OAK REGENERATION SUCCESS IN OPERATIONAL SHELTERWOOD CUTS: YEAR TWO RESULTS

Andrew B. Self, John L. Willis, and Andrew W. Ezell

Abstract—The efficiency of shelterwood cutting in providing natural regeneration of bottomland oaks (*Quercus* spp.) is well documented. Typically, assuming environmental conditions are satisfactory, research projects yield adequate regeneration levels for targeted oak species. However, skepticism is often encountered when promoting the method for commercial operations in landowner management practices. Much of this hesitancy results from observing insufficient levels of oak regeneration after application of poor management technique. This study assesses viability of the system when established under operational constraints. A post-regeneration-cut bottomland hardwood stand was selected near Starkville, MS, to evaluate second-year oak regeneration response. This partial harvest study area was embedded inside a larger commercial harvesting operation. No special provisions for research were employed. Initial stand age was 86 years, the overstory was dominated by oak species, initial stand basal area (BA) was 115 square feet per acre, and residual post-harvest BA was 48 square feet per acre. Midstory injection was performed 1 year prior to regeneration cutting in an attempt to limit resprout potential of shade-tolerant species. Little research evaluating regeneration response at ground location in relation to crown location has been performed in bottomland hardwood systems. Consequently, three ground locations were selected based upon crown radius for evaluating regeneration response. These locations were half of crown radius, straddling dripline, and 25 feet outside dripline. Year two regeneration results for eight oak species are presented.

INTRODUCTION

A common challenge encountered when attempting to obtain adequate advanced oak (*Quercus* spp.) regeneration in closed canopy bottomland hardwood forests is that of obtaining sufficient levels of light for seedlings (Abrams 1992, Peairs and others 2004). Combinations of overstory and midstory vegetation often limit available light in these stands to levels below 10 percent (Jenkins and Chambers 1989, Lockhart and others 2000). These low light levels on the forest floor are often below the compensation point required for photosynthesis in oaks (Hanson and others 1987) and successful oak regeneration is often limited. Consequently, some form of overstory and/or midstory removal is the first step in increasing light levels to those required by oak seedlings for germination, survival, and growth. Partial harvesting in the form of shelterwood cutting is often prescribed as a viable regeneration system for obtaining satisfactory results in natural regeneration efforts with oaks (Bellocq and others 2005, Hodges and others 2005, Johnson and others 2009).

Regeneration success in bottomlands using the combination of midstory control and partial harvesting is well documented (Barry and Nix 1993, Guttery 2006, Janzen and Hodges 1987, Peairs and others 2004). Research efforts in bottomland hardwood systems have suggested that an optimal basal area (BA) target would be close to 50 square feet per acre when implementing partial harvesting to maximize regenerated seedling densities. Gardiner and Hodges (1998) observed oak seedlings require an available light level exceeding 25 percent for seedling survival in a shade cloth study. The authors also found seedling height and root-collar growth to be maximized at 53 percent sunlight. Peairs and others (2004) and Cunningham and others (2011) offered field corroboration of these results by observing that a residual BA of 50 square feet per acre combined with midstory control yielded the greatest oak seedling density in partial harvesting operations. These and similar findings have resulted in the common recommendation for a prescription combining partial harvesting and midstory control for natural regeneration in bottomland hardwood efforts. However, due to regeneration failures observed sometimes in operational settings, many land managers are reluctant to attempt the process.

Author information: Andrew B. Self, Associate Extension Professor, Department of Forestry, Mississippi State University Extension, Grenada, MS 38901; John L. Willis, Assistant Professor, Department of Forestry, Mississippi State University Extension, Mississippi State, MS 39762; and Andrew W. Ezell, Professor Emeritus, Department of Forestry, Mississippi State University, Mississippi State, MS 39762.

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An additional, relatively unstudied, aspect of acorn production and the subsequent regeneration response in bottomland hardwoods centers around seed location and dispersal from parent tree crowns. Little investigation regarding oak regeneration as a function of position in relation to parent tree canopy has occurred. Acorn production occurs in younger portions of outer branches and twigs (Johnson and others 2009). In addition, greatest acorn production typically occurs on branches exposed to sunlight (Post 1998, Sharp and Sprague 1967), and in lower and mid-crown positions (Lewis 1992). Accordingly, greater acorn fall, and subsequent seedling production, is thought to occur near the dripline edge. The intent of this research was to evaluate regeneration establishment during operational shelterwood harvesting in bottomland hardwoods and to evaluate regeneration density by ground location in relation to parent tree crown.

MATERIALS AND METHODS

Site Description

A bottomland hardwood stand on the John W. Starr Memorial Forest near Starkville, MS, was selected for regeneration using the shelterwood system. Species composition, major topography, flooding regime, and soil series were similar across the area used in this study. Soil series was Mathiston silt loam and soil analysis indicated an average pH of 5.3. Estimated site index values (Baker and Broadfoot 1979) totaled 113 feet for cherrybark oak (*Q. pagoda*), 103 feet for Shumard oak (*Q. shumardii*), water oak (*Q. nigra*), and willow oak (*Q. phellos*), and 95 feet for swamp chestnut oak (*Q. michauxii*). Study plots were embedded inside a larger 200-acre commercial harvest sale area. Initial stand age was 86 years, the overstory was dominated by oak species, and initial stand BA was 115 square feet per acre.

Treatments

The intent of this study was to evaluate effectiveness of the shelterwood system in obtaining adequate oak regeneration under operational constraints; no special provisions for research were employed. All overstory and midstory stem manipulation was performed by non-research personnel and the intention to use the area for future research was not conveyed to logging contractors. Leave timber was marked by Mississippi State University Forest Operations personnel with the goal of retaining healthy, good form oaks at a residual BA of 50 square feet per acre. Harvesting was performed by an operational logging crew and occurred September through October 2015. Post partial harvest inventory estimated an average residual BA of 48 square feet per acre. Primary residual overstory species included cherrybark oak, water oak, willow oak, swamp chestnut oak, white oak (*Q. alba*), and sweetgum (*Liquidambar styraciflua*). Shumard oak and overcup oak (*Q. lyrata*) constituted a small component of residual stand BA. Midstory control was performed during October 2014 using the “hack and squirt” method with a 20 percent aqueous solution of a 52.6 percent imazapyr product. Midstory stems greater than 1 inch in diameter at breast height (d.b.h.) were targeted, resulting in the near elimination of midstory stems. Very few living midstory stems were present at initiation of this project. These included approximately 10 stems per acre of shade-tolerant species including red maple (*Acer rubrum*), American hornbeam (*Carpinus caroliniana*), and elm (*Ulmus* spp.). Due to previous overstory and midstory canopy closure, as well as logging disturbance, very little ground cover vegetation, including advanced oak regeneration, was present.

Study Design

Four stems of seven oak species were selected based on proximity to other trees, crown health and fullness, crown size, and distribution across the site. Oak species selected for evaluation were Shumard, water, willow, and cherrybark oak from the red oak functional group and white, overcup, and swamp chestnut oak from the white oak functional group.

The crown edge of individual trees selected was required to be a minimum of 100 feet from the crown edge of any tree of the same species. This stipulation was designed to eliminate skewing of regeneration estimates resulting from greater than normal acorn drop due to influx from multiple crowns. In addition, crowns were evaluated for health and fullness, with tree inclusion only occurring if the crown was determined to satisfactorily meet both qualifications. In addition, crown size was considered and if crown radius was not suitable for appropriate placement of regeneration subplots in at least three directions, the tree was deemed insufficient and was not used in this study.

Three lines of three, 9-foot-radius (0.006-acre) regeneration subplots were established based on relationship with live tree crown (fig. 1). Subplots were placed along lines positioned to fall directly underneath the crown where appropriate. Subplots were placed along lines at three locations based upon ground location in relation to mother tree crown radius. These locations were A (subplot center placed at half of crown radius from trunk), B (straddling crown dripline), and C (25 feet outside of crown dripline).

Oak Regeneration Measurements

Initial oak regeneration estimates were recorded during September 2015 and indicated an oak seedling density of eight seedlings per acre (SPA). Second year regeneration data were collected October 2018. Only seedlings of the species corresponding to the overhead mother tree were recorded in each subplot.

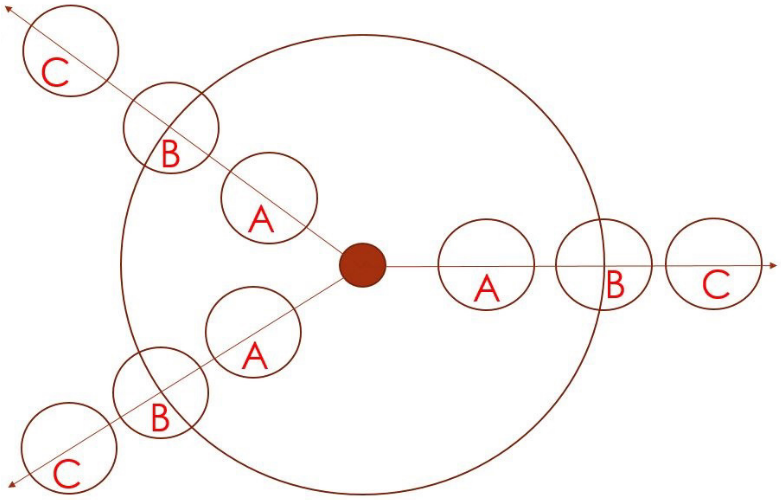

Figure 1—Relationship between regeneration subplots and tree crown.

Oak seedlings falling inside subplot boundaries were classified into height categories and recorded. Height classifications were less than 1 foot, 1 to 3 feet, and greater than 3 feet. Stocking calculations were performed using the stocking point system developed by Belli and others (1999). This stocking point system estimates the probability of one "free to grow" seedling 3 years after harvest. Using this system, a point total of 34 yields a 95 percent probability of at least one "free-to-grow" seedling/sapling at the end of the third growing season.

Data Analysis

Regeneration of oak species was pooled by red or white oak functional group to obtain seedling density by subplot ground location. Low seedling density in white oak species limited useful information when separated into the three subplot locations at the individual species level. Consequently, individual species calculations assessed species regeneration as a whole without separation into subplot locations. Regeneration height was used to calculate stocking point values and probability estimations using methodology established by Belli and others (1999).

RESULTS AND DISCUSSION

Second-year red oak regeneration was observed in greater abundance compared to white oak regeneration at the corresponding subplot location (table 1). An unseasonable April 2016 freeze occurred at the study area. It is possible that freezing temperatures during this period damaged white oak flowers which in turn lowered mast production and subsequent acorn germination during the 2016 growing season. Other literature has noted reduced or failed white oak seed crops in years when late spring freezes occurred (Cecich and Sullivan

Table 1—Seedlings per acre, stocking, and probability of regeneration success by oak functional group and regeneration subplot location

Functional group	Subplot location	Seedlings	Stocking points	Probability
		number per acre		*percent*
Red oak	A	2,145	44	95+
	B	2,361	59	95+
	C	1,434	43	95+
White oak	A	1,201	29	92
	B	863	24	88
	C	220	7	46

A = subplot center placed at half of crown radius from trunk, B = subplot center straddles crown dripline, C = subplot center located 25 feet outside of crown dripline.

Seedlings per acre and stocking points are averaged for that specific functional group/location combination.

Stocking point values calculated using method developed by Belli and others (1999).

Probability is likelihood of one "free-to-grow" tree at 3 years.

1999, Sharp and Sprague 1967). In addition, mammal species are known to preferentially select white oak acorns over those of red oaks due to lower tannin contents (Kirkpatrick and Pekins 2002, Robbins and others 1987, Short 1976). Decreased white oak seedling production is a logical assumption in cases of heavy white oak predation. The presence of white-tailed deer (*Odocoileus virginianus*) across the study area was apparent in the form of both tracks and browsing evidence. It is possible that lower white oak regeneration compared to that of red oaks was a result of one of these factors, or a combination thereof.

Observed SPA for red oak regeneration at A and B subplot locations was similar with greater SPA compared to C subplot locations; however, stocking point calculations at the B location were substantially higher compared to the other two locations (table 1). Regardless, stocking probabilities for all three red oak subplot locations exceeded 95 percent and thus indicated that regeneration levels were sufficient for future overstory recruitment in this particular study.

White oak regeneration followed a different trend with greatest SPA at A subplot locations, followed by nearly a third less regeneration at B subplot locations, and only 220 SPA at C locations (table 1). Stocking points followed a similar pattern, yet were at a level considered satisfactory in A and B subplot locations (92 percent and 88 percent, respectively), but fell to a level (7 points) where future regeneration was questionable in C subplot locations (46 percent probability).

While low seedling density of white oaks precluded splitting regeneration data for individual species comparisons into the three tested locations, an interesting observation arose when considering regeneration as a whole by species. Stocking point calculations indicated all seven species had been regenerated to at least a 50 percent probability of one "free-to-grow" seedling 3 years after partial overstory harvesting (table 2). When regeneration was evaluated by individual species, with the exception of swamp chestnut oak (50 percent probability), all individual species exhibited levels of regeneration considered acceptable (at least 71 percent probability) for considering the operation a success (table 2). This finding indicates that while white oak regeneration may be more clumped, regeneration of six of the seven species evaluated in this study would be considered sufficient for stand establishment on an individual species basis alone. Consequently, considering the likelihood of this regeneration being coupled with overlapping regeneration from adjacent stems of alternate oak species, realistic expectations of regeneration success are drastically increased.

CONCLUSIONS

This study was designed to evaluate oak regeneration response utilizing operational shelterwood cutting and to determine where regeneration established underneath oak crowns. Regeneration of both red and white oak species was more than adequate for establishment of a future oak-dominated forest. Red oak regeneration was deemed successful both underneath and outside of parent tree crown radius while white oak regeneration was considered successful only at positions underneath and straddling crown dripline. However, considering bottomland hardwood stands typically comprise a mixture of species and an influx of additional seedlings from adjacent trees is expected, natural regeneration using partial harvesting was successful and provided a sufficient level of advanced oak regeneration for the future in this study.

Table 2—Seedlings per acre, stocking, and probability of regeneration success by individual species

Functional group	Species	Seedlings	Stocking points	Probability
		number per acre		*percent*
Red oak	Shumard oak	863	14	71
	Water oak	2,031	64	95+
	Willow oak	1,269	36	95+
	Cherrybark oak	1,777	38	95+
White oak	White oak	385	26	90
	Overcup oak	141	14	71
	Swamp chestnut oak	114	8	50

Seedlings per acre and stocking points are averaged from subplot data at all subplot locations for that species.

Stocking point values calculated using method developed by Belli and others (1999).

Probability is likelihood of one "free-to-grow" tree at 3 years.

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