PERFORMANCE OF TWO OAK SPECIES AND THREE PLANTING STOCKS ON LANDS DAMAGED BY HURRICANE KATRINA

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Abstract--Hurricane Katrina had a devastating impact on bottomland hardwood forests in 2005. Artificial regeneration was considered the most appropriate method for reforesting these areas, but few studies have evaluated methods for artificially regenerating oaks on clear cut sites in the southern United States. First-year survival and growth of two oak species, live oak (*Quercus virginiana* Mill.) and Nuttall oak (*Quercus texana* Buckl.), and three planting stocks [1-0 bareroot, conventional containerized, and Root Production Method (RPM)™ seedlings] were compared. Seedlings were established using recommended methods for each respective planting stock. Conventional containerized live oak and bareroot Nuttall oak seedlings exhibited the greatest survival. RPM™ seedlings exhibited the lowest survival in both species. Conventional containerized seedlings exhibited greater groundline-diameter (GLD) growth and twice as much height growth as bareroot seedlings, regardless of species. RPM™ seedlings exhibited similar GLD growth compared to bareroot seedlings but the least height growth of all planting stocks, regardless of species.

INTRODUCTION

Bottomland hardwood forests were severely impacted by Hurricane Katrina in 2005 (Chapman and others 2008). Prompted by uncertainty about the future of these stands and the impact the storm had on non-industrial private landowners, Congress developed a cost share program to provide an incentive for landowners to regenerate hardwoods. Wildlife habitat and timber production were priority objectives of most landowners, and many desired to develop stands abundant in oaks. Although natural regeneration is the preferred method for regenerating oaks, artificial regeneration was considered more appropriate given the unplanned circumstance.

Artificial regeneration of bottomland hardwoods has traditionally been accomplished using 1-0 bareroot seedlings, but success has often been impeded by competing vegetation, drought, flooding, and herbivory (Stanturf and others 2004). Recent decades have been marked by efforts to reduce the impact of these factors by improving nursery, site preparation, and competition control techniques. The use of high-quality seedlings combined with herbaceous weed control has greatly improved survival of bareroot seedlings (Ezell and Catchot 1998, Ezell and Hodges 2002, Ezell and others 2007), and based on projections made by Grebner and others (2003), the practice is likely to be cost effective. Concurrently, techniques for containerized seedling production have improved, and some sources indicate that interest in using containerized seedlings is increasing (Dey and others 2008).

Compared to bareroot seedlings, containerized seedlings have a more fibrous root system which is better protected from damage and less vulnerable to desiccation prior to and during planting. Several studies have documented greater survival and growth of containerized seedlings compared to bareroot seedlings (Humphrey 1994, Rathfon and others 1995, Self and others 2010, Williams and Craft 1998). Others have also shown improved survival and growth with increasing container size (Howell and Harrington 2002). A relatively new method, the Root Production Method™ (RPM™), is a system of nursery techniques that has resulted in the development of large containerized seedlings with extensive root systems, characteristics which could potentially make them more resilient to drought, flooding, and terminal shoot-removal by white-tailed deer (*Odocoileus virginianus*) (Dey and others 2006). Some studies have reported greater early survival and growth of RPM™ seedlings compared to 1-0 bareroot seedlings (Dey and others 2003) and conventional-sized containerized seedlings (Alkire 2011). Although large containerized seedlings may have potential survival and growth advantages compared to smaller seedling types, they are extremely costly to purchase and plant (Shaw and others 2003).

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Comparative evaluations of planting stock performance are needed to help foresters make well-informed decisions about regeneration. While results of previous studies comparing oak planting stocks are available in the literature, most studies have been conducted on retired agricultural lands in major river bottoms and only involve the evaluation of a few key oak species (Dey and others 2008). Information comparing the performance of planting stocks on cutover or storm-damaged lands is lacking. The objective of this study was to compare the survival and growth performance of two oak species, live oak (*Quercus virginiana* Mill.) and Nuttall oak (*Quercus texana* Buckl.), and three planting stocks: 1-0 bareroot seedlings, conventional containerized seedlings, and RPM™ seedlings.

MATERIALS AND METHODS

Research was conducted on two privately owned tracts near Hattiesburg, MS. Both sites were positioned on minor stream bottoms. Average annual precipitation for the area is 158.7 cm. The Guiles tract is located in Perry County, approximately 16 km east of Hattiesburg. The soil series was Trebloc silt loam, and soil sample analysis indicated that the pH was 4.6. Following salvage, residual stems were injected with a 20 percent aqueous solution of Arsenal® AC (imazapyr), and the site was mechanically prepared using a roller drum chopper attached to a bulldozer. The site received a direct foliar application of 2 percent Accord® XRT solution in November 2010 to control winged sumac (*Rhus copallinum* L.). Herbicide was applied with a Solo® 11.4-L piston-pump backpack sprayer.

The second site, the Morgan Tract, is located in Forrest County, MS approximately 14 km northeast of Hattiesburg. The soil present was a complex of Bibb and Jena soil series. Analysis of soil samples indicated that the soil was a sandy-loam with a pH of 5.4. This site was sheared, raked, burned, and cleared with a bulldozer to prepare the site for planting. The intensity of mechanical site preparation abated the need for chemical site preparation on this site.

Two oak species, Nuttall oak and live oak, and three planting stocks [high-quality 1-0 bareroot, 0.24-L conventional containerized, and 11.4-L RPM™ seedlings] were selected for evaluation. Bareroot seedlings were purchased from Molpus Woodlands Group™ in Elberta, AL. Conventional containerized seedlings were purchased from Rennerwood Incorporated™ in Tennessee Colony, TX. RPM® seedlings were purchased from RPM Ecosystems™ in Ocean Springs, MS.

Three hundred seedlings per species and planting stock combination were planted on each site. Bareroot seedlings and conventional containerized seedlings were planted by Mississippi State University personnel on the first two weekends of February 2011. Bareroot seedlings were planted with OST dibble bars. Conventional containerized seedlings were planted with planting shovels. RPM™ seedlings were planted by a RPM Ecosystems™ planting crew on February 19, 2011 using planting shovels. Seedlings were planted next to pre-marked pin flags to ensure uniform spacing.

RPM™ seedlings were established according to the company's "plant and walk away" approach, and thus did not receive herbaceous weed control. Bareroot and conventional containerized seedlings were treated with a post-plant, pre-bud break application of Oust® XP (140 g/sprayed ha) in February 2009. An 11.4-L Solo® piston-pump backpack sprayer equipped with a TeeJet 8003 Visiflo® nozzle, specially designed to minimize wind drift, was used to apply the herbicide as a 1.5-m band over the top of seedlings. Herbicide was applied in the morning when wind was minimal as a primary precaution to avoid herbicide drift into untreated plots.

Survival and seedling parameter measurements were recorded at the conclusion of the first growing season. The cambial layer was nicked to affirm suspected mortality during each survival evaluation. Groundline diameter (GLD) and height measurements were recorded 2 weeks after seedlings were planted and at the conclusion of the first growing season. GLD measurements were recorded to the nearest tenth of a mm using Mititoyo® digital calipers. Height measurements were taken at the top of the living portion of the stem in the advent that a seedling exhibited dieback. Height of bareroot and conventional containerized seedlings was measured to the nearest cm using a meter stick. Height of RPM® seedlings was measured to the nearest tenth of a foot using a telescopic height pole.

The experimental design was randomized complete block. Each species and planting stock combination was replicated three times per site. Analysis of variance (ANOVA) was used to determine significant differences between species and among planting stocks. Mean separation was performed using the GLIMMIX procedure of Statistical Analysis Software (SAS) version 9.2®. Differences were considered significant when $P < 0.05$. Survival percentages were arcsine transformed prior to analysis, but actual means are presented for the purpose of interpretation.

RESULTS

Survival

All species and planting stocks exhibited lower survival on the Guiles site compared to the Morgan site (table 1). On the Guiles site, survival of bareroot live oak, conventional containerized Nuttall oak seedlings, and RPM™ seedlings of both species declined below 80 percent, which was considered a critical level (Ezell and Hodges 2002). Survival of conventional containerized live oak and bareroot Nuttall oak remained high at 86.0 and 87.7 percent, respectively. On the Morgan site, survival of conventional containerized live oak and all Nuttall oak planting stocks exceeded 95 percent. Lower survival on the Guiles site was attributed to greater competition. The Morgan site, which received more intensive site preparation, was mostly void of vegetation during May and June. It is thought that the lack of competition on the Morgan site during these early months allowed seedlings a better opportunity to overcome transplant stress.

Planting-stock comparisons were performed separately by species. For live oak, conventional containerized seedlings exhibited greatest survival (92.3 percent overall), and bareroot and RPM™ live oak seedlings exhibited similar survival (77.8 and 76.6 percent overall, respectively). Wind damage was common in live oak RPM™ seedlings. Many RPM™ live oak seedlings were either leaning or bent, and some were completely laid over with their root systems exposed. In contrast, bareroot seedlings exhibited the greatest survival in Nuttall oak (93.8 percent overall), and conventional containerized and RPM™ seedlings exhibited similar survival (87.5 and 84.1 percent overall, respectively). Wind damage was less prevalent in RPM™ Nuttall oak seedlings, which did not have their leaves when planted.

Table 1--Percent survival by species, planting stock, and site after the first growing season

Planting stock[a]	Guiles site[bc]	Morgan site[bc]	Overall[bc]
	percent survival		
Live oak			
BRT	68.0 Bb	87.7 Bb	77.8 Bb
CC	86.0 Aa	98.7 Aa	92.3 Aa
RPM™	70.6 Bb	82.6 Bb	76.6 Bb
Nuttall oak			
BRT	87.7 Aa	100.0 Aa	93.8 Aa
CC	77.3 Bb	97.7 Bb	87.5 Bb
RPM™	73.2 Ba	95.1 Ba	84.1 Ba

[a]BRT = bareroot, CC = conventional containerized, RPM™ = Root Production Method™.
[b]Means followed by the same uppercase letter in a column within a species do not differ significantly at $\alpha = 0.05$.
[c]For each respective planting stock, means followed by the same lowercase letter in a column do not differ signficantly between species at $\alpha = 0.05$.

GLD and Height Growth

Similar to survival, all species and planting stocks exhibited lower GLD and height growth on the Guiles site compared to the Morgan site (table 2). On both sites, Nuttall oak exhibited significantly greater GLD growth than live oak in all planting stocks. Conventional containerized seedlings exhibited the greatest overall GLD growth in live oak and Nuttall oak (5.7 and 7.9 mm overall, respectively). RPM™ seedlings exhibited slightly greater GLD growth than bareroot seedlings overall, but the difference was not significant in live oak (3.7 and 3.3 mm overall, respectively) or Nuttall oak (6.2 and 5.7 mm overall, respectively).

Height growth of live oak was comparable to Nuttall oak in both bareroot (9.7 and 11.2 cm overall, respectively) and conventional containerized planting stocks (18.9 and 20.3 cm overall, respectively) (table 2). In both species, conventional containerized seedlings exhibited

Table 2--Mean initial groundline diameter (GLD) and height plus first-year growth by species, planting stock, and site

	GLD (*mm*)[ab]				Height (*cm*)[ab]			
Planting stock[c]	Initial growth	First-year growth Guiles site	First-year growth Morgan site	Overall	Initial growth	First-year growth Guiles site	First-year growth Morgan site	Overall
Live oak								
BRT	6.1	1.6 ABb	4.5 Bb	3.3 Bb	43.6	2.2 Aa	15.3 Ba	9.7 Aa
CC	5.4	2.3 Ab	8.6 Ab	5.7 Ab	73.5	6.4 Aa	29.4 Aa	18.9 Aa
RPM™	16.5	1.4 Bb	5.3 Bb	3.7 Bb	201.8	-32.1 Bb	-41.9 Cb	-37.9 Bb
Nuttall oak								
BRT	7.2	3.6 Ba	7.5 Ba	5.7 Ba	50.2	10.2 Ba	12.1 Ba	11.2Ba
CC	5.8	4.3 Aa	10.6 Aa	7.9 Aa	50.0	13.8 Aa	25.2 Aa	20.3 Aa
RPM™	20.0	3.9 Ba	8.1 Ba	6.2 Ba	196.7	3.8 Ca	7.4 Ca	5.8 Ca

[a]Means followed by the same uppercase letter in a column within a species do not differ significantly (α = 0.05).
[b]For each respective planting stock, means followed by the same lowercase letter in a column do not differ significantly between species (α = 0.05).
[c]BRT = bareroot, CC = conventional containerized, RPM™ = Root Production Method™

greater mean height growth than bareroot seedlings, but the difference between these planting stocks in live oak was not significant on the Guiles site. RPM™ seedlings exhibited the least height growth in both species. The overall mean height growth of RPM™ Nuttall oak seedlings was 5.8 cm, but live oak RPM™ seedlings decreased in height by 37.9 cm.

DISCUSSION

Although seedlings are subject to a variety of detrimental factors during the first few growing seasons, competing vegetation is the most consistent factor limiting survival and growth (Ezell and others 2007, Russell and others 1998). In this study, sites differed appreciably in the level of competition, and this probably led to differences in survival and growth (tables 1 and 2). Although seedling survival and growth differed between sites, species and planting stock comparisons were, for the most part, consistent between sites.

Survival and growth of RPM™ seedlings was less than expected. In both species, RPM™ seedlings exhibited lower overall survival than bareroot or conventional containerized seedlings. This was primarily attributed to wind damage. Seedlings are known to increase diameter growth near the stress point in response to wind damage (Close and others 2010). The severity of damage was not reflected in GLD growth. However, it was reflected in relatively lower height growth. RPM™ live oak seedlings exhibited a 20 percent decrease in mean height (table 2). Dieback due to wind damage was presumably more severe in RPM™ live oak seedlings because they retained their leaves when planted. RPM™ Nuttall oak seedlings exhibited a slight increase in mean height (5.8 cm), but it was approximately two and three times less than that exhibited by bareroot and conventional containerized Nuttall oak seedlings [11.2 and 20.3 cm, respectively (table 2)]. In contrast, Alkire (2011) reported 23.8 cm height growth for RPM™ Nuttall oak seedlings after the first growing season, which was more than twice as much exhibited by bareroot or containerized seedlings during the first growing season.

In two preceding trials (Alkire 2011, Hollis 2011), bareroot seedlings exhibited greater than or comparable first-year survival and growth to conventional containerized seedlings when only bareroot seedlings received herbaceous weed control (HWC). In this trial, when both planting stocks received HWC, conventional containerized seedlings exhibited no clear advantage with respect to survival. Live oak conventional containerized seedlings exhibited appreciably greater survival than bareroot seedlings (92.3 and 77.8 percent, overall), but Nuttall oak bareroot seedlings exhibited the highest survival of all species and planting stocks (93.8 percent) (table 1). In both species, however, conventional containerized seedlings exhibited significantly greater GLD and height growth than bareroot seedlings. This was expected, because containerized seedlings have been shown to be less susceptible to transplant shock (Johnson and others 1984, Wilson and others 2007). An unexpected result, however, was that in bareroot and conventional containerized stock, height growth for live oak was comparable to Nuttall oak, which is known to exhibit more rapid juvenile growth than other bottomland oaks (Allen 1990, Miwa and others 1992).

Few trials have evaluated oak planting stock performance past the second growing season, but results of more long-term studies have been inconsistent. Teclaw and Isebrands (1993) reported greater height growth of containerized seedlings compared to bareroot seedlings after the third growing season, but survival of both planting stocks was high (94 and 98 percent, respectively). Howell and Harrington (2004) reported that height growth increased with increasing container size after 5 years, but survival was high (> 90 percent) for all seedling types. In contrast, Burkett and others (2005) reported that after seedlings were subjected to severe herbivory, bareroot seedlings exhibited similar or greater survival than containerized seedlings and had surpassed them in height after the fifth growing season. In a comparison of bareroot and RPM™ seedlings, Dey and others (2006) reported greater survival of RPM™ seedlings, but both planting stocks exhibited a decline in mean height after the third growing season due to severe herbivory by eastern cottontail rabbits (*Sylvilagus floridanus*). Mullins and others (1998) reported no significant differences in height or diameter between bareroot, conventional containerized seedlings, or large, greenhouse-forced seedlings by the end of the fourth growing season. Moreover, use of tree shelters to protect seedlings from herbivory did not increase height growth. In an 8-year trial, Henderson and others (2009) reported higher relative growth rates of bareroot seedlings compared to RPM™ seedlings and no significant differences in survival between the two planting stocks.

CONCLUSIONS

More long-term evaluations are needed to determine if early survival and growth differences among planting stocks persist. Based on first-year results, it appears that 1-0 bareroot seedlings, the least costly seedling type, can exhibit acceptable survival when competition is controlled for at least part of the first growing season (Ezell and Hodges 2002). Conventional containerized seedlings may be the more suitable choice when herbaceous weed control cannot be implemented, or for landowners willing to spend more for establishment. They are also recommended when plantings must be conducted during the growing season (Stanturf and others 2004). Large containerized seedlings may be best suited to situations when management objectives require fewer seedlings per acre, whereby more intensive management techniques could be financially feasible.

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