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Effect of Container Size at Time of Planting on Tree Growth Rates for Baldcypress (*Taxodium distichum* (L.) Rich), Red Maple (*Acer rubrum* L.), and Longleaf Pine (*Pinus palustris* Mill.)

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Abstract. The ecosystem restoration and wetland mitigation industries are challenged with recreating vegetative communities at an accelerated rate, while at the same time remaining cost effective. These created systems are typically bound by permit conditions to meet certain tree growth criteria in a specified time frame, commonly five years. Stock sizes of container grown trees are generally #1, #3, or #7 (gallons). The purpose of this study was to determine the relative cost effectiveness of these planting sizes for three commonly used species and to assess whether they achieve common success criteria for height, percent survival, and percent cover. These three species are baldcypress [*Taxodium distichum* (L.) Rich], red maple (*Acer rubrum* L.), and longleaf pine (*Pinus palustris* Mill.).

Based on the standard planting density of 174 trees/hectare, the most cost-effective size was #3 in all cases. All three sizes of baldcypress and red maple met the 3.7 m height criterion; no size of longleaf pine met the criterion. All sizes of all species failed to meet both the 85% survival standard and a theoretical minimum 50% cover calculated from canopy diameter measurements. If planting densities are increased to meet cover requirements and to offset mortality, container size #1 may be more favorable for baldcypress and red maple, but not for longleaf pine. The study was conducted in Pinellas County, Florida, U.S.

Key Words. Habitat Restoration; Permit Requirements; Success Criteria; Tree Growth; Wetland Mitigation.

Current and more focused research to support ecological restoration is needed and has become increasingly important (Dwyer et al. 2002). It is not obvious whether tree planting size #1, #3, or #7 (gallons) is most effective for ecological restoration or for meeting the success criteria for wetland mitigation projects required by environmental regulations. While much research has been completed to evaluate the factors affecting tree growth and establishment, it has largely been done for larger tree sizes and site conditions commonly associated with the landscape industry, rather than those associated with ecological restoration. Small trees have a perceived advantage of recovering from transplant shock and establishing more quickly (Watson 1985; Struve 2009), while larger trees are regarded as having a competitive advantage (Denton 1990; Richardson and Kluson 2000), offering immediate benefit (Watson 1985), and have a tendency to be more resilient when exposed to mechanical or other collateral damage (pers. observation). Container grown material has become favored over bare root seedlings in many cases for restoration projects because it tolerates transport and storage during staging better, and can be successfully planted during a greater portion of the year (Clewell and Lea 1990; Harris and Bassuk 1993). Previous studies have found no difference in the survival rate between various planting sizes (Denton 1990; Morgan and Roberts 1999), but offered no statistical support for these conclusions. Comparisons are conspicuously lacking regarding growth rates for transplanted #1, #3, and #7 container grown trees, or of similar sizes performed *in situ* in a restoration setting.

Frequently, restoration projects do not provide soils favorable for root growth development because the soils have been highly altered (e.g., by grading to achieve design hydrology, by previous mining efforts, or by associated road or other development construction). Nitrogen is impacted by construction activities (Scharenbroch and Lloyd 2004) and is frequently not available in usable form in wet soils (Kozlowski 1985). The saturated soils found in wetland restoration sites are prone to many growth-inhibiting characteristics, most notably deficiencies in phosphorus and oxygen in combination with toxic levels of soluble iron, manganese, and hydrogen sulfide (Kozlowski 1985; Ewel 1990).

Efforts to counteract soil deficiencies do not seem to be a suitable option in many cases. It has been shown that recently planted trees do not generally respond to fertilizer application during the first year (Gilman et al. 2000; Day and Harris 2007) or up to three years after planting (Ferrini and Baietto 2006). Soil amendments do not appear to benefit growth (Gilman 2004). Mulch may actually contribute to drought stress during the tree establishment phase if sufficient irrigation to penetrate the mulch layer is not also applied, and there is conflicting information in the literature as to whether or not mulch provides benefit with time (Schnelle et al. 1989; Gilman and Grabosky 2004; Ferrini et al. 2008; Gilman et al. 2008a; Struve 2009). Additionally, the scale of plantings for restoration projects would likely make any of these practices cost prohibitive even if they were found to be beneficial.

Determining the most successful and cost-effective planting size under less than ideal conditions is critical to maximizing restoration success and meeting permit success criteria. The purpose of this study was to determine the relative cost effectiveness of three planting sizes for three commonly used species and to assess whether they achieve common success criteria for height, percent survival and percent cover.

METHODS

Site Descriptions

Possum Branch Preserve

This primary study site is located in northern Pinellas County, Florida, U.S. (S 1/2 S-16/T-28/R-16). Within this 10.2-ha site, a constructed 2.2-ha forested seep slope was planted with various tree species, including two commonly used wetland restoration species, red maple (*Acer rubrum*) and baldcypress (*Taxodium distichum*). Soils consisted of marine clays deposited from the historic dredging of the adjacent Lake Tarpon Outfall Canal. Initial colonizing vegetation included halophytic species such as seaside heliotrope (*Heliotropium curassavicum*) and little hogweed (*Portulaca oleracea*), suggesting saline soils; however, these species did not persist after the first rainy season and initial saturation of the site with freshwater. For this reason, and the known tolerance of baldcypress to low salinities (Wilhite and Toliver 1990), soil testing was not performed for salinity or other parameters.

Brooker Creek Preserve

The second site is an area within Brooker Creek Preserve in the far northeast corner of Pinellas County (N 1/2 of S-11/T-27/R-16) known as the Upland Enhancement Area of the Bi-County Thruway Mitigation site. Historic use of the area was a cattle pasture cleared from pine flatwoods; no grade alteration or clearing had occurred for many years prior to this study. As an upland restoration project, the primary tree species planted was longleaf pine (*Pinus palustris*).

STUDY DESIGN

At the Possum Branch Preserve site, trees were planted in July and August 2002, with the initial set of measurements taken from September through December 2002. There were 600 trees at this location: 100 trees from each of three container sizes (#1, #3, and #7) for both red maple and baldcypress. The Brooker Creek Preserve site was not part of the initial study design, but the scheduled project planting in November 2002 offered the opportunity to represent longleaf pine as an additional species. There were 100 trees at this secondary location: 50 trees of both #1 and #3 container sizes. Initial measurements for longleaf pine were taken from January through February 2003. A similar annual schedule was followed for the remaining four years of the study. The later planting date at Brooker Creek Preserve would have provided cooler conditions and thus less heat stress at the time of planting, but would have reduced the overall growing season for the longleaf pines. Tree installation was accomplished by two different biological consulting firms, one at each study site, in a manner typical of a mitigation/restoration planting effort; no special instructions were given. Trees arrived on site in good condition and conformed to the standards for wetland plants as defined by Florida Grades and Standards for Nursery Plants (Florida Dept. of Agric. and Consumer Serv. 1998). Planting technique commonly applied to large scale restoration plantings, however, emphasizes speed and low unit cost. This means most trees were handled by the trunk, little attention was given to the proper size hole, nursery stakes were neither removed nor were field support stakes added, and soil was generally added on top of the root ball for stability. Although no watering or tamping was done, this should have been minimally important due to the saturated soils at both planting locations. Tree spacing was variable within the designated planting zones, but was approximately 3 m on center.

Measured parameters included tree height, canopy spread, and survival for each of the planted trees. Additional estimates of growth, specifically caliper and diameter at breast height (dbh) were taken but are not reported here, as they were found to be highly correlated with height. Reproductive status and anecdotal observations were also recorded concerning cone production and gall formation on the baldcypress. Height was measured using a telescoping measuring rod. The tallest point on the tree was used (tips of leaves or needles), as location of terminal buds or branch tips could not be determined consistently. For leaning trees, trees were held vertical for the height measurement. When this became impractical, height was measured at right angles to the lean (Bonham 1989). Canopy Spread was measured using a folding engineer's rule or the telescoping measuring rod as the canopy became larger. If the canopy was not symmetrical, the largest diameter was used (Denton 1990). Survival was noted annually for each tree. A tree was recorded as dead if no leaves were present and no green tissue was evident upon scraping the trunk near the base. At the initial measurement, container size was recorded and a unique consecutively numbered tag was attached to each tree.

Site maintenance at Possum Branch Preserve was performed monthly by a contracted firm and consisted primarily of backpack herbicide application to control nuisance species and periodic trimming with a bladed weed trimmer. No monthly maintenance occurred in the Brooker Creek Preserve site as the upland planting area was relatively free of nuisance species. Vines that jeopardized sample trees were removed annually prior to measuring canopy; these vines were particularly prevalent in the red maple planting zones. Trees were pruned as needed after measurements were taken; this was done to establish a dominant leader which is particularly important for the red maples (Gilman and Grabosky 2006), and to remove lower branches and thereby reduce vine entanglement.

Both study areas were subjected to the effects of tropical storm Frances on September 5, 2004, and tropical storm Jeanne on September 26, 2004. This resulted in a prolonged period of heavy rain associated with sustained winds of 72 kph and gusts over 97 kph. Planted red maples and longleaf pines suffered from wind throw during these storms, with tropical storm Jeanne causing the most damage. The largest, fullest trees appeared to have been most susceptible to the effects of the wind. All planted baldcypress remained erect.

Differences among container sizes for height and canopy spread were determined using Oneway ANOVA. Pairwise differences among container sizes within each species for height and canopy spread were determined using Tukey-Kramer

HSD tests. Differences among container sizes for survival were determined using Chi square tests. Statistical analyses were performed using the program JMP (SAS Institute, Inc., Cary, NC). Although measurements were made yearly, the results below reflect the status in 2007, five years post-planting.

RESULTS

Height

Differences in varying aspects of height were found for all three species (Table 1; Figure 1).

Baldcypress trees from the three container sizes differed significantly at time of planting (F = 86.48, P < 0.0001). At the end of five years, the #7 trees had grown significantly less (F = 19.22, P < 0.0001), and had a significantly smaller overall height than either the #1 or #3 trees (F = 10.78, P < 0.001).

At the time of planting, height of #3 and #1 red maples were not significantly different from each other, but both were significantly shorter than the #7 container-grown trees (F = 580.83, P < 0.0001). After five years, there was no significant difference in overall height among the three sizes (F = 0.44, P < 0.6436); however, trees grown from both #1 and #3 container sizes showed a significantly greater change in height compared to the #7 trees (F = 8.11, P < 0.0005).

At the time of planting, #3 longleaf pines were significantly taller than #1 longleaf pines (F = 158.38, P < 0.0001). Five years later, #3 trees exhibited significantly greater increase in height (F = 8.90, P < 0.0005) and overall height (F = 16.02, P < 0.0001) compared to #1 trees.

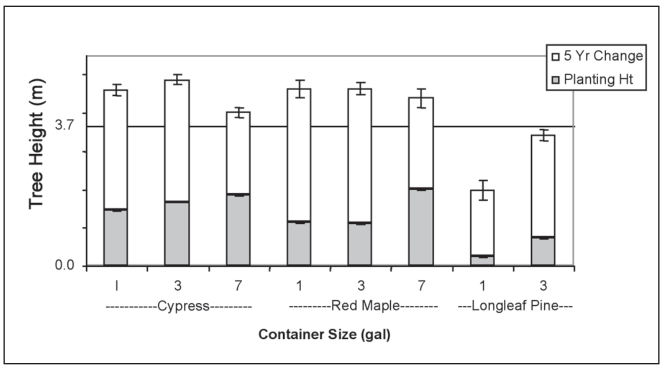

Figure 1. Height (mean ± SE) of baldcypress, red maple and longleaf pine trees in #1, #3, and #7 container sizes at time of initial planting and five years later. Shaded base is height at time of planting, nonshaded top section reflects five-year change in height; bar total represents cumulative five-year height. Reference line shown at 3.7 m represents target height (the height required to be attained within five years by regulatory permits).

Canopy Diameter

Differences in canopy diameter were found for all three species (Table 1; Figure 2).

Canopy diameter of baldcypress at time of planting was significantly different for all three sizes (F = 361.65, P < 0.0001). At the conclusion of the study, canopy diameter for the #3 and #7 baldcypress did not differ from one another, but were both significantly larger than the #1 (F = 81.26, P < 0.0001). Change in canopy diameter did not differ between #1 and #3, but both container-grown trees' canopies were significantly greater than trees grown in #7 containers (F = 23.07, P < 0.0001).

At the time of planting, there was a significant difference in canopy diameter of red maple among the three container sizes (F = 279.43, P < 0.0001). At the study's conclusion, there was no significant difference in canopy diameter between any of the three container sizes (F = 0.98, P < 0.3784); however, the change in canopy diameter for both the #1 and #3 was significantly greater than for #7 (F = 5.96, P < 0.0035).

At the time of planting, canopy diameter of longleaf pine was greater for #3 than for #1 trees (F = 15.27, P < 0.0001). At the study's conclusion, overall canopy diameter of #3 container-grown trees was significantly greater than for #1 (F = 7.32, P < 0.0017). Change in canopy diameter was no different among #3 and #1 (F = 4.77, P < 0.0129).

Survival

Baldcypress survival differed among container sizes (χ^2 = 10.76, P < 0.005). Survival was greatest for #3 trees at 74%, followed by 66% for the #7 trees, and 52% for the #1 trees. Red maple survival also differed among container sizes (χ^2 = 17.67, P < 0.0001). Survival was greatest for the #3 trees at 52%, followed by 33% for the #1 trees, and 24% for the #7 trees. Longleaf pine survival differed among container sizes (χ^2 = 30.46, P < 0.0001). Survival was greatest for the #3 trees at 62%, followed by the #1 trees at 20%.

Table 1. Summary of mean values in meters for canopy diameter and height at time of planting, change in canopy diameter and height over 5 years, and final canopy diameter and height after 5 years for baldcypress (container sizes #1, #3, and #7), red maple (sizes #1, #3, and #7), and longleaf pine (sizes #1 and #3).

Species and Size	Height (m) At Planting	5 Yr Change	5 Yr Total	Canopy Diameter (m) At Planting	5 Yr Change	5 Yr Total
Baldcypress						
#7	1.86 A	2.16 B	4.01 B	0.98 A	1.28 B	2.27 A
#3	1.68 B	3.20 A	4.85 A	0.55 B	1.77 A	2.30 A
#1	1.46 C	3.14 A	4.62 A	0.43 C	1.65 A	2.04 B
Red Maple						
#7	2.02 A	2.38 B	4.40 A	0.89 A	1.62 B	2.51 A
#3	1.11 B	3.54 A	4.67 A	0.38 B	2.26 A	2.66 A
#1	1.14 B	3.50 A	4.65 A	0.30 C	2.12 A	2.43 A
Longleaf Pine						
#3	0.73 A	2.66 A	3.37 A	0.71 A	1.28 A	1.97 A
#1	0.25 B	1.72 B	1.94 B	0.57 B	0.88 A	1.44 B

Letters following values indicate where significant differences within a column occur among container sizes for the selected species, e.g. baldcypress container sizes all had significantly different heights at time of planting.

Table 2. Planting densities and estimated costs per hectare (per acre values in parentheses), listed by species and planting container size required to achieve theoretical 50% canopy cover in five years based on observed survival rates and canopy diameters. All costs listed in U.S. dollars.

Species	Size	Planting Density	Unit Cost	Total Cost
Longleaf Pine	#3	843 (2,108/ac)	$10	$8,432 ($21,080/ac)
Longleaf Pine	#1	4919 (12,297/ac)	$5	$24,594 ($61,485/ac)
Red Maple	#7	676 (1,690/ac)	$35	$23,664 ($59,161/ac)
Red Maple	#3	278 (695/ac)	$10	$2,781 ($6,953/ac)
Red Maple	#1	524 (1,310/ac)	$5	$2,621 ($6,552/ac)
Baldcypress	#7	371 (928/ac)	$35	$12,994 ($32,485/ac)
Baldcypress	#3	260 (649/ac)	$10	$2,597 ($6,491/ac)
Baldcypress	#1	380 (948/ac)	$5	$1,897 ($4,743/ac)

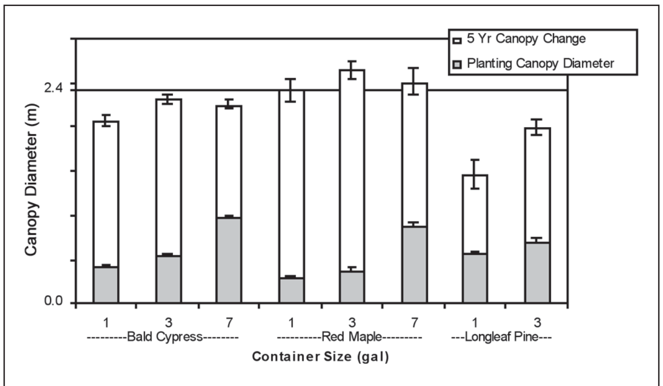

Figure 2. Canopy diameter (mean ± SE) of baldcypress, red maple and longleaf pine trees in #1, #3, and #7 container sizes at time of initial planting and five years later. Shaded base is canopy diameter at time of planting, nonshaded top section reflects five-year change in canopy diameter; bar total represents cumulative five-year canopy diameter. Reference value shown of 2.4 m represents the canopy diameter required to achieve theoretical 50% cover assuming 100% survival and an initial tree planting density of 174/ha.

DISCUSSION

Baldcypress

Growth rates of cypress vary considerably in the landscape, with competition for nutrients a major determining factor. In this study, increase in height over five years ranged from 2.2 m for the #7 trees, to 3.2 m for the #1 and #3 trees, similar to results in a previous study for cypress in a weed-controlled environment (Wilhite and Toliver 1990). A factor that may have influenced the relative height growth of both the baldcypress and the red maple in the #7 containers was their frequent use as a perch by birds in the early years when they were the tallest trees; this caused the apical stem to break off in many cases, resulting in stunted vertical growth. Additionally, although competition with weeds for nutrients can deter growth, tall weedy species can potentially convey nurse crop benefits (Richardson and Kluson 2000), which the initially taller #7 trees would not have received. While the #1 trees were comparable in height to the #3 trees, they lagged behind with regard to canopy diameter. This could be explained by the lack of shade tolerance of this species and the primary allocation of resources to reach sunlight at the top of the canopy. If this is the case, then the #1 trees would likely equal the #3 trees with respect to other growth measurements in the future.

Survival rates have a tendency to be low in large scale restoration plantings (Morgan and Roberts 1999; Gamble and Mitsch 2005), as compared to what would be expected for trees planted in a landscape or nursery setting. The most likely cause is drought stress (Ferrini et al. 2000), brought on by the higher transpiration rates of container grown trees (Harris and Bassuk 1993), in combination with the frequent absence of any irrigation or post-planting watering regime in many mitigation plantings. Poor initial soil conditions, the emphasis on speed during planting without regard to proper planting procedures, and the low standard of post-transplant care, all associated with restoration plantings, would also affect longer-term survival and are all generally detrimental to tree establishment and growth (Harris and Bassuk 1993; Gilman et al. 2009). The particularly poor survival rate of cypress grown in the #1 containers, in comparison to the #3 and #7 sizes, is most likely explained by their small size, making the trees most susceptible entanglement by vines or obscured by tall grasses and other components of the weedy landscape. Once obscured they could easily be trampled or suffer collateral herbicide or mechanical damage during nuisance species control efforts. They would also be more prone to damage by Florida wildlife, such as alligators and river otters observed utilizing the area.

Studies involving larger sizes of trees did not show a difference in growth rate between sizes (Gilman et al. 2008b; Struve 2009). This contrasts with results for the sizes used in this study, for which there were significant differences between sizes in each of the three species. The #3 cypress had the overall best growth rate and the highest survival rate five years post-planting. The trees may have been large enough to be recognizable and thus not subject to trampling and collateral damage, yet small enough to not suffer from transplant shock.

Anecdotal information was collected for the presence of cones and cypress twig gall midge (*Taxodiomyia cupressiananassa*), and revealed some patterns that bear further investigation. The presence of cones was not affected by height or container size, whereas the presence of galls was not affected by height but did increase with container size. For the final year only, those trees with galls were less likely to have cones, indicating the pattern may develop further as the trees continue to mature. Research that includes the quantity of galls or cones and which looks at this trend over a greater span of time would add additional insight into these relationships.

Red Maple

Heat stress may have been a major detriment to growth and survival of red maples in the study area, which may have been intensified by soil conditions and hydrology. Red maples may become less efficient in absorbing certain nutrients as soil fertility increases (Platt and Schwartz 1990); conversely, greater efficiency in less fertile soils may be offset by other effects of more stressful conditions. Under favorable conditions, red maple seedlings increase in height up to 0.3 m the first year, and 0.6 m or more annually for the next several years (Walters and Yawney 1990). The #1 and #3 red maples in this study both increased in height 3.6 m five years post-planting, while the #7 trees averaged 2.4 m increase over five years. A similar trend of larger trees having a slower growth rate has been noted for red maples planted into a nursery setting (Gilman et al. 2008a).

Following the tropical storms during the summer of 2004, a large number of red maples were blown over and suffered branch failure. This is consistent with the medium-low wind resistance rating reported by Duryea et al. (2007). Root development varies with soil conditions; in wet soils the taproot is short and the lateral roots become extensive, while in well-drained sites the taproot grows deep and the lateral roots are less prominent. The majority of the wind-thrown trees appeared to have occurred in the wetter soils, consistent with an explanation based on a shallower root system. Many of the wind-thrown trees developed adventitious roots and coppice shoots, which is a common response to flooding or injury (Kozlowski 1985; Schnelle et al. 1989). Secondary pathogens in the form of cankers were evident on many of the maples both alive and dead.

Survival for all three sizes of red maples was poor, with the #7 size faring the worst. This conforms to findings (Struve 2009), which note that larger caliper trees have higher mortality than smaller caliper trees. Although vine entanglement and collateral herbicide damage likely were contributing factors, secondary pathogens associated with heat stress, wind throw, and branch failure may also have contributed heavily to mortality.

Longleaf Pine

Longleaf pine seedlings have a grass stage during which they delay trunk development and instead develop a stout taproot; this grass stage ranges from one to 15 years (Duncan and Duncan 1988; Brown and Kirkman 1990; Myers 1990). The longer grass stage delays early height growth and is associated with poorer site conditions (Boyer 1990). When the trunk does start to develop, it grows at the rate of 0.9 to 1.5 m the first year (Myers 1990). In the present study, the longleaf pines in #1 containers did not fare as well as those in #3 containers in terms of survival or growth. The #1 trees may be especially vulnerable to damage due to their small size while in the grass stage. Damage was noted by armadillo burrows, trampling by feral hogs, trampling and browsing by white-tailed deer, and fire ant colonies extending up the trunks during periods of high groundwater. Inclusion of #7 trees in additional research is suggested, due to the unusual seedling-to-sapling transition of longleaf pine.

CONCLUSIONS

In determining optimum planting container size, cost must be balanced with performance. While costs vary, the approximate cost to install these three species of trees in recent wetland restoration projects in this area was USD $35 per #7 tree, $10 per #3 tree, and $5 per #1 tree.

For the three species studied, the #3 trees had the best survival, the greatest canopy development, and equal or greater overall height. There appears to be no advantage gained in planting the larger #7 containers, and at the current intermediate cost, the #3 size trees appear to offer the best overall value. When restoration projects occur as a requirement of an environmental regulatory permit, specific growth criteria are expected to be attained within five years. While the #3 trees had the best results, the question remains which, if any, of the three sizes examined would be in compliance with typical permit conditions. Three common growth criteria referenced in permits are height, percent survival, and percent cover.

The typical height criterion is 3.7 m after five years from the date of planting. All container sizes of bald cypress and red maple met this criterion. Although data for #7 longleaf pines are not represented, both the #3 and #1 pines fell substantially short of this requirement. This indicates the 3.7 m height criteria can be achieved by baldcypress and red maple in better than average conditions, but may not be practical for many sites or for all species.

The criterion for survival has been expressed as percent survival, or as density. Previous permits typically required 85% survival of trees planted 3 m on center. Current permits typically require a density of 174 trees per hectare (436 trees per acre), which is equivalent to 100% survival of an initial 3 m on center spacing. Baldcypress survival was greatest for the #3 container-grown trees and was 74%. Red maple survival was again best for the #3 trees, but was only 52%. Longleaf pine survival was better for the #3 size and was 62%. Neither the 85% survival nor the 174 trees per hectare/100% survival standards appear to be achievable with the standard initial planting density.

The percent cover criteria vary widely from 30% to 75%. For simplicity, 50% will be used as the requirement. To calculate this value from the canopy diameter data, canopy was assumed to be a uniform circle and trees were assumed to be planted uniformly 3 m on center. The resulting area was then adjusted to account for mortality by multiplying by percent survival. Baldcypress cover was best for the #3 container size and was 34%. Red maple cover was best for the #3 container size at 31%. Longleaf pine cover was best for the #3 container size and was 20%. The 2.4 m reference line in Figure 2 is the canopy diameter required to provide theoretical 50% cover based on the assumptions of 100% survival at planting densities of 3 m on center. Thus, even with 100% survival assumed, cover is, at best, 45% for baldcypress, 60% for red maple, and 33% for longleaf pine.

Although permits generally allow, in fact require, replanting to adjust for mortality, this practice leads to a temporal lag in growth and further contributes to failure of meeting growth criteria within the designated five-year period.

Possible solutions to bridging the gap between performance and requirements include: extending the five-year time frame, reducing the survival and cover requirements, and planting at greater initial densities. In any case, the requirements should also allow for individual species variation (e.g., longleaf pine's grass stage).

If initial planting densities were increased to achieve 50% cover, the approximate densities and costs are exhibited in Table 2. Although this shows it may possibly be more advantageous to plant #1 sized containers instead of #3 for baldcypress and red maples with this strategy, the possible effects of planting at increased densities are not known.

The factors influencing growth and establishment of transplanted trees, particularly in an ecological restoration or forest setting, are exceedingly numerous and in most cases difficult to control or even predict. One factor readily within the control of the project manager is the size of the trees to be installed; and under the conditions of this study, #3 container grown trees performed the best. There may be situations in which #1 container trees will have an advantage, but it appears that #7 container-grown trees are a poor choice with respect to both cost and performance.

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Résumé. L'industrie de la restauration des écosystèmes et celle des mesures de mitigation en milieu humide sont confrontées avec le recréation de communautés végétatives à une vitesse accélérée tout en devant se faire à des coûts intéressants. Ces écosystèmes recréés doivent rencontrer certains critères de croissance des arbres dans un horizon de temps défini, communément cinq ans. Les stocks d'arbres produits en contenants sont généralement de dimension #1, #3 ou #7. Le but de cette étude était de déterminer l'efficacité relative en terme de coût par rapport aux dimensions usuelles d'arbres utilisés lors de la plantation, et ce pour trois espèces communément employées, et d'évaluer s'il y avait rencontre des critères usuels de succès en terme de hauteur, de pourcentage de survie et de pourcentage de couverture. En se basant sur une plantation standard de 174 arbres/hectare, le coût effectif le meilleur était obtenu avec des arbres de dimension #3 à la plantation, et ce dans toutes les situations. Les trois dimensions à la plantation de cyprès chauve et d'érable rouge ont atteint le critère du 3,7 m de hauteur; aucune pin des marais, quelque soit sa dimension à la plantation, n'a atteint ce critère. Toutes les espèces de toutes les dimensions à la plantation ont failli face à l'atteinte du critère standard de 85% de taux de survie ainsi que celui du minimum théorique de 50% de couverture végétale calculé à partir des mesures du diamètre de la cime. Si la densité des plantations était accrue pour rencontrer la minimum de recouvrement et pour éliminer la problématique de la mortalité, l'emploi d'arbres de dimension #1 pourrait être plus intéressante dans le cas du cyprès chauve et de l'érable rouge mais pas dans le cas du pin des marais.

Zusammenfassung. Die Klimaschutzanstrengungen der Industrien werden zunehmend herausgefordert durch entstehende vegetative Habitate, während sie zur gleichen Zeit kostenintensiv bleiben. Diese entstandenen Systeme sind typischerweise gebunden durch Zulassungsverfahren, um bestimmten Baumwachstumskriterien in einem vorbestimmten Zeitraum zu begegnen, normalerweise fünf Jahre. Die Größen der Container-gezogen Bäume sind #1, #3 oder #7. Das Ziel dieser Studie war, die relative Kosteneffektivität dieser Pflanzgrößen für drei häufig verwendete Arten zu bestimmen und zu untersuchen, ob sie allgemeine Kriterien bezüglich Höhe, Überlebensrate und Bedeckungsgrad erreichen. Basierend auf der Standartpflanzdichte von 174 Bäumen/ha, war die Pflanzgröße #3 in allen Fällen besonders kosteneffektiv. Alle drei Größen von Sumpfzypresse und Rotahorn trafen bei 3,7 m die Höhenkriterien, von den Kiefern erreichte keine Größe das Ziel. Alle Größen von allen Arten versagten beim Erreichen der 85% Überlebensrate und einer theoretischen Bedeckung von wenigstens 50%, gemessen am Kronendurchmesser. Wenn die Pflanzdichte angehoben werden, um den gewünschten Deckungsgrad zu erreichen und die Mortalität auszusetzen, ist die Pflanzgröße #1 wahrscheinlich für Sumpfzypresse und Rotahorn besser. Das gilt aber nicht für die Kiefer.

Resumen. La restauración del ecosistema y la mitigación por industrias de los humedales es desafiada con la recreación de comunidades vegetales a una velocidad acelerada, mientras al mismo tiempo permanecen a un costo efectivo. Estos sistemas creados están típicamente conectados para permitir condiciones que encuentren ciertos criterios de crecimiento de los árboles en un tiempo específico, comúnmente cinco (5) años. Las existencias en los viveros de árboles en contenedor son generalmente #1, #3 o #7. El propósito de este estudio fue determinar la efectividad de costos relativos de estos tamaños de plantación para tres especies comúnmente usadas y evaluar si cumplen con los criterios para altura, supervivencia y porciento de cobertura. Con base en estándares de densidad de plantación de 174 árboles/hectárea (436 árboles/acre), el tamaño de costo más efectivo fue el #3 en todos los casos. Todos los tres tamaños de cipreses de los pantanos y maples rojos alcanzaron el criterio de 3.7 m (12 pies) de altura; ningún tamaño en pino de hoja larga lo hizo. Todos los tamaños de todas las especies fallaron en alcanzar el 85% de estándar de supervivencia y un mínimo teórico del 50% de cobertura calculado de las mediciones del diámetro de copa. Si las densidades de plantación son incrementadas para alcanzar los requerimientos de cobertura y compensar la mortalidad, el tamaño #1 posiblemente es más favorable para el ciprés y maple rojo, pero no para el pino de hoja larga.