RELEASING SHELTERED NORTHERN RED OAK DURING THE EARLY STEM EXCLUSION STAGE

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Abstract—The utility of releasing sheltered northern red oak was examined in mesic hardwood stands in north central West Virginia. Different levels of release were applied in the spring of 1996 - six growing seasons after planting 2-0 seedlings that were protected with 5 ft corrugated plastic shelters. The planting was done in a 7.77 acre forest opening that developed abundant natural regeneration, but lacked a self-sustaining oak component. The most intensive release consisted of cutting all stems within a 5 ft radius of the sheltered tree (n = 20). A less intensive release consisted of the removal of only stems that were significantly overtopping the sheltered tree (n = 20). A control group in which the trees were not released was also incorporated into the study (n = 19). Trees at the beginning of the study either were codominant or intermediate in crown class. Total height of northern red oak prior to treatment averaged 9.7 ft and did not differ among treatments. Height growth after two growing seasons was statistically different among treatments (p = 0.0151). Average height growth was 4.09 ft and 3.96 ft for the minimal release and the control group, respectively, and 2.78 ft for the full release. Height of the competing vegetation after two growing seasons also differed by treatment (p = 0.0045) and was 16.10 ft in the minimal release, 17.88 ft in the control, and 20.80 ft in the full release. There was also strong statistical evidence that crown class distribution differed among treatments after two growing seasons (p = 0.0032). In the control group, 26 percent of the trees were newly classified as overtopped in two growing seasons. In the full release, 5 percent of the trees were overtopped and none were classified as overtopped in the minimal release. Considering the height variation between the desired tree and the competing vegetation, preliminary results indicate release operations that leave a moderate level of woody competition around trees like red oak with weak epinastic control, may prove to be the most effective at retaining a favorable competitive status of the desired tree.

INTRODUCTION

The retention of oak species in mixed-oak forest ecosystems throughout the eastern and central United States has been an enduring problem for the last four decades (e.g. Carvell and Tyron 1961, Johnson 1993, Lorimer 1984, McGee 1975, Weitzman and Trimble 1957). Throughout this period, substantial reductions in the oak component of mixed species stands followed most harvesting and regeneration efforts. Leading Noss and others (1995) to conclude that high-quality oak-hickory forests had declined significantly in parts of the central and southern Appalachians. Furthermore, the problem is not avoided in older second-growth and old-growth forests excluded from harvesting. Such protected areas are currently undergoing changes in species composition toward greater abundance of shade-tolerant species and a reduction in oaks and other mid-seral species (Abrams and Downs 1990, Parker and others 1985, Smith and Miller 1987).

Restoration of the oak component following harvesting using natural regeneration methods continue to be evaluated (Loftis 1990, Schlesinger and others 1993, Schuler and Miller 1995) and the use of prescribed fire to improve oak competitiveness has recently received more attention (Keyser and others 1996, Kruger and Reich 1997). However, such methods may require a period of 10 to 20 years, or significantly longer, to develop sufficient oak regeneration. This time period may deter acceptance of such practices in forests characterized by short ownership tenure. An alternative regeneration technique being evaluated is the use of plastic tree shelters to protect planted or natural oak seedlings during the early stages of stand development after overstory removal (Lantagne and others 1990, Schuler and Miller 1996, Smith 1993).

Much has been reported on the operational use of tree shelters during the first few years after installation to enhance seedling establishment and early growth (Brissette 1996). Tree shelters have been shown to increase height growth, root growth, and total biomass of northern red oak seedlings (*Quercus rubra*) for several years after planting in new forest openings and in old fields (Lantagne 1996, Ponder 1996, Schultz and Thompson 1996). However, accelerated growth rates of sheltered trees return to normal after the tree's crown emerges from the shelter (Schuler and Miller 1996). As the effect of the shelter diminishes on northern red oak growth rates, sympatric species often exhibit accelerated rates of height growth as competition for growing space intensifies during the early stem exclusion stage. Black cherry (*Prunus serotina*), yellow-poplar (*Liriodendron tulipifera*), sweet birch (*Betula lenta*) and other species in the central Appalachians often reach 60 ft in total height 20 years after a major disturbance (Miller and others 1995). A vigorously growing codominant oak is expected to be about 40 ft tall in the same time period (Schnur 1937). In general, red oak height growth will lag behind black cherry and yellow-poplar on good to excellent growing sites (Lamson and Smith 1978, Smith 1983). To offset this discrepancy in height growth, silvicultural treatments may be useful to sustain the planted oaks until they are firmly established as codominant trees in the developing stand.

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The extent, number, and timing of needed treatments is unknown. In this paper, we evaluate the utility of releasing sheltered northern red oak in mesic hardwood stands. In doing so, we examined different levels of cleaning and assessed the effects on the crop tree, the competing vegetation and their competitive interaction.

METHODS

Study Area

The study took place on the Fernow Experimental Forest (39.03°N, 79.67°W) near Parsons, West Virginia. The area is referred to as the Allegheny Mountains Section of the Central Appalachian Broadleaf Forest (M221B) as designated by the U.S. Department of Agriculture, Forest Service National Hierarchical Framework of Ecological Units (McNab and Avers 1994). The draft landtype association has been nominally referred to as the Allegheny Front Sideslopes (M221Ba10) and represents over 99,000 acres within the Monongahela National Forest alone (DeMeo and others 1995). The potential natural vegetation of this area is referred to as mixed mesophytic (Braun 1950). Overstory species composition is often quite varied and may include over 20 different species within a spatial scale of roughly 10 or more acres. Common species include northern red oak, sugar maple (*Acer saccharum*), basswood (*Tilia americana*), yellow-poplar, black cherry, and sweet birch. The local climate is characterized by an annual precipitation of 55 to 58 inches (Pan and others 1997), a mean temperature of 61.5°F from April through September and 35.1°F from October through March, resulting in 120 to 140 frost-free days. Distinguishing topographic features of this landtype association include sideslopes of plateau blocks ranging from 2200 to 3500 ft in elevation.

This study was part of a larger study designed to develop an operational method for establishing northern red oak and other difficult to regenerate hardwood seedlings. The portion of the study reported here was initiated in a new forest opening in the spring of 1990. The study area was prepared by clearcutting the overstory during the 1989 growing season in 7.7 acre research compartment nominally referred to as Fork Mountain Gate. Sawlog-size material (11.0 inches dbh and larger) was skidded from the site, and all other stems (1.0 inch dbh and larger) were felled and left in place. Merchantable material removed from the site averaged 19,000 board feet•acre^{-1} (International 1/4 inch). The study area is classified as an excellent growing site equivalent to a northern red oak site index of 80. The initial study included treatment combinations involving 5-ft corrugated plastic tree shelters and transplanted northern red oak seedlings. Partial two-year results were reported by Smith (1993) and referenced as Site 4. Oak seedlings in all treatments involving shelters were significantly taller than those in unsheltered treatments.

Release Test Procedures

Different levels of release were applied in the spring of 1996 - six growing seasons after the initial outplanting. All saplings selected were protected by shelters from the beginning of the study. The shelters were still in place after the most recent remeasurement in the spring of 1998 without any notable decrease in structural integrity. The most intensive release consisted of cutting all stems within a 5-ft radius of the sheltered tree. A less intensive release consisted of the removal of only stems that were significantly overtopping the sheltered tree. A control group in which the trees were not released was also incorporated into the study. Trees at the beginning of the study either were codominant or intermediate in crown class. Dominant trees that were developing in the absence of significant competition from woody vegetation were not included. Total height of northern red oak prior to treatment averaged 9.7 ft and did not differ among treatments ($p = 0.433$) according to analysis of variance results. Three levels of thinning were replicated 20 times for each thinning level and 19 times for the control group. The assignment of treatments to individual trees was randomized. Therefore the design was an unbalanced completely randomized one-way analysis of variance.

Data Analysis

A fixed-effects model was assumed for all statistical analysis. Following data acquisition, the data were assembled and tested for model adequacy using graphical and statistical techniques two years after experimental implementation. The Shapiro-Wilkes statistic and p-value were generated using the SAS univariate procedure for each dependent variable of interest. The results did not indicate the error component deviated from normality for crop tree height growth ($p = 0.8481$). However, the normality assumption did not hold when the height of competing vegetation was used as the response variable in the model ($p = 0.0398$). Therefore, a transformation of the response variable was employed using the natural logarithm which yielded acceptable results with respect to the normality assumption ($p = 0.7473$).

The Brown-Forsythe test was used to evaluate the equal variance assumption related to height growth ($p = 0.9516$) and the log transformed height of competing vegetation ($p = 0.5105$). The associated large p-values do not provide any statistical evidence that the variance associated with either variable differed for the level of thinning. Graphical analysis of residuals corroborated these conclusions. Based on these findings, we established that the model format was adequately describing the response to the treatments and proceeded with tests of significance for both crop tree height growth and height of the competing vegetation. The Duncan's multiple range test was used to further break down the response to treatments when significant differences were found. This test controls the comparison-wise error rate, not the experiment-wise error. So the actual probability of incurring a type I error among all comparisons is greater than the stated alpha. Finally, the chi-square statistic was used to assess the treatment effects on crown class distribution two years after experimental implementation.

RESULTS

Height growth two years after release was significantly related to the degree of release ($p = 0.0151$). To interpret these findings we conducted a Duncan's multiple range test ($\alpha = 0.05$) on height growth response. The results identified two distinct responses and associated the minimal release procedure, hereafter referred to as a codominant release, and the no release as one group and the 5-ft release as another. The codominant release and the no release responses were superior to the 5-foot radial release in terms of height growth (Table 1). Similar to height growth, the average total height of released trees among treatments stratified in accordance with differences in height growth (Table 1, Fig. 1), although treatment means were not significantly different (p = 0.4603).

Not clear from the height growth response was the effect of the release treatment on the height of the competing vegetation. This requires consideration because it is the height of the released tree relative to the height of the competing vegetation that determines the potential vigor and survival of the released tree. The log-transformed height of the competing vegetation did not differ by release method (p = 0.1583) prior to treatment and averaged 12.57 feet. After two growing seasons, the log-transformed height

Table 1—Treatment means for two-year northern red oak height growth response as a function of release procedure

Treatment	2-yr height growth	Total height	N
	feet[a]	*feet*	
Codominant release	4.09a	13.73	20
No release	3.96a	13.25	19
5-foot release	2.78b	12.83	20

[a] Means with the same letter are not significantly different (α = 0.05).

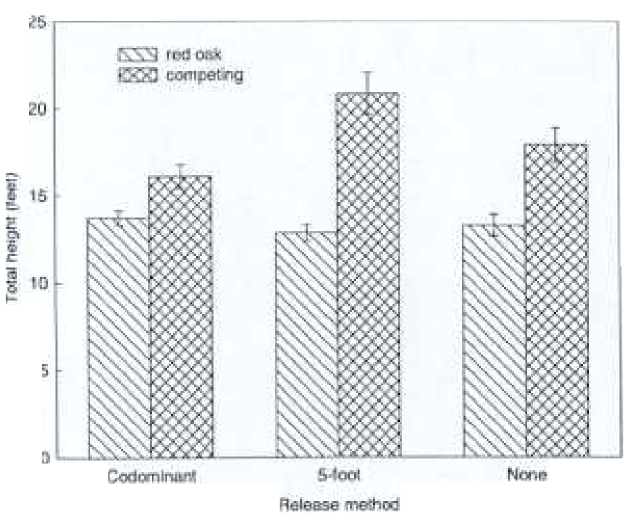

Figure 1—Mean total heights and standard errors of previously sheltered northern red oak and the natural regeneration two years after initiating release procedures and eight years after stand reinitiation.

of the competing vegetation differentiated by treatment (p = 0.0060). Transformation of the dependent variable was necessary both prior to and after treatment because the residuals from the general linear model were not normally distributed (p = 0.0398). The Duncan's multiple range test identified the codominant release and the 5-ft release as distinct responses (Table 2). The 5-ft release had a positive effect on the height of the competing vegetation relative to no release, while the codominant release had a negative effect. The mean total height of the competing vegetation with respect to the 5-ft release was more than 4 feet taller than the competing vegetation of the codominant release. Based on the results presented in Table 1, this difference equates to two or more years of red oak height growth. Such a discrepancy in total height could lead to substantial differences in northern red oak survival during the early stages of stand development.

The crown class distribution of the released oak trees further characterizes the relationship between the height of the competing vegetation and the height of released trees. In 1996 prior to treatment, crown class distribution did not differ by treatment (chi-square = 1.061, p = 0.588). Prior to treatment, 61 percent of the trees were classified as codominant and 39 percent of the trees were classified as intermediate. After two years, crown class distribution had changed among treatments (chi-square = 11.457, p = 0.022). The trees that were not released declined substantially in terms of competitive status. Only 37 percent of the unreleased trees retained codominant classification, while the same percentage was classified as intermediate, and 26 percent were newly classified as overtopped (Table 3). This illustrates the rate of which conditions can change during this stage of stand development. In only two growing seasons, one of every four unreleased northern red oak trees became overtopped. It is unlikely that an overtopped red oak will regain a more competitive crown position and high rates of mortality are anticipated for such trees.

In contrast to the unreleased red oak trees, crown class distribution improved for the group of trees that received the codominant release. No trees in this category were classified as overtopped either prior to or after two growing

Table 2—Treatment means for height of the competing vegetation two years after implementation as a function of release procedure

Treatment	Duncan group[a]	Total height	Total height
		log-feet	*feet*
5-foot release	A	3.00280	20.14
No release	AB	2.85793	17.43
Codominant release	B	2.76181	15.83

[a] Means with the same letter are not significantly different (α=0.05).

Table 3—Change in northern red oak crown class two years after release by treatment category. Table values are frequency and column percent in parentheses

	Treatment			
Crown class	Initial	Codominant release	5-foot release	No release
Codominant	36	16	13	7
	(61)	(80)	(65)	(37)
Intermediate	23	4	6	7
	(39)	(20)	(30)	(37)
Overtopped	0	0	1	5
	(0)	(5)	(5)	(26)

seasons and the ratio of codominant to intermediate trees changed from roughly 60/40 in the spring of 1996 to 80/20 after two additional growing seasons. This is to be expected because any and all overtopping trees were cut. However, this procedure has also resulted in greater height growth relative to the full 5-ft release. It is this combination of factors that led to a more favorable crown class distribution.

The 5-ft release resulted in one tree becoming overtopped and had little effect on the remaining crown class distribution (Table 3). However, the disparity between the height of the released tree and the height of the competing vegetation was greatest in this category (Fig. 1). A continuation of this trend will likely result in a substantial, and perhaps an abrupt, decline in the competitive status of these trees.

When release treatments began, competing vegetation comprised 16 species and did not differ by treatment category (chi-square = 31.975, p = 0.369). Sweet birch was the principal species with 37 percent of the total number of dominant competing stems. This species is an aggressive competitor during early stand development and has little commercial value in the central Appalachian region. The eventual species composition of third-growth stands dominated by this species is uncertain. Other major competitors included yellow-poplar (10 percent), pin cherry (*P. pennsylvanica*) (10 percent), and black cherry (7 percent). Only one sampled northern red oak representing about 2 percent of the total dominant competing stems was recorded in 1996 at the onset of release efforts.

Two years after initial release, species composition of the competing vegetation did not yet differ by treatment, but some evidence suggests a trend may be developing toward more stratification (chi-square = 31.458, p = 0.087). We anticipate that species with slower juvenile growth rates will dominate the competing vegetation of the codominant release method in the future because faster growing species will have been selectively removed. Species richness in 1998 declined to 11 species with sweet birch continuing to dominate the young stand (36 percent), while yellow-poplar increased to 20 percent and pin cherry increased to 22 percent over all treatment categories. Black cherry declined slightly to about 5 percent of the total and northern red oak was no longer represented in the sample.

DISCUSSION

Variations in stand density generally are assumed to have little effect on individual tree height growth (Smith 1986). Height growth is so closely associated with the productive potential of a site that the concept of site index, height of dominant and codominant trees at a convenient base age, is based on an understanding that height growth is relatively independent of stocking level. However, the height growth of trees used in site index equations are predicated on trees that have retained dominant or codominant status throughout their development. The use of dominant or codominant trees implies competition for above ground growing space is one factor that determines growth characteristics. This is evident when trees are isolated or are grown at low stocking levels. In particular, species with weak epinastic control (i.e., relatively minimal influence by the tree's terminal bud over the length and orientation of lateral branches) that are grown at low stocking levels might exhibit reductions in height growth (Oliver and Larson 1996). Weak epinastic control is a trait of northern red oak and many other angiosperms native to the eastern United States (Kramer and Kozlowski 1979).

A decline in height growth associated with extreme reductions in stand level density was documented for oak and yellow-poplar saplings in southeastern Ohio by Allen and Marquis (1970). They concluded that short-term height growth was maximized at about 70 percent stocking based on experimental manipulation of density. Codominant oaks thinned to 70 percent of full stocking grew 1.5 ft annually which was three times the growth rate of trees grown at 20 percent stocking. Concomitant yellow-poplar height growth at the same site was also optimized at the same stocking level. As such, total release of an individual oak (e.g. as in thinning to a 5-ft radius) may inadvertently provide a partial release to a bordering yellow-poplar. The unintentional consequence of such a cleaning would be to slow oak height growth and increase height growth of the competition. This may partially explain the results reported here regarding the accelerated height growth of the competing vegetation in the full release treatment (Fig. 1).

Some investigators have also concluded the effects of a full release on hardwood saplings decreases height growth, whereas a partial release can improve height growth. A full release of suppressed sapling-sized hickories in Ohio and Indiana generally slowed height growth for the first three years after release relative to unreleased trees (Nixon and others 1983). The authors speculated that release cutting around hardwood saplings would have been beneficial if the crown release had not been complete. In an extensive study conducted in Connecticut, Ward (1995) reported significant height growth depression of released codominant black (*Q. velutina*) and scarlet (*Q. coccinea*) oaks four years after treatment. Moreover, fully released dominant northern red oak also exhibited less height growth than partially released individuals. But response to release can also change over time and variable responses have been reported. In a seven-year-old even-aged hardwood stand in West Virginia, fully released red oak grew slower in height than unreleased trees for the first two years but differences were not evident after five years (Trimble 1974). Similar results were noted for yellow-poplar (Johnson and others 1997). Others have found that crop tree release did not affect height growth in young Appalachian hardwood stands (Smith and Lamson 1983, Wendel and Lamson 1987).

The results of this study and the work of others previously noted suggests release thinning in very young stands has the potential to be a useful silvicultural tool. It is apparent that partial release thinning has stimulated short-term juvenile height growth in some cases. It is not yet apparent if long-term survival and competitive status of mesic site oaks can be maintained or improved by release thinning in young stands. Existing recommendations indicate it is better to delay stand manipulations until competitive pressures have selected the most vigorous individuals. For example, to select the best quality timber trees for crop tree release, Perkey and others (1993) recommend waiting until the trees are at least 25 ft tall. However, to influence species composition, release work may need to begin before codominant trees reach this stage of development. This is especially true when objectives for the stand include the retention of oak that is often not abundant relative to other species. The need for work in very young stands when oak perpetuation is an objective is illustrated by the sharp decline in crown classification of unreleased oaks reported in this study (Table 3). Moreover, in a practical sense, the release of previously sheltered oaks protects the existing investment in tree shelters.

Oak regeneration problems continue to plague forest managers throughout the eastern and central United States. Forest stands that included a significant oak component during both old-growth and second-growth stages, are often characterized by a greatly diminished oak component following second-growth harvesting. Silviculturists continue to explore ways to develop abundant understory oak to promote oak regeneration following harvesting activities. However, harvesting and the regeneration of new stands continues unabated while prescriptions for abundant natural oak regeneration remain unresolved. As such, to meet common timber, wildlife, and diversity goals that include the retention of oak, forest managers will need to develop techniques for increasing the survival rate of the scarce oak stems common in many young third-growth forests. Release thinning in very young stands may be beneficial in that respect. Release thinning of previously sheltered northern red oak is essential to maintain competitive status of these trees on mesic sites. Future research needs to focus on the long-term survival of released trees and the degree, timing, number, and cost of releases necessary to achieve oak retention relative to site characteristics and the competing vegetation.

MANAGEMENT IMPLICATIONS

Preliminary results indicate that releasing previously sheltered northern red oak can be beneficial to retaining this species during the early stages of stand development. The following suggestions are offered as guidelines for implementing release procedures on small to medium-sized operations:

- Wait as long as possible to do the release work but not until the desired oak trees are overtopped by competing vegetation, usually five to six years after planting on good sites.

- Retain all trees not overtopping the desired tree. This will induce the released tree to sustain rapid height growth and maintain strong epinastic control.

- Schedule annual release work for individual stands for the best results. Individual trees receiving a codominant release require very little treatment time. With initial planting density on a 25-foot basis, it is reasonable for a two person crew to inspect and release, if required, 600 to 1,000 trees per day. Simple hand tools are sufficient for doing the release work. Do not plant and shelter more northern red oak than can be released in the central Appalachians as release work will be vital to their survival.

- Target faster growing, short-lived species with lower commercial value for removal and retain slower growing species, if possible. Altering the species composition immediately surrounding the desired oak by favoring slower growing species may lessen the need for repeated release efforts.

- Release work should be done during the dormant season to take advantage of better visibility. When releasing sheltered oaks, it is easier to find the desired trees when the shelters are retained on the tree, even though the shelter may be providing no protection to the tree. Occasionally, manually splitting the tree shelter is necessary because diameter growth becomes restricted by a shelter that has not degraded sufficiently.

- Scheduling early stand release work for sheltered oaks also facilitates selecting highly desirable natural regeneration for similar cultural efforts. If such trees are included, flag the tree so that it can be more easily relocated during the following years.

- On good to excellent growing sites in the central Appalachians, it may require a period of 10 to 15 years (e.g., from 5 to 15 years after stand reinitiation) of release work before long-term survival of oak throughout stand development will be achieved. The frequency of required release work will decline as tree sizes increase.

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