This article was listed in Forest Nursery Notes, Summer 2007

177. Survival of planted oak seedlings is improved by herbaceous weed control.
Ezell, A. W., Yeiser, J. L., and Nelson, L. R. Weed Technology 21:175-178. 2007.

Survival of Planted Oak Seedlings is Improved by Herbaceous Weed Control

Andrew W. Ezell, Jimmie L. Yeiser, and Larry R. Nelson*

Sulfometuron was applied at 0.1, 0.15, and 0.2 kg ai/ha over the top of oak seedlings. Three separate field studies were completed. In 1997, 0.1 and 0.2 kg ai/ha was applied PRE over six oak species. In 1998 and 1999, 0.1 and 0.15 kg ai/ha were applied PRE and 0.1 kg ai/ha was applied POST over two species of oaks. Results demonstrate that first-year survival of oak seedlings is greater in areas which receive competition control. Survival was 21 to 44% greater in treated areas as compared to nontreated areas. Observations indicate that survival differences are increased in droughty years. Competition control appears essential to obtaining desirable levels of survival when oak seedlings are planted in areas with established herbaceous competition.

Nomenclature: Sulfometuron, oak, *Quercus* spp.
Key words: Oaks, reforestation, survival.

Introduction

Thousands of hectares are being planted annually in the South with hardwood seedlings. Most of this planting is accomplished with various species of oaks (*Quercus* spp.) (Stanturf and Shepard 1995). On federal lands (including U.S. Fish and Wildlife Service [USFWS], national forest, and Corps of Engineer lands) and state properties, more than 77,000 ha were planted in hardwoods in the Lower Mississippi Alluvial Valley (LMAV) in the 1990s (King and Keeland 1999). By 2002, this afforestation effort under the auspices of federal programs exceeded 140,000 ha of federal, state, and private land (Gardiner 2002). The principal oak species for all these plantings include cherrybark (*Q. pagoda* Raf.), Nuttall (*Q. nuttallii* Palmer), Shumard (*Q. shumardii* Buckl.), water (*Q. nigra* L.), willow (*Q. phellos* L.), white (*Q. alba* L.), and swamp chestnut (*Q. michauxii* Nutt.). The establishment of these seedlings is an expensive process (Allen and Kennedy 1989; Gardiner 2002), and reported total costs for planting hardwood seedlings range from an average of $1190/ha (USFWS cost) to $1715/ha (independent contractor cost) (King and Keeland 1999).

Unfortunately, many of these trees do not survive. Oak mortality in first-year plantations has been noted in earlier studies (McGee and Loftis 1986). In surveys of young oak plantings in the LMAV, both C. J. Schweitzer (unpublished data, 2000) and James (2001) found excessive (>80%) mortality. Survival of these seedlings becomes a most important issue when millions of dollars are being expended annually for planting across the region.

The causes of oak seedling mortality have been examined in earlier studies. Seedling quality is notably important, and planting failures could be partially attributed to lower quality nursery stock (Clark et al. 2000). For years the importance of lateral roots has been recognized (Kormanik and Ruehle 1987), and previous reports have noted the correspondence between larger root collar diameters and enhanced survival and seedling performance (Kormanik et al. 2002).

Species–site relations can be an important factor in survival, but that impact is usually restricted to flooding (Krinard and Johnson 1981; Wood 1998). Miwa (1993) found that soil chemical and physical property differences could not account for differences in oak seedling survival. Ozlap (1997) confirmed that soil series did not have a significant effect on oak seedling survival.

Proper planting and handling of seedlings is always conducive to improved seedling survival, hardwood or pine (Johnson 1989; Smith et al. 1997). Reports vary in the influence of site preparation on oak seedling survival. Seifert et al. (1985) reported that mechanical site preparation did not significantly affect the performance of swamp chestnut oak. King and Keeland (1999) also noted that mechanical site preparation was rarely justified by differences in survival. By comparision, Kennedy (1984) reported a 28% increase in survival when clean cultivation (cross-disking plus hoeing) areas were compared to uncultivated areas. The positive impact could have been due to the hoeing when that study is considered with another report that stated weed control by bushhogging appeared to improve seedling survival and growth (Johnson and Krinard 1987). However, when working on reclaimed mine land, Anderson et al. (1983) reported that herbicide use to reduce ground cover did not significantly affect red oak survival.

The objective of our studies was to evaluate the influence of competition control on survival in first-year oak plantings. A total of three studies were conducted to evaluate the response from various species, sites, and the potential influence of growing season weather patterns.

Materials and Methods

The three field studies all included the use of sulfometuron for competition control. First, a preemergence evaluation trial was conducted in 1997 with six oak species (including Nuttall and cherrybark). Second, in 1998, a fully operational competition control effort was evaluated in a planting with Nuttall and cherrybark oaks. Third, in 1999, sulfometuron applications were compared with attention to both time of application and herbicide rate in an operational planting (total

DOI: 10.1614/WT-06-114.1
* Professor, Department of Forestry, Box 9681, Mississippi State University, MS 39762. Professor, Arthur Temple College of Forestry and Agriculture, Box 6109, Stephen F. Austin State University, Nacogdoches, TX 75962. Associate Professor, Department of Forest Resources, 272 Lehotsky Hall, Clemson University, Clemson, SC 29634. Corresponding author's E-mail: aezell@cfr.msstate.edu

planted area was approximately 40 ha) with Nuttall and cherrybark oaks.

General Procedures. All field testing was completed on former agricultural land being planted with trees in Oktibbeha and Clay counties, Mississippi. These lands had been fallow for 2 yr prior to being planted operationally with oak seedlings. The 1997 test area had a sandy clay loam soil with pH 5.2. The 1998 and 1999 test sites both had silty clay loam soil with pH 5.7. All study areas had a well-established mixture of grasses, sedges, broadleaf annuals, and broadleaf perennials, and vines. A list of these species and the control provided by the treatments is found in Ezell and Nelson (2001).

In all areas, oaks were planted by hand with planting shovels during February of the respective year on a operational spacing of 3.1 m between trees in a row and 4.6 m between rows. The planting stock for all studies consisted of 1–0 (1 = number of years in a nursery bed; 0 = number of years as a nursery outplant), bareroot seedlings that were obtained from a nursery without specification as to height (root collar to apical bud), root collar diameter, root system architecture, or other parameters. The lack of specification was utilized to most closely replicate the type of seedlings being utilized in operational plantings. Measurements were taken to characterize seedling size but not for comparative analyses. Overall, the cherrybark seedlings were the smallest, ranging in height from 35 to 46 cm with root collar (the area of the seedling where the above-ground and below-ground portions interface) diameters of 7.6 to 10.2 mm. Height and root collar diameter of all other species were comparable, with heights ranging from 43 to 61 cm with root collar diameters of 8.9 to 17.8 mm. Seedling sizes were consistent among all study years. In 1997, cherrybark, Nuttall, Shumard, water, willow, and white oaks were all planted in the initial screening study area, whereas only cherrybark and Nuttall were planted in the 1998 and 1999 study areas. In all years, at least one rainfall event occurred on the test site after the planting but prior to herbicide application. This rainfall served to settle the soil immediately surrounding the tree root system which was disturbed during the planting operation. The planting was the only soil disturbance on the study areas.

Herbicide application was completed at two timings: PRE, wherein treatments were applied after the trees were planted but before growth initiation by the oak seedlings (March), and POST, wherein treatments were applied when the oak seedlings were fully foliated and actively growing (June). All herbicide applications were completed using a CO_2–pressurized backpack sprayer equipped with a four-nozzle boom. The 8002 VS flat fan tips with spray pressure of 193 KPA delivered 192 L/ha total spray volume with all applications banded over the top of the planted seedlings.[1] No surfactants were used in any of the applications.

Survival Studies. Seedlings were evaluated weekly for 4 wk in each study after budbreak was first noted in order to establish the initial number of living trees in each plot. All treatment plots were 1.85 m wide and 46.15 m long and contained 15 seedlings. After all seedlings had broken dormancy, survival was not evaluated again until mid-October of each study year to establish survival percentage after one growing season.

The experimental design in the 1997 study was a randomized complete block with three replications of both herbicide applications on all species. PRE treatments were applied on March 2, 1997, and consisted of two rates of sulfometuron, 0.1 kg ai/ha and 0.2 kg/ha. No POST treatments were included in the initial study but a nontreated plot was included in each block for comparison. A total of 810 seedlings were evaluated in this study.

In the 1998 and 1999 studies, the experimental design was again a randomized complete block design with three replications of each treatment. PRE applications were completed during the first six days of March and consisted of two rates of sulfomenturon, 0.10 kg ai/ha and 0.15 kg/ha. A POST treatment was completed in early June of each respective year using 0.10 kg ai/ha sulfometuron. The trees in the POST treatment plots had received no PRE treatment. A total of 360 seedlings (180 per species) were evaluated in each of these studies.

Data Analysis. The number of living seedlings in each plot at the end of the growing season was compared to the number of living seedlings after planting to determine the percentage survival by species and treatment. Percentage data were arcsine transformed prior to analysis to stabilize variances. Data were analyzed as a randomized complete block design using ANOVA, and means were separated using Duncan's new multiple range test (% = 0.05).

Results and Discussion

First-Year Survival. The principal focus of this work was to evaluate the impact of competition control (and the lack thereof) on first-year survival of oak seedlings. The various projects allowed inspection of sulfometuron rates, application timing, and species response, but the primary thrust of this paper is the examination of "with" or "without" competition control. In 1997, survival did vary slightly among species but was very consistent among plots for each species–treatment combination (Table 1). Survival in plots receiving competition control ranged from 83% (white oak) to 92% (Nuttall oak). However, none of the survival percentages were significantly different statistically in these treated areas. Thus, while competition control may have been numerically better in the plots receiving 0.2 kg ai/ha (Ezell and Nelson 2001), the rate of 0.1 kg/ha was sufficient to allow the seedlings to establish and survive. Complete details of the control of competing vegetation in all three of these studies are found in Ezell and Nelson (2001). Notably, the survival in nontreated plots for all species was significantly less in nontreated than in treated plots. Overall, survival was 20 to 25% greater in plots receiving competition control than in the untreated areas, regardless of species. Climatic conditions for the 1997 growing season were considered "normal" with average monthly temperatures and precipitation for the nearest recording station (approximately 8 km away) being less than 5% different from long-term averages.

Survival in the 1998 trials provided an opportunity to evaluate the influence of herbicide rate, application timing, and climatic fluctuation. Survival was again very consistent

Table 1. First-year survival in 1997 preemergence application field trials (averaged over replications).

Species	Sulfometuron	Survival
	kg ai/ha	%
Cherrybark oak	0	61 b[a]
	0.1	85 a
	0.2	87 a
Nuttall oak	0	68 b
	0.1	90 a
	0.2	92 a
Shumard oak	0	63 b
	0.1	87 a
	0.2	87 a
White oak	0	60 b
	0.1	83 a
	0.2	87 a
Water oak	0	66 b
	0.1	87 a
	0.2	90 a
Willow oak	0	63 b
	0.1	85 a
	0.2	88 a

[a] Values followed by the same letter in a column do not differ at % = 0.05.

within a species–treatment combination among all plots with Nuttall exhibiting slightly better (two to four percentage points) overall survival than cherrybark (Table 2). Again, there was no significant response to herbicide rate with only a one or two percentage points increase in survival in the higher treatment rate areas. The sulfometuron rate 0.1 kg ai/ha appears adequate to provide sufficient competition control for establishment of these species. Evaluation of trees in POST treatment areas revealed two items of interest. First, no seedling damage or mortality resulted from the POST application (Ezell and Nelson 2001). Second, survival was only one to four percentage points less than in PRE treatment areas depending on application rate and species. The most notable response was the lower seedling survival in nontreated areas. Survival in these nontreated areas was 34 to 37 percentage points less for cherrybark seedlings and 32 to 35 percentage points less for Nuttall seedlings as compared to areas receiving competition control. While seedling survival rate in treated areas is comparable to the results from the 1997 study, survival in nontreated areas is notably lower. This difference is possibly due to climatic differences. The 1998 growing season would have been considered "normal" until late July. From that time until November, average monthly temperatures remained comparable to long-term averages, but precipitation was more than 40% less than long term averages. Seedlings in areas receiving competition control may have successfully established a root system which enabled them to survive the droughty conditions. Excavation of dead seedlings in nontreated areas revealed little or no root development. While no measurements were taken on any root systems, the lack of root development is considered to be directly related to decreased survival.

Table 2. First year survival of oak seedlings in 1998 application treatment areas (averaged over replications).

		Survival	
Sulfometuron rate	Timing	Cherrybark	Nuttall
kg ai/ha		%	
0.10	PRE	82 a[a]	86 a
0.15	PRE	84 a	87 a
0.10	POST	81 a	83 a
Nontreated	—	47 b	51 b

[a] Values followed by the same letter in a column do not differ at % = 0.05.

Table 3. First-year survival of oak seedlings 1999 application treatment areas (averaged over replications).

		Survival	
Sulfometuron rate	Application timing	Cherrybark	Nuttall
kg ai/ha		%	
0.10	PRE	74 a[a]	81 a
0.15	PRE	76 a	78 a
0.10	POST	67 a	71 a
Untreated	—	36 b	37 b

[a] Values followed by the same letter in a column do not differ at % = 0.05.

In the 1999 trials, survival demonstrated the same consistency among plots as in 1997 and 1998. Nuttall again exhibited slightly better survival than cherrybark, and no response to herbicide rate could be detected (Table 3). Survival in the POST plots was notably lower than in PRE plots but the difference was not statistically significant. The discrepancy between treated and nontreated areas was more pronounced in 1999. Almost two of every three seedlings died during the 1999 growing season in areas which did not receive competition control, and survival in treated areas was also lower than in 1997 and 1998. While temperatures were near the long-term averages in 1999, average monthly precipitation ranged from 34% to 78% less than long-term monthly averages at the nearest recording station (approximately 17 km away) from April until November. The growing season of 1999 represented the most severe drought conditions of any of the three trial years, and survival was correspondingly the lowest.

Overall, the results of these studies demonstrate that competition control does result in increased first-year survival of planted oak seedlings. PRE application of sulfometuron at a rate of 0.1 kg ai/ha is effective for competition control and provides acceptable first-year survival. Increasing the rate of sulfometuron application did not increase survival accordingly in these studies. Depending on the species and year, first-year survival in areas with competition control ranged from 21 to 44 percentage points higher than in nintreated areas.

Other studies have examined the influence of competition control on survival of planted oak seedlings. Oswalt et al. (2004) reported a negative association between total herbaceous biomass and northern red oak (*Q. rubra* L.) survival and development, but their work did not include competition control treatments. Buckley (2002) used a directed spray of glyphosate in a postemergence application and noted improved survival (although not significantly different statistically) of northern red oak seedlings in the treated area.

Ware and Gardiner (2004) reported results similar to Buckley (2002) when using postemergence directed sprays of glyphosate with Nuttall oak seedlings. Both studies delayed the herbicide treatment until August, allowing the herbaceous weeds to compete with the oak seedlings for 4 mo prior to application. Johnson et al. (1986) noted the need for competition control in oak planting efforts and Russell et. al. (1998) reported the need for grass control when oak seedlings are planted in established pasture areas. Kormanik et al. (2004) noted that complete competition control for the entire growing season is essential for optimal survival, growth, and development of oak seedlings. Not only is controlling the competition beneficial, additional benefits are obtained if the herbicide is applied early (preemergence or early postemergence). From a management perspective, survival rates of less than 75% are regarded as highly undesirable economically (Grebner et al. 2002), and competition control in planting areas such as those represented in these studies appears necessary to achieve survival greater than 75%.

Sources of Materials

[1] Spray equipment, R+D Sprayers, 419 Highway 104, Opelousas, LA 70570.

Acknowledgments

We acknowledge the support of DuPont Chemical Company and the cooperation of the Department of Wildlife and Fisheries in making study sites available.

Literature Cited

Allen, J. A. and H. E. Kennedy, Jr. 1989. Bottomland hardwood restoration in the Lower Mississippi Valley. U.S. Fish and Wildlife and USDA Forest Service Bulletin. 28 p.

Anderson, C. P., P. E. Pope, W. R. Byrnes, W. R. Chaney, and B. H. Bussler. 1983. Hardwood tree establishment in low plant cover on reclaimed mineland. Proc. of Third Ann. Conf. on Better Reclamation with Trees. Purdue Univ. Pp. 158–170.

Buckley, D. S. 2002. Field performance of high quality and standard northern red oak seedlings in Tennessee. Proc. of 11th Biennial South. Silv. Res. Conf. Pp. 323–327.

Clark, S. L., S. E. Schlarbaum, and P. P. Kormanik. 2000. Visual grading and quality of 1-0 northern red oak seedlings. South. J. Appl. For. 24:93–97.

Ezell, A. W. and L. R. Nelson. 2001. Weed control and crop tolerance after preemergent and postemergent applications of sulfometuron in oak (*Quercus* spp.) plantations. Weed Technol. 15:585–589.

Gardiner, E. J. 2002. Forest restoration in the Lower Mississippi Alluvial Valley. Proc. IUFRO Conf. on Restoration of Borealand Temperate Forests. Pp. 36–37.

Grebner, D. L., A. W. Ezell, D. A. Gaddis, and S. H. Bullard. 2002. Impacts of southern oak seedling survival on investment returns in Mississippi. J. Sustainable For. 17:1–19.

James, J. P. 2001. Afforestation of Bottomland Hardwood Forests in the Lower Mississippi Alluvial Valley: Trends, Planting Techniques, and Monitoring Recommendations. M.S. thesis. College of Forest Resources, Mississippi State University. Pp. 68–71.

Johnson, P. S., C. D. Dale, K. R. Davidson, and J. R. Law. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. North. J. Appl. For. 3:66–68.

Johnson, R. L. 1989. Guidelines for planting hardwood trees in southern bottomland fields. USDA Forest Service Field Day Handout, Stoneville, MS. 6 p.

Johnson, R. L. and R. M. Krinard. 1987. Direct seeding of southern oaks—a progress report. Proc. of 15th Ann. Hardwood Symp. Memphis, TN. Pp. 10–16.

Kennedy, H. E. Jr. 1984. Hardwood growth and foliar nutrient concentrations best in clean cultivation treatments. For. Ecol. Manag. 8:117–126.

King, S. L. and B. D. Keeland. 1999. Evaluation of reforestation in the Lower Mississippi Alluvial Valley. Restor. Ecol. 7:348–359.

Kormanik, P. P. and J. L. Ruehle. 1987. Lateral root development may define nursery seedling quality. Proc. Fourth Biennial South. Silv. Res. Conf. Pp. 225–229.

Kormanik, P. P., S. S. Sung, D. Kass, and S. J. Zarnoch. 2002. Effect of seedling size and first-order lateral roots on early development of northern red oak on a mesic site: eleventh year results. Proc. of 11th Biennial South. Silv. Res. Conf. Pp. 332–337.

Kormanik, P. P., S. S. Sung, T. Kormanik, T. Tibbs, and S. J. Zarnoch. 2004. Northern red oaks from acorns to acorns in 8 years or less. Proc. of 12th Biennial South. Silv. Res. Conf. Pp. 555–558.

Krinard, R. M. and R. L. Johnson. 1981. Flooding, beavers, and hardwood seedling survival. USDA For. Serv. Res Note 50-270. 6 p.

McGee, C. E. and D. L. Loftis. 1986. Planted oaks perform poorly in North Carolina and Tennessee. North. J. Appl. For. 3:114–115.

Miwa, M. 1993. Reestablishment of Bottomland Oak Species in Lower Mississippi Valley Alluvial Soils. M.S. thesis. College of Forest Resources, Mississippi State University. Pp. 57–61.

Oswalt, C. M., W. K. Clatterbuck, S. E. Schlarbaum, and A. E. Houston. 2004. Growth and development of outplanted high-quality northern red oak seedlings and the effects of competing herbaceous production within four overstory treatments—first-year results. Proc. of 12th Biennial South. Silv. Res. Conf. Pp. 559–564.

Ozlap, M. 1997. Influence of Soil Properties and Planting Methods on Fifth-Year Survival and Growth of Four Bottomland Oak Species in a Farmed Wetland. M.S. thesis. College of Forest Resources, Mississippi State University. Pp. 22–24.

Russell, D. R., J. D. Hodges, and A. W. Ezell. 1998. An evaluation of hardwood reforestation methods on previously farmed lands in central Alabama. Proc. of 9th Biennial South. Silv. Res. Conf. Pp. 272–276.

Seifert, J. R., P. E. Pope, and B. C. Fischer. 1985. The effects of three levels of site preparation on planted swamp chestnut oak on a poorly drained site. Proc. of Third Biennial South. Silv. Res. Conf. Pp. 53–56.

Smith, D. M., B. C. Larson, M. J. Kelty, and P. M. S. Ashton. 1997. The Practice of Silviculture. 9th ed.. New York: John Wiley and Sons. Pp. 264–286.

Stanturf, J. A. and J. P. Shepard. 1995. Bottomland hardwood restoration in the Lower Mississippi River Alluvial Floodplain. Proc. of Eighth Conf. on Research and Resource Manag. in Parks and on Public Lands. Pp. 250–255.

Ware, B. P. and E. S. Gardnier. 2004. Partial cutting and establishment of artificial Nuttall oak regeneration in the Mississippi Alluvial Plain. Proc. of 12th Biennial South. Silv. Res. Conf. Pp. 587–591.

Wood, F. A. 1998. First-year performance of direct seeded Nuttall and willow oak in response to flooding in a farmed wetland of the Mississippi Delta. M.S. thesis. College of Forest Resources, Mississippi State University. Pp. 5–66.

Received July 6, 2006, and approved July 10, 2006