Response of Advance Cherrybark Oak Reproduction to Midstory Removal and Shoot Clipping

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ABSTRACT: *Midstory competition control and shoot clipping have been proposed to increase the vigor and height of advance bottomland oak reproduction. Results from a study in east-central Mississippi showed that advance cherrybark oak* (Quercus pagoda *Raf.) released from midstory competition had greater survival than nonreleased seedlings, 64% and 48%, respectively, 9 yr after treatment. Released seedlings were also 2.5–3.4 ft taller than nonreleased seedlings depending on site. However, this significant growth response was not observed until 3 to 5 yr after release. Clipping oak seedlings at the time of release did not result in greater seedling heights after 9 yr, but subsequent sprouts were similar in height to unclipped seedlings. Midstory competition control is recommended to increase the vigor and height of advance bottomland oak reproduction. This practice may need to be conducted 5 to 10 yr prior to final overstory removal to maximize height growth of advance reproduction. South J. Appl. For. 24(1):45–50.*

Numerous problems have been reported in the natural regeneration of oak (*Quercus* spp.) species (Johnson 1979, Crow 1988, Loftis and McGee 1993). Hodges and Janzen (1987) summarized these problems for bottomland oaks into three main areas: adequate density and stocking, acceptable response following release, and lack of knowledge on basic seedling biology.

Adequate density of oak seedlings remains an unresolved issue in bottomland hardwood management. Results from upland oak stands indicated that approximately 400 seedlings/ac more than 4.5 ft tall must be present before the overstory is removed (Sander 1979). However, results from stand development studies indicated that only about 45–60 well-spaced seedlings/ac represent adequate density (Oliver 1978, Clatterbuck and Hodges 1988, Kittredge 1988). These lower values assumed high survival of well-established advance regeneration (regeneration present prior to overstory removal) and stand stratification processes.

Distribution of oak seedlings across a stand appears as important as density. Belli, et al. (1999) recently modified Johnson's (1980) preharvest stocking evaluation guide for bottomland red oaks and ash (*Fraxinus* spp.). Using probabilities based on Johnson's (1980) point system to determine adequate stocking, a greater probability for success was given to seedlings more than 3 ft tall compared to those in the 1 ft and less, and 1–3 ft size classes. Taller seedlings were assumed to have a larger root system; therefore, these seedlings would be more competitive with other species following complete overstory removal. Other oak regeneration evaluation guides have also given a greater probability of success to large seedlings. Sander (1972) gave greater weight to seedlings at least 4.5 ft tall prior to harvest. Hodges and Janzen (1987) have also noted that a 4.5-ft tall seedling would be the minimum height needed for successful regeneration of cherrybark oak (*Q. pagoda* Raf.) although recent observations indicate a smaller seedling size may be acceptable for bottomland red oaks.

The second problem area involves the slow initial height growth response of oak seedlings following release from overstory and/or midstory competition. Beck (1970) found that released 1-yr-old northern red oak (*Q. rubra* L.) seedlings grew less than 1 ft in height 2 yr after release and only 2.4 ft after 6 yr. Janzen and Hodges (1987) found similar results with advance bottomland oak reproduction. Three years after chemical injection of all competing

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stems in the midstory and understory canopies, advance oak reproduction had grown less than 2 in. in height. Graney (1989) found less than 1 ft in height growth of advance upland oak reproduction 5 yr after midstory competition control. Hypotheses offered for these slow growth responses included changes in budbreak phenology (McGee 1986), unfavorable root/shoot ratios and limited water transport capabilities.

A potential silvicultural treatment to alleviate this slow initial response to release involves clipping oak seedlings just prior to or immediately following release from midstory competition. Janzen and Hodges (1987) found clipped bottomland red oak seedlings responded better to release than unclipped seedlings. Clipped seedlings had twice the height growth of unclipped seedlings several years following release. Changes in carbohydrate allocation between shoots and roots, combined with increases in light levels, allowed sprouts to grow in height at a faster rate than unclipped seedlings (Lockhart 1992). These differences in height growth resulted in taller seedlings 7 yr after midstory removal (Deen et al. 1993).

Recent findings in the area of oak seedling biology indicated that regeneration develops best in partial shade (Gardiner and Hodges 1998, Ziegenhagen and Kausch 1995). Gardiner and Hodges (1998) reported that moderate amounts of sunlight resulted in more favorable environmental conditions for cherrybark oak seedling height growth. In particular, greatest seedling heights were noted in shadehouses with 53% and 27% of available sunlight compared to 100% and 8% of available sunlight. Higher light levels resulted in possible seedling moisture stress with a subsequent reduction in photosynthesis. Lower light levels, which are typical of bottomland hardwood stands with a shade-tolerant midstory, simply do not provide enough energy for adequate photosynthesis in oak seedlings (Hanson et al. 1987).

The objective of this study was to determine the long-term response of advance cherrybark oak reproduction to release from midstory competition and seedling clipping. Of interest was to determine if these treatments could result in the development of a seedling to about 4.5 ft tall and the time required to attain this height.

Methods

Site Descriptions

Three study sites, each containing advance cherrybark oak reproduction, were located on the Noxubee National Wildlife Refuge in Oktibbeha and Noxubee Counties, MS. The climate of this region is described as having wet winters and hot, dry summers with periodic droughts. Average temperatures are 81°F in the summer and 46°F in the winter. Annual precipitation is 51 in., occurring mostly from November to April. Each site had a different stand history and structure as described below.

Site 1—River Road

The River Road site was located on a terrace adjacent the Noxubee River floodplain. Stand composition was old-field, mixed loblolly pine (*Pinus taeda* L.) and hardwoods. The hardwoods consisted primarily of cherrybark oak, water oak (*Q. nigra* L.) and sweetgum *(Liquidambar styraciflua* L.) in the overstory and sweetgum, oaks, hornbeam (*Carpinus caroliniana* Walt.), hophornbeam (*Ostrya virginiana* Mill.), and red maple (*Acer rubrum* L.) in middle and lower canopy positions. Overstory stand age was about 48 yr. Soil on the site was a Stough fine sandy loam (course-loamy, siliceous, semiactive, thermic Fragiaquic Paleudults). Although this soil was poorly drained, the site rarely if ever floods. Site index for cherrybark oak was about 84 ft at base age 50 (Baker and Broadfoot 1979).

Site 2—Keaton Tower Road

The Keaton Tower Road site was located within a 2 ac horseshoe bend adjacent to the Noxubee River. Stand composition was mixed bottomland hardwood consisting of cherrybark oak, Shumard oak (*Q. shumardii* Buckl.), water oak, pignut hickory (*Carya glabra* [Mill.] Sweet), and American beech (*Fagus grandifolia* Ehrh.) in the overstory. Species occupying the middle and lower canopy strata included hornbean, hophornbeam, hickory, flowering dogwood (*Cornus florida* L.), and pawpaw (*Asimina triloba* [L.] Dunal). Overstory age was about 80 yr. Soil on this site was an Ochlocknee sandy loam (coarse-loamy, siliceous, active, acid, thermic Typic Udifluvents). This site is subjected to annual winter/early spring flooding. Cherrybark oak site index was about 114 ft (Baker and Broadfoot 1979).

Site 3—Dummy Line Road

The Dummy Line Road site was adjacent to Loakafoma Creek, a tributary of the Noxubee River. Stand composition was old-field mixed pine and hardwood consisting of loblolly pine, cherrybark oak, and sweetgum in the overstory and sweetgum, oaks, green ash (*F. pennsylvanica* Marsh.), red maple, hornbeam, and hophornbeam in the middle and lower canopy positions. Overstory stand age was about 46 yr. Soil was the Urbo series (fine, mixed, active, acid, thermic Vertic Epiaquepts). The site receives short-period annual inundation. Site index for cherrybark oak was about 106 ft (Baker and Broadfoot 1979).

Treatments

Treatments were arranged in a split-plot design with two replications per site. Midstory removal/no removal was the whole plot treatment with seedling clipping/no clipping the split-plot treatment. Midstory removal involved chainsawing each stem over 1 in. dbh with a crown class of intermediate or overtopped (Smith et al. 1997). Stumps were sprayed using a squirt bottle with Tordon 101R® to prevent sprouting. Care was taken to not spray any cherrybark oak seedlings although one seedling on Site 1 and about ten seedlings on Site 3 showed evidence of herbicide damage by curling margins on their leaves. The seedling on Site 1 perished while those on Site 3 did not.

Plot size was variable, averaging about one-quarter acre. Unfortunately, no pre- or post-treatment basal areas were measured. About 40 cherrybark seedlings were located and flagged in each plot. After midstory removal, one-half of the flagged seedlings were randomly selected for clipping. Clipping was done by severing each seedling 1 in. above the ground with hand-held shears. Treatments were installed in February 1989 on Sites 1 and 2 and February 1990 on Site 3.

Measurements

Seedling height was measured from groundline to the base of the terminal bud on each flagged cherrybark oak seedling during study installation. Post-treatment measurements were conducted each fall from 1989–1992 and every other year since to determine survival and height growth. Seedlings were relocated by tying flagging to each seedling and placing a stake flag next to each seedling during every other measurement period.

Additional measurements were taken on light levels in released and adjacent unreleased plots. Two photodiode sensors each were placed in a released and associated nonreleased plot. These sensors determined light levels about every minute with averaged readings entered every 15 min. in a datalogger recorder. Readings from each sensor within a plot were averaged and reported in photosynthetically active radiation units.

Analyses

Analysis-of-covariance (ANCOVA), using initial seedling height as the covariate, was used to determine if differences existed between treatments (alpha = 0.05). Duncan's Multiple-Range Test was used to determine significant differences among treatment combination means where significant interaction occurred. Data from each site were analyzed separately because of differing site histories, soils, vegetation communities, possible seedling ages, and time of treatment installation. Since only two replications were installed for each treatment on each site, a considerable difference and low variance must occur among means to obtain a statistically significant difference. Therefore, observations on seedling development in each treatment are included even if statistical significance was not present.

Results and Discussion

Survival

Ninth-year survival averaged 55% for advance cherrybark oak reproduction across all sites and treatments. Greatest seedling survival occurred in released plots (64%) while lowest survival occurred with clipped seedlings in nonreleased plots (Table 1). Mortality of nonreleased clipped seedlings was particularly acute on Sites 1 and 2. These seedlings initially had smaller heights compared to Site 3, an indication of possible smaller root systems with less root carbohydrate reserves. Subsequent sprouts following clipping drained these root systems of carbohydrates which could not be replaced due to the low light levels found in nonreleased plots (Figure 1). Greater survival for all seedlings on Site 3 (78%) compared to Sites 1 and 2 (53% and 35%, respectively) could be attributed to taller seedlings with assumed greater root biomass and carbohydrate storage (Table 1).

Patterns of survival indicated that nonreleased, clipped seedlings sustained considerable mortality within the first 2 yr following treatment with only slight decreases in survival thereafter (Figure 2). Again, depletion of carbohydrate reserves appears to be the reason. Rapid mortality of seedlings on Site 2 for the first 3 yr following treatment may be attributed to the location of seedlings near the Noxubee River. Flooding was more prominent on this site compared to Sites 1 and 3. Furthermore, several seedlings perished due to streambank erosion and herbivory, particularly by beavers.

Height

Release of advance cherrybark oak reproduction increased seedling height compared to nonreleased seedlings while seedling clipping appeared to have no effect. After 9 yr, released seedlings were 1.5–3 times taller than nonreleased seedlings (Table 1). Larger seedlings in the released treat-

Table 1. Initial height and mean total height and survival after nine growing seasons for advance cherrybark oak reproduction on the Noxubee National Wildlife Refuge, east-central Mississippi.

Treatment	n	Initial ht		1997 ht		1997 survival (%)
		(in.)				
Site 1—River Road						
Nonreleased—intact	61	14a*	(2)†	25b	(4)	51b
Nonreleased—clipped	45	16a	(2)	19b	(3)	32b
Released—intact	62	13a	(<1)	62a	(17)	69a
Released—clipped	52	14a	(<1)	58a	(18)	61a
Site 2—Keaton Tower Road						
Nonreleased—intact	44	9a	(<1)	39b	(3)	42a
Nonreleased—clipped	40	8a	(<1)	31b	(7)	10b
Released—intact	67	10a	(3)	60a	(5)	50a
Released—clipped	26	11a	(2)	85a	(1)	41a
Site 3—Dummy Line Road††						
Nonreleased—intact	40	27a	(4)	38b	(5)	80a
Nonreleased—clipped	53	27a	(3)	27b	(<1)	70a
Released—intact	50	24a	(8)	69a	(16)	82a
Released—clipped	57	21a	(10)	51a	(17)	83a

* Means within a column and site followed by the same letter are not statistically different $P \leq 0.05$).
† One standard error.
†† Results based on eight growing seasons following treatment.

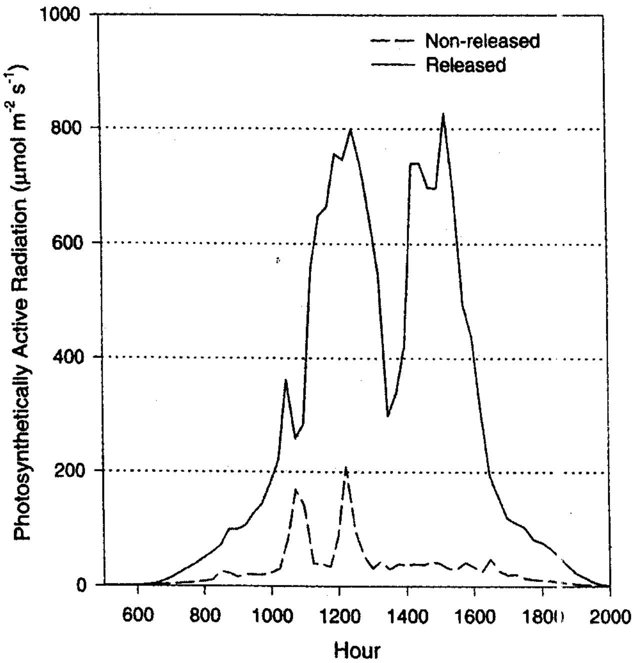

Figure 1. Light levels in a plot that received no midstory control and an adjacent plot that did receive midstory control on Site 1—River Road on August 19, 1990. Readings are reported in photosynthetically active radiation (400–700 nanometer range) in 15 min. intervals and represented the average of two photodiode sensors for each plot.

ment can be attributed to increased light levels (Figure 1) which resulted in increased photosynthetic rates (Lockhart and Hodges 1994).

Similar patterns of height growth were noted on each site (Figure 3). On Site 1, release resulted in seedlings three times taller than their nonreleased counterparts. This increase in height was most apparent over the last 4 yr. Nonreleased seedlings grew less than 1 ft over the 9 yr measurement period, or about 1 in./yr. Clipped seedlings were not different in their height patterns compared to unclipped seedlings. Similar height patterns were noted on Site 2 with the exception of zero height growth between the last two measurements periods for released intact seedlings. Beaver damage to the larger released seedlings resulted in an overall net height growth of zero. While these seedlings did resprout, subsequent sprout growth has yet to reach the seedling height prior to damage. A greater height response of nonreleased seedlings compared to Site 1 can be attributed to the death of several large overstory trees on one of the two nonreleased plots. Subsequent light from these canopy gaps gave these seedlings more light for growth than was normally found under nonreleased plots. Seedlings on Site 3 appeared to take approximately 2 years longer to respond to release relative to Sites 1 and 2. We speculate that their larger initial seedling sizes with possible smaller diameter xylem cells may have resulted in a less-efficient water transport system that took longer to adjust to the new, higher light environment.

Management Implications

Bottomland hardwood stands typically receive partial cutting in the overstory during their history (Hodges 1987).

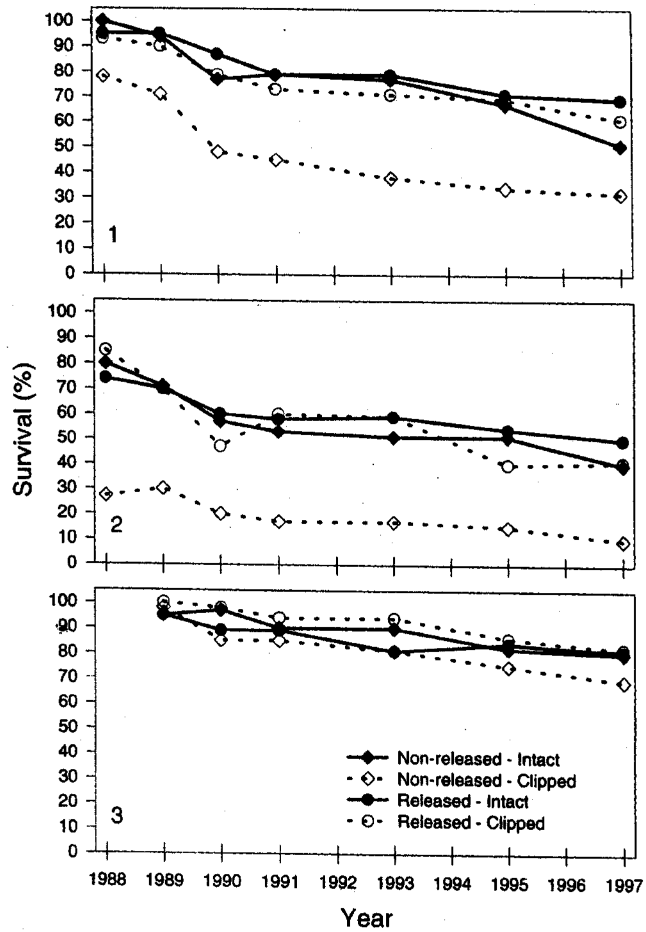

Figure 2. Survival of advance cherrybark oak regeneration 9 yr following release from midstory competition and seedling clipping. Site 1 = River Road, 2 = Keaton Tower Road, and 3 = Dummy Line Road.

These operations may lead to the development of a shade-tolerant midstory canopy. Light levels below such canopies can be less than 1% of full sunlight (Lockhart 1992). Therefore, silvicultural operations for natural oak regeneration must regulate the light levels reaching the forest floor. Too much light may result in the development of shade-intolerant vegetation at the expense of oak reproduction. Too little light may result in poor establishment of oak seedlings, poor growth of established oak regeneration, and enhance development of shade-tolerant regeneration. Midstory competition control of shade-tolerant trees has been recommended as a way to increase light levels reaching the forest floor (Janzen and Hodges 1985, 1987). Sunlight must still pass through the overstory canopy, which is usually not completely closed in mature bottomland hardwood stands, thereby creating the partial shade environment that is best suited for bottomland red oak species, especially cherrybark oak (Gardiner and Hodges 1998). The residual stand structure following the midstory control operation would be similar to a shelterwood harvest (Loftis 1990). Response of advance bottomland red oak reproduction to midstory competition control has been positive. Results from this and other studies have shown that bottomland red oak reproduction takes about 3 yr before a significant response occurs to

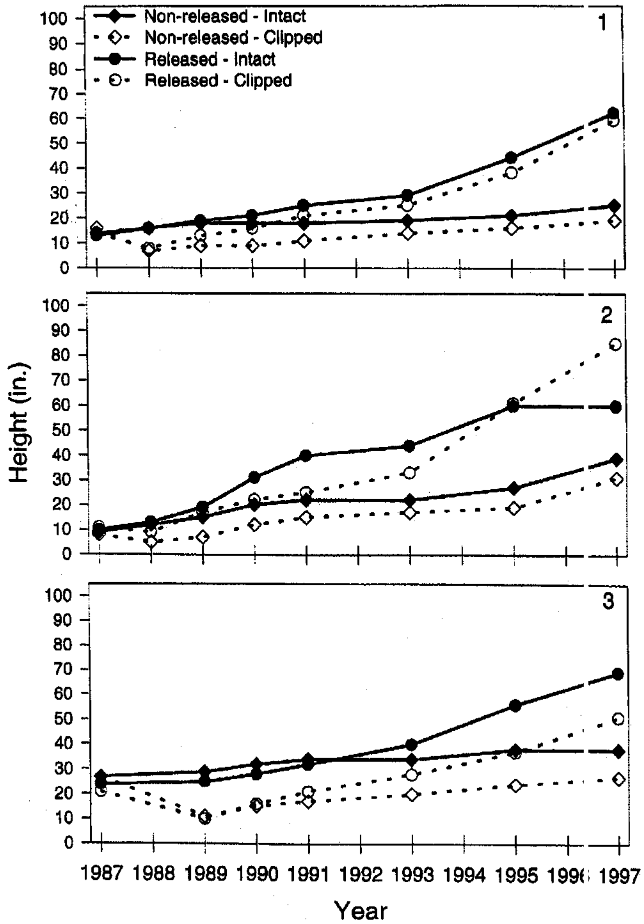

Figure 3. Height of advance cherrybark oak regeneration 9 yr following release from midstory competition and seedling clipping. Site 1 = River Road, 2 = Keaton Tower Road, and 3 = Dummy Line Road.

increased light levels (Janzen and Hodges 1987, Deen et al. 1993). This time period may be necessary for oak seedlings previously growing in relatively heavy shade conditions to acclimate, possibly through creating a more efficient water distribution system, to an enriched light environment. Another explanation may involve the timing of budbreak of released advance cherrybark oak reproduction. McGee (1975, 1976) demonstrated that budbreak and subsequent stem development of northern red oak (*Q. rubra* L.) and scarlet oak (*Q. coccinea* Muenchh.) seedlings occurred about 1 to 3 wk earlier under a forest canopy compared to seedlings grown in the open. Seedlings released late the previous growing season or during the dormant season responded as if still growing under a canopy, i.e., they broke their buds earlier than expected for seedlings grown in the open the previous year. Earlier budbreak exposes seedlings to a greater risk of damage from freezing temperatures, which may result in seedling dieback and resprouting. Therefore, it may take 2–3 yr before released seedlings adjust their timing of budbreak and become less exposed to potential damage from freezing temperatures. The effect of midstory removal only, with an overstory canopy still intact, has not been investigated on timing of budbreak in oak seedlings.

Clipping oak seedlings at the time of midstory release has been proposed as a silvicultural treatment to alleviate the slow initial height growth response of advance oak reproduction (Hodges and Janzen 1987). Subsequent seedling sprouts typically have increased height growth compared to unclipped seedling. This increased growth is due to seedlings receiving increased levels of carbohydrates from two sources: the root system due to increased demand of sprout stems on root resources (Lockhart 1992) and from sprout leaves from prolonged greater rates of photosynthesis during the day (Kruger and Reich 1993). These two sources of carbohydrates give sprouts their rapid initial height growth. Deen et al. (1993) found that clipping seedlings prior to release from midstory competition resulted in selected seedlings 26% taller than unclipped seedlings 7 yr after release. Similar results were not found in this study, with clipping essentially having no effect on height compared to unclipped seedlings 9 yr after release. The value of the clipping experiment is that the clipped seedlings did grow enough to match the heights of unclipped seedlings, which indicates that damage to advance cherrybark oak reproduction during thinning operations, short of uprooting seedlings, would appear to have a negligible effect on the development of advance reproduction prior to a final overstory harvest. Subsequent sprouts are expected to grow to a height similar to nondamaged seedlings, at least under partial harvest conditions. How clipped seedlings would respond if, instead of midstory competition control, a complete harvest was conducted in which seedling sprouts would be exposed to full sunlight is unknown.

Assuming the goal of midstory competition control operations is to increase seedling vigor and height to the 4.5 ft level considered minimal for successful regeneration, then it will take approximately 7 yr following release to reach this height with initial seedling heights of approximately 1 ft (Figure 3). Midstory control operations can either treat stems in place with the hack-n-squirt method or fell trees with a followup stump treatment. In either operation, the objective is to increase the light levels reaching the advance reproduction.

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