EARLY RESPONSE OF INTERPLANTED NUTTALL OAK TO RELEASE FROM AN EASTERN COTTONWOOD OVERSTORY

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Abstract—Forest restoration activity in the Lower Mississippi Alluvial Valley has generated a demand for alternative afforestation practices that can accommodate diverse landowner objectives. An alternative afforestation practice now being studied involves rapid establishment of a forest canopy of eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.), followed by interplanting with seedlings of slower-growing bottomland hardwood species. An experiment conducted in Mississippi shows that Nuttall oak (*Quercus nuttallii* Palm.) seedlings can develop into vigorous sapling-sized reproduction when interplanted in the understory of eastern cottonwood, and that the cottonwood overstory can be harvested without adversely affecting the interplanted reproduction. Harvesting damage was minimal, and excellent survival, vigorous sprouting, and adequate growth of Nuttall oak reproduction interplanted beneath eastern cottonwood indicate that Nuttall oak reproduction can be established under and released from an eastern cottonwood overstory.

INTRODUCTION

Over the past 15 years, a substantial area of cropland in the Lower Mississippi Alluvial Valley (LMAV) has been converted to hardwood forest plantations (Gardiner and Oliver 2005). Due to the extensiveness of afforestation in this region, plantation establishment practices and costs are often minimized, and this conventional approach frequently contributes to poor stocking or slow growth of stands. It has been found that conventional afforestation practices may not be the best means of accomplishing certain landowner objectives (Stanturf and others 2000, Stanturf and others 2001). Recent interest in establishing plantations for objectives such as biodiversity, carbon sequestration, economic sustainability, and water quality has led managers to seek alternative afforestation practices that promote development of complex plantations (Gardiner and others 2002).

In one alternative afforestation system now being tested in the LMAV, rows of bottomland hardwood species of later successional seres, such as Nuttall oak (*Quercus nuttallii* Palm.), are interplanted between previously established rows of eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) (Gardiner and others 2001, Gardiner and others 2004). In this system, the cottonwood stand serves as a nurse for the other hardwood reproduction developing in the understory. At the end of the 10- to 15-year cottonwood rotation, the cottonwood is harvested and the hardwood reproduction that has been established in the understory is released. This alternative has several ecological and economic advantages over conventional afforestation practices in the LMAV. These advantages include more rapid carbon sequestration (Stanturf and others 2003), quicker development of forest bird assemblages (Hamel 2003), earlier economic return on the afforestation investment (Stanturf and Portwood 1999), and favorable stand conditions for regeneration of other bottomland tree and shrub species (Gardiner and others 2004). Thus, this interplanting system can provide for multiple objectives while catalyzing bottomland hardwood ecosystem processes.

Though substantial benefits of this interplanting system have been documented, it has not been demonstrated that the cottonwood biomass can be harvested without significant damage to the developing reproduction in the understory. Also, it has not been shown that the interplanted Nuttall oak reproduction will respond satisfactorily once the eastern cottonwood overstory is harvested. In this study, a mature plantation of eastern cottonwood interplanted with Nuttall oak was harvested experimentally to address these questions. More specifically, the objectives of this research were to (a) quantify the extent of harvesting damage to interplanted Nuttall oak reproduction when the eastern cottonwood overwood was removed; and (b) quantify sprouting frequency, survival, and growth of interplanted Nuttall oak reproduction following release from the eastern cottonwood overstory.

METHODS

The study was conducted in a 10-year-old eastern cottonwood plantation adjacent to Steele Bayou on the Fitler Plantation, Issaquena County, MS. Soil on the site is mapped to the Commerce series (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) (Wynn and others 1959), and this series is generally well suited for culture of eastern cottonwood. Operational practices described in Gardiner and others (2001) were employed to establish the cottonwood stand on a conventional spacing of 12 by 12 feet in the winter of 1991-92. In the winter of 1993-94, rows of 1-0 bareroot Nuttall oak seedlings were planted between rows of cottonwoods. The oak rows were 24 feet apart, and the oaks were 12 feet apart within rows. Oak seedlings were hand planted and did not receive competition control or other cultural treatments after planting.

Six plots were delineated. Each measured approximately 180 by 240 feet and encompassed 15 rows of eastern cottonwood and 7 rows of Nuttall oak, each row being 240 feet long. We inventoried all Nuttall oak reproduction in each plot, assigning a unique number to each stem. Forty Nuttall oak stems in each plot were randomly selected to serve as sample plants (240 total plants). We measured the height (feet), root-collar diameter (inches), and diameter at breast height (inches) of each sample plant.

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In November 2001, the plots were harvested with a John Deere 843H feller buncher. There were two harvesting treatments, and these were assigned to plots randomly. Three plots received each harvesting treatment. In one treatment, all cottonwood stems were felled and removed from the site as whole trees with a grapple skidder. In the other treatment, all cottonwood stems were felled, all Nuttall oak stems were severed by the feller buncher, and a grapple skidder was used to skid all harvested cottonwood from the site. The first treatment was designed both to show how much damage a typical harvesting operation might do to Nuttall oak reproduction in a stand of this kind and to determine the growth response to release by the interplanted Nuttall oak reproduction. The second treatment was designed to provide insight into the amount of damage to, and stool viability and growth response of, interplanted Nuttall oak reproduction that was coppiced.

Immediately after the harvest, we assessed physical damage sustained by sample plants. We noted if reproduction had bark removed, a broken shoot, or was uprooted during harvesting. Following three consecutive growing seasons after the harvest, we measured stem height and the number of sprouts on all surviving Nuttall oak sample plants. Analysis of variance for a completely random design was conducted on plot means of stem damage and stem height for each growing season. Tests were conducted at an $\alpha = 0.05$ level.

RESULTS AND DISCUSSION

Logging Damage to Reproduction

Logging damage to Nuttall oak reproduction averaged 6 percent across the study site. Most of the observed logging damage was recorded as leaning or bent stems, and this damage appeared to be caused as cottonwood trees were felled rather than by maneuvering of logging equipment. No uprooting of plants was observed. Previous experience of harvesting operations in other cottonwood stands suggested that the felling and skidding equipment would require about 16 feet to maneuver between trees. The 24-foot spacing between Nuttall oak rows in this study made it possible to maneuver harvesting machinery without significantly damaging reproduction interplanted in the understory.

Damage to and Sprouting of Nuttall Oak Stumps

In plots that were harvested completely, Nuttall oak stems were clipped about 10 inches above groundline by the feller buncher. Typical logging damage was not observed in these plots because shoots that might have been injured by cottonwood felling were cut during the harvest. However, cutting of the small-diameter Nuttall oak stems with the feller head caused splintering of about 64 percent of the Nuttall oak stumps. Also, nearly 12.5 percent of the stems were not completely severed from the stump but were partially severed and broken over by the feller buncher. The Nuttall oak reproduction remained viable and sprouted readily. After the first growing season, there was an average of 4.3 ± 0.7 sprouts per stump. Mortality within clumps progressed slowly, and stumps supported 3.8 ± 0.4 sprouts 3 years after harvest. At that time, 99 percent of all stumps had live sprouts.

Natural or anthropogenic disturbances in bottomland hardwood stands often kill or remove the shoot of advance oak reproduction. Vigorous oak saplings generally coppice readily following disturbance if the root system and root collar remain intact (Hodges and Gardiner 1993). Because established oak saplings sprout readily, they typically maintain a high value in regeneration of natural bottomland stands (Belli and others 1999). Our findings are consistent with literature on oak sprouting in natural stands in that Nuttall oak artificially established in the understory of eastern cottonwood coppiced readily and survived well following overstory harvest. Our findings on Nuttall oak coppicing and the lack of logging damage to stumps when only the cottonwood overstory was removed may support interplanting of reproduction in a more dense configuration if desired, e.g., a 12 by 12 foot spacing.

Height Development of Reproduction

Prior to the harvest, Nuttall oak reproduction averaged 11.6 ± 1.1 feet in height, and mean height did not differ by harvest treatment ($P = 0.5304$) (fig. 1). Saplings released by the cottonwood harvest had not shown an above-ground response by the end of the first growing season when they had an average height of 11.7 ± 1.3 feet. Nuttall oak stump sprouts responded vigorously, growing to almost half of their preharvest height (5.7 ± 0.4 feet). By the end of the third growing season, reproduction that was not coppiced maintained a 25 percent height advantage over coppiced plants ($P = 0.036$). However, coppice was growing vigorously, averaged 13.0 ± 0.7-feet tall, and had surpassed its preharvest height (fig. 1).

Height distributions of the released Nuttall oak illustrate the development of each reproduction type into taller height classes (fig. 2). Fifty-five percent of saplings that were not coppiced were in a height class taller than 10 feet prior to harvest. Three years following release, 89 percent had advanced into height classes taller than 10 feet. Sixty-five percent of saplings that were coppiced were in a height class taller than 10 feet prior to harvest, and 87 percent had grown into these taller height classes 3 years after treatment (fig. 2).

Slow above-ground response to release has often been cited as a factor that makes bottomland oak reproduction less competitive than reproduction of more intolerant species following stand disturbance (Hodges and Gardiner 1993, Lockhart and others 2000). Several physiological and morphological factors

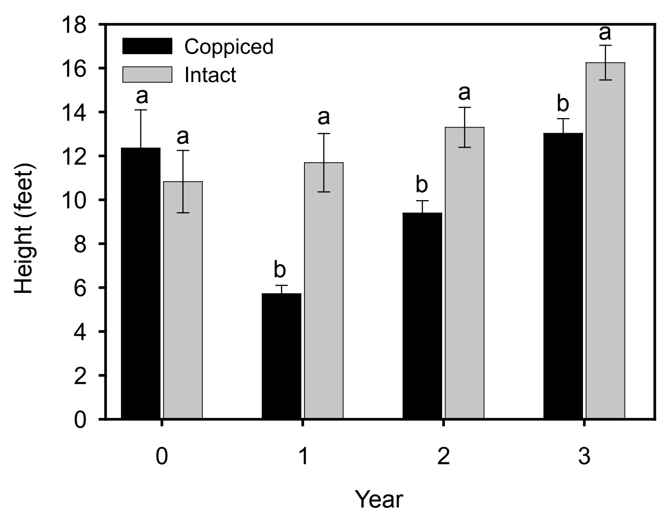
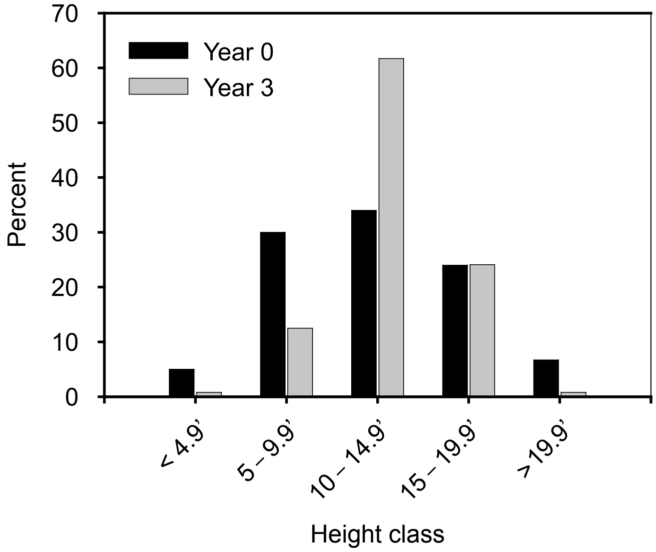


Figure 1—Mean height of coppiced and intact Nuttall oak reproduction interplanted beneath eastern cottonwood. This reproduction was released from the cottonwood overstory following year zero.



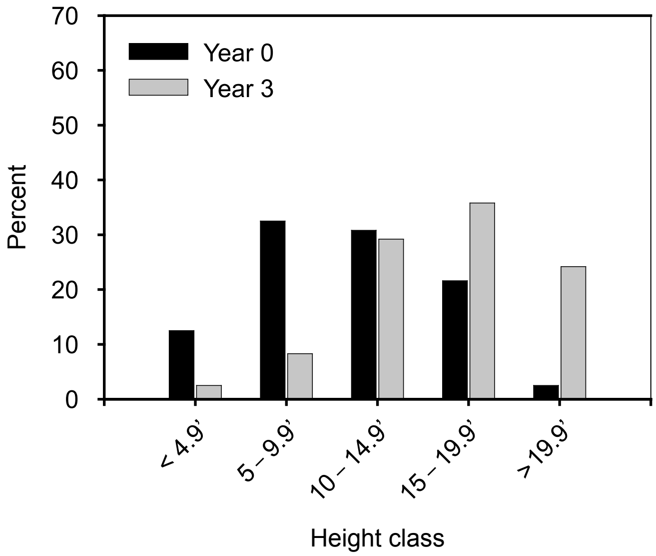


Figure 2—Height distribution of intact (below) and coppiced (above) Nuttall oak reproduction that was interplanted beneath eastern cottonwood. This reproduction was released from the cottonwood overstory following year zero.

characteristic of oak reproduction may contribute to this sluggish response (Hodges and Gardiner 1993), but some authors have suggested the use of shoot clipping or coppicing to rejuvenate above-ground growth of oak reproduction, particularly where this reproduction exhibits poor apical vigor (Deen and others 1993, Gardiner 1998, Janzen and Hodges 1987, Lockhart and others 2000). In this study, established Nuttall oak saplings responded slowly to release from the eastern cottonwood overstory, showing no appreciable height increment the first growing season after harvest. These saplings, however, eventually acclimated to the disturbance and made substantial height growth by the third growing season after harvest. Height growth of Nuttall oak stump sprouts responded rapidly to release, but this growth had not compensated for the reduction in stem length 3 years after clipping. In contrast, Stanturf and Kennedy (1996) demonstrated that the 5-year height of top-pruned cherrybark oak (*Q. pagoda* Raf.) seedlings did not differ from the average height of seedlings that were not top-pruned. Nevertheless, oak reproduction established in the understory of eastern cottonwood will respond to removal of the canopy on afforestation sites and should attain upper canopy positions in the subsequent stand.

SUMMARY

A valid concern when designing and establishing interplanted plantations for forest restoration is providing for harvest of the nurse crop and effective release of the understory reproduction. We found that an eastern cottonwood overstory can be harvested with minimal damage to interplanted Nuttall oak reproduction if spacing between and within rows is as it was in this experiment. Mortality of Nuttall oak reproduction was minimal through three growing seasons whether stems remained intact or were severed by felling equipment. Additionally, splintering of the Nuttall oak stumps observed in this study did not reduce coppicing. Our results may support interplanting of reproduction in a more dense configuration if desired, e.g., a 12 by 12 foot spacing. Height development of released Nuttall oak saplings was slow initially, but these saplings eventually acclimated to the open environment and were growing well by year three. Nuttall oak coppice developed rapidly over three growing seasons but still lagged behind saplings that were not coppiced. The lack of harvesting damage and the excellent survival, vigorous sprouting, and adequate growth of Nuttall oak reproduction interplanted beneath eastern cottonwood indicate that reproduction of this species can be interplanted and established under an eastern cottonwood overstory and then released successfully. These results support establishment of more complex plantations to address multiple management objectives when restoring forests on former agricultural land.

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