PARTIAL CUTTING AND ESTABLISHMENT OF ARTIFICIAL NUTTALL OAK REGENERATION IN THE MISSISSIPPI ALLUVIAL PLAIN

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Abstract—In the fall of 1998, we harvested a mixed bottomland hardwood stand in Sharkey County, MS, to establish two replicates of three residual stocking levels (0, 25, and 50 percent). We compared the various stand densities for suitability in establishment and growth of artificial oak regeneration. Following the overstory harvest, treatment plots received chain saw site preparation, then in March 1999 1-0 Nuttall oak (*Quercus nuttallii* Palmer) seedlings were hand-planted across the study site. To examine the efficacy of competition control on improving seedling survival and growth, half of the seedlings received a spot application of a broad-spectrum herbicide. Third-year survival of planted seedlings averaged 77 percent across the site, providing > 570 stems/ha. Third-year measurements on surviving seedlings indicated more vigorous growth under 0-percent residual stand stocking where seedlings developed to a mean height of 152±9 cm (mean ± standard error) and a mean root-collar diameter of 17.8±1.4 mm. Height and root-collar diameter of seedlings planted beneath partial overstories did not differ by overwood stocking level and averaged 95±8 cm and 12.3±0.9 mm, respectively. Competition control did not improve seedling survival or height growth but slightly increased root-collar diameter 3 years after treatment. However, seedlings receiving competition control were 44 percent more likely to be free to grow than seedlings that did not receive competition control. We present silvicultural implications of these results for bottomland oak regeneration.

INTRODUCTION

Adequate advance oak reproduction on bottomland sites has long been seen as problematic (Chambers and Henkel 1989, Lockhart and others 2000, Nix and Cox 1987). Acknowledging this problem, Johnson (1979) predicted a bleak long-term outlook under current regeneration practices on bottomland sites. Interestingly, some oak reproduction is usually present in the understory of mature oak stands, but it is usually too sparse, poorly distributed, or, more commonly, too small to release (Sander 1972). Any of these conditions often lead to a significantly smaller component of oak in the stand that develops after harvest. New practices demonstrate potential for increasing the size and vigor of natural oak reproduction (Lockhart and others 2000), but reliable techniques are needed for artificially regenerating bottomland oak stands.

Johnson and others (1986) demonstrated that controlling undesirable vegetation, increasing light levels on the forest floor by removing a portion of the canopy, and seedling underplanting provide a promising practice for establishing advance northern red oak (*Quercus rubra* L.) reproduction in the Missouri Ozarks. Earlier studies in bottomlands indicate that similar practices may be useful for establishing bottomland oaks (Chambers and Henkel 1989, Gardiner and Yeiser 1999). However, partial cutting operations and underplanting to establish advance oak reproduction on bottomland hardwood sites have not been broadly examined, and sufficient knowledge to reliably prescribe these practices is lacking. Specifically, guidelines for intensity of partial cutting and competition-control techniques do not exist for bottomland oak underplanting practices, and underplanting partially cut stands has not been directly compared with the clearcut method of regeneration. The objectives of this study were to examine (1) the influence of a partial overstory on the establishment and growth of Nuttall oak (*Q. nuttallii* Palmer) seedlings and (2) the importance of woody competition control for establishment and growth of Nuttall oak seedlings beneath a partial canopy. In this manuscript we present third-year results from the study.

METHODS

Study Site

The study was conducted in Sharkey County, MS, on a 16th-section property under the management of the Mississippi Forestry Commission. The site (90°43'W. longitude, 32°58'N. latitude) is approximately 10 km east of Anguilla, MS, and 3 km north of the Delta National Forest. Soils on this site are Alligator series (very fine, smectitic, Thermic Dystraquerts) and Dowling series (very fine, smectitic, Thermic Endoaquepts). Annual rainfall in Sharkey County averages 1320 mm, and the mean annual temperature is 17.8 °C (January mean 7.5 °C, July mean 27.8 °C) (Scott and Carter 1962). Overstory and midstory species prevalent on the site included willow oak (*Q. phellos* L.), Nuttall oak, overcup oak (*Q. lyrata* Walt.), American snowbell (*Styrax americana* Lam.), deciduous holly (*Ilex decidua* Walt.), cedar elm (*Ulmus crassifolia* Nutt.), and American elm (*U. americana* L.). Prior to treatment, trees on the site had an average diameter at breast height (d.b.h.) of 44.2 cm, and basal area averaged 25.5 m^2/ha.

Experimental Design

The study was designed to test the effect of two factors, stand-stocking level and competition control, on survival and growth of artificial Nuttall oak regeneration. We examined three target levels of stand stocking (0, 25, and 50 percent) and two levels of competition control (none and single-spot application of a broad-spectrum herbicide).

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Thus, we established six treatment combinations according to a split-plot design, assigning stand-stocking level to whole plots and competition control to split plots.

The site was divided into two blocks (based on soil type) in which three 1.7-ha whole plots were delineated. Within each block, whole plot treatments were assigned according to a randomized block design. Assigned stocking levels were marked in each plot following bottomland hardwood stocking equations outlined in Goelz (1995). In fall 1998, plots were harvested to their target stocking level by a conventional chain saw and skidder logging operation. After logging, each plot received chain saw site preparation to sever at groundline all midstory stems with a d.b.h. ≥ 2.5 cm and to reduce the height of logging slash piles. After harvest, plots targeted to receive 25-percent residual stocking actually had a residual overstory of 39 trees/ha, an average d.b.h. of 48.8 cm, an average basal area of 7.6 m^2/ha, and a residual stand stocking of 26 percent. Plots targeted to receive 50-percent residual stocking actually had a residual overstory of 89 trees/ha, an average d.b.h. of 46.8 cm, an average basal area of 15.37 m^2/ha, and a residual stand stocking of 53 percent.

Prior to planting, each whole plot was split and randomly assigned a competition control level. In March 1999, a contracted planting crew hand-planted 100 bareroot Nuttall oak seedlings (1-0) on 3.6- by 3.6-m spacing in each split plot. In May 1999, seedlings assigned competition control received a directed application of Roundup Ultra™ (10-percent solution) within a 1.5-m diameter circle centered over the seedling. Oak seedlings were covered with a PVC pipe during herbicide application to prevent herbicide contact with the seedling. Height and root-collar diameter of all planted seedlings in each measurement plot were measured immediately after planting and at the end of the third growing season.

Statistical Analyses

We analyzed survival, height growth, and root-collar diameter growth of planted seedlings according to a split-plot design (SAS Institute Inc., Cary, NC). Table 1 presents the analysis of variance (ANOVA) sketch for the randomized block design with split plots. All tests were conducted at an $\alpha = 0.05$.

Table 1—Analysis of variance sketch for a randomized block design with split plots used for analysis of response variable plot means

Source	Degrees of freedom[a]
Total	rab-1 = 11
Block	(r-1) = 1
Stocking	(a-1) = 2
Error (stocking)	(r-1)(a-1) = 2
Competition control	(b-1) = 1
Stocking x competition control	(a-1)(b-1) = 2
Error (stocking x competition control)	a(r-1)(b-1) = 4

[a] r = two blocks; a = three residual stand stocking levels; b = two competition control levels.

RESULTS

Seedling Response to Stand-Stocking Level

Nuttall oak seedling stock averaged about 70 cm tall at planting (table 2). Three years after planting, we observed the most vigorous height growth on seedlings established under the 0-percent stand-stocking level. These seedlings grew 120 percent relative to their initial planting height (table 2). Height growth of seedlings established under the 25-percent and 50-percent stand-stocking levels both showed an average growth of 39 percent relative to their initial height. The reduced rate of height growth on seedlings beneath partial overstories yielded seedlings that were 37 percent smaller than those in the open (table 2).

Based on differences in the mean height of seedlings, we expected a shift in the distribution of seedling height classes among the three residual stand-stocking levels. Figure 1 illustrates the more rapid advancement of seedlings into higher size classes when they are planted in the open. In contrast, relatively few seedlings established beneath a residual canopy developed into the largest size classes. When established beneath the 50-percent residual stand stocking, only 6 percent of the surviving seedlings, amounting to 35/ha, grew into a size class 150 cm tall or greater. Twenty percent of the surviving seedlings established under 25-percent stocking, or 115/ha, grew into a size class 150 cm tall or greater. This growth is in contrast to 52 percent, or 289 seedlings/ha, that grew into these size classes when planted in the open.

The mean root-collar diameter of the 1-0 Nuttall oak planting stock was about 8.7 mm (table 3). Third-year root-collar measurements agreed with height measurements: the most vigorous growth occurred on seedlings established under a 0-percent stocking level. These seedlings exhibited 107-percent growth relative to their root-collar diameter at planting. Root-collar diameter of seedlings established under the 25-percent and 50-percent stand-stocking levels both averaged 48-percent growth relative to their initial size. Seedlings under a canopy developed an average root-

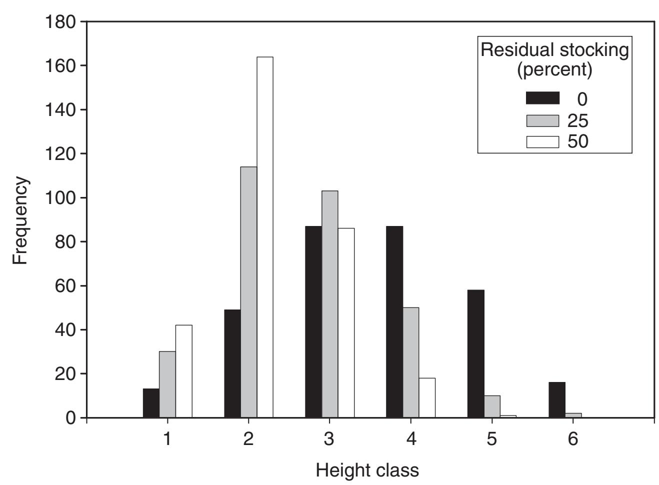

Figure 1—Height distribution of surviving Nuttall oak seedlings three growing seasons after planting under three residual stand-stocking levels on a bottomland site in Sharkey County, MS.

Table 2—Initial height, third-year height, and relative growth (mean ± standard error) of Nuttall oak seedlings underplanted in the Mississippi Alluvial Plain, Sharkey County, MS

Treatment effect[a]	Initial	Final	Growth
	- - - - - - - - - *cm*	- - - - - - - - -	*percent*
Stocking			
0%	70.4 ± 2.3 a	151.6 ± 8.8 a	120.7 ± 0.2 a
25%	70.1 ± 1.0 a	104.3 ± 8.5 b	49.0 ± 0.1 b
50%	68.5 ± 0.8 a	85.8 ± 8.5 b	29.9 ± 0.1 b
P-value	0.6373	0.0002	0.0078
Competition control			
Spot application	71.2 ± 0.9 a	114.7 ± 14.7 a	61.9 ± 0.2 a
None	68.1 ± 1.1 a	113.1 ± 13.4 a	71.2 ± 0.2 a
P-value	0.1542	0.7701	0.3077

[a] For each treatment effect, means followed by the same letter are not different at $\alpha = 0.05$.

Table 3—Initial root-collar diameter, third-year root-collar diameter, and relative growth (mean ± standard error) of Nuttall oak seedlings underplanted in the Mississippi Alluvial Plain, Sharkey County, MS

Treatment effect[a]	Initial	Final	Growth
	- - - - - - - - - *mm*	- - - - - - - - -	*percent*
Stocking			
0%	9.0 ± 0.2 a	17.8 ± 1.4 a	107.6 ± 0.2 a
25%	8.4 ± 0.1 a	13.3 ± 1.1 b	61.0 ± 0.2 b
50%	8.7 ± 0.2 a	11.3 ± 0.7 b	36.3 ± 0.1 b
P-value	0.1784	0.0394	0.0354
Competition control			
Spot application	8.8 ± 0.2 a	15.0 ± 1.5 a	76.7 ± 0.2 a
None	8.6 ± 0.1 a	13.2 ± 1.4 b	59.9 ± 0.2 a
P-value	0.1701	0.0466	0.2131

[a] For each treatment effect, means followed by the same letter are not different at $\alpha = 0.05$.

collar diameter 31 percent smaller than those in the open (table 3).

Third-year survival of planted seedlings averaged 77 percent, resulting in > 570 stems/ha for all overstory treatments (table 4). Residual stand-stocking level did not influence seedling survival. Furthermore, stand-stocking level did not affect the seedlings' ability to achieve free-to-grow status (table 5). Across the study site, 49 percent of all surviving seedlings were free to grow 3 years after establishment.

Seedling Response to Competition Control

A single application of a broad-spectrum herbicide did not improve seedling growth or survival in this study (tables 2, 3, and 4). Height after 3 years of growth for treated and untreated seedlings both averaged 114 cm (table 2). Similarly, mean root-collar diameters between treated and untreated seedlings both averaged 14.0 mm (table 3). Seedlings exhibited 66-percent height growth and 68-percent root-collar diameter growth relative to the initial planting stock.

Nuttall oak seedlings that were not overtopped by competing vegetation were assigned a free-to-grow status during the third-year measurements. Competition control may have had an effect on the reduction of competition, as the analysis shows a significant amount (58 percent, or 333 stems/ha) of the surviving treated seedlings were free to grow after the third year (table 5). After three growing seasons, seedlings receiving competition control were 44

Table 4—Third-year survival of Nuttall oak seedlings underplanted in the Mississippi Alluvial Plain, Sharkey County, MS

Treatment effect[a]	
	percent
Stocking	
0%	77.5 ± 0.1 a
25%	77.5 ± 0.1 a
50%	77.8 ± 0.1 a
P-value	0.9990
Competition control	
Spot application	77.0 ± 0.1 a
None	78.2 ± 0.1 a
P-value	0.8205

[a] For each treatment effect, means followed by the same letter are not different at $\alpha = 0.05$.

Table 5—Percent (mean ± standard error) of Nuttall oak seedlings that were free to grow 3 years after underplanting in the Mississippi Alluvial Plain, Sharkey County, MS

Treatment effect[a]	Free to grow
	percent
Stocking	
0%	52.7 ± 0.1 a
25%	49.8 ± 0.0 a
50%	45.3 ± 0.1 a
P-value	0.1939
Competition control	
Spot application	58.1 ± 0.1 a
None	40.4 ± 0.0 b
P-value	0.0323

[a] For each treatment effect, means followed by the same letter are not different at $\alpha = 0.05$.

percent more likely to be free to grow than the untreated seedlings.

DISCUSSION

Light availability may be a primary factor restricting early development of oak reproduction in mature bottomland hardwood stands (Lockhart and others 2000). This influence generally relates to stand structure, as the heavy midstory layer of many mature bottomland hardwood stands restricts light availability in the understory (Jenkins and Chambers 1989, Lockhart and others 2000). Additionally, seedlings of most bottomland oak species are shade intolerant, but oak reproduction is often out-competed by faster growing intolerant species under full light availability (Hodges and Gardiner 1993). Applying a partial harvest to prepare a bottomland hardwood stand for regeneration may increase understory light availability to oak reproduction without completely releasing competitors to full sunlight. Accordingly, we question if an optimal level of partial cutting will invigorate the growth of oak reproduction and minimize the response by competition.

Few studies have examined the response of artificial oak reproduction to a range of canopy or stand structures in bottomland hardwood forests. Chambers and Henkel (1989) have reported the most comprehensive study of oak seedling response to various levels of overstory removal in bottomland stands to date. They observed 77-percent survival of underplanted Nuttall oak seedlings 2 years after establishment beneath six different levels of overstory removal, and survival did not differ by the level of overstory removal (Chambers and Henkel 1989). Survival of Nuttall oak in our study, consistent with the findings of Chambers and Henkel (1989), confirms that light availability does not greatly influence early survival of underplanted Nuttall oak seedlings. Nix and others (1985) reported similar results for cherrybark oak (*Q. pagoda* Raf.) planted beneath a shelterwood and a clearcut in a hardwood bottom of the Wateree River, SC.

In contrast to survival, the presence of a partial overstory impacted Nuttall oak seedling height and diameter growth. Greatest growth occurred where the overstory was completely removed, but we did not detect growth differences between seedlings established under the two levels of residual stand stocking. Similarly, Nix and others (1985) observed that 2-0 cherrybark oak seedlings showed relatively greater growth 3 years after establishment in a clearcut vs. a shelterwood. Growth of underplanted Nuttall oak seedlings relative to degree of canopy removal appeared inconclusive for Chambers and Henkel (1989). However, though the presence of the overwood reduced height and diameter growth of Nuttall oak, underplanted seedlings did maintain positive shoot growth during the 3-year study.

Two additional thoughts should be noted for seedling growth. First, annual precipitation in at least two of the three growing seasons in this study was well below the annual average. If competition for soil moisture would be greatest where overstory trees are retained, this competition in addition to the relatively dry growing seasons may have reduced growth of underplanted seedlings more than expected. Second, we would expect the growth response by existing Nuttall oak seedlings in the understory to differ from that of underplanted seedlings. This, we speculate, would be due to differences in root architecture and seedling acclimation to the forest understory.

Directed application of woody competition control can potentially favor desirable species in regenerating bottomland hardwood stands. However, improper application of herbicides in hardwood stands creates the potential to damage desirable stems (Nix and others 1985). Survival and height growth of seedlings in this study did not respond to the competition control treatment. We did detect a slight increase in the root-collar diameter of seedlings receiving competition control, and these findings agree with those reported for cherrybark oak receiving similar competition control (Nix and others 1985). Our finding is also consistent with Miller (1993), who reported that competition control generally initiates a relatively greater response in seedling diameter growth than height growth. In our study, a single-spot application of a broad-spectrum herbicide appeared to decrease the vigor of competing vegetation enough to allow oak seedlings freedom to grow. This result will potentially influence future stand development. Schmeckpeper and others (1987) also reported more free-to-grow stems after glyphosate treatment of Japanese honeysuckle in a bottomland hardwood stand.

CONCLUSIONS

Artificial Nuttall oak regeneration was successfully established under a wide range of residual stand-stocking levels in a bottomland hardwood stand of the Mississippi Alluvial Plain. Seedlings established in clearcuts showed the most vigorous height and diameter growth, while establishment beneath a partial overstory reduced the rate of height and diameter growth over the 3-year study. Nevertheless, seedlings beneath partial canopies maintained positive growth and should be in a condition to respond positively to overstory removal. Competition control in this study had no effect on the growth of Nuttall oak seedlings, but did reduce competing vegetation such that a greater percentage of oak seedlings were able to attain a free-to-grow status. It remains to be seen if this will influence future stand development.

Establishment and growth of Nuttall oak seedlings observed in our partially cut stands provide promise for development of alternative regeneration practices that temporarily maintain vertical structure in bottomland hardwood forests.

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LITERATURE CITED

Chambers, J.L.; Henkel, M.W. 1989. Survival and growth of natural and artificial regeneration in bottomland hardwood stands after partial overstory removal. In: Miller, J.H., comp. Proceedings of the fifth biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 277-283.

Gardiner, E.S.; Yeiser, J.L. 1999. Establishment and growth of cherrybark oak seedlings underplanted beneath a partial overstory in a minor bottom of southwestern Arkansas: first year results. In: Haywood, J.D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 171-175.

Goelz, J.C.G. 1995. A stocking guide for southern bottomland hardwoods. Southern Journal of Applied Forestry. 19: 103-104.

Hodges, J.D.; Gardiner, E.S. 1993. Ecology and physiology of oak regeneration. In: Loftis, David L.; McGee, Charles E., eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 184-195.

Jenkins, M.W.; Chambers, J.L. 1989. Understory light levels in mature hardwood stands after partial overstory removal. Forest Ecology and Management. 26: 247-256.

Johnson, P.S.; Dale, C.D.; Davidson, K.R.; Law, J.R. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. Northern Journal of Applied Forestry. 3: 66-68.

Johnson, R.L. 1979. Adequate oak regeneration – a problem without a solution. In: Management and utilization of oak: Proceedings of the seventh annual hardwood symposium of the Hardwood Research Council. Asheville, NC: Hardwood Research Council: 59-65.

Lockhart, B.R.; Hodges, J.D.; Gardiner, E.S. 2000. Response of advance cherrybark oak reproduction to midstory removal and shoot clipping. Southern Journal of Applied Forestry. 24: 45-50.

Miller, J.H. 1993. Oak plantation establishment using mechanical, burning, and herbicide treatments. In: Loftis, David L.; McGee, Charles E., eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 264-289.

Nix, L.E.; Cox, S.K. 1987. Cherrybark oak enrichment plantings appear successful after seven years in South Carolina bottomlands. In: Phillips, Douglas R., comp. Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE-42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 129-132.

Nix, L.E.; Haymond, J.L.; Woodrum, W.G., III. 1985. Early results of oak enrichment plantings in bottomland hardwoods of South Carolina. In: Shoulders, Eugene, ed. Proceedings of the third biennial southern silvicultural research conference. Gen. Tech. Rep. SO-54. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 154-158.

Sander, I.J. 1972. Size of oak advance reproduction: key to growth following harvest cutting. Res. Pap. NC-79. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Scott, F.T.; Carter, R.C. 1962. Soil survey of Sharkey County, Mississippi. [Place of publication unknown]: U.S. Department of Agriculture, Soil Conservation Service, 36 p.

Schmeckpeper, E.J.; Lea, R.; Phillips, D.; Jervis, L. 1987. Piedmont bottomland hardwood regeneration responds to preharvest Japanese honeysuckle control. In: Phillips, Douglas R., comp. Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE-42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 592-596.