Observational Assessment of the Effects of Tree Shelters on Growth and Survival of Bottomland Saplings

Barrett Vaughan
Assistant Professor

Ronald C. Smith
Forester

Ramble Ankumah
Professor and Assistant Dean
Academic Affairs

Tuskegee University
College of Agriculture
Environment and Nutrition Sciences (CAENS)
110B Henderson Hall
Tuskegee, AL 36088, USA

Abstract

Bottomland hardwood and conifer saplings, primarily oaks, planted with and without tree shelters in an Alabama created, mitigation wetland were assessed for survival and height after two years of growth. The assessment included trees planted with shelters and a field inventory of areas with where trees were planted without shelters. Three shelter lengths were observed: 0.76-m (30-in.), 0.91-m (36-in.), and 1.52-m (60-in.). The survival rates for trees planted with the 0.76-m, 0.91-m, and 1.52-m shelters were 83%, 94%, and 98%, respectively. The average heights were 0.85 m (34 in.), 0.96 m (38 in.), and 1.75 m (69 in.), respectively. The use of a longer shelter was also found to promote growth beyond the shelter. For the trees planted without tree shelters, a survival rate between 39% and 48% was found. The height of these unsheltered trees varied between 0.30 m (12 in.) and 0.91 m (36 in.), depending on competition.

Keywords: Oak, wetland, length, tree tube, Alabama

1. Introduction and Background

The use of tree shelters has been shown to be effective in improving the rates of survival, growth, and health of saplings since the first studies began over a quarter of a century ago (Tuley 1985). Researchers have reported that these translucent plastic tubes provide saplings the benefits of protection from wind, thereby creating a favorably warm and humid microclimate, and, as importantly, protection from animal browsing (Potter 1988; 1989). Tree shelter use has also been shown to reduce forest management requirements and improve forest aesthetics (Potter 1989; Kerr 1996).

Many studies have shown the effects of planting saplings with tree shelters in comparison with planting without shelters. In a two-year study in Britain with sessile oak, tree shelters promoted an over five-fold increase in height growth and a greater stem diameter and volume (Tuley 1985). A study in North Carolina used shelters with white oak, chestnut oak, and northern red oak, and, over a two-year period, observed a survival rate of 94% with shelters versus a 31% survival rate without (Manchester et al. 1988). Similarly, in a study in southern New England with northern red oak, tree shelters yielded a greater height growth albeit with less diameter growth (Kittredge et al. 1992). In a long-term study with hardwoods in Missouri, tree shelters were observed to produce much larger and healthier trees in a multitude of aspects including survival, stem growth, dry weights, and foliar nutrition (Ponder 1995; 2003).

In Alabama, tree shelters were studied with eleven commonly-used, urban shade tree species, which included five oaks—sawtooth oak, white oak, nuttall oak, swamp chestnut oak and northern red oak. After two years, the study yielded survival rates of 85% for sheltered seedlings versus 56% for non-sheltered seedlings. The vast majority, 82%, of the mortalities occurred within the first year. In addition, tree shelters increased the height growth of all five oak species and three others (West 1997; West et al. 1999).

Tree shelters have also been shown to aid trees in surviving environmental stresses. In terms of insects and diseases, a study with oak in New Hampshire showed that even though trees with shelters were more susceptible to attacks, greater height growths were still observed (Allen 1994). In tropical saline soils in Australia, a setting which is potentially not supportive of growth, tree shelters were shown to increase survival and growth in a nine-month study with river red gum (*Eucalyptus camaldulensis*) (Sun et al. 1994).

Tree shelter use has also been studied in combination with other tree culture technologies such as fertilization and weed or brush control. The studies have shown a variety of effects of tree shelters with respect to the other technologies. Forest irrigation with nutrient-rich papermill sludge has been studied in conjunction with tree shelters in Virginia with American sycamore and in Ohio with white ash, sycamore, and walnut (Torbert and Johnson 1993; Kost et al. 1997). The Virginia study showed that the irrigation accompanied with tree shelters produced the lowest survival. This was due to the sludge staining the shelter, which blocked light transmission to the tree. Overall, however, tree shelters were shown to produce a significant increase in height (Torbert and Johnson 1993). In contrast, in the Ohio study, tree shelters were shown to produce greater survival and total height. These results prompted a recommendation that tree shelters be used to augment papermill sludge amendment (Kost et al. 1997).

Weed and brush control with herbicides has been studied in conjunction with tree shelters in Michigan and Pennsylvania with red oak, and in Alabama with cherrybark oak (Walters 1993; Lantagne et al. 1990; Dubois et al. 2000). In the Michigan study, tryclopr and oil were used as woody brush control with planted seedlings. This was found to have no effect on height of the planted seedlings. The tree shelters, however, were shown to significantly increase the height—2.5 times in the first year, and 1.8 times after the second (Walters 1993). In the Pennsylvania study, using glyphosate as the herbicide, seedlings and acorns were planted with shelters or fences. It was found that the tree shelter increased survival by 10 percent over the control (no shelter) due to the reduction of browsing. In comparison to fencing, however, the use of the shelter reduced light levels and consequently survival. This was significant in the cases without herbicide where the vegetation surrounding the shelter decreased the light further and cut the survival by half (Lantagne et al. 1990). Sulfometuron was used as the herbicide in an Alabama study on weed control and tree shelters, alone and in combination, versus a control. After two years, the differences in survival were not statistically significant. However, the use of tree shelters with the weed control was found to produce the largest seedling diameter, height, and stem volume growth (Dubois et al. 2000).

In several studies, different types of tree shelters have been evaluated to show the effects of differences in design, construction, and/or color. All these studies included trees grown without shelters as the control for the experiments, so such comparisons could also be made. A USDA Forest Service study in California compared vented and non-vented tree shelters with three oaks and one fir in irrigated and non-irrigated plots over one season. It was shown that the survival was 100% for the irrigated plots for both tree shelters. Both shelters were also roughly equal in terms of height and diameter increase, and consistently greater than the control (Costello et al. 1991). A study in Indiana compared two shelters with red oak seedlings: a shelter made from perforated, translucent, white plastic drainage tile, and a commercial, square, brown, translucent polypropylene tree shelter. The survival was not found to be different between the shelters or from the control. However, the height growth was greater for the shelters than the control, and a difference in interior light intensities between the shelters was observed (Minter et al. 1992). The USDA Forest Service also conducted a series of studies in West Virginia concerning plastic shelters used with red oak seedlings. One of the studies examined brown and white shelters and showed that the use of shelters increased survival by almost 20% and height almost three times. There were no significant differences in height or survival found between the two colors of shelter (Smith 1993). In a study in Australia, a translucent polyethylene tree shelter was compared with a perforated tin metal shelter with three tree species. The study showed no difference in survival between the shelters and the control. Although one species of tree grown in the polyethylene shelter had heights that were 23% greater than the control, it was concluded that neither shelter had any effect at all in this setting (Dunn et al. 1994).

White and tan shelters were evaluated in a study on northern red oak and eastern white pine seedling in Connecticut. Overall, the results showed that both shades of tree shelters significantly reduced browse damage and increased height growth. However, the white shelters were shown to transmit more light and thereby maintain desirably higher temperatures than the tan shelters, a difference which became more pronounced as the shelters aged (Ward et al. 2000). In a study in southwestern Colorado, four colors of tree shelter ranging from nearly clear to brown were tested with Englemann spruce. The survival percentages and total height growths with the three more transparent shelters were not different from each other, but greater than the brown shelter. It was concluded that though the shelters protected the seedlings from the external environment and gophers, a shelter that is too dark will not permit enough light to reach the tree (Jacobs and Steinbeck 2001). Black locust, honey locust, and honey mesquite in western Oregon were examined in a study with two tree shelters, a rigid plastic mesh tube and a solid plastic tube. The results showed that the solid plastic tube tree shelter increased the survival of all three species. In addition, the solid plastic tube tree shelter increased the height, diameter, and percentage of trees which had broken bud. These differences could be attributed to changes in the microclimate around the trees (Sharrow 2001).

The height, or length, of the shelter has also been evaluated to determine the effects of different shelter sizes. One of the earliest studies examined the effects of replacing 1.2 m tree shelters with either a 4.0 m tree shelter or no shelter on a small group of trees that had surpassed the 1.2 m height. The study, while not essentially comparing a 1.2 m shelter with a 4.0 m shelter, showed that the continued use of a shelter promoted increase height and diameter growth over the unsheltered trees (Tuley 1985). There are, however, several studies that have specifically shown the effects of tree shelter height. A study in Australia where 1 m, 2 m, and 3 m tree shelters were examined with red cedar seedlings showed greater height growths with the height of the shelter (Applegate and Bragg 1989).Another study in Australia evaluated 0.9 m, 1.9 m, and 2.9 m shelters used with four Australian tree species also found that increasing tree shelter length increased the height growth (Beetson et al. 1991). In California, a five-year study examined three different sizes of tree shelter, 0.6 m, 1.2 m, and 1.8 m, with blue oak. In terms of survival, the results showed no significant differences between the three sizes or the control. In contrast, the results also showed that greater heights were achieved with a greater size of shelter (McCreary and Tecklin 2001).The present study is an observational assessment of the effects of tree shelters in a comparatively uncontrolled environment. The site examined was a publicly-held and managed created mitigation wetland located in rural, northeastern Alabama. At this site, tree shelters were used with a small percentage of the trees that were planted in a nearly arbitrary fashion in terms of shelter length, location, and species. The authors were not involved in the planning process of the site because the relationship between our institution and the public agency began in 2003, two years after the planting. At that time, we inventoried the tree species on the site, natural and planted, with and without tree shelters.

2. Site Description and History

A tract of partially forested farmland located in northeastern Alabama was purchased by a public agency in 1999.The main purpose for the purchase was to create a wetland for mitigation banking. The wetland creation plan involved the construction of a dike and trench with outflow control structures around the approximately 182-hectare (450-acre) site. It also included the planting of conifer and broadleaf hardwood trees on about one third of the area. The planting of the trees was intended to establish the last stage of natural vegetative succession on the fields, as well as supply food and support for wildlife. The site lay in a valley and was intended to be used for wildlife recreation once established.

In 2001, about 61 hectares (150 acres) of the existing fields which were traditionally sown in a corn-soybean rotation were planted instead with 22,000 saplings. The saplings comprised the following tree species: red maple (*Acer rubrum*), shumard oak (*Querus shumardii*), sawtooth oak (*Querus acutissima*), water oak (*Querus nigra*), willow oak (*Querus phellos*), tupelo gum (*Nyssa sylvatica*), and bald cypress (*Taxodium distichum*) saplings. These species were chosen by the public agency because of their status as forested wetland or swamp species, and their ability to provide acorns or seeds, and habitat for wildlife. The planting of the saplings followed a scheme that included a large, small, and random spacing. The "large" spacing used for a majority of the area (~80%) was 9.1 by 9.1 meter (30 by 30 foot), in theory, a density of 120 trees per hectare (48.4 trees per acre).The "small" spacing used at the edges of the fields closest to the dike and trench, a road, or the forest (~5%) was three by three meter (ten by ten foot), in theory, a density of 1076 trees per hectare (436 trees per acre). Random spacing was used in certain fields and sections of fields (~15%).

The rest of the site remained forested with several natural species including red maple, willow, sweet gum, green ash, eastern red cedar, box elder maple, chalk maple, hickory, cottonwood, and winged elm. There were two areas on the site where saplings were planted with tree shelters. One area was a small field of about two acres surrounded by forest. The other area was a section of a larger planted field of about 52 acres. Approximately 400 to 600 of the 22,000 saplings were planted with Tubex brand tree shelters (Tubex Limited. http://www.tubex.com/tree.htm. November 2003.). Three lengths of tree shelters were used, 0.91-m (36-in.), 1.52-m (60-in.), and 0.76-m (30-in.). The 0.76-m shelters were not a standard size and were made by cutting 1.52-m tubes in half. The 0.91-m shelters were used in the small field, and the 0.76-m and 1.52-m shelters were used in the section of the larger field. The plant spacing in these areas followed the normal scheme. At the time of planting, a small number of the existing natural trees were also covered with the shelters.

3. Methods

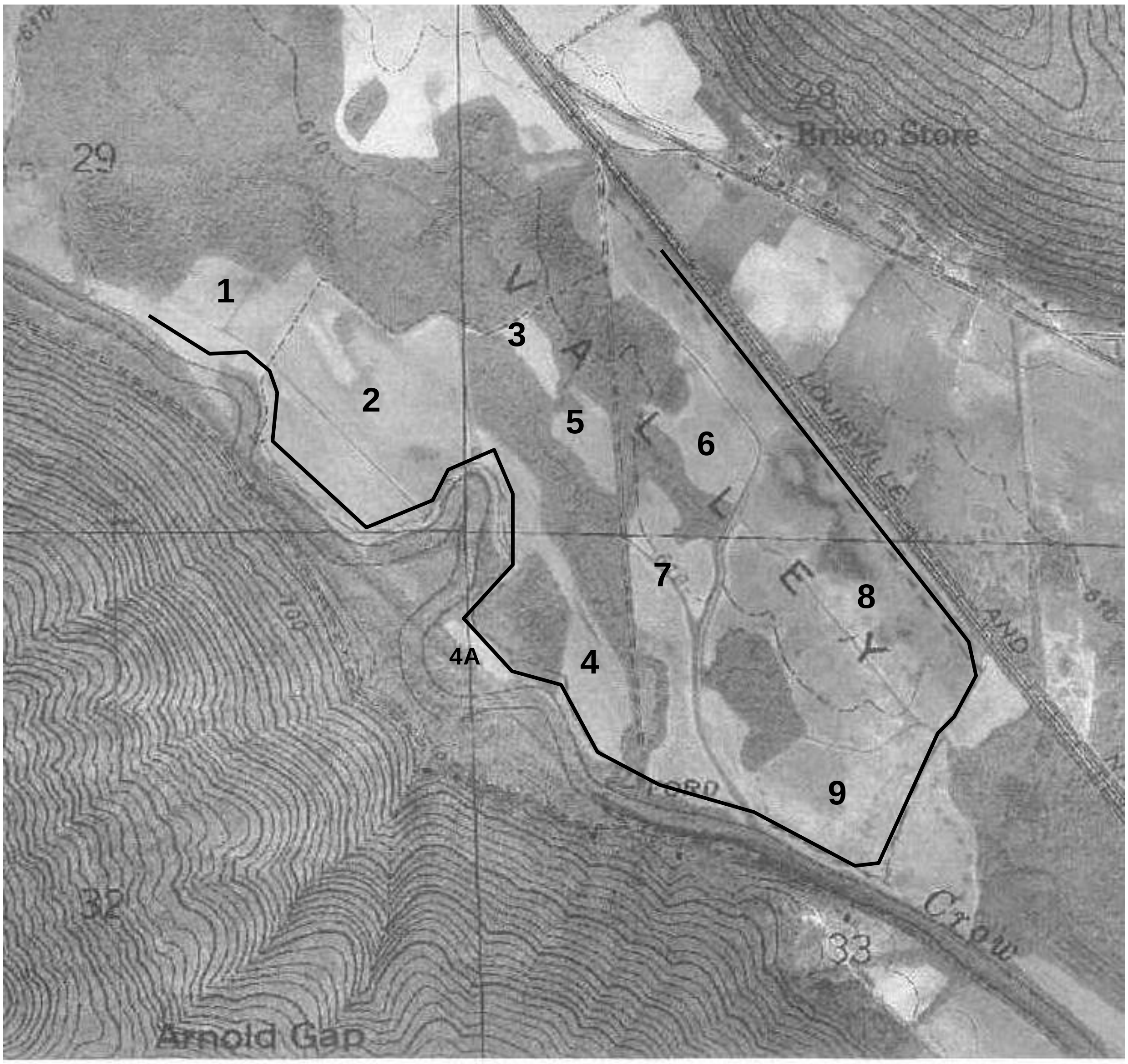

Figure 1. Aerial map of mitigation wetland site with field numbers and dike and trench outline (United States Geological Survey (USGS)).

An inventory was taken to determine the species, condition, density, and survival rate of the trees on the wetland site during the latter half of the summer of 2003. The initial step was to identify the planted areas on the site and assign them a number for identification (Figure 1). The two areas that were planted with tree shelters were Field 3 and a section of Field 2. There were seven areas identified and evaluated on the site that were planted without tree shelters (Fields 8, 9, 6, 2, 4, 4A, and 7). Trees that were planted with shelters were surveyed to determine the species, height, and condition of the saplings. A complete census of the 0.91-m shelters was accomplished in the small field, Field 3. An approximately 25 to 40 percent sample of the 0.76-m and 1.52-m tree shelters was completed at the section of the larger field, Field 2. A census of the 0.76-m and 1.52-m tree shelters was not performed due to inaccessibility. A total of 262 saplings with shelters were assessed: 46 0.76-m shelters, 162 0.91-m shelters, and 54 1.52-m shelters.

Trees that were planted without shelters in the fields were inventoried with circular plots spaced on a five-chain or 101-m (330-ft) grid in the seven planted fields. An approximately one-twenty-fifth hectare (one-tenth acre) plot or approximately one fiftieth hectare (one-twentieth acre) plot was inventoried for planted trees. In the inventory, the species, general growth and condition, and number of the trees were assessed. A total of 63 plots were taken, and the plant spacing was noted for each plot.

4. Results

4.1 Survival

For the total of 262 tree shelters surveyed, 244 were found to have live saplings (Table 1). The survival rates for the 0.76-m, 0.91-m, and 1.52-m shelters were 83%, 94%, and 98%, respectively. Using binary logistic regression analysis with the survival data, the survival for the 0.76-m tree shelter was found to be significantly different from those of the 0.91-m and 1.52-m tree shelters, which were not found to be significantly different. The analysis showed that the use of longer (0.91-m and 1.52-m) shelters increased the odds of survival by over 4 times that of the shorter shelter (0.76-m) ($p = 0.004$). In one-to-one comparison with the 0.91-m shelter, only 0.15 (6 in.) taller, the odds of survival increased three and a half times alone ($p = 0.014$). Another binary logistic regression analysis conducted to compare the survival between the two field locations, showed that the odds of survival between the two locations did not differ ($p = 0.289$).

Table 1. Numbers of the saplings with shelters assessed by species, condition, and shelter length.

	Total planted	Tree shelter length		
		0.72-m	0.91-m	1.52-m
Shumard Oak	125	8	85	32
Willow Oak	50	20	30	—
Sawtooth Oak	40	—	19	21
Water Oak	10	9	1	—
Other Species*	19	1	18	—
All Live Saplings	244	38	153	53
Dead Saplings	18	8	9	1
All Saplings	262	46	162	54

*Other species includes any non-oak planted sapling (bald cypress, black gum, and red maple), natural sapling (green ash, box elder maple, and sweet gum), or unidentified sapling.

4.2 Height

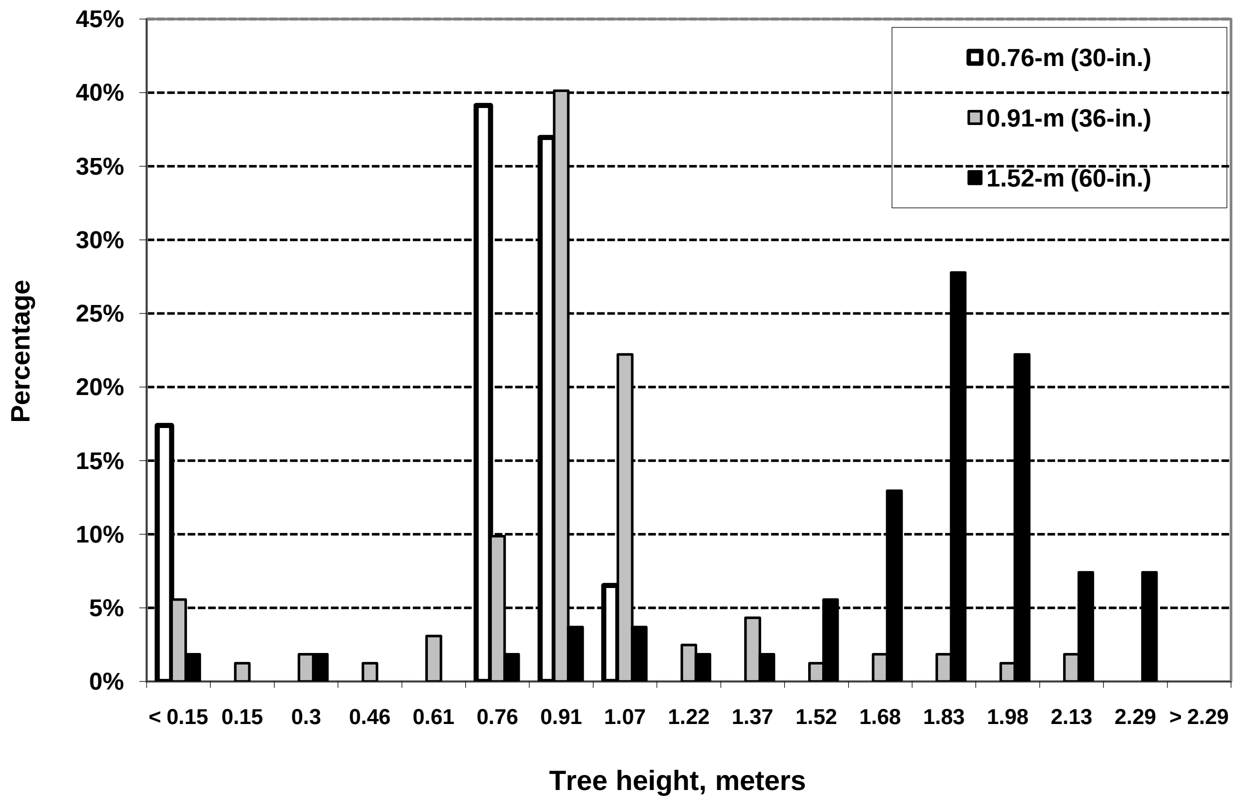

Figure 2. Relative frequency histogram of assessed tree height by tree shelter length.

The height for all saplings ranged from 0.15 m to 2.29 m (Figure 2). The average heights for the saplings in the 0.76-m, 0.91-m, and 1.52-m tree shelters were 0.85 m, 0.96 m, and 1.75 m, respectively (Table 2). This analysis included only the 237 surviving trees of planted species: 38 trees in 0.76-m shelters, 146 trees in 0.91-m shelters, and 53 trees in 1.52-m shelters. It excluded the natural or volunteer tree species, which were advanced in growth at the time of tree shelter emplacement.

Table 2. Average heights of the live planted saplings with shelters by species and shelter length.

	Tree shelter length		
	0.72-m	0.91-m	1.52-m
Shumard Oak	0.80	1.01	1.78
Willow Oak	0.88	0.95	—
Sawtooth Oak	—	0.89	1.70
Water Oak	0.83	0.91	—
Other Planted Species*	0.91	0.96	—
All Planted Saplings	0.85a†	0.96a	1.75b

* Other planted species includes any non-oak planted sapling (bald cypress, black gum, and red maple) or unidentified planted sapling.

† Average heights for all planted saplings followed by different letters are significantly different between the tree shelter lengths at p-values ≤ 0.05 by Tukey pairwise comparison.

The effect of tree shelter length and tree species on tree height were evaluated using a general linear model analysis of variance (without an interaction term) with Tukey pairwise comparisons. The heights were shown to be statistically different for the three tree shelter lengths ($p = 0.000$); however, the height was not shown to be different between the 0.76-m and 0.91-m tree shelters (adjusted $p = 0.2183$). In terms of the different planted species, the heights were not found to be statistically different between the nine species ($p = 0.420$).

4.3 Analysis of Growth Extending Past the Tree Shelter Height

This analysis yields the percentage of trees planted with tree shelters that had achieved a height sufficiently greater than the height of the tree shelter, more than 0.15 m (6 in.), at the time of inventory. This simple measure is an indication of the protection from predators, such as deer, and the microclimate environment provided by a certain length of tree shelter. For saplings planted in the 0.76-m tree shelters, 76% were found to have heights below or at the height of the tree shelter, with 7% sufficiently above the shelter. In terms of only live trees, 92% were found to be below or at the height, and 8% above the height. With the 0.91-m tree shelters, 80% of the saplings were found below or at the tree shelter height, and 15% were found sufficiently above—percentages of 84% below or at height, and 16% sufficiently above height for live trees. In comparison, for the 1.52-m tree shelters, 33% of the saplings were found below or at the height of the tree shelter, whereas 65% were found to be sufficiently above. Similarly, in terms of live trees in the 1.52-m tree shelters, 34% were found below or at height, and 66% were found sufficiently above the height (Figure 3).

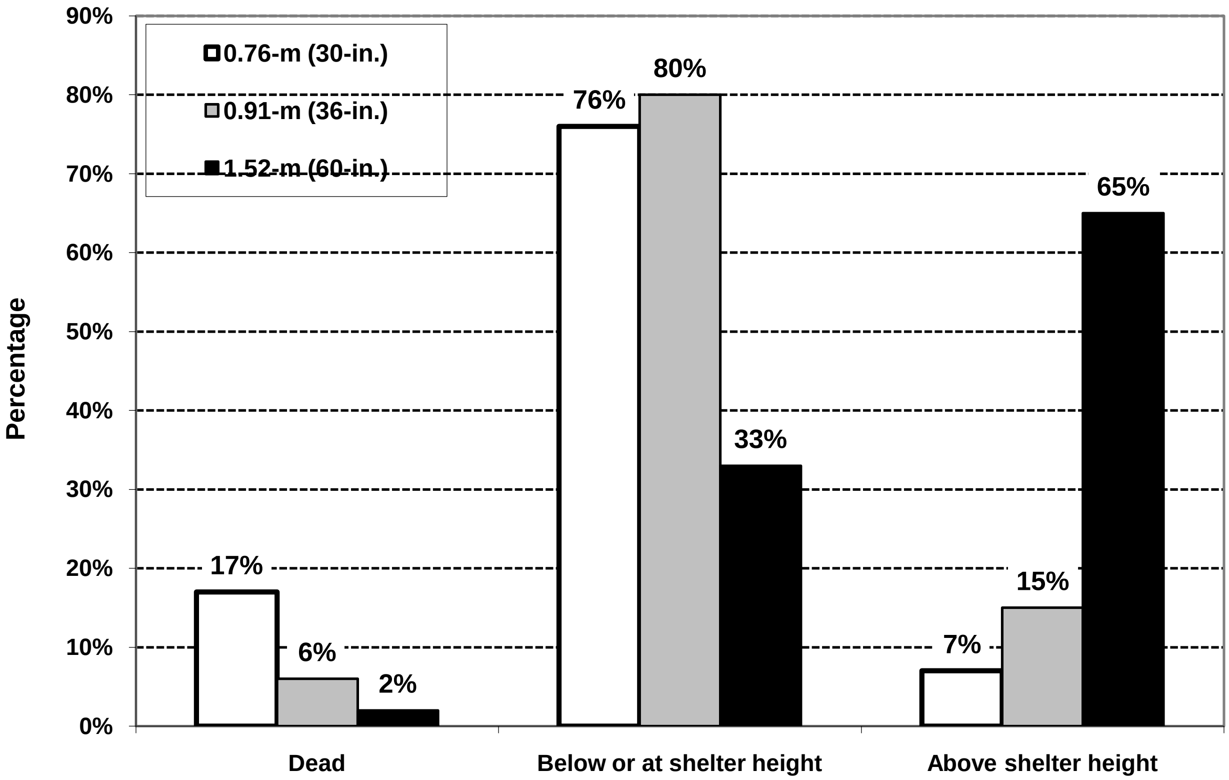

Figure 3. Percentages of sapling mortality and level of extended growth by tree shelter length.

4.4 Inventory of Trees Planted Without Shelters (Control Saplings)

Of the 63 plots inventoried in the field that were planted without using shelters, 47 plots were taken in “large” spacing (9.1 by 9.1 meters) areas, seven plots were taken in “small” spacing (three by three meters) areas, and nine plots were taken in random spacing areas. For the 47 plots taken in the “large” spacing areas, 13 plots were sized approximately one-twenty-fifth hectare, and 34 plots were sized approximately one-fiftieth hectare; a total of 1.21 hectares (3.0 acres) was assessed. Sixty-four planted trees were inventoried in the “large” spacing areas, yielding a density of 53 trees per hectare (21 trees per acre). For the seven plots taken in the “small” spacing areas, six plots were sized approximately one-twenty-fifth hectare, and one plot was sized approximately one-fiftieth hectare; a total of 0.26 hectare (0.65 acre) was assessed. Forty planted trees were inventoried in the “small” spacing areas, yielding a density of 152 trees per hectare (62 trees per acre). For the nine plots taken in the random spacing areas, seven were sized approximately one-twenty-fifth hectare, and two were sized approximately one-fiftieth hectare; a total of 0.32 hectare (0.80 acre) was assessed. Twenty-nine planted trees were inventoried in the random spacing areas, yielding a density of 90 trees per hectare (36 trees per acre).

4.5 Height and Estimated Survival of Trees Planted Without Shelters (Control Saplings)

The height of the trees planted without shelters was observed to vary between 0.30 and 0.91 meters. Trees were observed to have shorter heights particularly in those areas with denser vegetation. The estimated survival rate was calculated as the percentage of the initial planting density, which could be estimated from the known plant spacing. In theory, for the "large" spacing (9.1 by 9.1 meter), there would have been an initial density of 119.6 trees per hectare (48.4 trees per acre). Assuming a linear error of plus or minus five percent (as opposed to an area (planar) error, to correspond more with planting in rows), the initial density would have been between 108.5 and 132.5 trees per hectare (between 43.9 and 53.6 trees per acre). Similarly, for the "small" spacing (three by three meter), there would have been an initial density of 1076 trees per hectare (436 trees per acre). Again, assuming two perpendicular linear errors of plus or minus five percent, the initial density would have been between 976 and 1193 trees per hectare (between 395 and 483 trees per acre).

From the estimated initial density range (linear error ± 5%) for the "large" spacing (9.1 by 9.1 meter), with an inventory density of 53 trees per hectare (21 trees per acre), an estimated survival rate of 39% to 48% is calculated. From the estimated initial density range for the "small" spacing (three by three meter), with an inventory density of 152 trees per hectare (62 trees per acre), an estimated survival rate of 13% to 16% is calculated.

5. Discussion

This observational assessment found that the use of tree shelters increased the survival of saplings at this created mitigation wetland site. The survival rates found for the trees planted with shelters and without shelters were very similar to those found in the earlier two-year study conducted in Alabama (West et al. 1999). The findings were also similar to those from studies at other locations in the Southeastern United States (Manchester et al. 1988; Ponder 1995).

There also was observed a greater increase in height of the saplings using the shelter over using no shelter, and a greater increase with the length of the tree shelter. This finding was also similar to other previous studies where different sizes of shelters were used (Applegate and Bragg 1989; Beetson et al. 1991; McCreary and Tecklin 2001). These results were concluded here to be due to the protection and climate provided by the shelter, and the benefits were proportionate to the shelter length.

In addition, the analysis of growth extending past the tree shelter height showed a greater incidence of growth extension with the use of a longer tree shelter. In fact, the longer shelters were observed to have less browsing and bunching of the leaves within the shelter. The use of the shorter shelter was beneficial in terms of promoting survival over planting without a shelter, but the amount of growth (the height) was usually not much greater than the height of the shelter itself (Figure 4).

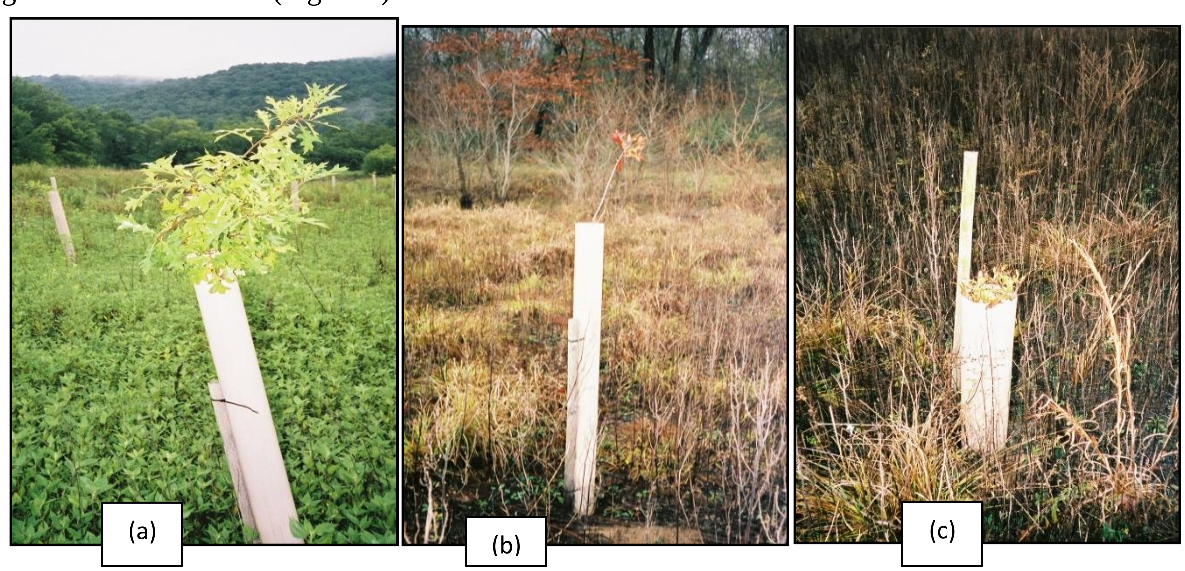

Figure 4. (a) Sapling with height extending past the top of a 1.52-m (60-in.) tree shelter during the growing season. (b) Sapling with height extending past the top of a 1.52-m (60-in.) tree shelter after the growing season. (c) Sapling with bunching of leaves at the top of a 0.76-m (30-in.) tree shelter after the growing season.

As a result of this study, in the winter of 2004, the public agency replanted their fields with shelters. It is important to point out, however, that the prices of tree shelters had declined to about one third between 2001 and 2004. At the time of the second planting, the expense was considered to be acceptable and affordable, as much as it was justifiable.

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