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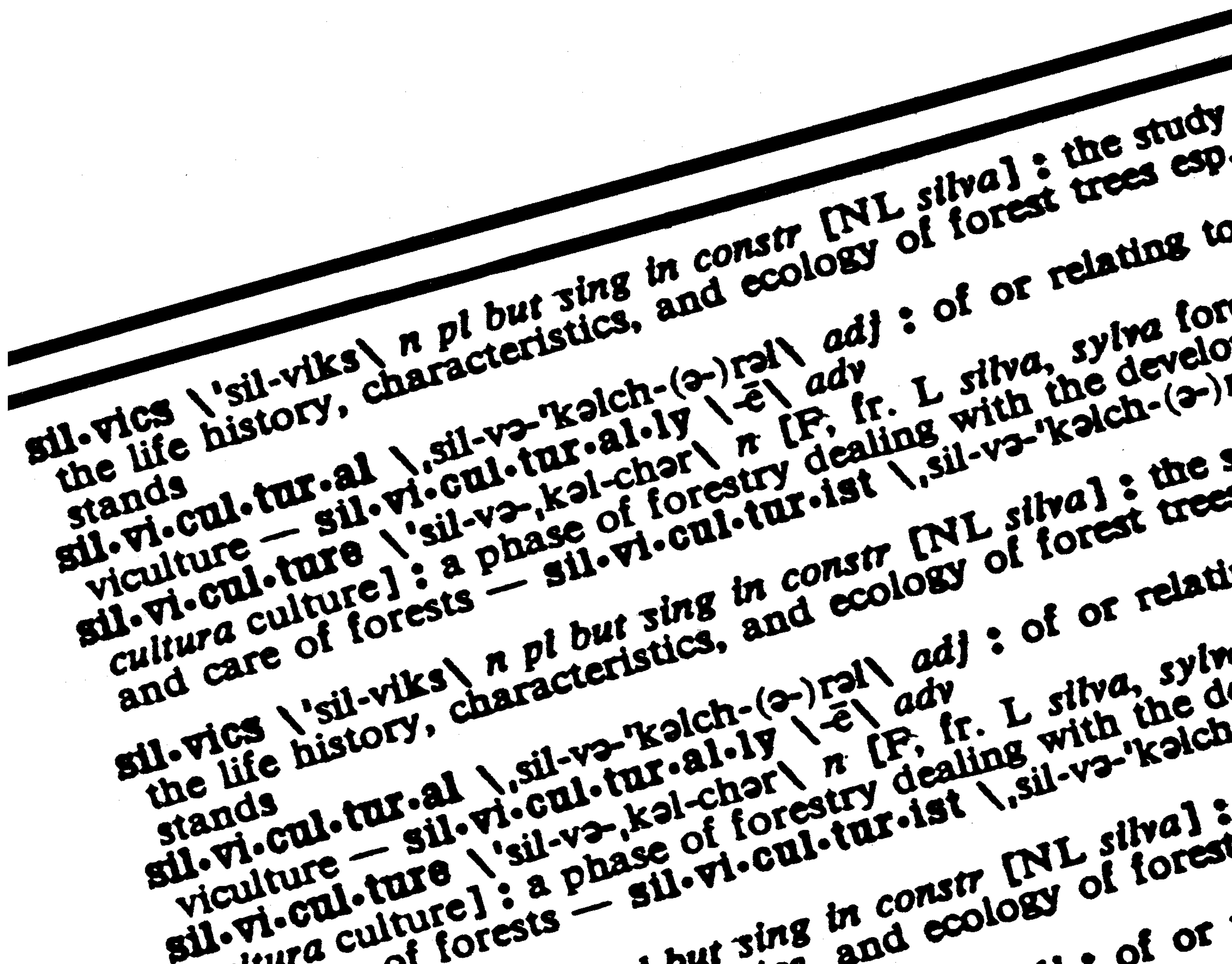

SUPPLEMENTAL PLANTING OF EARLY SUCCESSIONAL TREE SPECIES DURING BOTTOMLAND HARDWOOD AFFORESTATION

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Abstract—Reforestation of former bottomland hardwood forests that have been cleared for agriculture (i.e., afforestation) has historically emphasized planting heavy-seeded oaks (*Quercus* spp.) and pecans (*Carya* spp.). These species are slow to develop vertical forest structure. However, vertical forest structure is key to colonization of afforested sites by forest birds. Although early-successional tree species often enhance vertical structure, few of these species invade afforested sites that are distant from seed sources. Furthermore, many land mangers are reluctant to establish and maintain stands of fast-growing plantation trees. Therefore, on 40 afforested bottomland sites, we supplemented heavy-seeded seedlings with 8 patches of fast-growing trees: 4 patches of 12 eastern cottonwood (*Populus deltoides*) stem cuttings and 4 patches of 12 American sycamore (*Platanus occidentalis*) seedlings. To enhance survival and growth, tree patches were subjected to 4 weed control treatments: (1) physical weed barriers, (2) chemical herbicide, (3) both physical and chemical weed control, or (4) no weed control. Overall, first-year survival of cottonwood and sycamore was 25 percent and 47 percent, respectively. Second-year survival of extant trees was 52 percent for cottonwood and 77 percent for sycamore. Physical weed barriers increased survival of cottonwoods to 30 percent versus 18 percent survival with no weed control. Similarly, sycamore survival was increased from 49 percent without weed control to 64 percent with physical weed barriers. Chemical weed control adversely impacted sycamore and reduced survival to 35 percent. Tree heights did not differ between species or among weed control treatments. Girdling of trees by deer often destroyed saplings. Thus, little increase in vertical structure was detected between growing seasons. Application of fertilizer and protection via tree shelters did not improve survival or vertical development of sycamore or cottonwood.

INTRODUCTION

Throughout the world, and specifically within the southeastern United States, forested wetlands have been lost (Turner and others 1981, Noss and others 1995). Within the Mississippi River floodplain, over 7 million ha of bottomland hardwood forest have been lost (Knutson and Klaas 1998, Twedt and Loesch 1999). Most of this land is now used for agriculture, but continued intermittent flooding and unfavorable agricultural prices often result in marginal profitability. The uncertainty of financial return and concurrent environmental concerns associated with the loss of forested wetlands have prompted conservation initiatives to reverse the loss of forested wetlands throughout the United States and particularly within the Mississippi Valley (Lower Mississippi Valley Joint Venture Management Board 1990, Creasman and others 1992, Mueller and others 2000). Spurred by both economic considerations and increased awareness of the ecological and societal benefits afforded by forested wetlands, >180,000 ha currently in agricultural production are anticipated to be afforested within the Mississippi Alluvial Valley by 2005 (Stanturf and others 1998).

The ecology of bottomland hardwood forests reveals succinct successional progressions influenced by soil and hydrology (Hodges 1997) and high species diversity (Allen 1997). Despite the temporal and taxonomic diversity within bottomland hardwood forests, afforestation of bottomland sites on public lands and on private lands, through forest easements, has historically emphasized planting seedlings of heavy-seeded hardwood species such as oaks (*Quercus* spp.) and pecans (*Carya* spp.) or sowing seeds (acorns) of these species. Indeed, oaks and sweet pecan (*Carya illinoensis*) have been planted on nearly 80 percent of all afforestation in the Mississippi Alluvial Valley (King and Keeland 1999).

Planting predominantly oaks in bottomland restorations is intended to provide a "jump-start" for succession toward seasonally wet oak-hardwood forests (Kennedy and Nowacki 1997) that have oaks as dominant canopy species. This species selection has been justified because of high value of subsequent timber harvest, potential mast production for wildlife food, and an assumption that light-seeded species would naturally colonize these afforested sites. However, sites planted with only heavy-seeded species are slow to develop vertical forest structure, often requiring 7 to 10 years to emerge from the competing herbaceous vegetation. Vertical forest structure is a key predictor of colonization by forest breeding birds (Twedt and Portwood 1997, Wilson and Twedt In Press).

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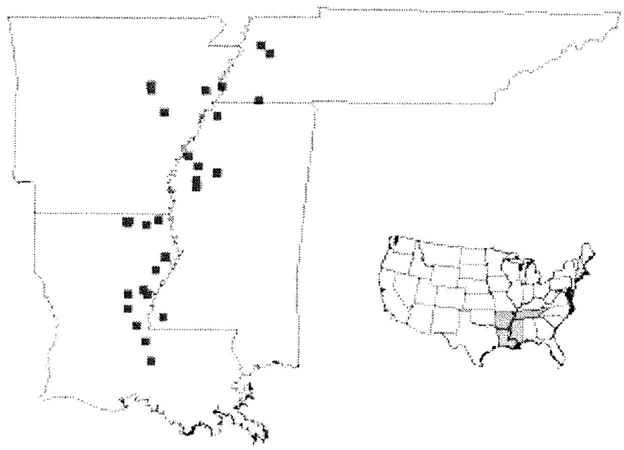

Figure 1—Location of afforested study sites in which we provided supplemental patches of fast-growing trees to enhance habitat for forest birds.

When distance from existing seed sources (i.e., mature trees) is >100 m, woody species (both light- and heavy-seeded) are insignificant invaders (Allen 1990, Wilson and Twedt In Press). This is particularly true in some areas of the Mississippi Alluvial Valley where afforestation occurs several km from extant forests and in areas no longer subject to periodic inundation from flood events that transport seeds. Lack of naturally invading early-successional tree species further restricts the development of vertical forest structure. Under these time and distance constraints, afforested sites may remain inhospitable to colonizing forest avifauna for up to 20 years.

A further limitation on the rapid growth of trees on afforested sites is that typically no weed control is provided for these plantings. The lack of weed suppression, or any other intermediate silvicultural management, has been attributed to limited financial and personnel resources. However, substantial competition from weeds may induce significant mortality of some species of fast-growing trees (Ezell 1994). Given their inability to provide weed control, managers are reluctant to risk increased tree mortality by planting susceptible species.

Regardless of which tree species are planted, species must be compatible with on-site edaphic and hydrologic conditions. However, with species selections that match site conditions, we believe that afforestation that incorporates fast-growing tree species is more conducive than historical afforestation practices to colonization by forest birds (Twedt and Portwood 1997, Twedt and Portwood, in press). Production of short-rotation woody crops, "under-planted" with other forest species, is one agroforestry option that rapidly produces forest conditions. Intercropping or alley cropping (i.e., growing agricultural crops between tree rows) using wide (> 12 m) alleyways represents another transitional agroforestry management option that is particularly suitable for converting large areas of cropland to forest. However, many land managers are reluctant to adopt these progressive methods of afforestation because of (1) an erroneous (in our opinion) perception that the tree species commonly used in agroforestry are not beneficial to wildlife, (2) continued belief that light-seeded species will naturally colonize afforested sites, and (3) lack of resources to ensure adequate weed control for newly established trees. As a compromise step that could provide limited vertical development within sites afforested using traditional methods, we supplemented oak-dominated plantings on bottomland sites with a series of systematically distributed patches of fast-growing trees.

Through the addition of small patches (100 m^2) of eastern cottonwood (*Populus deltoides*) and American sycamore (*Platanus occidentalis*) we sought to promote more rapid development of vertical forest structure and more quickly provide elevated sites for avian perches and nest platforms. We predict that providing rapid vertical structure for perching and breeding birds will increase the recruitment of woody species that use birds as vectors for seed dissemination and promote more rapid colonization of afforested sites by forest birds.

Within this paper, we assess the survival and development of supplemental planted cottonwood and sycamore after their first and second growing seasons. Additionally, we assessed the effect of fertilization, four methods of weed control applied at planting, and tree shelters on tree survival and development.

METHODS

Our study sites were agricultural fields, within the Mississippi Valley and adjacent bottoms, scheduled to be afforested during winter of 1997-98 or 1998-99. All study sites formerly supported bottomland hardwood forests. Each site was planted predominately to oak following traditional afforestation practices of the U.S. Fish and Wildlife Service and USDA Natural Resources Conservation Service. However, because restoration philosophies differed among land managers and because of different soil and hydrology, additional species were planted on some sites and included sweet pecan (*Carya illinoensis*), baldcypress (*Taxodium distichum*), persimmon (*Diospyros virginiana*), or green ash (*Fraxinus*

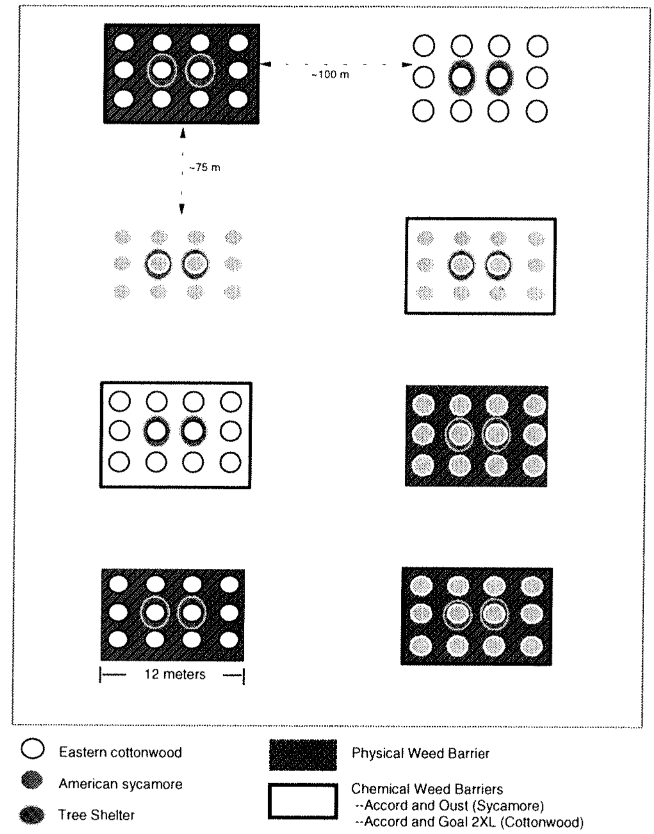

Figure 2—General distribution of 8 randomly assigned treatments (2 tree species x 4 weed control methods) applied to afforested study sites to assess the effect of small patches of fast-growing trees within oak dominated plantings.

pennsylvanica). We planted supplemental tree patches on a total of 40 sites (21 during 1998 and 19 during 1999; figure 1). Sites were disked or mowed before afforestation.

On all treated sites, we randomly applied different treatments to 8 systematically distributed patches using a 2 x 4 factorial design (2 tree species x 4 weed control methods). Our objective was to apply these treatments to patches that were at least 50 m from field edges and 100 m apart (figure 2). However, restrictions imposed by field size and dimensions often reduced between patch distance: the minimum distance between patches was 60 m.

Within each of the 8 treatment patches, we planted 12 trees in a 3-tree by 4-tree grid (figure 2). Trees were 4m apart within this planting grid. Eastern cottonwood was planted in 4 of the 8 patches whereas the other 4 patches were planted with American sycamore. These species were selected because they are often found on bottomland sites during early-succession, and because their use in agroforestry within the Mississippi Alluvial Valley made planting stock readily available. Planting stock was obtained from commercial pulpwood producers (Crown Vantage and Westvaco). We planted 30 centimeter (Crown Vantage) and 45 centimeter (Westvaco) stem cuttings of eastern cottonwood and 1-year-old, bare-root seedlings (Westvaco) of American sycamore. Sycamore seedlings were planted to the root collar as they were growing in the seedbed. All cottonwood stem cuttings planted on a site were from the same source (Crown Vantage or Westvaco) and were vertically inserted into the ground such that 1 to 3 inches were emergent with dormant buds facing up.

Because survival of these fast-growing species is likely enhanced when competition from weeds is reduced (Krinard and Kennedy 1987), we compared the effect of 4 different levels of weed protection. The 4 weed control treatments were: (1) no weed control, (2) physical weed barriers using commercially available wood fiber mats (RTI Mulch Mats, Reforestation Technologies International) or landscape fabric weed barriers (VisPore® Tree Mats, Treessentials Company), (3) single application chemical weed control at planting following practices used and recommended by industrial pulpwood producers, and (4) combined physical and chemical weed control.

On 24 afforested sites (19 during 1997-98 and 5 during 1998-99) we used both wood fiber and landscape fabric weed barriers. Within the patches that received physical weed control or both physical and chemical weed control on these 24 sites, we protected one-half the trees (6 trees) using wood fiber mats and the other half were protected using landscape fabric barriers. We used only landscape fabric barriers on the remaining 16 afforested sites.

Chemical weed control for cottonwood consisted of a single spray at planting of a glyphosate contact herbicide [Accord®] applied at a rate of 64 ounces/acre and a pre-emergent herbicide [Goal 2XL®]) applied at a rate of 64 ounces/acre. A similar dual herbicide treatment was applied to sycamore patches but the pre-emergent herbicide was Oust® applied at a rate of 4 ounces/acre. Pre-emergent herbicides differed between treatments because of industry recommendations and label restrictions. Herbicides were applied only to the vicinity of the planted patches and a small (~ 4 m) buffer. This application resulted in only about 0.1 ha per site treated with herbicide.

Because our objective was to achieve rapid vertical growth of planted trees, we fertilized all supplemental trees on 23 randomly selected sites. On these sites, we buried a 10 g fertilizer packet (18-6-6) or 10 g fertilizer tablet (20-10-5) adjacent to each planted tree.

Additionally, during 1998-99, we attempted to further enhance growth and survival by placing 1-m-tall (3-ft) Supertube® tree shelters (Treessentials Company) around 2 trees within each supplemental patch of trees. The lower edge of each tree shelter was below ground level and they were held upright by 1.2 m tall bamboo stakes.

We assessed survival and development of supplemental trees after 1 and 2 growing seasons. During these assessments, we classified each tree as alive or dead. For each live tree, we measured basal diameter to the nearest

Table 1—Survival (percent), height (centimeters), and basal diameter (millimeters) of American sycamore (*Platanus occidentalis*) and eastern cottonwood (*Populus deltoides*) planted in supplemental patches on afforested bottomlands during 1998-1999 and 1999-2000

Survival or size	Cottonwood	Sycamore
1st Year Survival	24.8 ± 4.6	47.0 ± 4.7
1st Year Height	83.0 ± 2.4	74.7 ± 1.1
1st Year Basal Diameter	14.4 ± 0.3	11.7 ± 0.1
2nd Year Survival of trees alive after 1 year	52.0 ± 6.8	76.9 ± 4.4
2nd Year Height	112.7 ± 3.3	109.2 ± 1.6
2nd Year Basal Diameter	21.8 ± 0.5	16.9 ± 0.3
Survival of re-planted trees	9.1 ± 2.6	35.8 ± 5.8
Survival of all trees after 2 growing seasons	19.0 ± 4.0	44.3 ± 5.3

millimeter and tree height (highest live bud) to the nearest centimeter.

We replanted tree mortalities using subjective criteria within which we attempted to ensure >1 live tree within each supplemental patch within the limitations of available planting stock. Survival of replanted trees was assessed after 1 year (i.e., after the second growing season for the original plantings) but data were maintained separate from data on our original plantings.

ANALYSIS

Mean percent tree survival, mean tree height, and mean basal diameter were compared between fertilizer treatments and among the 8 species-weed control treatments using a split plot analysis of variance (ANOVA). The 40 planted fields were the experimental units for comparing fertilizer treatments (WHOLE PLOTS) whereas the 8 patches of supplemental trees (SPLIT PLOTS) within each field were the experimental units for comparing species and weed treatments (2 species x 4 weed treatments x 40 sites = 320 experimental units). Individual trees within each planted patch were sub-sample units within these experimental units. Thus mean height, mean diameter, and proportion of trees surviving within each patch were the statistics compared. We applied an angular transformation to proportion data before subjecting to ANOVA.

We wrote specific contrast statements within the context of the ANOVA to compare between tree species and among the weed control treatments within each tree species. We assessed the effect of weed control treatments within each of the 2 tree species by writing contrast statements to compare (1) no weed control vs. the mean of the 3 weed control treatments and (2) chemical weed control vs. physical weed barriers. Additional contrasts were made based on the results of these comparisons.

We used separate analyses to compare weed barrier types and tree shelters. To compare weed barrier types we used only data from the 96 patches where we applied both landscape fabric weed barriers and wood fiber mulch mats. Similarly, we used data only from sites where tree shelters were deployed to compare survival and height of trees with and without shelters. Because survival data were categorical, and because the few trees treated within any individual patch (6 trees for barriers, 2 trees for shelters) made computation of proportion survival estimates unreliable, we used logistic regression to compare survival between weed barrier types and between tree shelter treatments. Thus, we assumed weed barrier types and tree shelters were randomly assigned to individual trees. However, we compared tree heights between weed barrier types and between tree shelter treatments using ANOVA wherein barrier type and shelter treatment were SPLIT plots within each species-weed control treatment patch.

RESULTS

After two growing seasons, the mean number of surviving supplemental trees of the 96 originally planted was 26.6 ± 3.6 per site. Five sites had no surviving trees and five additional sites had <10 live trees. The maximum number of surviving trees on any site was 81. Two sites were

Table 2—Mean survival (percent), tree height (centimeters), and basal diameter (millimeters) of eastern cottonwood (*Populus deltoides*) subjected to no weed control (None), physical weed barriers (Physical), herbicide treatment of Accord and Goal 2XL (Chemical), or a combination of physical weed barrier and herbicide (Both) treatments when planted in supplemental patches on afforested bottomlands during 1998-1999 and 1999-2000. Second year survival is with respect to those trees that were alive after one growing season. Height and basal diameter are of live trees

Survival or Size	None	Physical	Chemical	Both
1st Year Survival	17.5 ± 4.5	29.6 ± 5.5	26.5 ± 4.8	25.6 ± 4.9
1st Year Height	66.5 ± 9.2	75.4 ± 8.0	71.2 ± 9.0	79.9 ± 8.8
1st Year Basal Diameter	12.2 ± 1.4	13.6 ± 1.3	12.6 ± 1.5	13.7 ± 1.2
2nd Year Survival	47.8 ± 10.3	64.5 ± 8.4	53.9 ± 8.4	54.4 ± 7.4
2nd Year Height	81.7 ± 12.9	85.0 ± 10.2	94.8 ± 10.5	103.2 ± 14.2
2nd Year Basal Diameter	18.2 ± 1.6	18.2 ± 1.3	18.5 ± 1.3	20.8 ± 1.5

Table 3—Mean survival (percent), tree height (centimeters), and basal diameter (millimeters) of American sycamore (*Platanus occidentalis*) subjected to no weed control (None), physical weed barriers (Physical), herbicide treatment of Accord and Goal 2XL (Chemical), or a combination of physical weed barrier and herbicide (Both) treatments when planted in supplemental patches on afforested bottomlands during 1998-1999 and 1999-2000. Second year survival is with respect to those trees that were alive after one growing season. Height and basal diameter are of live trees.

Survival or size	None	Physical	Chemical	Both
1st Year Survival	48.8 ± 6.4	64.2 ± 6.0	34.8 ± 5.6	40.2 ± 5.4
1t Year Height	69.2 ± 4.1	76.9 ± 4.4	62.3 ± 6.4	59.4 ± 3.9
1st Year Basal Diameter	9.9 ± 0.4	12.0 ± 0.4	10.5 ± 0.8	11.3 ± 0.5
2nd Year Survival	76.7 ± 6.6	87.7 ± 3.8	57.2 ± 8.3	78.7 ± 5.9
2nd Year Height	94.3 ± 8.0	108.9 ± 7.1	91.4 ± 8.1	98.0 ± 4.9
2nd Year Basal Diameter	13.8 ± 0.9	17.1 ± 1.0	14.5 ± 1.2	15.6 ± 0.9

considered complete failures after the first year and were not revisited after the second growing season.

Fertilizer

Application of fertilizer did not effect tree survival ($F_{1, 38}$ = 2.01, P = 0.16), tree height ($F_{1, 38}$ = 1.01, P = 0.32), or tree basal diameter ($F_{1, 38}$ = 1.84, P = 0.18) after the first growing season. This effect of fertilizer application was consistent among the 8 factorial treatments with regard to tree survival ($F_{7, 266}$ = 0.77, P = 0.61), tree height ($F_{7, 214}$ = 1.02, P = 0.42), and tree basal diameter ($F_{7, 214}$ = 1.64, P = 0.13). The mean proportion of surviving trees after the first growing season was 0.43 ± 0.02 (x ± SE) when unfertilized and 0.31 ± 0.02 when fertilized. Tree height, however, was 60.9 ± 3.3 centimeter without fertilizer and 70.3 ± 2.9 centimeter with fertilizer. Similarly, tree basal diameter was 10.6 ± 0.5 millimeter without fertilizer and 12.0 ± 0.5 with fertilizer. Although not statistically significant, the greater height and basal diameter of fertilized trees suggested that fertilization was having a biological effect. If so, this effect was not accentuated during the second growing season. Neither tree height ($F_{7, 151}$ = 0.58, P = 0.45) nor tree basal diameter ($F_{7, 151}$ = 0.01, P = 0.93) differed between fertilizer treatments after 2 growing seasons.

Tree Species

We found significant differences in survival between tree species ($F_{1, 266}$ = 62.7, P < 0.01) with 0.47 ± 0.05 American sycamore and 0.25 ± 0.05 eastern cottonwood surviving after the first growing season (table 1). Of the trees that survived the first growing season, 0.77 ± 0.04 of the sycamore remained alive after 2 growing seasons whereas only 0.52 ± 0.07 of the cottonwood survived the second growing season (table 1). Survival of 331 replanted sycamores (0.36 ± 0.06) was markedly greater than survival of 587 replanted cottonwoods (0.09 ± 0.03) (table 1). After two growing seasons, a total of 741 sycamores and 323 cottonwoods remained alive within supplemental patches.

Despite differences in survival between tree species, mean tree height did not differ between species after either the first ($F_{1, 163}$ = 0.08, P = 0.78) or second ($F_{1, 151}$ = 3.70, P = 0.06) growing season (table 1). However, cottonwood had greater basal diameters than did sycamore after the first ($F_{1, 163}$ = 3.96, P = 0.03) and second ($F_{1, 151}$ = 15.90, P < 0.01) growing seasons (table 1). Mean tree heights increased for both species between the first and second growing seasons (table 1). However, the maximum tree height attained by any tree of 3.0 meters after 1 growing season did not increase after the second growing season (3.0 meters).

Weed Control Treatments

Weed control near cottonwood (table 2) had a positive effect on their first year survival ($F_{1, 266}$ = 6.57, P = 0.01) but did not effect mean tree height ($F_{1, 163}$ = 2.40, P = 0.12) or mean basal diameter ($F_{1, 163}$ = 0.99, P = 0.32). Similarly, second year survival of cottonwood (table 2) was greater with weed control then without weed control ($F_{1, 266}$ = 5.12, P = 0.02) but weed control did not influence second year height ($F_{1, 151}$ = 0.76, P = 0.39) or diameter ($F_{1, 151}$ = 0.33, P = 0.56). Physical and chemical weed control afforded similar survival to cottonwood ($F_{1, 266}$ = 0.58, P = 0.45) and resulted in similar heights ($F_{1, 163}$ = 0.32, P = 0.57) and basal diameters ($F_{1, 163}$ = 0.39, P = 0.53). Further, we detected no synergistic effect of the combination of chemical and physical weed protection on first year survival ($F_{1, 266}$ = 0.23, P = 0.63).

For sycamore, the mean survival of patches with weed control (table 3) did not differ from survival of untreated controls after the first growing season ($F_{1, 266}$ = 0.35, P = 0.55) nor after the second growing season ($F_{1, 266}$ = 0.01, P = 0.91). However, this apparent lack of benefit from weed control was the indirect result of extreme differences in survival between physical weed barriers and chemical weed control (($F_{1, 266}$ = 27.03, P < 0.01). Indeed, treatments that employed chemical weed control on sycamore significantly increased tree mortality over treatments where no herbicide was used ($F_{1, 266}$ = 22.69, P < 0.01). In contrast, physical weed barriers increased tree survival compared to untreated controls ($F_{1, 266} = 6.97$, $P < 0.01$).

For surviving sycamore, neither height ($F_{1, 163} = 0.06$, $P = 0.80$) nor basal diameter ($F_{1, 163} = 3.39$, $P = 0.07$) differed between the mean of all weed control treatments and the untreated control (table 3). However, in addition to limiting survival, chemical weed control reduced tree height (table 3) compared with patches of sycamore where no chemical was applied.

Weed Barrier Type

Tree survival was similar ($x^2 = 0.34$, $P = 0.56$) for trees protected by wood fiber mulch mats (44 percent) and for trees protected by landscape fabric weed barriers (42 percent). Similarly, mean tree height did not differ ($F_{1, 54} = 0.73$, $P = 0.40$) between trees protected with wood fiber mats (68.3 ± 3.5 centimeters) and those protected by landscape fabric barriers (67.5 ± 3.9 centimeters).

Tree Shelters

Unexpectedly, survival of trees protected with tree shelters was significantly decreased ($x^2 = 105.55$, $P < 0.01$) by the addition of tree shelters. Only 26 percent of trees in shelters survived compared to 33 percent of trees that were not protected. Moreover, for those trees that did survive the first growing season, protection within tree shelters did not result in a significant increase in height over unprotected trees ($F_{1, 48} = 0.31$, $P = 0.57$). After one growing season, the mean height of trees protected by shelters was 85.8 ± 5.8 centimeters whereas mean height of unprotected trees was 76.6 ± 4.1 centimeters.

DISCUSSION

Drought conditions prevailed during the growing season of the 3 years of this study. Long-term average rainfall for April-September in the Mississippi Alluvial Valley at Baton Rouge, LA is 82 centimeters. During our study, rainfall for this 6-month period was 58, 59, and 43 centimeters in 1998, 1999, and 2000, respectively. Physical weed barriers not only limited competition with weeds for moisture but also helped to reduce moisture loss to the atmosphere. However, even with weed protection, survival of supplemental trees, especially cottonwood was below our expectations.

On sites where survival was adequate, vertical development of both species did meet our expectations. In particular, cottonwood on several sites approached 3 m (10 ft) in height after the first growing season. Unfortunately, these were generally the only vertical substrates within these fields and thus, they were used extensively by white-tailed deer (*Odocolyis virginiana*) for browsing and more detrimentally as rubs for their antlers. Rubbing against these saplings invariably removed the cambium and thereby girdled the trees. Thus, during the next year, shoots developed from below the girdled area (usually about 1 meter from the ground). In addition to starting re-growth far below the previous terminal bud, girdling produced multiple competing stems. Because multiple stems compete for resources, vertical development of any single stem was reduced. Thus, our expectation of greatly increased vertical development during the second growing season was not realized.

Because sycamores tended to be smaller and developed many more lateral branches during their first growing season, deer rubbing of sycamore was not a significant problem after the first growing season. However, after 2 growing seasons, sycamores were incurring the same damage from deer rubbing that cottonwoods previously received. Furthermore, it appears that girdling of stems by deer will continue to be a recurring problem during tree dormancy.

The effect of chemical weed control on sycamore survival varied among sites but complete mortality of all trees and herbaceous vegetation within patches treated with Oust was not uncommon. We recalibrated spray equipment, verified application rate prior to planting, and took care to avoid spraying directly on planted seedlings during the second year of our study but increased mortality of sycamore within treated patches persisted. Soil conditions, particularly soil PH, likely contributed to the excessive mortality of sycamore associated with herbicide treatment.

Although we had hoped for greater survival of supplemental trees, we believe that the >10 trees that survived on 30 of our 40 study sites will be adequate to assess the effect of this technique on woody species diversity and avian colonization. An additional set-back was the small increase in vertical development after the first growing season. However, surviving trees likely have established root systems and substantial increased growth is likely during the next 3 years. As we do not plan to evaluate woody species diversity or bird response until 5 or 6 years after establishment, this time frame should be sufficient to provide supplemental trees that are well above the herbaceous vegetation and much taller that the trees planted via traditional afforestation methods. Indeed, observations by the author (DJT) indicate that supplemental patches are obvious anomalies within these otherwise homogeneous fields. Additionally, several bird nests, including at least one shrub nesting species (Orchard Oriole [*Icterus spurius*]), were built in supplemental trees during their second growing season. Therefore, we are hopeful that provision of these few supplemental patches of fast-growing trees within the context of large afforested sites will attract forest birds and ultimately will yield a more species rich forest at maturity.

RECOMMENDATIONS

When extending this concept from research to operational afforestation practice, we recommend increasing the number of species that are candidates for placement in small patches. Additional species that could be planted in supplemental patches include: honey locust (*Gleditsia triacanthos*), yellow poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), or where non-native species are acceptable, royal paulownia (*Paulownia tomentosa*). Because we planted eastern cottonwood and American sycamore on all study sites, we made no attempt to ensure tree species compatibility with soil type or hydrology. However, planting only species that are compatible with site conditions should increase tree survival.

To increase the likelihood that some trees will survive within each supplemental patch, we recommend planting 2 or more tree species within each patch. Further, we recommend providing protection from weed competition through use of weed barriers. Planting more than 12 trees within a patch, for example 18 or 24 trees, increases the probability that at least some of these trees will be overlooked by deer and will exhibit substantial height increases between years.

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