IMPLICATIONS OF LARGE OAK SEEDLINGS ON PROBLEMATIC DEER HERBIVORY

Christopher M. Oswalt, Wayne K. Clatterbuck, Allan E. Houston, and Scott E. Schlarbaum[1]

Abstract—Seedling herbivory by whitetail deer [Odocoileus virginianus (Boddaert)] can be a significant problem where artificial regeneration is attempted. We examined the relationship between deer herbivory and morphological traits of northern red oak (Quercus rubra L.) seedlings for two growing seasons for both browsed and non-browsed seedlings. Logistic regression analyses indicate that seedling height in each dormant season was related to terminal shoot removal (TSR) through herbivory in each of the subsequent growing seasons, 2002 and 2003 ($P<0.0001$ and $P<0.0001$, respectively). Browse line was defined as the maximum height deer attempted to browse on seedling shoots and was identified as 148 cm for the 2002 growing season. Seedlings with observed TSR in both 2002 and 2003 were 36 cm ($P<0.001$) smaller than seedlings with observed TSR in only one or no growing seasons. The results indicate that deer browse is inversely related to seedling size. Larger seedlings would be more likely to surpass the browse line much faster, if not at the time of planting. The cost of producing taller seedlings may be higher per capita, but higher seedling survival and the reduced need for high-density plantings may help offset the higher cost per seedling.

INTRODUCTION

Challenges to successful regeneration of oak (*Quercus* spp.) have been discussed in a wide array of scientific literature. However, natural regeneration of oak can be problematic in many stands, particularly on highly productive sites, where aggressive pioneer species colonize following disturbance, (e.g., harvest). Large wildfires following complete overstory removal (Abrams 1992, Lorimer 2001), the loss of American chestnut [*Castanea dentata* (Marsh.) Borkh.], Native-American's and colonial use of fire (Delcourt and Delcourt 1998, Hough 1878), and regional stand development patterns (Clatterbuck and Hodges 1988, Oliver 1981) all appear to have contributed to the dominance of oak throughout the eastern deciduous forest. However, many of the conditions favorable to the regeneration of oak are no longer present (Loftis and McGee 1993). Moreover, favorable conditions for oak regeneration are unlikely to be regained.

Difficulty in naturally regenerating oak can be viewed as a result of social and economic constraints imposed on an existing biological solution. Loftis (1983, 1990) demonstrated that oak regeneration can be developed on highly productive sites using a shelterwood approach. However, economic and temporal constraints render this approach unacceptable to many non-industrial private forestland (NIPF) owners. Many NIPF owners rely on short-term economic considerations to dictate forestland management decisions, particularly harvest timing. This tendency does not usually allow for pre-harvest planning and/or intermediate operations necessary to ensure a viable advance oak reproduction population. One alternative could be artificial regeneration, which, over the past 10 years has received a great deal of attention and in which numerous challenges have been identified.

Obstacles to widespread use of artificial oak regeneration include competitive influences of faster-growing species, production of quality seedling stock, and of particular importance, the influence of whitetail deer herbivory. The whitetail deer population has increased significantly through the 20th century, and deer are now the most abundant wild ungulate on the North American continent (Russell and others 2001). Concomitantly, deer browsing has profoundly impacted both the composition and structure of many plant communities, including the depression of natural (Rooney and Waller 2003) and artificial (Buckley and others 1998) oak regeneration. In addition, deer herbivory can result in increased seedling mortality (Buckley and others 1998) and has significant impacts on height growth (Oswalt and others 2004). The aggregate effect is the reduced competitive capacity of planted oak seedlings.

Management options for reducing the impact of deer herbivory on planted seedlings are limited. The primary techniques used to protect planted seedlings from deer herbivory include the use of tree shelters (Dubois and others 2000), deer repellents (Romagosa and Robison 2003), and fenced exclosures (Opperman and Merenlender 2000). While the use of larger tree shelters (> 4 feet) has generally been successful, their cost can be prohibitive for many NIPF owners. Fencing can also be cost-prohibitive and is often more expensive than tree shelters. Repellents vary in effectiveness (Romagosa and Robison 2003) and may retard growth and development. Planting large and vigorous seedlings, i.e., high-quality seedlings, is one alternative to eliminate or reduce deer herbivory. Inherent in the idea of a tree shelter is the assumption that a seedling will reach a height in which the probability of adverse impacts is significantly lessened. Planting taller seedlings may benefit from the same relationship.

This study examines the impacts of deer herbivory on height growth of planted high-quality northern red oak (*Q. rubra* L.) seedlings. Specifically, we investigate the hypothesis that the impact of deer herbivory on smaller seedlings is more substantial than on taller seedlings. In addition, we quantify the associated impacts of variable levels of deer herbivory on

[1] Graduate Research Assistant and Associate Professor, respectively, The University of Tennessee, Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, Knoxville, TN 37996-4563; Director, The Ames Plantation, Grand Junction, TN 38039; and James R. Cox Professor of Forest Genetics, Department of Forestry, Wildlife and Fisheries, The University of Tennessee, 274 Ellington Plant Sciences Building, Knoxville, TN 37996-4563.

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seedling height growth and explore the possibilities of planting taller seedling stock to reduce problematic deer browse.

STUDY SITE

The study was conducted on the Ames Plantation in southwest Tennessee, along an intermittent stream in the headwaters region of the North Fork of the Wolf River (NFWR) (35°09´ N, 89°13´ W). The site encompasses approximately 100 acres of mixed bottomland and riparian hardwood forest dominated by various oak species and is part of the Southeastern Mixed Forest Province (Bailey 1995). Two distinct landforms were identified within the immediate study site: a minor bottom near the confluence of the stream with the NFWR and ancestral terraces of the minor stream.

The headwaters region of the NFWR is located within the Mississippi Embayment of the Gulf Coastal Plain. The geology is dominated by the highly erodible Wilcox and Claiborne formations of Tertiary age exposed by the erosion of Quaternary and Tertiary fluvial deposits and the overlying Pleistocene loess deposits common in western Tennessee (Fenneman 1938, Safford 1869). The principal soil groups are Grenada-Loring-Memphis on the terraces and Falaya-Waverly-Collins within the minor bottom (U.S. Department of Agriculture 1964).

MATERIAL AND METHODS

In the fall of 2001, three experimental blocks were identified based on landform and position. Significant differences in average stand basal area ($P < 0.05$) were found among the blocks. Twelve 2-acre treatment units were designated within the experimental blocks; four units were located within the minor bottom (Bottom block), and eight units were located within the terrace sites upstream from the minor bottom (four each within the East and West blocks). Species composition at the time of establishment was dominated by oak spp. on the ancestral terraces and by cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), yellow-poplar (*Liriodendron tulipifera* L.), and sweetgum (*Liquidambar styraciflua* L.) in the Bottom block.

Four overstory treatments (table 1), including a control (no cut), with 3 replications were randomly assigned to the 12 units using a randomized complete block design. Harvesting for all treatments was completed in the winter of 2001-2002.

Seedlings originating from two genetic families (families 321 and 234) in a seedling seed orchard on the Ames Plantation (Schlarbaum and others 1998) were chosen for planting following harvest. The seedlings were grown at the Georgia Forestry Commission's Flint River Nursery under fertilization and irrigation protocols developed by Kormanik and others (1994a). The seedlings were lifted in February, 2002, and were evaluated using procedures developed by Kormanik and others (1994a, 1994b), as modified by Clark and others (2000). Height, root collar diameter (rcd), and the number of first-order lateral roots (folr) *sensu* (Ruehle and Kormanik 1986) were recorded, and seedlings were visually classified into one of three categories (cull, good, premium). Thirty seedlings from the good and premium classes in each family were planted by shovel (20 by 20 feet) in March, 2002, within each of the 12 units for a total of 720 seedlings.

Survival, height growth, and browse pressure data were obtained in January, 2003, and January, 2004, for all seedlings after they entered dormancy. A "browse pressure classification" was used (Buckley 2001) to investigate the effects of deer herbivory on planted seedlings. Browse pressure was classified into one of four categories: no browse, terminal browse, lateral browse and complete browse. No browse was defined as no visible signs of herbivory, lateral browse was defined as herbivory limited to lateral shoots only, terminal browse was herbivory limited to only the terminal shoot, and complete browse was defined as observed herbivory on both lateral and terminal shoots. In addition, a binary variable called "terminal shoot removal" (TSR) was created by combining the complete browse and the terminal browse categories. This variable allowed consolidation of seedlings where terminal shoots were browsed.

Mean 2-year seedling height growth and survival by TSR category were analyzed for differences between growing seasons using mixed effects ANOVA models and post-ANOVA mean separation using Fisher's Least Significance Difference Procedure (SAS Institute Inc. 1989). An error level of $\alpha = 0.05$ indicated significant differences. Logistic regression and chi-square analyses were used to explore the possible relationship between seedling height before bud break and the probability of TSR and to determine the limiting height for browse.

RESULTS

Mean initial rcd, initial shoot height, and number of folr for premium seedlings ($n = 216$) were 12.55 mm, 124.30 cm, and 21, respectively. Mean initial rcd, initial shoot height, and number of folr for good seedlings ($n = 504$) were 10.23 mm, 103.85 cm, and 16, respectively.

Seedlings experienced browse pressure during both growing seasons. Seedlings exhibited signs of TSR following the 2002 growing season only ($n = 104$, 18 percent of surviving seedlings), the 2003 growing season only ($n = 58$, 10 percent), and

Table 1—Overstory treatment descriptions for the oak regeneration study on Ames Plantation, Fayette County, TN, December 2001

Treatment	Description
Commercial clearcut	Removal of all stems > 6 inches diameter breast height.
Two age	Residual stand basal area of 15-20 square feet per acre was targeted. Residual stems were chosen based on spacing criteria and the desire to leave stems of desirable species with an opportunity to increase in value. Desirable species included oaks, hickories (Carya spp.), and yellow-poplar.
High grade	Removal of all stems > 14 inches diameter breast height.
No cut (control)	Designed to act as the study control. No removals.

both growing seasons (n = 76, 12 percent), irrespective of overstory treatment. However, many seedlings did escape TSR in both 2002 and 2003 (n = 355, 60 percent). Mortality, primarily in the control units, accounted for 127 seedlings. Herbivory by whitetail deer had no significant influence on seedling survival following two growing seasons but did influence 2-year height growth ($P < 0.0001$) through TSR. Mean 2-year height growth was greatest for seedlings that did not exhibit signs of TSR and least for seedlings that exhibited signs of TSR following both growing seasons (table 2). Seedlings that experienced TSR in both 2002 and 2003 were on average 36 cm shorter than seedlings exhibiting no signs of TSR. Chi-square analysis identified 148 cm as the limiting height for TSR ($P < 0.0001$). TSR did not occur on any seedling > 148 cm initial planting height (5 percent of population) during the 2002-growing season. Following the 2003 growing season, 47 percent of the seedlings had surpassed the 148 cm “browse-line”. Consequently, logistic regression analysis of pooled seedling data (pooled across treatment) suggested that dormant season seedling height influenced TSR in both 2002 and 2003 ($P < 0.0001$ and $P < 0.0001$, respectively).

DISCUSSION AND CONCLUSIONS

While TSR was not extensive (15 percent of total planted in 2002, 8 percent in 2003, and 11 percent for both growing seasons), it did show that deer herbivory had a significant impact on 2-year seedling height growth, particularly on seedlings that were browsed in both years. Seedlings with observed TSR in both 2002 and 2003 were on average 36 cm smaller than seedlings that maintained an unbrowsed terminal shoot. The study demonstrated that planting taller seedlings reduces deer herbivory of the terminal shoot without the associated expense of tree shelters (Clatterbuck 1999), repellents, or exclosures. The cost of seedlings, however, is greater due to using only a portion of the seedlings purchased. In this study, roughly 45 percent of the available seedlings were selected for planting. This selection regime almost doubles the price per seedling. The increased cost can be somewhat mitigated, however, by a reduction in planting density due to relatively higher survival and greater growth. Concomitantly, taller seedlings not only provide some protection from deer herbivory but also appear to have higher rates of growth (Oswalt and others 2003). As a result, the benefits of planting taller seedlings appear to be multi-dimensional.

Table 2—Season of occurrence, number (N), mean height growth after two growing seasons and associated standard error of northern red oak (Quercus rubra L.) seedlings with observed terminal shoot removal (TSR) pooled across treatments within the oak regeneration study on Ames Plantation, Fayette County, TN

Season	N	Mean	S.E.
2002 Only	104	34.21[a]	2.68
2003 Only	58	10.10[b]	2.78
2002 & 2003	75	4.67[b]	2.13
No TSR	355	40.72[c]	1.71

Different lettering indicates differences ($P < 0.05$).

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