ABSTRACT

In this study, we report the results of a comparison of 5-year survival and 14-year growth of black, white, and swamp white oaks grown from planting stock produced by a conventional bareroot method and stock produced by the Root Production Method (RPM®) of Forrest Keeling Nursery. Five-year survival was 100% for black and white oak grown from RPM® stock, but only 63 and 75%, respectively, for trees grown from bareroot stock. The odds ratio for survival of RPM® planting stock of black and white oaks compared to bareroot stock were 21.9 and 12.1, respectively. All swamp white oak survived. After 14 years, diameter growth was greater for the RPM® than bareroot planting stock and ranged from a 35% increase in black oak to a 6% increase in swamp white oak. Average aboveground fresh weight for trees from RPM® planting stock equaled 330 lb compared to 333 lb for trees from bareroot seedlings ($P < 0.0001$). Compared with traditional bareroot seedlings, survival and growth of RPM® oak planting stock was greater through 14 years.

Keywords: Quercus alba, Quercus velutina, Quercus bicolor, whole tree weight, afforestation, plantation management, survivability, RPM®

RPM® Seedling Production

In early February 1996, germination flats were removed from coolers and placed in a heated greenhouse on wire benches. As roots elongated, air pruning of the tap root occurred at a shallow depth (1.5–2 in.) forcing development of first-order, lateral roots near the root collar. Following completion of the first flush of growth (early March), the largest and most vigorous seedlings were selected (40% cull rate) and potted in plastic bottomless band containers (3.0 × 3.0 × 5.5 in.). These containers were filled with the same potting medium used in the flats, placed on wire benches in greenhouses and grown for approximately 60 days. During early May, seedlings were transplanted into 2.0-gal containers filled with the same potting medium used in the flats, held under mist outside the greenhouses for 2 days, and then lined out under overhead irrigation on white gravel beds for the remainder of their 210-day growing season. RPM® seedlings used in this study had a mean height of 2.23 ft and a mean caliper (1 in. above root collar) of 0.35 in. at the time of planting.

METHODS

Seed Collection and Handling

Seed was collected from a single mother tree for each of black oak, white oak, and swamp white oak in the fall of 1995 and separated into two equal lots. One lot of each species was placed in plastic bags and stored for 4 weeks under moist conditions at 34°F before early-November planting in a tree nursery. The other lots were sown in bottomless mesh germination flats (18.5 × 14.5 × 2.5 in. deep) filled with a potting medium consisting of composted rice hulls, pine bark, and sand (4:4:2 by volume) amended with Scott’s slow release fertilizer (22-3-8, NPK), micronutrients (Scott’s Micromax granular), and a wetting agent (Terra-Sorb). Germination flats were wrapped in plastic and held inside a walk-in cooler at 34°F.

Survival and 14-Year Growth of Black, White, and Swamp White Oaks Established as Bareroot and RPM®-Containerized Planting Stock
Bareroot Seedling Production

In November of 1995, acorns were sown at 20/ft² to a depth of 1 in. and covered with 2 in. of mulch. One thousand lb/acre of 28-14-14 NPK had been previously incorporated into the tilled silty loam soil before mounding to create 4 ft-wide raised beds. An additional 1,000–1,500 lb/acre of the 28-14-14 NPK were applied in increments of 300–400 lb/acre throughout the remainder of the growing season. Seedlings were lifted in early March of 1997, graded for size (15% culled) and stored at 34° F until planted. At the time of planting, another 25% of the seedlings were culled, resulting in a mean seedling height of 0.81 ft and a caliper (1 in. above root collar) of 0.15 in.

Seedling Establishment

RPM®-containerized seedlings were field-planted during early October 1996. Bareroot seedlings were field-planted in March 1997. The planting site was located at the Horticulture and Agroforestry Research Center, New Franklin, Missouri (39° 02' N and 92° 46' W). Soils are Menfro silt loam with a 2% slope. The long-term mean annual precipitation for the study area is 38 in.

Prior to planting, 5-ft strips (20 ft center-to-center) were treated with a combination of glyphosate and simazine for weed control. Seedlings (RPM® and bareroot) were planted in the strips at 10-ft intervals. Four pairs of RPM® and four pairs of bareroot planting stock were randomly planted within single species rows for each of the three oak species. Each species was randomly assigned to 4 of 12 strips.

Data Collection

Survival of RPM® and bareroot planting stock was monitored annually through age 5 before an initial thinning. During a second dormant season thinning in February 2010 (13 years after outplanting), an additional 10, 15, and 5 trees from RPM® planting stock and 10, 7, and 6 trees from bareroot stock of swamp white, black, and white oaks, respectively, were harvested. Selection was made randomly in the office to remove one tree of each surviving pair. The trees to be removed were dictated by the need to create strategically positioned canopy gaps. Trees were cut at groundline and measured for dbh, total height, aboveground fresh weight, and stem-only fresh weight (tree weight minus branch weight). A 1,000-lb load cell connected to a SGCN Dillon electronic meter was hung from the bucket of a skid loader to determine tree and stem-fresh weight. Trees were attached to the load cell by a short cable and lifted until each tree cleared the ground.

Data Analysis

Survival data (first 5 years for all 32 RPM® and bareroot planting stock) were analyzed as a split plot in space. Trees on four of six treatment combinations had 100% survival and, since a logit value cannot be calculated on 100 or 0%, a dead tree (0) was added to each treatment within each of the four replications (rows) for each species. The main plot contained the effect of species and the subplot contained the effect of treatment and species × treatment interaction. Replication within species was used as the denominator to test main plot effects. Since each replication had multiple trees for each treatment (eight trees, four pairs for each treatment), the replication within species × treatment interaction was used as the denominator to test the subplot effects to avoid pseudoreplication. Procedure GLIMMIX in SAS, with logit link and a binomial distribution, was used for the analysis. Differences between logit means were tested using Fisher’s least significant difference (LSD). These differences were expressed as odds ratio (antilog of the difference between two average logits).


table

<table>
<thead>
<tr>
<th>Number</th>
<th>% Surv</th>
<th>Odds ratio</th>
<th>P-value</th>
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<tbody>
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<td>21.9</td>
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<td>32</td>
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<td>12.1</td>
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<td>32</td>
<td>75</td>
<td>1.1</td>
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<td>6.4</td>
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<tr>
<td>BR (all species)</td>
<td>96</td>
<td>79</td>
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Results and Discussion

Early 5-Year Survival of Bareroot and RPM® Oak Seedlings

For black and white oaks, RPM® survival was greater than bareroot. All RPM® black and white oak survived, compared to 63 and 75% survival, respectively, of bareroot seedlings. At a 95% confidence interval, survival differences between RPM® and bareroot planting stock were significantly better for both black and white oak RPM®s ($P = 0.019$ and $0.048$, respectively; Table 1). Higher mortality of black and white oak trees of bareroot origin compared to containerized stock is consistent with what others have reported (Dixon et al. 1981, Parker et al. 1986). In floodplain plantings, Dey et al. (2004) reported RPM® oak seedlings consistently had higher survival (>94%) than the bareroot 1–0 planting stock (76%). Harris and Bassuk (1993) noted that nursery-dug trees may lose more than 90% of their tap root and lateral roots during lifting and transplanting severely impacting survival and growth response. Kormanik et al. (1995) found that 1–0 bareroot seedlings of northern red oak with more than 12 first-order lateral roots (FOLRs) survived and performed better in clearcuts than smaller seedlings with fewer than seven FOLRs. While specific measurements were not taken on the root systems of either the RPM® or bareroot planting stock used in our study, Shaw et al. (2003) found that RPM® planting stock of pin and swamp white oak had 3–7 times the dry mass and 4–9 times the volume of 1–0 bareroot seedlings (Figure 1).

It is apparent from the findings of our research, and those of others, that the use of planting stock with intact large root systems, such as those produced using the RPM® technology, has great potential for significantly improving the survival of some oak species.
and could be a valuable tool in the regeneration of oak and other hardwood species.

**Fourteen-Year Growth Responses**

Following 14 growing seasons, diameters were consistently greater for the RPM® planting stock of black and white oak, ranging in advantage from 35% in black oak to 33% in white oak, as compared to bareroot stock. A 6% increase in diameter of swamp white oak was not significant. RPM® black and white oak also exhibited significant height growth advantages of 11 and 26%, respectively, over their bareroot counterparts (Table 2).

With the emphasis placed on biomass yield in today’s markets for carbon sequestration and feedstock for energy, the fresh weight of stems and aboveground tree (stem plus branches) is of great importance. Total aboveground tree weight of RPM® white and black oak was significantly greater (2.16 and 1.74 times greater, respectively) than that of bareroot planting stock. RPM® swamp white oak had 8% greater fresh weight than its bareroot counterpart. The patterns for differences in stem weights (stem minus branches) were similar, with RPM® white oak planting stock producing 2 times greater weight, followed by 76 and 14% increases for RPM® black and swamp white oak, respectively, as compared to bareroot trees.

Many studies have demonstrated the importance of seedling quality in the successful regeneration of oak species (Johnson 1993, Spetich et al. 2002, Dey et al. 2010). Our results suggest a strong correlation between the size and quality of the planting stock and its success 13 years after outplanting. Survival and overall growth of RPM®-produced white and black oak seedlings were significantly greater than survival and growth of their 1–0 bareroot counterparts. While RPM® planting stock of swamp white oak outgrew bareroot seedlings, the differences in survival and growth were not significant.

These results have important implications in the establishment and growth of oak plantations whether for conventional timber, biomass, or other forest values. Our data demonstrate significant survival and growth advantages of using RPM® over 1–0 bareroot planting stock for white and black oak when intensively managed as a plantation on high-quality sites. The cost of RPM® planting stock is much greater than for bareroot seedlings. Although a cost-benefit analysis was not conducted in this study, it is likely that RPM® planting stock is not suited to all regeneration settings. However, numerous forest values exist that might justify the use of superior oak seedlings with large root systems appears to have merit.

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**Figure 1.** Comparison of root volume between 1-year-old RPM® (a) and bareroot (b) planting stock of white oak (A) and swamp white oak (B).

**Table 2.** Comparison of 14-year diameter at breast height (dbh), height (ht), tree, and stem-fresh weight for three oak species using RPM® or bareroot (BR) planting stock.

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>dbh (in.)</th>
<th>P-value</th>
<th>ht (ft)</th>
<th>P-value</th>
<th>Tree weighta (lb)</th>
<th>P-value</th>
<th>Stem weightb (lb)</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Black oak (RPM®)</td>
<td>15</td>
<td>8.40</td>
<td>0.0002</td>
<td>38.2</td>
<td>0.0088</td>
<td>622</td>
<td>0.0003</td>
<td>405</td>
<td>0.0002</td>
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<td>7</td>
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<td></td>
<td>357</td>
<td></td>
<td>229</td>
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<tr>
<td>White oak (RPM®)</td>
<td>5</td>
<td>7.76</td>
<td>0.0084</td>
<td>31.7</td>
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<td>499</td>
<td>0.0043</td>
<td>326</td>
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<td>White oak (BR)</td>
<td>6</td>
<td>5.85</td>
<td>25.2</td>
<td></td>
<td></td>
<td>231</td>
<td></td>
<td>161</td>
<td></td>
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<tr>
<td>Swamp white oak (RPM®)</td>
<td>10</td>
<td>7.41</td>
<td>0.4088</td>
<td>33.6</td>
<td>0.1931</td>
<td>409</td>
<td>0.6481</td>
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<td>Swamp white oak (BR)</td>
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<td>6.99</td>
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<td>378</td>
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<td>RPM® (all species)</td>
<td>30</td>
<td>7.96</td>
<td>&lt;0.0001</td>
<td>35.6</td>
<td>&lt;0.0001</td>
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<td>BR (all species)</td>
<td>23</td>
<td>6.46</td>
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<td>30.9</td>
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<td>333</td>
<td></td>
<td>216</td>
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</tbody>
</table>

a Aboveground stem plus branches fresh weight.

b Total aboveground tree weight minus branch weight.
Literature Cited


