Isebrands and Dickson, 1994). Additionally, urban expansion, conversion of mixed-oak forests to pasture and cropland, and accelerated harvesting has resulted in additional losses of oak stands across the Region (Abrams and Nowacki 1992; Johnson, 1993). This decline is particularly true for northern red oak (*Quercus rubra* L.) stands, which currently are being heavily harvested by private landowners because of the species' high lumber value and susceptibility to pests such as the gypsy moth. Consequently, the establishment and restoration of northern red oak stands are important issues facing resource managers in the Central Hardwoods Region.

Unfortunately, the silvical characteristics of northern red oak are such that it is often difficult to successfully regenerate these stands. As an intermediate species in shade tolerance with heavy seeds (Burns and Honkala 1990), northern red oak will not rapidly invade open areas such as old fields or out-compete other species following harvest operations or in closed canopy conditions. Acorn production is also often highly erratic from year to year, and predation losses due to insects, birds, and mammals can be very high. These characteristics when coupled with fairly high moisture requirements for early growth make northern red oak a prime candidate for restoration planting.

Although considerable research has been conducted over the past half-century on the regeneration dynamics and establishment patterns of northern red oak (e.g., Martin and Hix 1988; Nowacki et al. 1990), relatively little information on the early stand development of planted northern red oak stands is available. Since the goal of ecosystem restoration is to return a disturbed area to a successional trajectory that is similar to the area prior to disturbance (SER 2002), it is not clear whether planted stands of northern red oak over time begin to emulate the composition, structure and function of naturally regenerated northern red oak stands. In an effort to address this issue, we have begun to analyze growth and development data collected over the past 31 years from northern red oak

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plantations initially established as provenance tests at the Ohio Agricultural Research and Development Center (OARDC) located at Wooster, Ohio.

The objective of this paper is to summarize the early stand development patterns of one such stand of planted northern red oak located at OARDC, and compare these patterns with those of naturally regenerated northern red oak stands and plantations of the Central Hardwoods Region. With this information, we can begin to understand how these planted northern red oak stands develop over time and determine whether they are beginning to emulate the patterns of development exhibited in naturally regenerated stands.

Study Site and Methods

Mortality and growth have been monitored in the Apple Creek Provenance Test (AC-9) at the Ohio Agricultural Research and Development Center, Wooster, Ohio (40’45”N, 81’55”W) over the past 31 years. The 1.9 ha site is located along Apple Creek on fluvial terraces with Bogart loam, Euclid silt loam, and Orrville silt loam soils. These soils are classified as either moderately well drained or somewhat poorly drained.

In 1961, northern red oak seeds from 35 locations in 15 states and two Canadian provinces were collected and sown at a nursery in Green Springs, Ohio. In 1962, approximately 4,000 of these nursery-grown northern red oak seedlings were planted in seven randomized blocks totaling 1.9 ha (with double border rows). Sixteen trees were planted per plot at a 2.7 m by 2.7 m spacing. Seedlings that died in 1962-64 were replaced annually. As part of the provenance test maintenance, each block was fertilized (ammonium nitrate) in spring 1962, 1967 and 1968. Additionally, each block was treated with herbicide (Simazine and Atrazine) in 1965 and in 1968, mowed in 1967, and the spaces between rows were disked in the fall of 1968 in an effort to reduce competition.

Mortality was recorded in November 1962, October 1963, April 1965, and October 1965. However, seedlings that were dead were replaced until 1965. Consequently, we only present mortality rates since 1968. Stem diameter was measured in December 1968 (at 1 ft above the ground as many individuals were not yet 1.4 m tall), while the diameter at breast height (dbh; 1.37 m from the ground) of each stem was recorded in March 1983 and April 1993.

Results and Discussion

Mortality – After the first ten years of stand development (1962-1973), seedling survival was 54% (Kriebel 1976). Most of the mortality occurred prior to 1968. This level of survivorship is considerably lower than other studies from the region. McNeel et al. (1993) report first-year survival rates of 88% for planted northern red oak stems in northern West Virginia, and Pubanz et al. (1989) reported first-year survival rates of planted northern red oak seedlings in Wisconsin ranging from 85% in untreated stands to > 95% in cut and herbicide-treated stands. Johnson et al. (2002) report mean annual survival rates range from 96-99% for the red oak group (which includes northern red oak).

Most models of stand development predict that mortality rates peak during the stand initiation stage and then decline to 1-2% year^{-1} at maturity (Buchman 1983; Bell 1997; Allen and Sharitz 1999). However, the specific mortality rates vary by species depending on specific life history traits (e.g., species longevity or shade tolerance). For example, Bell (1997) found that mortality rates were size- and species-specific, with smaller stems having a higher mortality rate. In the AC-9 stand, mortality rates have declined over time as the stand has progressed through the stand initiation and stem exclusion stages of development (Fig. 1). From 1968 (the point at which dead seedlings were not replaced) to 1983, the mean (± 1 SD) mortality rate was 1.5 (0.3) % year^{-1}. Over the next ten years (1983-1993), the mortality rate further declined to 0.8 (0.3) % year^{-1}. These rates are comparable to those reported by Lorimer et al. (1994) for treated (all understory trees >1.5 meters cut and stumps treated with herbicide) northern red oak stands on mesic sites in southern Wisconsin (1.8% year^{-1} over the first four years following planting). However, it should be noted that in the untreated northern red oak stand sampled by Lorimer et al. (1994) seedling mortality was extremely high (72% over four

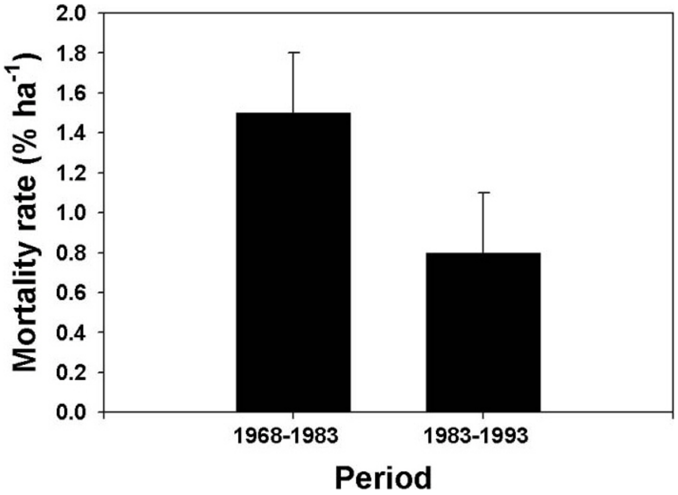

Figure 1.—Average (± 1 SD) mortality rate (% stems yr^{-1}) of northern red oak from 1968-1983 and 1983-1993 for the AC-9 northern red oak plantation, OARDC, Wooster, Ohio.

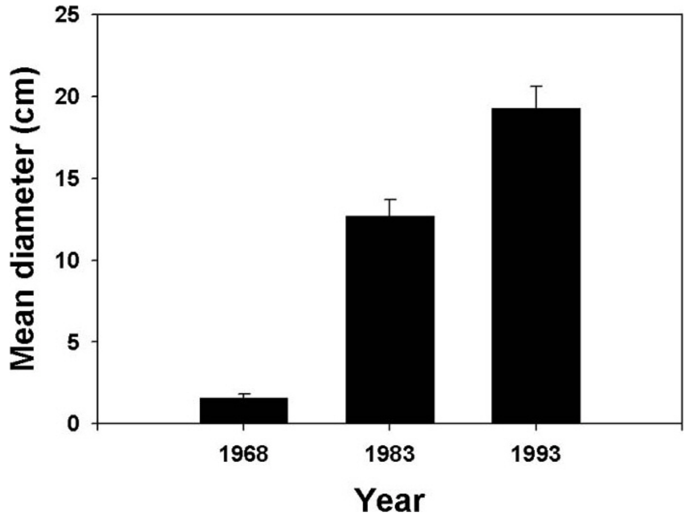

Figure 2.—Changes in mean (± 1 SD) diameter (dbh) from 1968 to 1993 for the AC-9 northern red oak plantation, OARDC, Wooster, Ohio.

years or 18% $year^{-1}$). In Illinois, Bell (1997) found a mortality rate of 3.1% $year^{-1}$ for trees ≥ 4 cm dbh in streamside forests along Hickory Creek and associated the high mortality with slow tree growth. Upland forests at this site were dominated by *Quercus rubra* that had a mortality rate of 1% $year^{-1}$ over 18 years. As a comparison, in old-growth forests of the Congaree Swamp National Monument in central South Carolina, background mortality rates for stems >10 cm dbh ranged 0.5 to 1.0% $year^{-1}$ (Allen and Sharitz 1999).

Diameter growth – In 1968, six years after planting, the mean dbh of the planted northern red oak stems was 1.6 (±0.2) cm (Figure 2). By 1983, the mean dbh of the AC-9 stand had increased to 12.7 (±1.0) cm, and by 1993 the mean dbh was 19.3 (±1.3) cm. While the dbh has increased over time, diameter growth rates have declined. During the first twenty years of stand development, mean diameter growth was 0.74 (±0.06) cm $year^{-1}$, and then over the next ten years (1983-1993) it averaged 0.66 (±0.06) cm $year^{-1}$. Northern red oak growth rates in the AC-9 plantation greatly exceeded growth in forest understories in Wisconsin where the average dbh was 4.8 cm 26 years after a shelterwood cut (Martin and Hix 1988). More rapid growth would be expected where the overstory density is low and competition has been reduced by planting at wide spacing and there has been control of the competing vegetation. Northern red oak diameter growth rate, averaged over a wide range of initial tree diameters, as compiled from several studies by Johnson et al. (2002), was found to be 0.41-0.74 cm $year^{-1}$.

In natural northern red oak stands, somewhat similar patterns of diameter growth have been observed. For example, Abrams and Nowacki (1992) found that radial growth in northern red oak fluctuated in natural stands, initially increasing with tree size, followed by slower dbh growth rates until releases from suppression have occurred.

Density and basal area – Six years following the initial planting and four years following the last replacement of dead seedlings, mean stand density was 921.4 (±40.3) stems ha^{-1} (Fig. 3). Fifteen years later (in 1983), stem density had declined to 708.5 (±37.2) stems ha^{-1}, and by 1993 density declined further to 617.5 (±34.9) stems ha^{-1} (Fig. 3). Thus, there was a decline of 14.1 stems ha^{-1} $year^{-1}$ during the early portions of the stem exclusion stage, and a decline of 9.1 stems ha^{-1} $year^{-1}$ during the later portions of the stem exclusion stage. Mean basal area in 1968 was 0.27 (±0.05) m^2 ha^{-1} and increased to 10.37 (±1.97) m^2 ha^{-1} by 1983 (Fig. 3). Thirty-one years following establishment, mean basal area had increased to 20.32 (±2.71) m^2 ha^{-1}. Over the first 15 years of the stem exclusion stage (1968-1983), basal area accumulation averaged 0.72 (±0.18) m^2 ha^{-1} $year^{-1}$. Over the next 10 years (1983-1993), the rate of basal area accumulation had increased to 1.00 (±0.08) m^2 ha^{-1} $year^{-1}$.

In comparison, Schnur (1937) indicated that even-aged upland oak forests at age 30 years typically had basal areas of approximately 19.5 m^2 ha^{-1}, on average sites. The decline in mean density and concurrent increase in mean basal area are similar to patterns observed in other forest types in the stem exclusion stage of development (Oliver and Larson 1996, Johnson et al. 2002).

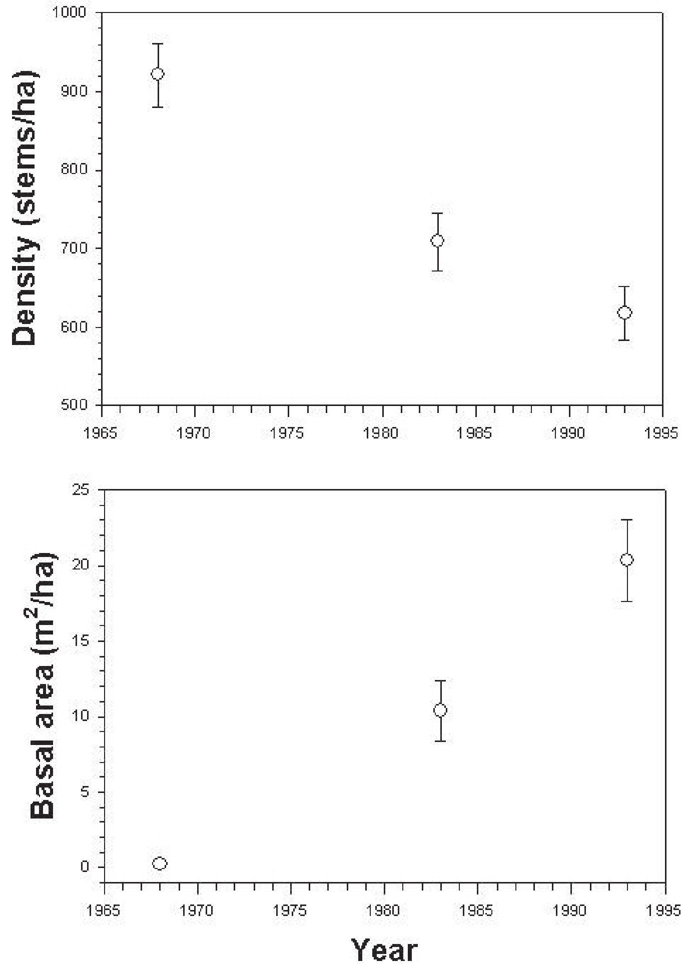

Figure 3.—Changes in mean (± 1 SD) stem density (stems ha^{-1}) and basal area (m^2 ha^{-1}) from 1968 to 1993 for the AC-9 northern red oak plantation, OARDC, Wooster, Ohio.

Conclusions

Early stand development patterns observed in the AC-9 provenance test plantation are comparable to those observed in natural northern red oak stands of the Central Hardwood Forest Region. Mortality rates after the first five years were initially higher than those of some naturally regenerated stands. However, the wide initial spacing may have delayed the onset of competition, and the monitored mortality rates are similar to those observed in natural stands, after the first five years. Diameter growth rates greatly exceeded those of northern red oak in natural stands. The lack of an existing overstory and removal of competition as part of plantation management accelerated dbh growth and hence stand development. The basal area after 30 years reflects the rapid diameter growth of the stand. Thus, our initial results suggest that the AC-9 plantation has followed the expected trajectory of stand development, with a relatively accelerated diameter growth rate. Given these outcomes, this plantation serves as a successful model of how it is possible to plant the desired species and restore the northern red oak forests of the region.

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