EFFECT OF MECHANICAL SITE PREPARATION TREATMENTS ON OAK SURVIVAL IN A RETIRED FIELD AFFORESTATION EFFORT – FIRST-YEAR RESULTS

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Abstract.—Mechanical site preparation is frequently proposed to alleviate poor soil conditions when afforesting retired agricultural fields. Without management of soil problems, oak seedlings planted in these areas may exhibit poor survival. While mechanical site preparation methods currently employed in hardwood afforestation are proven, there is a substantial void in research comparing subsoiling, bedding, and combination plowing treatments. In this study, 1,440 bare-root Nuttall oak (*Quercus texana* Buckley) seedlings were planted in February 2008 on three Mississippi sites. All sites had comparable soils and received above-average precipitation throughout the first growing season. Four site preparation treatments were replicated at each site, with 360 seedlings planted in each. Mechanical treatments were implemented using 10-foot row centers, with treatments as follows: control, subsoiling, bedding, and combination plowing. These treatments were applied to evaluate survival. Oak seedlings exhibited excellent survival in all treatments, ranging from 96.7 to 100 percent. No significant difference in overall survival was observed among sites or site preparation treatments. The only observed difference occurred among treatments on one site.

INTRODUCTION

Oaks (*Quercus* spp.) are an important component of southern U.S. forests. Attempts at artificial regeneration frequently fail. For instance, survival of planted seedlings in retired fields is often unsatisfactory, resulting in a low percentage of oaks in established stands (McGee and Loftis 1986, Schoenholtz and others 2001, Stanturf and others 2001, Schweitzer 2004, Stanturf and others 2004). The preponderance of these failed afforestation efforts suggests a need for greater understanding and proper use of techniques in plantation establishment.

Several factors can decrease seedling growth and survival, including: soil conditions, planting techniques, seedling quality, and competing vegetation. With the exception of poor soil conditions, these problems can be alleviated at or after planting time through proper use of high-quality seedlings, as well as by applying proper silvicultural practices to enhance growth and survival. Many retired fields have compacted soils due to past land-use practices (Allen and others 2001, Gardiner and others 2002, Stanturf and others 2004). Seedling growth and survival can potentially be improved through the use of mechanical site preparation to correct compaction problems.

Subsoiling, bedding, and combination plowing are mechanical site preparation treatments which could ameliorate compaction commonly found in these areas. Subsoiling, also known as ripping, is generally

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performed by pulling a 3- to 6-inch wide shank through the soil behind a tractor. Typical cutting depth is 16 inches to 24 inches using traditional straight or parabolic shanks with or without winged tips. If winged tips are used, planting should not occur for up to 1 year (Stanturf and others 2004). This method exposes less mineral soil than other ameliorative methods of mechanical site preparation. Mineral soil is required by most pioneer hardwood species for establishment; thus, subsoiling should result in lower numbers of germinants undesirable for management objectives. Of the various mechanical treatments available, subsoiling is the least expensive and most easily performed due to availability of contractors and the simplicity of the treatment.

The objective of subsoiling is to fracture restrictive layers in the soil, such as those common to retired agricultural fields. Compacted layers are known to restrict plant development and their removal increases tree survival and growth (Russell and others 1997, Ezell and Shankle 2004, Stanturf and others 2004). Subsoiling improves seedling performance by enhancing soil moisture availability, planting depth uniformity, root development, and soil exploitation (Morris and Lowery 1988, Miller 1993, Russell and others 1997).

Significant increases in pine (*Pinus* spp.) survival and growth have been noted when seedlings were planted in subsoil-treated areas (Berry 1986, Morris and Lowery 1988, Fallis and Duzan 1994, Gwaze and others 2006). These benefits should not change when applied to planting oak seedlings. Rathfon and others (1995) reported that subsoiling improved rooting depth in the first growing season for northern red oak (*Q. rubra* L.). Improvements in root growth would be helpful under conditions of low moisture and low fertility.

Ezell and Shankle (2004) stated that subsoiling significantly increased height and groundline diameter growth during the first growing season for Shumard oak (*Q. shumardii* Buckley), water oak (*Q. nigra* L.), willow oak (*Q. phellos* L.), and green ash (*Fraxinus pennsylvanica* Marsh.) seedlings. Improved black walnut (*Juglans nigra* L.) survival has been observed on compacted mine soil after subsoiling (Ashby 1996). Twelfth-year survival of black walnut in subsoiled plots was 33 percent greater than in untreated plots (41 percent and 74 percent, respectively), and average height growth was 7.2 feet and 14.7 feet, respectively. An unspecified red oak species exhibited similar growth and survival responses. Self and others (2010) reported that when oaks were planted under intense herbaceous competition, greater survival was observed in areas receiving only a subsoiling treatment, compared to areas receiving both subsoiling and chemical site preparation. Lower survival in treatment areas receiving both subsoiling and chemical applications was thought to result from greatly increased broadleaf weed regeneration in chemically treated areas compared to areas receiving only the subsoil treatment. Moree and others (2010) observed that Nuttall oak (*Q. texana* Buckley) seedlings planted in subsoiled plots exhibited 11.2 percent greater survival than seedlings planted in untreated plots. The authors indicated that seedlings planted in subsoil trenches were better equipped to tolerate vegetative competition than flat-planted seedlings.

Bedding, also known as hipping or mounding, is typically performed utilizing a moldboard plow, offset disk, levee plow, or furrow plow (Kabrick and others 2005). Soil is turned inward, creating a planting site 3- to 6-feet wide and 6 inches to 2 feet high above the soil surface (Williams 1988, Kabrick and others 2005). Bedding is typically used in the establishment of conifer seedlings on poorly drained soils (Londo and Mroz 2001, Xu and others 2002, Kabrick and others 2005). Increased pine survival has been documented in bedded areas that were inundated and/or saturated regularly (McKee and Wilhite 1986, Morris and Lowery 1988, Xu and others 2002). Greater survival probably resulted from raising the elevation of the rooting zone. Many oak species do not tolerate poorly drained soils and could benefit from the increased aeration found on slightly higher elevations (Hodges and Switzer 1979, Hodges 1997).

Bedding can increase growth of hardwood seedlings through improved soil aeration and drainage, concentrated organic matter and nutrients, and competition control (Fisher and Binkley 2000, Kabrick and others 2005). Patterson and Adams (2003) stated that fifth-year Nuttall oak height growth and survival were greater on bedded sites than on unbedded sites. This response was stronger on heavier clay soils, indicating that the seedlings were probably benefiting from better aeration in the elevated rooting zone. Overall survival observed across bedded sites was approximately 10 percent greater than on unbedded sites.

Not all bedding research has generated positive results. Patterson and Adams (2003) did not note any significant differences in green ash growth or survival between bedded and unbedded sites. Kabrick and others (2005) observed no bedding effects on growth or survival in pin oak (*Q. palustris* L.) and swamp white oak (*Q. bicolor* Willd.) seedlings. Seifert and others (1984) reported a similar lack of effect with swamp chestnut oak (*Q. michauxii*) on a poorly drained upland flat site.

Combination plowing is accomplished by combining subsoiling and bedding treatments into one mechanical treatment. Typically, a subsoil shank or coulter is pulled in front of a bedding plow. Problems with soil compaction, poor drainage, and vegetative competition are improved, enhancing growth and survival of planted seedlings. This technique has been used in pine plantation management and can provide satisfactory results (Will and others 2002, Lincoln and others 2006, Morris and others 2006). Corresponding work has not been performed in hardwood plantings.

STUDY AREAS

This study was located on three sites. The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) owns two of the sites: Copiah County Wildlife Management Area (WMA) and Malmaison WMA. The third site is located near Arkabutla Lake on land owned by the U. S. Army Corps of Engineers.

COPIAH COUNTY WMA

The Copiah County WMA study area is located approximately 16 miles west of Hazlehurst, MS (90.6719°W, 31.8189°N) in Copiah County and was retired from row crop production in the late 1980s. It was maintained as an opening for wildlife through mowing and disking from the time of production retirement until the initiation of this study. The study area encompasses approximately 5.25 acres. The soil series is Oaklimeter silt loam (coarse-silty, mixed, thermic Fluvaquentic Dystrochrept), and is moderately well drained and moderately permeable. Average annual precipitation is 56.33 inches. Soil tests indicate that the site has silt loam texture with an average pH of 5.2.

The woody competition component prior to mechanical treatment primarily comprised sweetgum (*Liquidambar styraciflua* L.), American elm (*Ulmus americana* L.), sycamore (*Platanus occidentalis* L.), and common persimmon (*Diospyros virginiana* L.). Estimated woody coverage was less than 1 percent. Dominant herbaceous species onsite were crimson clover (*Trifolium incarnatum* L.), ladino clover (*T. repens* L.), and ryegrass (*Lolium multiflorum* Lam.). Cumulative herbaceous coverage by these species was 100 percent. Other herbaceous species occurred in small quantities.

MALMAISON WMA

The Malmaison WMA study area is located approximately 14 miles north of Greeenwood, MS (90.0531°W, 33.6876°N) in Grenada County. The site was formerly used in row-crop production and retired from agricultural production in the late 1990s. It was also maintained as an opening for wildlife through mowing and disking from the time of retirement until this study began. The study area encompasses approximately 5.25 acres. The soil series is Collins silt loam (coarse-silty, mixed, acid, thermic Aquic Cumulic Haplorthent) with slopes between 0 and 3 percent, and is moderately well drained and moderately permeable. Average annual precipitation is 52.30 inches. Soil tests indicate that the site has silt loam texture with an average pH of 6.3.

Onsite woody competition prior to mechanical treatment was composed mainly of sweetgum, black willow (*Salix nigra* Marsh.), sycamore, green ash, and eastern cottonwood (*Populus deltoides* Bartr. ex. Marsh.). Estimated woody species coverage was less than 1 percent. Dominant herbaceous species onsite were ryegrass, bermudagrass (*Cynodon dactylon* L.), Brazil vervain (*Verbena brasiliensis* Vellozo.), and Carolina horsenettle (*Solanum carolinense* L.). Cumulative herbaceous coverage by these species was 100 percent. Other herbaceous species occurred in minor quantities.

ARKABUTLA LAKE

The Arkabutla Lake study area is located approximately 5 miles northwest of Coldwater, MS (90.079°W, 33.744°N) in DeSoto County. The site was in soybean production until September 2007. The study area encompasses approximately 5.25 acres. Soil series are Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs) and Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs). Both are well drained gray-brown Podzolic soils with slopes between 2 and 5 percent. Average annual precipitation is 47.69 inches. Soil tests indicate that the site has silt loam texture with an average pH of 6.2. Dominant herbaceous species on site are Brazil vervain, poorjoe (*Diodia teres* Walt.), and thorny amaranth (*Amaranthus spinosus* L.). Cumulative herbaceous coverage by these species was approximately 5 percent at project initiation. Other herbaceous species occurred in very small quantities.

METHODS

EXPERIMENTAL DESIGN AND PLOT ESTABLISHMENT

The study was replicated at all three sites. A randomized complete block design was utilized, and each site received its own unique installment of randomized treatments. Each of the three replicates at each site contained all possible site preparation treatments. Each replication consisted of four planting rows approximately 390 feet by 10 feet and contained 40 seedlings. Each planting row constituted a plot, and received a randomly selected site preparation treatment. All plot and tree locations were determined using a 300-foot surveyor's tape and a handheld compass. Plot ends were marked with 4-foot pieces of 3/8-inch rebar. Individual tree planting locations were marked with 15-inch pin flags.

SITE PREPARATION TREATMENTS

Four mechanical site preparation treatments were used in this study: control (no mechanical treatment), subsoiling, bedding, and combination plowing. Mechanical treatments were applied on 10-foot centers using an agricultural tractor during the first week of November 2007. Subsoiling was performed using Case International's ecolo-til™ 2500 subsoiler system, with trenches cut to a depth of 15 inches using a 3/4-inch straight shank with an 8 inch tiger no-till point. Bedding was performed using a furrow plow with blades set to pull a soil bed approximately 3 feet wide and between 12 and 16 inches deep. The same equipment was used for combination plowing, which consisted of pulling a soil bed over the top of subsoiled trenches.

A 2-ounce application of Oust® XP (E.I. du Pont de Nemours and Co., Wilmington, DE) was applied during March 2008 for herbaceous weed control during the growing season. The Oust® XP treatment was applied in 5-foot bands over the top of seedlings prior to budbreak. A Solo® backpack sprayer (Solo, Newport News, VA) was used for herbicide application at 10 gallons per acre. No surfactant was added in the application.

SEEDLING ESTABLISHMENT

Nuttall oak was chosen for this study. It is a commonly planted species in retired field afforestation, is commercially important, and is a good mast producer for wildlife. Seedlings were purchased from Joshua Timberlands Elberta Nursery in Elberta, AL, and were lifted mid-January 2008. Seedling specifications required 1-0 bare-root seedlings with stems between 18 and 24 inches, and required root systems to be between 8 and 10 inches long with a minimum of 8 first-order lateral roots. Mississippi State University personnel planted 1,440 seedlings (480 seedlings per site) during February 2008. Seedlings were planted at root collar depth using planting shovels. A spacing of 10 feet was chosen to give a seedling density of 435 seedlings per acre.

SURVIVAL AND PRECIPITATION OBSERVATIONS

Survival checks were recorded monthly from May 2008 through October 2008. All seedlings were inspected each month. Seedling survival was based on visual evaluation. The cambium was examined on seedlings which appeared dead to confirm survival status.

Onsite precipitation totals were recorded in 0.01-inch intervals using a RainWise® Model 111 rain gauge (Rainwise, Inc., Bar Harbor, ME) and a HOBO® Event Rainfall Logger. The HOBO® Event Rainfall Logger can record up to 80 inches of rainfall, and data were off-loaded monthly. This precipitation measuring system meets National Weather Service specifications for statistical accuracy. Precipitation totals were recorded for the entire first year and are considered as explanatory variables.

DATA ANALYSIS

Survival averages were calculated using Statistical Analysis System (SAS) software version 9.1 (SAS Institute, Cary, NC). All survival data for Nuttall oak at each site were analyzed for interaction among sites and mechanical site preparation treatments. Seedlings were pooled by site to test for overall seedling survival among sites. Seedlings were also pooled by site preparation treatment to test for overall seedling survival among site preparation treatments. PROC GLM was used to test for significance among site and treatment data. Data were analyzed using least square means (LSMEANS). Means separation was performed using Duncan's New Multiple Range test. Differences were considered significant at $\alpha = 0.05$.

RESULTS

No statistical differences were observed in overall survival of oak seedlings among sites or site preparation treatments (Tables 1 and 2, respectively). No statistical difference in survival was noted among site preparation treatments at the Arkabutla Lake or Malmaison WMA sites (Table 3). Seedlings planted in bedding treatment areas at the Copiah County WMA site exhibited significantly lower survival (96.7 percent) than seedlings in the subsoiling or combination plowing treatments (99.1 percent, and 99.2 percent, respectively). This difference was also present in the comparison among sites for bedding; the Arkabutla Lake and Malmaison WMA sites both exhibited 99.2-percent survival. No survival differences among sites were found among the control, subsoiling, and combination plowing treatments.

Table 1.—First-year Nuttall oak survival for three Mississippi sites.

Study site	Survival (%)
Arkabutla Lake	99.4 a*
Copiah County WMA	98.3 a
Malmaison WMA	99.6 a

*values within a column followed by different letters are significantly different at α = 0.05 according to Duncan's New Multiple Range Test.

Table 2.—First-year Nuttall oak survival by site preparation type for three Mississippi sites.

Site preparation	Survival (%)
Control	99.4 a*
Subsoiling	99.2 a
Bedding	98.3 a
Combination plowing	99.5 a

*values within a column followed by different letters are significantly different at α = 0.05 according to Duncan's New Multiple Range Test.

Table 3.—First-year Nuttall oak survival by site preparation type at three Mississippi sites.

Site preparation	Arkabutla	Copiah County WMA	Malmaison WMA
	Survival (%)		
Control	100.0 A*a‡	98.3 ABa	100.0 Aa
Subsoiling	99.2 Aa	99.1 Aa	99.2 Aa
Bedding	99.2 Aa	96.7 Bb	99.2 Aa
Combination plowing	99.2 Aa	99.2 Aa	100.0 Aa

*Values followed by different uppercase letters within a column are significantly different at α = 0.05 according to Duncan's New Multiple Range Test.

‡Values followed by different lowercase letters within a row are significantly different at α = 0.05 according to Duncan's New Multiple Range Test.

DISCUSSION

Generally, greater survival would be expected in areas receiving more intense mechanical site preparation. Several factors may have been involved in the lack of statistical differences in the survival observed in this study. These factors include good seedlings, proper planting, the Oust® XP application, and above-average rainfall. Of particular interest is that all three sites received rainfall well above average for the year. Rainfall for the Arkabutla Lake, Copiah County WMA, and Malmaison WMA sites was 73.23 inches, 69.24 inches, and 60.85 inches, respectively. These values represent 25.54 inches, 12.91 inches, and 8.55 inches more than the average annual expectation, respectively. This additional rainfall was distributed relatively evenly across the year.

A difference in survival was observed among sites for the bedding treatment and among mechanical treatments at the Copiah County WMA site. While the slightly lower survival in bedded areas was significant, this difference was very small (2.5 percent) and was not noted on the other two sites. Even if similar results had been found on the other two sites, the difference was so slight that management strategy would not be impacted. Additionally, the Copiah County WMA site exhibited slightly lower survival for most of the treatments compared to the other two sites. Thus, the lower survival observed in this particular treatment was possibly a result of site differences.

The results of this study concur with those of previous studies (Haynes and others 1995, Moree and others 2010). When high-quality seedlings are planted properly, receive proper growing-season herbaceous weed control, and are supplied with good growing conditions, good survival can be achieved. Also, while mechanical treatment may result in growth differences, it may not be necessary for initial survival if rainfall is adequate. While hardwood plantings are never guaranteed, land managers can control most of the inputs into an afforestation effort. If these inputs are correct and nature cooperates, excellent survival is possible.

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