DETERMINING THE FACTORS ASSOCIATED WITH SEEDLING HERBIVORY ON AFFORESTED CARBON SEQUESTRATION SITES IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY: PRELIMINARY RESULTS

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Abstract—One causal factor of failed afforestation attempts in the Lower Mississippi Alluvial Valley (LMAV) is mammalian herbivory. Herbivory of seedlings generally reduces growth and can also lead to seedling mortality. Seedlings were randomly selected for monitoring throughout the first growing season. Growth and survival data were recorded, as were signs of mammalian herbivory. Analysis of variance (ANOVA) was conducted and it was determined that species mix and the application of slow-release fertilizer tablets had a significant effect on seedling survival rates and overall seedling herbivory rates after one growing season. Future research will provide additional input as to what factors are most responsible for determining seedling survival and anticipated seedling herbivory in afforested areas in the LMAV. Based on the results of this study, we hope to identify a cost-effective species mix that can be utilized in the LMAV to promote carbon sequestration and withstand the negative impacts of potential browsing by mammalian herbivores.

INTRODUCTION

There is rising global concern in light of possible negative consequences of climatic change due to increasing atmospheric levels of carbon dioxide. A contributing factor responsible for rising levels of atmospheric carbon dioxide is the decreasing amount of forest land in the world (Mickler 2004). The Lower Mississippi Alluvial Valley (LMAV) has experienced widespread loss of bottomland hardwood forests and forested wetlands as lands in this region have been cleared for agricultural use over the past two centuries (Stanturf and others 2000). However, it is projected that nearly 34 million acres of retired agricultural land in the LMAV will be available for hardwood plantings by 2040 (Wear and Greis 2002). These areas will provide landowners with opportunities for potential income through timber production, enhanced wildlife habitat, potential income from fee hunting, and the sale of credits associated with carbon sequestration.

While it has been suggested that production of forest products can be financially superior to agricultural production on marginal lands in the LMAV (Amacher and others 1998), it is important to note that these analyses assume afforestation success and full stocking of target species. Early afforestation efforts undertaken in the LMAV over the last several decades have been characterized by inconsistent crop tree survival, species composition, and site productivity (Stanturf and others 2004). Thus, it is important to consider what causes the failures and inconsistencies that have marred afforestation activities. Many factors are responsible for poor survival and growth of afforestation areas in the LMAV. These include mammalian herbivory, herbaceous plant competition, nutrient deficiency, poor site suitability, lack of site preparation, and low-quality planting stock (Stanturf and others 2004).

When establishing hardwood species in the LMAV, one problem that hinders seedling establishment is the occurrence of mammalian herbivory (Stanturf and others 1998). Herbivory of seedlings generally reduces growth; increases competitive disadvantage; and can also lead to seedling mortality (Buckley 2002). Herbivory in the LMAV can be attributed to mammalian species such as white-tail deer (*Odocoileus virginianus*), rabbits (*Sylvilagus* spp.), and various rodent species such as hispid cotton rats (*Sigmodon hispidus*) and wood rats (*Neotoma floridanus*) (Stange and Shea 1998). In a bottomland hardwood planting, herbivory can cause regeneration delays (Stanturf and others 1998). These delays can have significant economic impacts on landowners who are interested in planting bottomland hardwoods in the LMAV (Straka and Hotvedt 1985).

Little empirical research has been conducted examining which environmental factors influence the occurrence and likelihood of wildlife herbivory on afforested areas in the LMAV. Jones and others (1997) reported that herbivores show selective preference toward specific browse species. Additionally, numerous studies have indicated that various red and white oak species are favored by herbivores (Cadenasso and Pickett 2000, Lockhart and others 2000, Taylor and others 2006, Oswalt and others 2006).

It has been suggested that perhaps the most feasible means of herbivory control is proper site preparation activities (Stanturf and others 2004). Small mammals such as rodents, voles, and rabbits prefer a densely vegetated ground layer that provides escape cover from aerial and terrestrial predation (Ostfeld and others 1997, Schnurr and others 2004). Thus, the removal of neighboring herbaceous competition through mechanical or chemical means has been suggested as a tactic that will limit or reduce small mammal habitat in afforested settings. However, it has been documented that open seedlings are more vulnerable to

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predation by white-tail deer (Buckley and others 1998, Dubois and others 2000, Castleberry and others 2000, Sweeney and others 2002). However, Stange and Shea (1998) suggest that small mammal herbivory is often more detrimental to seedlings than deer browsing.

STUDY SITE AND METHODS

In February 2006, seedlings were planted at Entergy Company's Delta steam electric generating station located approximately 2 miles north of Cleveland, MS as part of a larger carbon sequestration project that was undertaken by Entergy and Mississippi State University. Hardwood seedlings were hand-planted at a spacing of 10 by 10 feet, resulting in approximately 435 trees per acre. Plots were established as a 6 by 2 by 2 completely randomized factorial design using six species mixes by two fertilizer treatments (fertilized vs. non-fertilized) by two competition treatments (chemical vs. no chemical control). Fifty percent of all seedlings were treated with a 15:10:20 slow release fertilizer tablet following planting. Additionally, 50 percent of all seedlings received chemical competition control in the form of a post-emergent application of Goal 2XL at a rate of 64 ounces per acre in May 2006. Herbicide treated seedlings also received an additional treatment of Goal 2XL at a rate of 32 ounces per acre in August 2006. Thus, 25 percent of seedlings from each species mix received the following treatments: fertilizer only, herbicide only, fertilizer and herbicide combination, or neither fertilizer nor herbicide (control).

Three replications of each of the 24 treatment combinations (afforestation regimes) were established, resulting in 72 0.25-acre plots at both study sites. Seedlings from each afforestation regime were randomly selected for monitoring throughout the first growing season. Selected seedlings were marked using aluminum tree tags and 3-foot pin flags to compensate for dense herbaceous vegetation. Selected seedlings were visited three times during the 2006 growing season (March, July, and October) and once more in February 2007. Seedling herbivory, when evident, was recorded and the herbivore species responsible for that damage was determined using browsing characteristics described by Jackson (1990).

Analysis of variance (ANOVA) was used to identify treatment effects and factor-level interactions that existed in survival, growth, and herbivory data. Statistical analysis was conducted using the mixed procedure in SAS 9.1. All statistical analysis was done at the 95 percent confidence level.

RESULTS

The results discussed in this publication refer to data recorded between February 2006 and February 2007 at Entergy's carbon sequestration site in Cleveland, MS. The three species mixes analyzed are composed of the following seedling species: Mix A- eastern cottonwood (*Populus deltoides*) monoculture, Mix B–red mulberry (*Morus rubra*) monoculture, and Mix C–50 percent eastern cottonwood and 50 percent mix of willow oak (*Quercus phellos*), Nuttall oak (*Quercus nuttallii*), and water oak (*Quercus nigra*).

Survival

Overall seedling survival during the 2006 growing season was poor, as approximately 31 percent of selected seedlings remained after one growing season. Seedling species was determined to have a significant effect on seedling survival ($p = <0.0001$). Eastern cottonwood seedlings performed exceedingly poorly, as merely one percent of selected seedlings survived until October 2006, regardless of herbicide/fertilizer treatment (table 1). Thus, Species Mix A and Species Mix C exhibited survival rates that were significantly lower than the survival rates exhibited by all other species mixes. Species Mix B, the red mulberry monoculture, expressed survival rates that were among the highest observed, as approximately 60 percent of selected red mulberry seedlings survived. Oak seedlings in Mix C survived at a rate of approximately 20 percent during the first growing season.

It was also determined that the application of slow-release fertilization tablets had a significant effect ($p = 0.0218$) on seedling survival rates. Seedlings receiving a first year fertilizer application were less likely to survive than seedlings receiving no fertilization (table 2). The application of post-emergent herbicide was determined to have no significant effect ($p = 0.9347$) on seedling survival at the Cleveland, MS carbon sequestration site.

Herbivory

Herbivory occurred on a substantial number of seedlings the year following afforestation. Approximately 22 percent of selected seedlings were browsed by a mammalian herbivore. More than 60 percent of observed mammalian herbivory was attributed to hispid cotton rats while rabbits accounted for nearly 25 percent of seedling herbivory. Pine voles were only responsible for browsing approximately 15 percent of observed seedling herbivory. Herbivore damage ranged from severance of the root system to clipping of minor branches and twigs.

Seedling species was determined to have a significant effect ($p = < 0.0001$) on the likelihood of seedling herbivory (table 1). Eastern cottonwood browsing was rare, as less than

Table 1—First-year seedling survival and herbivory rates by planting mix observed at the Cleveland, MS site of the Entergy Afforestation Project during the 2006 growing season. Data were analyzed at the 95 percent confidence level

Species Mix	% Survival[a]	% Herbivory[a]
A- Eastern cottonwood monoculture	1.0c	0.0c
B- Red mulberry monoculture	66.4a	33.9a
C- Eastern cottonwood/oak mix	5.7b	16.3b

[a]Values followed by the same letter do not differ statistically at $\alpha = 0.05$.

Table 2—First-year seedlings survival and herbivory rates by fertilization and herbicide application observed at the Cleveland, MS site of the Entergy Afforestation Project during the 2006 growing season. Data were analyzed at the 95 percent confidence level

Treatment	% Survival[a]	% Herbivory[a]
Fertilization		
Yes	26.1b	17.3b
No	34.8a	25.6a
Herbicide		
Yes	29.2a	22.6a
No	31.6a	21.0a

[a]Values followed by the same letter do not differ statistically at $\alpha = 0.05$.

one percent of selected seedlings in Mix A exhibited signs of mammalian browsing. More than 30 percent of selected red mulberry seedlings from Mix B exhibited browsing from an herbivore. Oak seedlings were typically browsed more readily than any other species, as up to half of selected oak seedlings were browsed in some afforestation regimes. Mix C, the eastern cottonwood/oak mix was browsed at a rate of approximately 16 percent during the 2006 growing season.

It was determined that fertilization had a significant effect ($p = 0.0233$) on expected mammalian herbivory rates (table 2). Seedlings receiving fertilization were less likely to be browsed than seedlings not fertilized. Post-emergent herbicide application was determined to have no significant effect on seedling herbivory.

DISCUSSION

Overall seedling survival during the 2006 growing season was low. Poor seedling survival can likely be attributed to the combined effects of intense herbaceous competition, wildlife herbivory, and drought conditions during the early part of the growing season. The use of Goal 2XL for chemical competition control was dictated by the inclusion of eastern cottonwood into this project, because more aggressive herbicides such as Oust XP are not available for use on eastern cottonwood seedlings. The selected herbicide application had little effect on competition from herbaceous species such as tall fescue (*Festuca arundinacea*), verbena (*Verbena brasiliensis),* peppervine (*Ampelopsis arborea*), and blackberry (*Rubus argutus*). Thus, the use of this particular herbicide regime had no significant effect on seedling survival although effective first year competition control can tremendously improve hardwood seedling growth and survival (Ezell 1994, Ezell and others 2007).

As expected, species mix was a significant factor effecting seedling survival. Mix A, the eastern cottonwood monoculture, performed very poorly. These results were expected as eastern cottonwood seedlings are poor competitors and successful establishment typically requires complete competition control during the first growing season (Ezell 1994). Species Mix B, the red mulberry monoculture, exhibited survival rates in excess of 60 percent for each treatment combination. However, surviving red mulberry seedlings were typically characterized by die-back and displayed minimal first year height growth. Monitored oak seedlings survived at a rate of approximately 40 percent during the first growing season for all treatment combinations. These poor survival rates are characteristic to the results of many afforestation efforts in the past, yet could be improved with proper site preparation, chemical competition control, and increased rainfall.

Fertilization significantly decreased survival rates for seedlings in each seedling mix examined. Due to the dense herbaceous layer at this site, it is likely that seedlings were not able to utilize the added nutrients provided by fertilization. Furthermore, it is likely that competing herbaceous vegetation was able to utilize the nutrients provided by fertilization much more efficiently than first year hardwood seedlings, thus compounding competitive disadvantage (Hopper and others 1993). Due to the apparent lack of efficacy provided by herbicide application, it was determined that the selected chemical competition control had no effect on seedling survival rates.

Small mammal herbivores such as hispid cotton rats, rabbits, and pine voles were responsible for browsing over 20 percent of selected seedlings during the year following planting. The dense herbaceous layer characterizing this site likely created suitable escape cover and feeding habitat for these herbivores, thus subjecting seedlings to substantial browsing pressure. Effective chemical competition control likely would have decreased small mammal abundance and herbivory, increasing seedling growth and survival rates (Stanturf and others 2004).

Seedling species was identified as a significant factor determining seedling herbivory rates. Eastern cottonwood seedlings were rarely browsed, most likely due to poor survival rates exhibited by eastern cottonwood seedlings. However, few studies have indicated that herbivory is a major problem in eastern cottonwood plantings. During the 2006 growing season, red mulberry and oak seedlings were browsed much more readily than eastern cottonwood seedlings. The seemingly increased vulnerability of these species is supported by previous research (Cadenasso and Pickett 2000, Lockhart and others 2000, Oswalt and others 2006, Taylor and others 2006).

Fertilized seedlings were less likely to be browsed than seedlings receiving no fertilization. Since fertilized seedlings were less likely to survive, it can be inferred that fewer fertilized seedlings were available to be browsed upon. Research conducted by Taylor and others (2006) reported

that fertilization of Nuttall oak seedlings had no effect on observed herbivory rates. Herbicide application had no effect on seedling herbivory rates for any species mix. Due to the inefficacy of the selected herbicide regime at controlling competing vegetation, differences among seedlings were not expected.

CONCLUSIONS

The occurrence of wildlife herbivory during the early stages of afforestation attempts is an area of concern to landowners in the LMAV. The early results of this study indicate that mammalian herbivory can occur over a wide range of seedling species and silvicultural activities. The results are important because substantial browsing by various herbivore species can impact seedling vigor, growth, and survival. In extreme cases, the additional stress caused by wildlife herbivory can lead to afforestation delay or stand establishment failure.

It is currently uncertain to what extent mammalian herbivory impacts survival, growth, and carbon sequestration in young bottomland hardwood forests. It is also unknown what monetary implications herbivory may have for landowners and natural resource professionals who invest in planting hardwood seedlings in the LMAV. Since recent trends and predictions suggest that afforestation efforts in the LMAV will continue to expand over the next several decades, it is important to assess the impact of mammalian herbivory in this area. Increased understanding of the ecological interactions that take place on afforested sites will allow land managers to better implement silvicultural activities that best promote successful seedling establishment.

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