INITIAL RESPONSE OF UNDERPLANTED YELLOW POPLAR AND CHERRYBARK OAK SEEDLINGS TO FOUR LEVELS OF MECHANICAL MIDSTORY REMOVAL

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Abstract—Midstory removal has been suggested as a possible enhancement strategy to develop seedling pools in stands lacking vigorous advanced oak (*Quercus* spp.) reproduction. However, for successful implementation, silviculturists must understand the differential growth responses of oak and its competitors to conditions created by midstory removal. To further quantify the competitive dynamics between cherrybark oak (*Q. pagoda* Raf.) and yellow-poplar (*Liriodendron tulipifera* L.), this study was designed to assess the initial height growth responses of these species to four levels of midstory removal and to understory vegetation control. The study was installed within a riparian corridor located in western Georgia, and treatments were completed in the fall of 2003. One-year data suggests cherrybark oak height increment was not significantly increased by any level of midstory removal. In contrast, yellow-poplar growth was significantly greater in the removal treatments and was highest under full midstory removal. Results also show that the height growth of cherrybark oak was significantly higher and yellow-poplar was significantly lower within understory control treatment. Overall, data suggest that underplanted yellow-poplar may have initial height growth advantage over cherrybark oak following midstory removal.

INTRODUCTION

Historically, both even- and uneven-aged methods have been used to regenerate oak (*Quercus* spp.). Unfortunately, the success of these treatments varies greatly across regions, and regeneration failure is not uncommon regardless of the method employed. In many situations, clear-cutting has resulted in forest conditions that favor the development of intolerant species such as yellow-poplar over oak (Beck and Hooper 1986). This pattern can be explained by species-specific growth strategies and resource allocation of oak and its associated species (Kolb and others 1990). At the other end of the silvicultural spectrum, application of single-tree selection has often favored the development of shade-tolerant species over more desired intolerant and mid-tolerant species (Della-Bianca and Beck 1985). The flexible nature of the shelterwood method has shown the most promise in successful natural regeneration of oak in both upland and bottomland systems (Hodges and Janzen 1987, Loftis 1983). The residual forest cover present with the shelterwood prior to final removal provides conditions that sustain continued oak growth but does not create optimal growing conditions for fast-growing intolerants (Loftis 1990).

The absence of favorable advance reproduction and the presence of a dense shade tolerant midstory in many mature upland and bottomland oak stands are major issues contributing to the oak regeneration problem. The development of these multi-stratum forest canopies has been linked to microclimatic conditions that inhibit the developmental potential of oak and other shade-intolerant reproduction (Heitzman and others 2004, Lorimer and others 1994, Zaczek and others 2002). Research has suggested that both mechanical and chemical control of midstory canopy layers can be employed to enhance the development of existing oak reproduction within a shelterwood system (Janzen and Hodges 1985, Lockhart and others 2000, Loftis 1990). In stands without the desired natural reproduction, underplanting has been suggested as a method to enhance reproduction pools (Spetich and others 2002, Weigel and Johnson 2000). The inclusion of activities that increase the number, size, and competitive position of oak seedlings is critical because the presence of large advance reproduction prior to overstory removal is crucial for successful oak regeneration (Crow 1988, Larsen and Johnson 1998, Sander 1972).

Given the demonstrated relationship that oak tend to be outcompeted by shade-intolerant species under open conditions and by shade-tolerant species under dense canopy cover, it seems that the essential problem surrounding the design of silvicultural operations to favor oak seedling development is understanding how the interaction between residual canopy structure and understory microclimate influences species-specific growth rates. Because of differential growth strategies, intolerant species such as yellow poplar will outgrow oak in high resource conditions. Therefore, structural manipulations must create conditions that inhibit the development of this source of competition, while still providing sufficient resources for survival and growth of oak (Johnson and others 1989). In a generalized view, treatments must find an optimized range that favor oak development over more shade-intolerant or tolerant species. More specifically, midstory treatments must be designed to culture oak reproduction but also must consider the response of potential competition to residual forest structure. The objective of this study was to quantify the differential response between oak and a shade-intolerant competitor to varying levels of midstory removal. Specifically, we assessed first year growth of underplanted yellow-poplar (*Liriodendron tulipifera* L.) and cherrybark oak (*Q. pagoda* Raf.) to four levels of midstory removal and two levels understory vegetation control.

PROCEDURES

Site Description

The study was conducted within a riparian forest corridor on the Blanton Creek Wildlife Management Area located in Harris

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County, GA. This site is considered part of the Lower Piedmont physiographic region of western Georgia. The corridor's overstory is primarily composed of yellow poplar and sweetgum (*Liquidambar styraciflua* L.). Water oak (*Q. nigra* L.), green ash (*Fraxinus pennsylvanica* Marsh.), and boxelder (*Acer negundo* L.) are also present but serve as minor components. A dense midstory is present across much of the area and is dominated by flowering dogwood (*Cornus florida* L.), two-winged silverbell (*Halesia diptera* Ellis.), musclewood (*Carpinus caroliniana* Walt.), and ironwood [*Ostrya virginiana* (Mill.) K. Koch]. The flora occupying the area's understory include Japanese honeysuckle (*Lonicera japonica* Thunb.), Nepal grass [*Microstegium vimineum* (Trin.) A. Camus], and blackberry (*Rubus* spp.).

Design and Analysis

Fifty, 0.05 ha (12.62-m-radius) circular plots were installed within those areas of the Blanton Creek riparian corridor that were at least 38 m wide. These plots were systematically located along a transect bisecting the riparian corridor and were placed with at least 38 m separating plot centers. It was essential that the plots be located within existing closed canopy forest; therefore, specific criteria were evaluated to prevent plots from being placed within or adjacent to a forest gap. Forest gaps were defined for the purpose of plot establishment as openings in the forest canopy > 0.025 ha in size. If a plot fell adjacent to a gap, the plot center was moved an additional 12.6 m along the same transect to allow for a buffer between the plot and the gap. Similarly, if a plot fell within in forest gap, the center was moved an addition 25 m to provide sufficient buffer. Finally, if a plot fell within a section of the riparian corridor area that was < 38 m wide, the plot was relocated 38 m further along the transect.

To assess how different levels of midstory cover influence initial seedling growth, the 50 plots were randomly assigned 1 of 4 midstory removal treatments. These treatments include: (1) uncut - no trees were removed; (2) Light - removed 1/3 of all midstory trees; (3) Moderate - removed 1/2 of all midstory trees; and (4) Heavy - removed all midstory trees. Midstory trees were defined as those stems not present in the dominant/co-dominant canopy layer. Midstory removals were completed in the summer/fall of 2003 using directional chainsaw felling. Tree bole and top material were left on site and were cut-up to speed decomposition. No vegetation < 1.4 m in height was removed unless it created a hazard during the felling operation.

During November and December, 2003, 12 yellow-poplar and cherrybark oak 1-0 containerized seedlings were systematically planted in pairs on each of the 50 plots. The seedlings were planted approximately 15 inches apart using a gas-powered auger and were watered following planting. Because of known problems with deer browse in Piedmont forests, seedling pairs were protected using 28 by 48 inch circular wire cage enclosures (Romagosa and Robison 2003). The enclosures were secured using two bamboo stakes driven into the ground.

After planting, half of each plot was randomly selected to receive the understory competition control treatment. Due to the systematic planting design, six seedling pairs received the competition treatment on each plot. This understory control was conducted in June of 2004 and included hand-weeding within each cage and application of Roundup® Pro (3 percent solution) surrounding each cage.

Pre- and post-growing season total height (cm) was measured in the spring and fall of 2004, respectively. Split-plot analysis of variance (ANOVA) was used to test for differences in height increment between treatments by species. Understory competition control was the split-plot factor within a whole-plot factor (midstory removal) completely randomized design. A mixed models approach was used for this ANOVA, because the whole-plot error term is random in nature (Steel and others 1997). Following non-significant interaction and significant omnibus test (α=0.05), pair-wise comparisons were completed using the Tukey-Cramer method (Neter and others 1996). Height increment for yellow-poplar was natural-log transformed for the ANOVA analysis to stabilize non-constant variance. However, untransformed data are presented to facilitate interpretation and understanding of the results.

RESULTS

Cherrybark oak and yellow-poplar differ with regard to height increment response following midstory removal and understory competition control treatments. A pattern of increasing cherrybark oak height increment was seen with increasing midstory removal. However, analysis showed no significant difference ($p = 0.1460$) among the four levels of removal (table 1). Conversely, yellow-poplar height increment differed among the midstory treatments ($p < 0.001$) and increased with increasing removal. The three levels of removal had significantly larger height increments than did the no removal treatment. The complete removal was significantly greater than the one-third ($p = 0.0241$) or one-half removal ($p = 0.0084$). However, growth increment for one-third and one-half midstory removal did not differ from one another ($p = 1.000$). Finally, yellow-poplar's height increment was greater than cherrybark oak within all levels of removal.

Response to understory competition control also differed between species. Application of herbicide/weeding treatment resulted in significantly greater ($p = 0.0328$) cherrybark oak height increment than did the no control treatment (table 1).

Table 1—Least-square mean height increment for cherrybark oak (CBO) and yellow poplar (YP) by treatment

	Height increment (± SE)[a]	
Treatment	CBO	YP
	- - - - - - - - - - *cm* - - - - - - - - -	
Whole-plot factor		
No midstory removal	5.35^{A} (1.265)	9.04^{A} (1.093)
1/3 midstory removal	6.34^{A} (1.265)	6.90^{B} (1.094)
1/2 midstory removal	7.69^{A} (0.920)	6.86^{B} (1.075)
Full midstory removal	8.67^{A} (0.920)	7.80^{C} (1.075)
Split-plot factor		
No understory control	6.61^{A} (0.630)	8.60^{A} (1.049)
Weeding/herbicide application	8.04^{B} (0.630)	25.23^{B} (1.049)

[a] Means followed by the same letter within a factor indicates no significant difference (α=0.05).

In contrast, yellow-poplar's height growth was significantly lower ($p = 0.0182$) in herbicide/weeding treatment when compared with no understory competition control (table 1).

DISCUSSION

Much research has focused on developing treatments to address the problem of successfully regenerating oak in both upland and bottomland systems. Complex interactions of biotic and abiotic factors are known to influence the stochastic nature of oak germination and establishment (Gribko and others 2002, Sork and others 1993), but development of established reproduction may be directly affected through silvicultural operations. Sander (1972) highlighted the need for developing large oak reproduction, which are more likely to survive than are smaller seedlings that are in competition with associated species. Following this sage advice, development of vigorous oak seedlings has been the focus of many management strategies. In highly productive oak ecosystems, midstory control has been suggested as a method to enhance oak development prior to the final removal harvests in a shelterwood system (Hodges and Janzen 1987, Loftis 1990). This pre-release development is crucial because of the height growth differential that can occur between oak its intolerant competitors in high resource environments (Beck and Hooper 1986, Kolb and others 1990, Walters 1963). Gardiner and Hodges (1998) have also suggested that cherrybark oak may exhibit greater height growth in moderate light environments than in full sun. Loftis (1990) demonstrated that it is possible to create conditions that inhibit intolerant competitors, such as yellow-poplar, while at the same time favoring oak development. To take advantage of differential growth strategies, researchers have suggested midstory control as a method to increase height development and competitive advantage of cherrybark oak (Janzen and Hodges 1985, Lockhart and others 2000).

First-year height increment data suggest that planted yellow-poplar has the potential to outgrow cherrybark oak following all levels of midstory removal (table 1). In the complete midstory removal treatment, mean height increment for yellow poplar was approximately 38 cm, which was 29 cm greater than the height growth of cherrybark oak. From a management prospective, this pattern highlights the importance of competitor response to residual structure.

It is possible that the initial height growth patterns observed in this study may not be representative of the response in naturally occurring advanced reproduction. It is suggested that residual effects of nursery practice may be influencing the study's initial height growth patterns. This notion is supported by past research that indicates nursery conditions and practices can influence seedling morphology (Howell and Harrington 2004, Zaczek and others 1993) and potential growth response following outplanting (Dey and Parker 1997, Spetich and others 2002). In other words, it is possible that the observed height growth may have been more influenced by growth and carbohydrate storage in the previous year within the nursery bed than by current conditions at the planting site. In addition, field observations suggest that natural establishment of yellow-poplar may be inhibited by the current understory environmental conditions. This is supported by the fact that the study area has a large overstory component of yellow-poplar and thus an adequate supply of seed (Beck and Della-Bianca 1981) but has little naturally established poplar reproduction present. Therefore, data and observation suggest that while yellow-poplar may be able to respond if already present in the understory, the conditions created by midstory removal may not stimulate germination and establishment.

Regarding the competitive capacity of oak, it should be noted that past studies have documented lag periods of 2 or more years prior to height growth response of cherrybark oak (Gardiner and Hodges 1998, Lockhart and others 2000). Also, other factors such as the timing and intensity of overstory removal and species-specific mortality trends in the seedling populations could affect the future dynamics of these seedlings. For all of these reasons, the long-term competitive advantage of either species cannot truly be assessed at this time, but their respective developmental patterns will continue to be observed.

A final management implication that should be addressed is the effect of understory vegetation control on height growth. For yellow-poplar, the competition control treatment resulted in a significantly smaller height increment when compared to no understory control. Due to obvious foliar injury evident within several of the study's plots, it seems likely that this difference is a function of herbicide damage caused by spray drift and species-specific sensitivity to glyphosate. In cherrybark oak, the application of weeding/herbicide resulted in a statistically significant increase in height growth. However, given that the total difference in growth was < 3 cm, it is questionable whether this difference is biologically significant. Again, interacting factors such as nursery practices and initial growth delay of cherrybark oak have the potential to mask the influence of this treatment.

CONCLUSIONS

The results from 1-year height growth data suggest that established yellow-poplar may have the potential to create a competitive problem for cherrybark oak following midstory removal. While first year data is undoubtedly insufficient to predict long-term competitive dynamics, this study does highlight the importance of considering establishment and growth of intolerant competition when implementing midstory removal to enhance oak development. Finally, because understory conditions created by these midstory removals seem to promote positive height growth of shade-intolerant yellow-poplar, it is suggested that these same environmental conditions may also benefit the development of the more tolerant cherrybark oak following the lag period in height growth commonly seen with this species.

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