EVALUATING THE USE OF ENHANCED OAK SEEDLINGS FOR INCREASED SURVIVAL AND GROWTH: FIRST-YEAR SURVIVAL

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Abstract—Oaks (*Quercus* spp.) are very important in the southern landscape for timber production and wildlife habitat. More landowners are attempting to establish oak plantations as the demand for wood products and wildlife habitat continues to increase. These attempts are not always successful with early growth and survival becoming major concerns. In this study, 6,480 1-0 bareroot Nuttall oak (*Quercus nuttallii* Palmer) and white oak (*Quercus alba* L.) seedlings were planted in February 2005 on the Malmaison and Copiah County Wildlife Management Areas (WMAs) in MA. Half of the seedlings are high quality nursery-run seedlings and the other half are "enhanced" seedlings grown under a special nursery protocol developed by Dr. Paul Kormanik. The impact of various planting method, competition control, and fertilization treatments on seedling survival was evaluated during the first year following planting. First year survival did not differ significantly among nursery stocks. Seedling survival differed significantly among competition control and planting method treatments at Malmaison WMA.

INTRODUCTION

Oaks (*Quercus* spp.) are a very important component of the southern landscape for timber production as well as wildlife habitat. Thousands of acres are artificially regenerated with oak seedlings annually. As of 2002, more than 300,000 acres of retired agricultural land have been afforested in the Lower Mississippi Alluvial Valley (LMAV) (Ezell and Shankle 2004). By 2040, it is estimated that more than 30 million acres of retired agricultural land across the South will be planted in trees, with millions of these acres being planted in hardwoods (Wear and Greis 2002). This is largely due to increasing landowner participation in federal cost-share programs and interest in improving wildlife habitat (Ezell and Nelson 2001).

More landowners are attempting to establish oak plantations as demand for wood products and wildlife habitat continues to increase. However, artificial regeneration attempts are not always successful, and early growth and survival have become major concerns as newly planted oak seedlings are often subjected to harsh site conditions including herbaceous competition, herbivory, drought, and flooding (Schweitzer and others 1999). Also, landowners with wildlife interests are concerned about the length of time required for an oak tree to produce acorns. Benefits would be tremendous if oak establishment could be facilitated and the length of time required to produce acorns shortened.

Few forest tree nurseries were growing hardwoods in the Southern United States before the mid 1980s because the primary emphasis was on pine seedling production. This began to change as groups such as furniture manufacturers and wildlife organizations became concerned about the decline of oak forests in the Southern United States. Oak seedlings being grown in nurseries often were of poor quality. In 1984, the USDA Forest Service Institute of Tree Root Biology (ITRB) in Athens, GA initiated research to develop a nursery protocol for growing oak seedlings that would enable the formulation of a biologically based grading system (Kormanik and others 2003). The major ITRB goal was to develop a reliable nursery protocol to consistently produce seedlings of sufficient size for advance oak regeneration in cleared areas. This protocol has proven successful in producing quality oak seedlings from 10 oak species and many other hardwood species (Kormanik and others 2002a).

Studies have shown that using "enhanced" oak seedlings (seedlings produced under the special nursery protocol) in conjunction with intensive establishment procedures can improve early growth and survival, and reduce the length of time required for an oak tree to produce acorns (Kormanik and others 2002b). However, the relative importance of seedling parameters, site preparation methods, planting methods, competition control, and fertilization in this process is currently unknown. Very few studies have compared the initial performance of "enhanced" seedlings to nursery-run seedlings. Also, more information is needed on the effects that these practices have on establishing oak plantings and facilitating growth and development.

OBJECTIVES

The objectives of this study were:

1. To evaluate survival and initial growth response of oak seedlings produced under special nursery protocols ("enhanced" seedlings) compared to nursery-run oak seedlings of the same species.
2. To evaluate influence of various cultural practices including competition control, planting method, and fertilization on initial seedling performance of these same nursery stocks.

MATERIALS AND METHODS

Site Description

This study was conducted on Malmaison WMA and Copiah County WMA. Malmaison WMA is located in Grenada County approximately 14 miles north of Greenwood, MS. Copiah County WMA is located in Copiah County approximately 16 miles west of Hazlehurst, MS. Each study area encompasses approximately 7.5 acres of retired agricultural land. Soils within

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research plots on Malmaison WMA consisted of silt loam with a pH ranging from 6.1 to 7.4. Copiah County WMA research plots consisted of silt soils with a pH ranging from 5.2 to 5.8.

Seedlings

Nuttall oak (*Quercus nuttallii* Palmer) and white oak (*Quercus alba* L.) seedlings were chosen for this study because they are two of the most commonly planted species in the South. At each study site, 3,240 1-0 bare-root seedlings were planted at a spacing of 10 by 10 feet in February 2005. Half of seedlings planted are nursery-run seedlings of good quality from the Molpus Timberlands Nursery near Elberta, AL. The other half of seedlings ("enhanced" seedlings) were grown at the Flint River Nursery near Byromville, GA. Enhanced seedlings are very high-quality seedlings that are capable of acorn production at early ages and growing exceptionally well when managed intensively (Kormanik and others 2002a, Kormanik and others 2003). The management regime that has resulted in this growth/acorn production included planting in augered holes, fertilization, and complete competition control for each growing season after planting.

Treatments

Planting method—Three planting methods were utilized in this study. These methods included hand planting with shovels in subsoiled trenches, augering, and hand planting with planting shovels with no soil treatment ("flat" planting). Subsoiling was done with a tractor to a depth of approximately 18 inches. A tractor-mounted, eight-inch auger was used for augering. If necessary, augered holes were backfilled prior to planting so that seedling root collars were placed close to or slightly above ground level.

Fertilization—Half of seedlings received fertilization at planting. A 30-gram packet of 22-10-7 NPK fertilizer designed specifically for hardwood seedlings was used for each seedling to be fertilized. The fertilizer packet was placed in a separate slit approximately one inch from the planted seedling for the hand planting only and subsoiling methods. For auger planted seedlings, the fertilizer packet was placed at the bottom of the augered hole and covered with soil to keep from having direct contact with seedling roots.

Competition control—Three competition control treatments were used in this study. These treatments included pre-emergent application only, control for one full growing season, and total competition control (all years). The pre-emergent application only treatment consisted of one application of Oust XP® applied over the top of seedlings at a rate of two ounces per sprayed acre in March 2005. The one growing season and total competition control treatments were the same for the first growing season. These treatments also included a pre-emergent application of Oust XP® in March 2005. Additionally, these treatments included an application of Select® or Clethodim 2EC® at a rate of 16 ounces per sprayed acre in June 2005 to help control bermudagrass (*Cynodon dactylon* (L.) Pers.) not controlled by the previous application of Oust XP®. Finally, the one growing season and total competition control treatments also consisted of directed applications of glyphosate (1.5 percent v/v) as needed from June to November 2005 for control of forbs and other plants not controlled by the earlier applications.

Experimental Design

A three-split strip-plot in a randomized complete block design with sub-sampling was used in this experiment. Each study site consists of three replications. Each replication contains one of each possible species/nursery stock/planting method/fertilization/competition control combination. Each replication consists of 72 plots that are approximately 150 by 10 feet. Each plot contains 15 seedlings.

Seedling Evaluation

Seedling survival was recorded monthly during the 2005 growing season with an exception of September due to complications from Hurricane Katrina. Seedling survival was based on ocular evaluation. All missing seedlings were considered dead. If a seedling was observed as a resprout in later observations, it was reinstated in earlier survival estimations. The cambium was checked on seedlings which appeared dead to ensure survival status.

Statistical Analysis

Analyses were performed using a mixed procedure in Statistical Analysis System (SAS) software version 9.1®. Analyses were separated by species and site. Survival data for both species at each site were analyzed for interactions among nursery stock, planting method, fertilization, and competition control treatments. A mixed model analyses of variance (ANOVA) was used to test for main effects and interactions. Data were analyzed using least square means (LSMEANS). Survival percentages were arcsine square root transformed to normalize the data. However, actual means are presented for ease of data interpretation. Means were considered significant if $P < 0.05$.

RESULTS AND DISCUSSION

Nuttall oak seedlings exhibited excellent survival at Copiah County WMA during the first growing season. Survival did not differ significantly among treatments. Survival of enhanced and nursery-run Nuttall oak seedlings in October was 99.96 percent and 99.98 percent, respectively (table 1). White oak seedling survival was also excellent during the first growing season at Copiah County WMA. Again, there were not any significant survival differences among treatments. Survival of enhanced and nursery-run white oak seedlings in October was 99.24 percent and 98.62 percent, respectively (table 2). Planting method, fertilization, and competition control treatments had no significant effect on survival. This excellent survival probably resulted from controlling competing vegetation, using high- quality seedlings, and proper handling and planting of these seedlings. This is similar to other studies which have attributed excellent first year survival to quality seedlings, quality handling and planting, and proper species selection for the study site (Schweitzer and others 1999, Gardiner and others 2002, Heitzman and Grell 2003).

Nuttall oak seedlings also exhibited excellent survival during the first growing season at Malmaison WMA. Significant differences in Nuttall oak survival did occur among competition control treatments and among planting method/competition control combinations. Survival of enhanced and nursery-run Nuttall oak seedlings in October was 97.85 and 97.42 percent, respectively (table 3). Nuttall oak seedlings

Table 1—Average Nuttall oak seedling survival during the first growing season, June - October 2005, at Copiah County WMA (includes all treatments)

	Timing of Observation			
Nursery stock	June	July	August	October
	Percent			
E[a]	100.00a[b]	99.98a	99.96a	99.96a
NR	100.00a	99.98a	99.98a	99.98a

[a]E = enhanced, NR = nursery-run.
[b]Values within a column with the same letter do not differ at $\alpha = 0.05$.

Table 2—Average white oak seedling survival during the first growing season, June - October 2005, at Copiah County WMA (includes all treatments)

	Timing of Observation			
Nursery Stock	June	July	August	October
	Percent			
E[a]	100.00a[b]	99.93a	99.57a	99.24a
NR	99.99a	99.44a	98.74a	98.62a

[a]E = enhanced, NR = nursery-run.
[b]Values within a column with the same letter do not differ at $\alpha = 0.05$.

receiving total competition control had significantly greater survival than seedlings receiving pre-emergent only or first growing season treatments (table 4). Survival of seedlings receiving total competition control, pre-emergent only, and first growing season treatments was 99.06, 96.75, and 96.12 percent, respectively. Even though these differences were statistically significant, they were not biologically significant as survival for Nuttall oak was greater than 96 percent in all competition control treatments. Also, the one growing season and total competition control treatments were the same for the first growing season. Therefore, survival differences occurring between these two treatments could have been the result of individual seedlings coming in contact with drifting spray of glyphosate solution. Some mortality was noticed early in the growing season. It is possible that other factors such as improper handling or planting of individual seedlings resulted in these minor differences in Nuttall oak seedling survival.

Survival of Nuttall oak seedlings at Malmaison WMA was greater than 90 percent for all planting method/competition control combinations except the pre-emergent only/hand planting combination (87.58 percent) (table 5). Subsoil and auger planted Nuttall oak seedlings receiving pre-emergent only competition control had survival 11.24 to 11.86 percent greater than survival of hand planted seedlings receiving pre-emergent only competition control. These results indicate that the hand planted seedlings did not tolerate the competition as well as the subsoil and auger planted seedlings. Subsoil and auger planted seedlings were likely able to gain better root establishment before the onset of heavy competition. Subsoiling increases the amount of soil exploited by seedling roots, improves aeration, and can increase soil moisture availability (Russell and others 1997, Gardiner and others 2002). Other studies have shown that subsoiling improved first year oak seedling survival (Johns and others 1999, Self 2006).

Table 3—Average Nuttall oak seedling survival during the first growing season, June - October 2005, at Malmaison WMA (includes all treatments)

	Timing of Observation			
Nursery Stock	June	July	August	October
	Percent			
E[a]	99.68a[b]	99.50a	98.09a	97.85a
NR	99.49a	99.25a	97.93a	97.42a

[a]E = enhanced, NR = nursery-run.
[b]Values within a column with the same letter do not differ at $\alpha = 0.05$.

Table 4—Average seedling survival in different competition control treatments after one growing season at Malmaison WMA (includes all nursery stock, planting method, and fertilization treatments)

Competition Control	Nuttall Oak	White Oak
	Percent	
PEO[a]	96.75b[b]	79.72a
1GS	96.12b	77.97a
T	99.06a	71.13b

[a]PEO = pre-emergent only, 1GS = first growing season, T = total (all years)
[b]Values within a column with the same letter do not differ at $\alpha = 0.05$.

Table 5—Average Nuttall oak seedling survival after one growing season in different planting method/competition control combinations at Malmaison WMA (includes all nursery stock and fertilization treatments)

	Competition Control		
Planting Method	PEO[b]	1GS	T
	Percent		
H[a]	87.58b[c]B[d]	96.44aA	98.61aA
S	98.82aAB	94.94aB	99.04aA
A	99.44aA	96.84aA	99.44aA

[a]H = hand, S = subsoil, A = auger
[b]PEO = pre-emergent only, 1GS = first growing season, T = total (all years)
[c]Values within a column with the same lower case letter do not differ at $\alpha = 0.05$.
[d]Values within a row with the same upper case letter do not differ at $\alpha = 0.05$.

First growing season white oak seedling survival at Malmaison WMA was the lowest among all seedlings. Significant differences in white oak survival did occur among competition control treatments. Survival of enhanced and nursery-run white oak seedlings in October was 76 and 76.74 percent, respectively (table 6). Survival remained above 90 percent until after July observations. In August, survival had dropped to 78.92 and 79.21 percent for enhanced and nursery-run seedlings, respectively. Survival of white oak seedlings receiving total competition control was significantly lower than survival of seedlings receiving pre-emergent only or one growing season treatments (table 4). Survival of white oak seedlings receiving total competition control, pre-emergent only, and one growing season treatments was 71.13, 79.72, and 77.97 percent, respectively.

White oak seedlings suffered greater than 20 percent mortality, regardless of which competition control treatment was applied (table 4). Additional mortality occurred with seedlings receiving one growing season or total competition control treatments. As mentioned earlier, the one growing season and total competition control treatments were the same for the first growing season. Again, survival differences occurring between these two treatments could have been the result of individual seedlings coming in contact with drifting spray of glyphosate solution. Also, variations in the intensity of herbaceous competition could have resulted in white oak seedling survival differences across these treatments.

The drop in white oak seedling survival between July and August observations was probably the result of a rapid increase in competition early in the growing season combined with droughty conditions. White oak seedlings were much smaller than Nuttall oak seedlings, and many were overtopped by herbaceous competition before competition could be treated. It is also very likely that drifting spray of glyphosate solution contacted some seedlings, especially those that were overtopped by competing vegetation. This could have also resulted in seedling mortality. However, survival of seedlings in plots not receiving glyphosate treatment was almost as low, indicating that herbicide drift was not the only cause of seedling mortality. Other studies have reported seedling mortality resulting from herbicide drift (Buckley 2002, Krekeler and others 2006).

Table 6—Average white oak seedling survival during the first growing season, June - October 2005, at Malmaison WMA (includes all treatments)

	Timing of Observation			
Nursery Stock	June	July	August	October
	Percent			
E[a]	97.84a[b]	92.95a	78.92a	76.00a
NR	98.66a	92.49a	79.21a	76.74a

[a]E = enhanced, NR = nursery-run.
[b]Values within a column with the same letter do not differ at $\alpha = 0.05$.

CONCLUSION

Enhanced and nursery-run seedling survival did not differ significantly. The smaller nursery-run seedlings were just as competitive as enhanced seedlings. Seedling survival did not differ significantly between fertilized and non-fertilized seedlings. There were no significant treatment effects on seedling survival at Copiah County WMA, as all seedlings exhibited greater than 98 percent survival after one growing season. In most cases, survival did not differ significantly among planting methods. However, when survival did differ significantly among planting methods, it was with seedlings receiving pre-emergent only competition control. Survival of hand planted seedlings receiving pre-emergent only competition control was significantly lower than survival of subsoil and auger planted seedlings receiving pre-emergent only competition control. The effect of competition control on seedling survival was different by species. Nuttall oak survival was greatest with seedlings receiving total competition control, while white oak survival was greatest with seedlings receiving pre-emergent only competition control. However, differences in Nuttall oak seedling survival among competition control treatments were not biologically significant. Additional white oak seedling mortality occurred at Malmaison WMA in plots receiving glyphosate treatment. Increased mortality resulted from herbicide spray drift contacting some of the white oak seedlings.

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