IMPROVING SPECIES COMPOSITION IN MISMANAGED BOTTOMLAND HARDWOOD STANDS IN WESTERN ALABAMA

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Abstract—Forests of the Coastal Plain of Alabama are among the most diverse, productive, and complex in the United States. Long-term mismanagement, however, coupled with a lack of refined scientific knowledge on bottomland oak silvical characteristics and on their regeneration dynamics, has resulted in a reduction in both the quantity and quality of the oak component in many of these stands. A study was implemented in western Alabama to compare survival, growth, and animal browse of planted Nuttall oak seedlings using plastic tube shelters, wire browse protection, fertilization, mulch mats, and control. Treatment effects on seedling height and caliper growth indicate that fertilization application and type of seedling protection significantly affect both groundline diameter and height. The use of seedling protection positively affected tree growth form and protected seedlings from herbivory compared to those unprotected.

INTRODUCTION

There are thousands of mismanaged acres of bottomland forests that exist in Alabama today from past highgrading and other destructive practices. As a result, the proportion and quality of oaks retained in these forest stands has been diminished. The consequence has been the establishment of a higher fraction of stems that are composed of non-oak and other undesirable tree species. Stands that typically have included moderate proportions of high-value tree species, such as cherrybark and Nuttall oak, have been reduced to mixed-species stands of lower economic value.

A decrease in the number of mature oaks growing on productive bottomland hardwood sites can create special problems in successfully regenerating them after a harvest. Even when good seed years occur, the stocking densities and spatial arrangement of oak reproduction is sporadic at best and sometimes non-existent. Much of this is due to a lack of silvical knowledge concerning the natural reproduction dynamics of oaks within these productive sites. Limited knowledge of the formulae to successfully recruit and establish oak seedlings is largely stochastic in nature; that is, we know what silvicultural methods should encourage oak seedlings to become established, but success cannot be predicted with any certainty. As a result, numerous plant species have been able to capitalize on the high light environments created during harvest operations.

Many plant species that have the ability to flourish in these highly productive bottomland hardwood forests are shade tolerant (e.g. *Carpinus caroliniana, Halesia diptera*, etc.). This is one of the primary reasons that oak regeneration is futile in these environments. Stand prescriptions that encourage oak regeneration are often similar to those that favor the development of potentially faster growing competitor species (Kormanik and others 1995). The ramifications are that oak reproduction is often subject to well-developed understories dominated by shade tolerant species. The lower stratum of these forests often includes *Vitis, Smilax, Arundinaria*, and numerous other tolerant non-commercial tree species. These undesirable species have the ability, unlike the oaks, to become established and persist in an understory almost completely lacking in direct sunlight for many years. As a result, these species create a dense mat of vegetation that covers the forest floor so completely that penetration by direct sunlight is almost fully impeded.

These predicaments are extremely problematic for bottomland oak seedlings, because they are notoriously slow in attaining the vertical height required to rise above this layer of vegetation. They are so slow, in fact, that even when ample light is available they still are shorter in height relative to adjacent vegetation. A large proportion of oak reproduction present in this type of understory usually experiences mortality caused, at least in part, by their inability to become fully established. Extreme low-light environments at the ground level in these forests creates a situation where many desirable oak species cannot compete successfully for the necessary light, nutrients, and other resources that limit plant growth.

The initial inability of oak seedlings to grow rapidly in height makes them especially vulnerable to animal browse. Although a number of seedlings experience mortality due to stresses associated with competing vegetation, there still are many that become established in these conditions. Those seedlings unable to rise above 1.25 m (Castleberry and others 1999) however, will in many instances experience heavy browse pressure from the high population densities of both white-tailed deer (*Odocoileus virginianus*) and feral pigs (*Sus scrofa*). The potential impact of animal browse on desirable hardwood regeneration is poorly understood. Herbivory of naturally-regenerated commercial species has adversely impacted other habitat types by changes in species composition (Anderson and Loucks 1979, Hough 1965, Marquis 1981, Ross and others 1970, Tilghman 1989, Walters 1993). The presence of these animals makes it especially difficult to regenerate valuable timber, because they feed heavily on seedlings and sprouts

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Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

of preferred species. These problems are further exacerbated by the fact that these animals tend to stay within small pockets in the forest until the area is overbrowsed (Moore and Johnson 1967). Although light browsing usually will have no detrimental effects on the future stands in these areas, heavy browse damage can potentially lead to stem deformities, changes in species composition, reduced stocking, or extended rotations.

High population densities of herbivores and heavily shaded understory environments in mature forests have led to oak regeneration failures (Gillespie and others 1996) and stimulated an increase in the number of stems of undesirable species. In southern forests, undesirable shade-tolerant species have been increasing in dominance over time at the expense of the oak component. The fate of these forests that were once heavily stocked with oak trees is in question; quality oak seedlings are now scarce, and sapling-size specimens are virtually non-existent. Techniques to recruit oak reproduction using natural regeneration methods are still being developed and, as yet, are not reliable.

If some assurance of oak species' stature in recently cutover floodplain forests is desired, the supplemental establishment of oaks through planted seedlings could partially alleviate some of the problems associated with natural regeneration methods (species composition, density, spatial distribution, etc.) (Pope 1993). In order for artificial oak regeneration to be successful, however, two factors need to be considered: (1) faster growing competitor species (vines, herbaceous weeds and undesirable tree species), and (2) high population densities of both white-tailed deer and feral pigs.

Rapid early height growth is the key to overcoming both herbivory and the dense mat of vegetation that is present in the lower strata of these forests. In an effort to promote this growth, some measure of seedling protection may be necessary to ensure that plantings are successful. Efforts to protect seedlings from animal browse damage led to the invention of plastic tree shelters in England in 1979. These plastic tubes were approximately 4 feet tall and allowed enough light to the seedling so they were able to survive and become established, and also protected seedlings from animal browse until they emerged from the end of the tube. Not only did the tree shelters protect seedlings from browse damage, but improved seedling survival and rapid early height growth were also observed (Manchester and others 1988). Since that time, many different styles of tree protection devices have been tested throughout the world. In the United States, research programs in Michigan have shown that tube shelters effectively increased oak seedling survival and early height growth (Lantagne 1995, Lantagne and Miller 1997, Lantagne and others 1990). Comparable tests in North Carolina, Pennsylvania, and Connecticut also showed similar trends (Manchester and others 1988, Walters 1993, Ward and others 2000). In the Southeastern United States, several studies have investigated the effectiveness of tree shelters in urban environments (West and others 1999, West and others 2002) and in abandoned agricultural fields as a method of reforestation (Schweitzer and others 1999) with excellent success. While Dubois and others (2000) investigated the growth and establishment of cherrybark oak in a harvested area in eastern Alabama, there have been no reportings of tree shelters being used to aid in the establishment of bottomland oak species on recently cutover bottomland hardwood floodplain forests.

If protection from animal browse is the main factor limiting oak regeneration success, then any method of seedling protection (i.e., tube shelters or wire cages, for example) should afford similar results. However, if plastic tube shelters can stimulate greater height growth than by browse protection alone, then their use in southern bottomland forests should be encouraged. Our objectives were to examine the synergy of browse protection type and enhanced height growth on oak reproduction at the site of a recent clearcut in west Alabama. Specifically, we investigated the difference in the growth, survival, and animal browse intensity on planted Nuttall oak (*Quercus nuttallii* L.) that have been subjected to various combinations of plastic tree shelters, wire cages, and fertilization.

METHODS AND PROCEDURES

Nuttall oak seedlings were purchased in January 2000 and stored in a cooler at 40 °C until they were transported to the planting site. Prior to outplanting, the root systems of each seedling were dipped in a 10 g solution of Viterra™ to aid in keeping the roots moist.

This study was conducted in a second-bottom mixed hardwood community adjacent to the Black Warrior River in Greene County, AL, approximately 10 miles due north of Demopolis. The landowners' intent originally was to plant the area with pine. As a result, the area was clearcut and the site prepared by shearing and windrowing following logging operations. Pre-harvest vegetation on the study area ranged from the swamp chestnut oak/cherrybark oak type on drier sites to the willow/water-laurel oak type on wetter sites (Shropshire 1980). The swamp chestnut/cherrybark stands contained a large proportion of water oak (*Quercus nigra* L.) and sweetgum (*Liquidambar styraciflua* L.) but also included green ash (*Fraxinus pennsylvanica* Marsh.), white oak (*Q. alba* L.) and hickory species (*Carya* spp.). Also present in smaller numbers were American elm (*Ulmus americana* L.), winged elm (*U. alata* Michx.), and southern red oak (*Q. falcata* Michx. var. *falcata*) (Shropshire 1980).

Two planting areas were located in close proximity to each other, situated with an east-west orientation, and separated by a windrow approximately 3 m in width. A portable laser-distancing device and flagging were used to delimit each planting area and to establish planting rows. The planting area on the north side of the windrow measured approximately 82 m by 40 m and accommodated six planting rows. The planting area south of the windrow measured approximately 90 m by 41 m and received seven planting rows. Each planting spot within each row was then differentiated using color-coded pin flags to discern which treatment was to be applied at each particular location. In the spring of 2000, a total of 324 Nuttall oaks were planted in holes dug using a portable gas-powered auger with a 15 cm bit. A total of 144 seedlings were planted on the north side of the windrow, while 180 were planted on the south side.

Seedlings were watered one time with approximately two cups of water 1 week after planting to aid in their establishment due to a coincident drought. After planting, baseline measures of seedling height and groundline diameter were recorded. Groundline diameter was measured at approximately 2.5 cm above true groundline to avoid swelling that is common at the base of all trees. Seedling height and groundline diameter data were again measured at the end of each growing season in October 2000, 2001, and 2002. Due to the high population density of both white-tailed deer and feral pigs, a measure of browse intensity was documented as well. Browse incidence was quantified based on the presence or absence of the terminal bud and the amount of forking along the seedling bole as a result of herbivory. Treatment differences were tested at the $\alpha = 0.05$ level.

Herbicides were applied around seedlings of each protection type several times during the first two growing seasons to control competing vegetation. The first application was in May 2000 using a 4 percent (by volume) RoundUp Pro™ solution. To more effectively control some of the more tolerant weed species, subsequent herbicide applications were amended with 0.5 percent (by volume) of an additional surfactant (Timberland 90™). Applications were made in late June and August of 2000, and May and July of 2001. Most competing vegetation was controlled by the use of the chemicals, but some stems were manually severed.

EXPERIMENTAL DESIGN

Three hundred twenty-four Nuttall oaks were planted in a completely randomized design at the study area in February 2000 at 3 m by 6 m spacing. One-third of the seedlings were placed in 1.2 m tall opaque plastic tube shelters, one-third in 1.2-m-tall wire cages, and the remaining one-third of the seedlings were unprotected. One-half of all seedlings within each treatment received 2 10-gram fertilizer tablets (20-10-5, NPK) at the time of planting, for a total of six treatment combinations with 54 seedlings each. Black plastic mulch mats (approximately 1 m by 1 m) were employed at each planting hole across the study to further reduce the effects of competing vegetation.

RESULTS

Of the 324 Nuttall oak seedlings planted for this experiment in spring 2000, 309 (95.4 percent) were still alive after two growing seasons. While there were no significant differences in survival among treatments, 18.75 percent (3) of the seedlings that died were from the control group while 43.75 percent (7) and 37.5 percent (6) were from the wire cage and tube shelter protection type, respectively. Sixty-two percent (10) of the seedlings that experienced mortality had received a one-time fertilizer application at the time of planting, 38 percent (6) had not.

General Linear Model analyses ($\alpha = 0.05$) were used to examine the relationships between treatment/protection type and seedling height and groundline diameter growth after two growing seasons. Height growth differed significantly ($P < 0.0001$) among treatments (fig. 1). Treatment type was significant ($P < 0.0001$) as was fertilizer use ($P = 0.0019$). Groundline diameter growth differed significantly ($P < 0.0001$) between the different treatment combinations (fig. 2). Treatment type was significant ($P < 0.0001$) as was fertilizer use ($P = 0.0002$).

Duncan's Multiple Range Tests indicate the use of plastic tube shelters stimulated significantly greater height growth among seedlings than either the use of wire cages or control (table 1). Height growth by seedlings in wire cage protection was also significantly greater than for those in the control group, and fertilized seedlings exhibited greater height growth after two growing seasons than those unfertilized. Groundline diameter was also affected by seedling

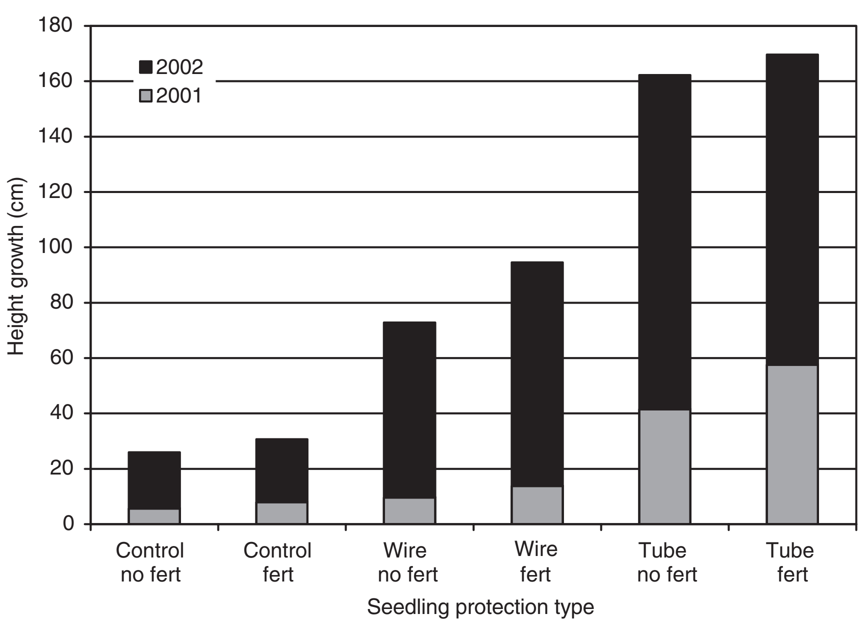

Figure 1—Height growth (cm) of planted Nuttall oak seedlings by seedling protection type and fertilizer use after two growing seasons.

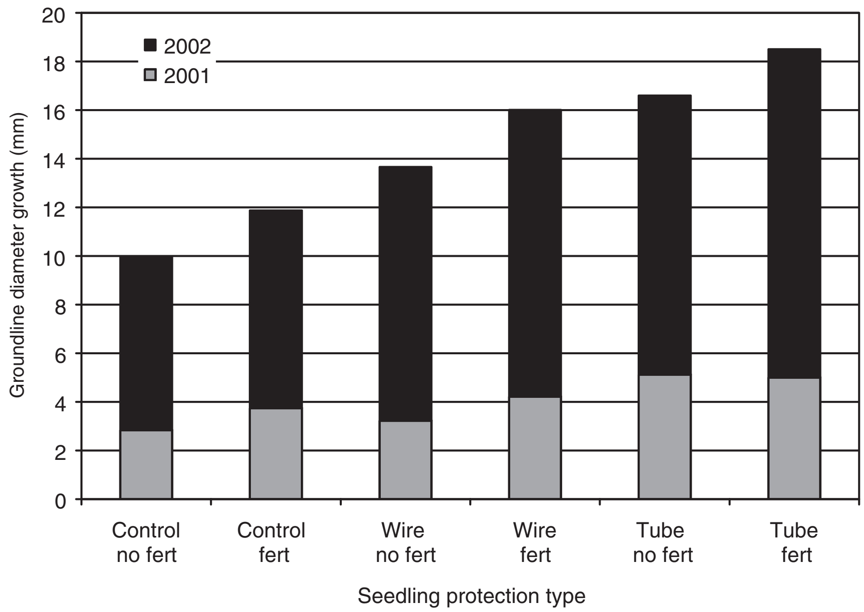

Figure 2—Groundline diameter growth (mm) of planted Nuttall oak seedlings by seedling protection type and fertilizer use after two growing seasons.

Table 1—Mean height and diameter growth of planted Nuttall oak seedlings by protection type and fertilizer use after two growing seasons

	N	Mean height[a] growth	Mean GLD growth
		cm	*mm*
Protection type			
S	102	167.18a	17.10a
W	101	84.18b	14.99b
C	105	28.46c	10.94c
Fertilizer usage			
Yes	152	99.12a	15.31a
No	156	87.43b	13.08b

S = plastic tube shelter; W = wire cage; C = control.

[a] Means followed by the same letter within the same column are not significantly different ($\alpha = 0.05$) using Duncan's New Multiple Range Test.

protection type. Seedlings in plastic tube shelters were significantly larger in caliper than those in the wire cages, and seedlings in wire cages were larger than the control. Similarly, fertilized seedlings exhibited greater groundline diameter growth than unfertilized.

Analysis of variance (ANOVA) results suggest there were significant differences in herbivory among the protection types over the duration of this study. Post-hoc tests reveal that the degree of browse incidence on the control seedlings was significantly greater than either the wire cages or plastic tube shelters. Ninety-five percent of the unprotected (control) seedlings were damaged by animal browse and no longer retain their terminal buds. Twenty-eight percent of those were browsed heavy enough to cause extensive forking along the bole while 67 percent sustained only slight browse damage. In contrast, less than 5 percent of seedlings in tube shelters or wire cages sustained browse damage to the terminal leader. There were no significant differences in browse incidence between the wire cage and plastic tube treatments.

DISCUSSION

Results from the first growing season indicated that fertilizer use significantly affected seedling height growth but not groundline diameter growth. Data from the second growing season indicated that fertilizer enhanced diameter growth but not height growth. Total seedling height and diameter growth was significantly elevated by the use of fertilizer over the 2-year period. Over the course of the study the groundline diameter of seedlings increased approximately 15 percent while height growth increased 25 percent by the use of fertilizer, compared to those unfertilized. Based on these results it appears that the use of fertilizer does provide an initial boost in seedling height growth which may help them overcome the destructive influences of both competing vegetation and herbivory. Whether or not these effects are lost over time is of little importance if the initial height gains in enable seedlings to rise above browse level (1.25 m).

The use of seedling protection devices significantly increased both groundline diameter and height growth after two growing seasons. Seedlings in wire cage protection were approximately 300 percent taller than those in the control group, whereas seedling which utilized plastic tree shelters were nearly 650 percent taller than those in the control group. These figures are slightly higher than those previously reported in the literature. Lantange and Miller (1997) reported gains in height of 375 percent, and Manchester and others (1988) report gains of 132 percent after two growing seasons for trees in shelters compared to those in the control group. Differences in growth may be attributable to the fact that those studies were done in the Northern United States where growth rates are typically slower. However, previous studies in the South also suggest height growth differentials may indeed be in the 300-400 percent range (Dubois and others 2000, Schweitzer and others 2000) even without intensive competition control. Differences in height growth between this study and others may be due to the fact that there was nearly 100 percent vegetation control surrounding all planted seedlings at this study site. In addition, there was virtually no competition for light, nutrients, or other factors that limit plant growth. This likely enhanced the growth rates and may be atypical of results found in less intensive planting regimes. The nearly complete vegetation control may also have impacted survival rates across all treatments. Some studies involving tree shelters reported high mortality rates for control seedlings (Manchester and others 1988), and this was not true for this study, where we had 95 percent survival across all treatment groups.

The intense browse pressure evidenced in seedlings in the control group may also have been an artifact of our vegetation control. There are abundant white-tailed deer in the area; however, because competing vegetation had been treated with herbicide and was either dead or dying, alternate browse was unavailable. Planted oaks were the main vegetation within the planting areas in early spring. Wire cages and plastic tube shelters protected two-thirds of the seedlings from browse with the remaining one-third of seedlings in the control group free to be browsed. This resulted in a high proportion of the control seedlings actually losing height, some by nearly 23 cm, from repeated browse since the time of planting. This not only affected tree height, but subsequent tree form was drastically altered. Control seedlings tended to be short and shrubby compared to the taller and typically single-stemmed form of protected seedlings.

The control treatment was the least costly of the protection types, but poor growth rates and tree form are an outcome of herbivory that can often lead to poor success rates in re-establishing a forest stand. Costs of both the wire cages and the plastic tube shelters are comparable but have different qualities associated with them. For example, the wire cages do protect seedlings from browse damage to the terminal leader, but do not protect seedlings from side browse as branchlets extend through the wire. As a result, cage-protected seedlings are not as straight and generally have poorer form compared to those in plastic tube shelters. Unless side branches are removed, the cage protection devices will be very difficult to remove when the seedlings rise above browse level. Plastic tube shelters are the most costly of the treatments studied, but their use ensures that requisite rapid early height growth, coupled with good tree form, can be attained for desirable species. Although not investigated, plastic tube shelters might have a lower cost per successful seedling compared to other methods.

SUMMARY

The 1.2-m-tall opaque plastic shelters stimulated both greater seedling height and groundline diameter growth over two growing seasons compared to those enclosed in wire cages or those in the control treatments. Partially as a result of the growth rate differential, tree form also was superior with increasing levels of protection with the best form attained through the use of plastic tube shelters and the worst form for seedlings in the control treatment. The effects of fertilizer on planted Nuttall oak seedlings were demonstrated through enhanced seedling height and groundline diameter growth compared to those unfertilized. Incidence of animal browse was significantly reduced by the presence of seedling protection devices. The use of protection devices and fertilizer, either separately or in concert, can enhance early seedling growth and aid in the establishment of artificially regenerated bottomland hardwood species.

ACKNOWLEDGMENTS

The authors would like to thank Mr. John Caldwell for his generous support. Additional support was provided by the Auburn University graduate school through research grants and by Capital Veneer Works through the Robert Lewis Adams Fellowship for research in hardwood management.

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