

EFFECTS OF PROLONGED STORAGE ON SURVIVAL AND GROWTH OF OUTPLANTED BOTTOMLAND OAKS

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Abstract.—A prominent difficulty during bottomland hardwood afforestation is that sites are often flooded during the preferred months of planting (January-March), which results in delayed planting (April-June) and reduced survival. We monitored growth and survival of oak seedlings planted in 11 different months (February through December) after varying periods of humidified cold storage to investigate the hypothesis that seedlings held over the summer months in cold storage and planted in autumn months would fare better than seedlings planted in late spring and summer. Results for Nuttall oak (*Quercus nuttallii* Palmer) generally agreed with this hypothesis, whereas results for overcup oak (*Quercus lyrata* Walt.) did not. Both species' height growth during the second growing season decreased with increased time in cold storage. These results suggest that although reduced height growth can be expected, long-term storage over the summer months and subsequent planting in autumn need not result in heavy mortality of some bottomland oak species.

INTRODUCTION

Over the course of the past century, considerable acreage of bottomland forest has been deforested and drained for row crop farming throughout the southeastern United States (MacDonald and others 1979, Turner and others 1981). Since the 1980s, natural resource professionals and federal and state agencies have focused on restoring portions of these cleared acres to native hardwood trees through various conservation programs (Stanturf and others 2001). Restoration of bottomland hardwoods has been a recent focus in the management of agricultural wetlands in Tennessee (Johnson 2007).

Professional foresters and contractors often follow conventional tree planting procedures that are well established for upland sites but pose problems in bottomlands. High water tables, overland flooding, poor soil drainage, and other seasonally exacerbated soil conditions make tree planting difficult during the commonly accepted optimum planting period between mid-winter and mid-spring (January through April). These hydrologic obstacles, instead, often cause seedlings to be planted in late spring and summer (from May on). Late planting results in poor survival. In some cases the sites may go unplanted, leading to disposal of seedlings and a follow-up attempt to plant the following year.

A previous investigation involving upland hardwood seedlings suggested that increasing the length of time in cold storage decreases post-planting root growth and percent bud break, and increases stem dieback and mortality (Englert and others 1993). We investigated whether results would be similar with bottomland

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species on a bottomland site. Our hypothesis was that seedlings held over the summer months in cold storage and planted in autumn months would fare better than seedlings planted in late spring and summer.

STUDY AREA

The study was conducted on the University of Tennessee West Tennessee Research and Education Center (WTREC), located in Jackson, TN. The site is located adjacent to the South Fork of the Forked Deer River (35°37'34" N, 88°51'22" W, 120 m mean elevation). It includes a 122-m x 92-m section nested into a larger 49-ha bottomland area that underwent afforestation in winter 2004. The predominant soil type is Waverly silt loam (0 to 2 percent slope), which is deep and poorly drained (Sease and Springer 1957). Flooding of the site occurs five to six times per year (R.M. Hayes, West Tennessee Research and Education Center, pers. comm., 2009) and inundation often lasts several days. The site was used for row crop farming until 2004 when it was enrolled in the Conservation Reserve Program (CRP).

METHODS

Nuttall oak (*Quercus texana* Buckley, NTO) and overcup oak (*Quercus lyrata* Walt., OCO) were planted in this study. NTO and OCO were selected because both species were previously found to tolerate extended inundation on the site available for this study (McCurry and others 2006). All seedlings planted were 1-0 stock and were grown at the Tennessee Department of Agriculture Forestry Division East Tennessee Nursery in Delano, TN. Initial height measurements were taken to the nearest cm using a custom-made PVC pipe calibrated in cm. The average aboveground height at the time of planting, measured from ground to terminal bud, was 51.3 cm for NTO and 104.1 cm for OCO. Initial stem caliper was also measured with a Plasti-cal Digital Caliper (Mitutoyo America Corp., Aurora, IL) to the nearest 1.0 mm at ground level. The average caliper for NTO was 7.9 mm, and for OCO, 10.8 mm. Prior to shipping from the nursery, the roots were dipped in Viterra root dip (potassium propenoate propenamide copolymers, Amereq, Inc., New City, NY) to conserve moisture. The Viterra root dip was mixed at a rate of 14.2 gm per gallon of water. After dipping, they were then packaged (without mulch) into bundles of 25 seedlings. After delivery, the seedlings were stored in a humidified cold room at 2.2 °C, with 94-percent relative humidity. An unforeseen, 30-hour power outage occurred on August 24-25, 2007. The maximum temperature in the cold room during the outage reached 25.2 °C, with an average of 19.6 °C. The relative humidity dropped to a low of 81.9 percent.

The study was established as a randomized complete block design with all treatments appearing once in each of three blocks established in relation to elevation of the site. Twelve treatments, corresponding to plantings in every month of the year, were assigned at random to 12 plots within each block, which resulted in 36 plots for the entire study (Fig. 1). One row containing 20 NTO seedlings on 1-m spacing and a second row containing 20 OCO seedlings on 1-m spacing were established in each plot. With a total of three replications, 60 NTO and 60 OCO seedlings were planted per month. Seedlings for each month were planted successively between 7 and 10 a.m. and between the 10th and 20th day of any given month. No seedlings could be planted during the month of January at the outset of the study in 2007 because the study site was flooded. As a result, the January treatment was dropped from the study.

Site preparation, conducted in August 2006, consisted of a single application of a 2 percent solution of Roundup (glyphosate, Monsanto, St. Louis, MO) in 76-cm bands applied directly over the designated rows. In addition, during the year of planting (2007) and the two following years, seedlings were side-dressed with

the same herbicide at the same rate, once per month (April through September). The band width was 38 cm on both sides of each row. Weeds were controlled carefully throughout the entire study to minimize effects of differences in the abundance of competing vegetation during the study. Mowing between the rows occurred each month during the growing seasons. Survival and seedling heights were recorded in September 2008 and again in 2009.

Data were analyzed through one-way ANOVA with models appropriate for a randomized complete block design. Pairwise comparisons were conducted between months with Tukey's honestly significant difference ($\alpha = 0.05$). All analyses were conducted using SAS, Version 9.9 (SAS Institute, Cary, NC, 2008).

RESULTS

As of September 2009, mean survival calculated across all treatments and sample periods was 78.3 percent for NTO and 32.0 percent for OCO. As expected, survival for both of the species was favorable in the Feb.-Apr. planting treatments; NTO averaged 90.6 percent and OCO, 78.3 percent. Survival for both species was less favorable during the late spring and early summer (May-Aug.); NTO averaged 62.1 percent and OCO, 29.2 percent. There were no differences in mean NTO survival between planting dates in this period, but mean survival for OCO was lower during some late spring and summer planting months. The results for the final planting period (Sept.-Dec.) were promising for NTO. Mean Sept.-Dec. NTO survival averaged 85.4 percent, and was not different in any of these months from survival in February, March, or April. In contrast, OCO survival during all months within this period was zero (Fig. 2). Seedlings were considered dead if there was no indication of living tissue above ground. Scratch testing to reveal green cambium was conducted on questionable seedlings.

Mean seedling height for both NTO and OCO decreased from early to late planting dates (Fig. 3). Mean heights (as of September 2009) for both species were greatest for seedlings planted in the early months of Feb.-Apr.; NTO averaged 173.0 cm and OCO, 164.0 cm. Heights for both species were less for most months within the late spring and summer planting period (May-Aug.) than in the Feb.-Apr. period (Fig. 3); NTO averaged 114.9 cm and OCO, 94.5 cm in the May-Aug planting period. NTO height averaged 76.7 cm in the final period (Sept.-Dec.), and heights were less in this period than in the Feb-Apr period (Fig. 3). No OCO seedlings survived in the final period. When we observed height measurements for NTO during the project, Feb.-Apr. planted seedlings were 131.9 percent taller than Sept.-Dec. planted seedlings in 2008 and 125.6 percent taller than Sept.-Dec. planted seedlings in 2009. Although data on resprouting were not formally collected, resprouting of late planted seedlings was observed to be more prevalent.

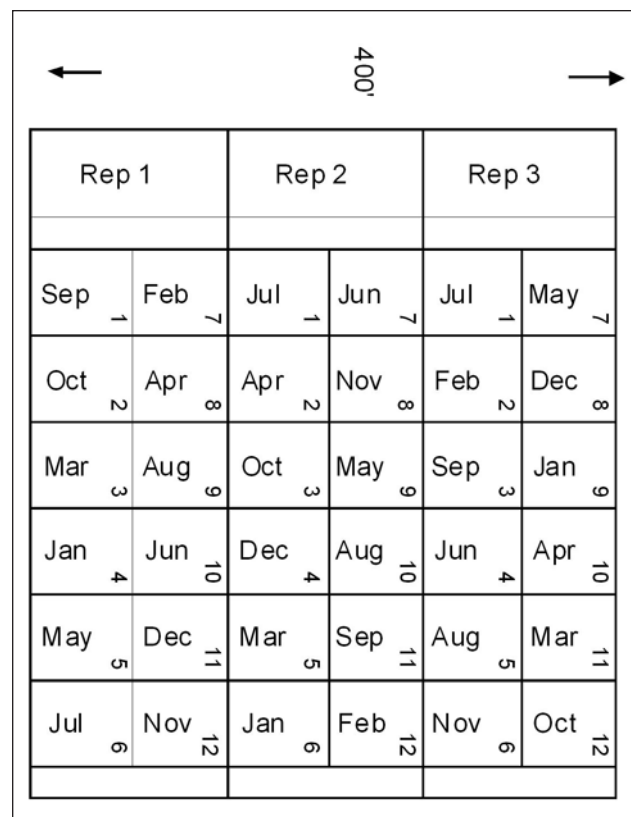


Figure 1.—Study design.

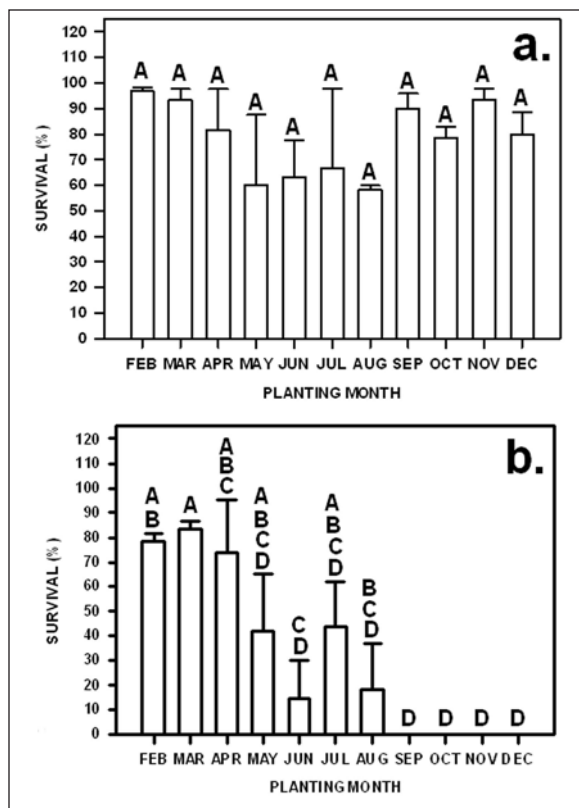


Figure 2.—Mean percent survival of Nuttall oak (a.) and overcup oak (b.) as of September 2009 by planting month treatment. Bars with the same letters are not significantly different at the $\alpha = 0.05$ level. Error bars represent 1 standard error.

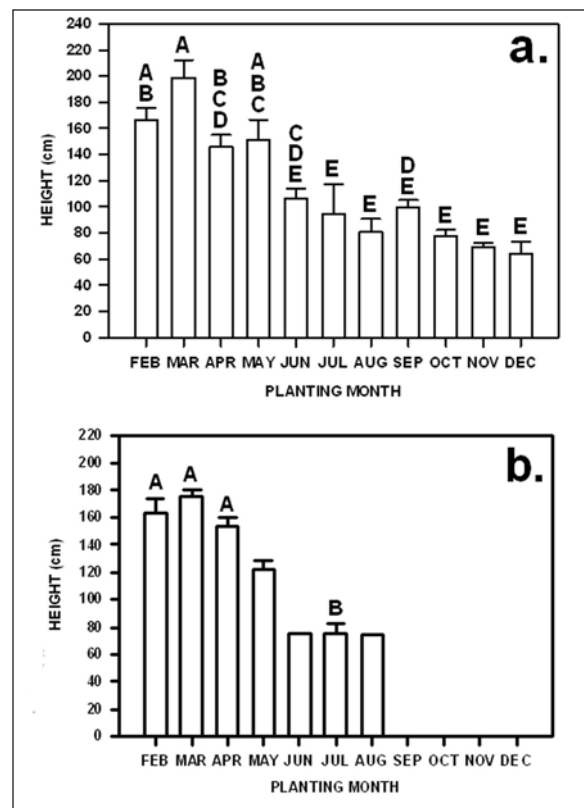


Figure 3.—Mean height of Nuttall oak (a.) and overcup oak (b.) as of September 2009 by planting month treatment. Bars with the same letters are not significantly different at the $\alpha=0.05$ level. Error bars represent 1 standard error.

DISCUSSION

Due to limitations in the number of species studied, the types of stock examined, and other factors, this study is not a definitive test of the hypothesis that holding seedlings in a humidified cold room over the summer months, and then planting them during the autumn months, is a viable solution to the problem of early-season flooding of bottomland restoration sites. The findings do suggest, however, that in the case of NTO, it is at least possible to have acceptable survival rates (80 percent or better) with seedlings planted in September-December. It can be argued that the very different results obtained for OCO may be the result of innate differences in the two oak species. These differences could include differences in respiration rate, desiccation resistance, or other species-specific characteristics. For instance, the two species were shown to differ in carbohydrate changes in response to flooding (McCurry 2006). It is also possible that differences in initial seedling size between the two species influenced the results.

At the time of planting, the initial seedling size and caliper measurements were noticeably larger for the OCO than for NTO. At 104.1 cm (initially), OCO were 103 percent taller than the NTO. Similarly, OCO, with an initial stem caliper of 10.8 mm, were 37 percent larger in caliper than NTO. It is well documented that seedlings with a larger stem caliper experience more favorable survival than those with a smaller caliper (Weigel 1999). Why this was not the case in our project is not clear.

The potential effects of two occurrences during the study should be noted. First, during the year of implementation (2007), the west Tennessee region experienced an extreme drought. Eight months received below normal precipitation in 2007, and year-end total precipitation was 33.4 cm below normal. During the growing season months of May-August, the precipitation deficit was 31.3 cm (NOAA 2009). This drought could have substantially increased mortality overall, particularly in the summer months. Secondly, the power outage that occurred for 30 hours in August that allowed the temperature in the cold room to climb to 25.2 °C may have influenced seedling viability. Since none of the OCO planted in September-December (after this power outage) survived, it is possible to speculate that this occurrence may have had a greater effect on OCO than NTO, although the reasons for this disparity are unclear. If these events had not taken place during the study, survival could have been greater for all planting dates in the study.

Results suggest that, at least in the first two growing seasons, height growth is suppressed by delayed planting. The average height of autumn-planted NTO seedlings, when measured 2 years after establishment (September 2009), was considerably less than the average height of those planted in the spring. The percent difference in height had declined slightly from 2008 to 2009, and if this trend continues, early height differences could become less substantial over the duration of the rotation. Initial height can be important, however, in influencing the competitive status of planted seedlings relative to other vegetation.

The promising results obtained for NTO in this study suggest that additional research involving the performance of delayed plantings of other species used in bottomland hardwood restoration is warranted. We are planning to examine the viability of a range of seedling size classes for an expanded set of species stored for various periods of time in a cold room.

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