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Survival and Growth Performance of Two Oak Species and Three Planting Stocks on Lands Disturbed by Hurricane Katrina

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By

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Survival and growth of two oak species, water oak (*Quercus nigra*) and swamp chestnut oak (*Quercus michauxii*), and three planting stocks: 1-0 bareroot, conventional containerized, and EKOgrown™ seedlings were compared for two growing seasons. Conventional containerized seedlings had the best survival. Bareroot seedlings had the second highest survival and EKO™ seedlings had the lowest at the end of two growing seasons. Conventional containerized planting stock exhibited greater groundline diameter (GLD) growth for both species at the end of the first growing season compared to bareroot and EKO™ planting stock. Bareroot seedlings had similar GLD growth to EKO™ seedlings for both years. Conventional containerized seedlings height differed in water oak but did not differ in swamp chestnut oak at the end of year two compared to bareroot seedlings. EKO™ seedlings exhibited severe dieback at the end of both growing seasons and the least amount of height growth.

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CHAPTER I

INTRODUCTION

The southern states of North America have some of the most productive bottomland soil in the United States. These fertile deposits from rivers coupled with a warmer climate and longer growing season make these sites the primary area for bottomland hardwoods in the region. Hardwoods such as oaks (*Quercus spp.*) are valuable resources to the southern forest for timber production, flood storage, and nutrient charge (Hall and Lambou 1989, Ezell et al. 2007, Moree et al. 2010). Bottomland hardwoods provide many benefits to both non-industrial private landowners (NIPL) and industry landowners including aesthetics, excellent wildlife habitat, recreational activities, endangered species refuges, and opportunities to generate money from harvesting. Bottomland hardwood forests in Mississippi were damaged by Hurricane Katrina in 2005 when it made landfall along the Gulf Coast. A major problem resulting from the damage is lack of oak regeneration, which can be problematic without advance planning. Thus, the preferred practice of natural regeneration, which requires a well-structured plan and timing to be successful, may not be an option (Coder 1994, Belli 1999, Dey et al. 2008). Typically, oaks will be a much smaller percentage of the new overall stand component when compared to the parent stand (Beck and Hooper 1986, Loftis 1988). Some studies suggest that this can be a result of oaks being much slower to grow when compared to light-seeded competitors (Smith 1993, Thompson and Nix

1995). In the South, oaks are not strong competitors with rapid and aggressively growing herbaceous vegetation. Herbaceous competition is the main cause for seedling mortality during the establishment period of 1-2 years (Smith et al. 1997). With these circumstances, artificial regeneration of desirable hardwoods is a viable option and may be the only one available in areas disturbed by a major storm.

Regeneration efforts on bottomland sites are mainly focused to enhance wildlife habitat, produce timber, and increase/protect water quality which is a main concern with managers in the South (Witter 1991). Artificial regeneration has become an important forest management option when a stand lacks natural regeneration to restore the oak component of a stand. However, this practice has potential to be problematic on mesic sites (Lorimer 1993, Johnson et al. 2002). Seasonal flooding on poorly drained sites causes more problems for oak re-establishment on a floodplain site and favors undesirable species that are more tolerant of wet conditions.

Planting a high quality and vigorous seedling is an essential element of any artificial regeneration prescription (Dey and Parker 1997). These seedlings will have taller stems, more fibrous roots, ideal shoot to root ratio, and larger diameters. These characteristics lead to better survival and growth rates. According to Dey and Parker (1997), larger seedlings perform better against competing vegetation. Couple a high quality seedling with proper chemical and mechanical methods and survival and growth has shown to increase (Ezell et al. 2007).

Proper planting is also an essential component. Improper planting such as J-rooting, excessive root pruning or shallow planting can increase the chances of mortality and seedling stress. Using a high quality seedling is negated if improper planting and handling techniques are used. Many research studies have correlated mortality of seedlings with improper planting. These research studies mainly focused on one planting stock, but little has been done to compare survival and growth of various oak planting stocks. This study will help fill the void of information to help landowners make a more well-informed and more cost-effective decision.

Objectives

The goal of this study is to evaluate the two year performance of three different planting stocks of two species of oaks on Hurricane Katrina disturbed site.

The objectives are:

I. Compare the two year survival, height growth, and groundline diameter growth of water oak (*Q. nigra*) and swamp chestnut oak (*Q. michauxii*).

II. Compare the two year survival, height growth, and groundline diameter growth of three planting stocks:

   a. High-quality 1-0, bareroot seedlings
   b. Conventional containerized seedlings produced with typical nursery practices
   c. Large containerized seedlings (EKOgrown™)

CHAPTER II

LITERATURE REVIEW

Hurricane Katrina

Hurricane Katrina made landfall along the gulf coast of Mississippi on August 29, 2005. As a Category III hurricane, it was the third largest storm to strike the coastal United States in the past century (Graumann et al. 2005, Chapman et al. 2008). From landfall, it proceeded on a northern trajectory into Mississippi, and although it was relegated from hurricane status 241 km inland, peak wind gusts greater than 129 km hr were observed throughout the state (Graumann et al. 2005). It impacted every Gulf Coastal state, but the majority of damage was created along coasts of Alabama, Mississippi, and Louisiana.

This storm not only decimated homes, but also a large area of Mississippi forests. Initial assessment of damage estimated that 37% of timberland in Mississippi experienced damage. Nearly 90% of the damage occurred in the southernmost eight counties (USDA Forest Service 2005). Oswalt and Oswalt (2008) and Wang and Xu (2009) found similar results. Chambers et al. (2007) estimated that approximately 320 million large trees (DBH > 10 in.) either died or were severely damaged as a result of the storm. It was first thought that loss of softwoods exceeded that of hardwoods (USDA Forest Service 2005), until further evaluations indicated that bottomland hardwood forests were most affected (Chapman et al. 2008, Oswalt and Oswalt 2008, Wang and Xu 2009).

Oak Regeneration

Some characteristics of oaks make them extremely challenging to regenerate on high-quality sites, primarily due to their poor competitive ability on moist soils (Clark 1993, Hodges and Gardiner 1993). Mostly oaks are moderately intolerant of shade, slow to respond to release, and exhibit delayed juvenile shoot growth (Janzen and Hodges 1987, Loftis 1990, Hodges and Gardiner 1993, Smith 1993). Unfortunately, rapid initial shoot growth is a characteristic of some shade tolerant and many undesirable shade intolerant species. Generally, only oak seedlings with established root systems have the competitive ability to survive to successive growing seasons (Meadows and Hodges 1997). When present in high densities, competitors may be deleterious to oak persistence and development. Fresh oak germinates can be a good source of regeneration when the previous fall produced a good acorn crop and harvesting operations were performed in a timely manner the following spring. Combined with adequate precipitation, this would allow seedlings to flourish with multiple flushes during the first growing season. However, because of the uncertainty in meeting these conditions, older seedlings are a more dependable source of regeneration.

Advanced regeneration is widely accepted as the best indication that oaks will achieve dominant canopy positions in the succeeding stand (Hodges 1987, Loftis 1990, Clatterbuck and Meadows 1993, Meadows and Hodges 1997, Meadows and Stanturf 1997). Establishment of advanced regeneration often requires control of non-commercial species prior to, or during harvest operations by use of injection or other mechanical operations (Janzen and Hodges 1987, Meadows and Stanturf 1997). Oak stems should be established and well distributed to compete with shade intolerant, light-seeded species following release. Adequate distribution of advanced regeneration prior to harvest is a cardinal principle applied when natural regeneration is used to favor oaks.

When feasible, natural regeneration should be implemented in conjunction with a harvesting method that creates openings large enough to meet the light requirements of the target species. Clearcutting, shelterwood, and patch cutting are the most appropriate options (Meadows and Hodges 1997). Clearcutting has been the most dependable method of regenerating oaks in southern bottomlands, and when combined with natural regeneration, is the most cost-effective of all the harvest-regeneration systems (Clatterbuck and Meadows 1993, Dey et al. 2008). A modified shelterwood method, proposed by Hodges (1987), may be used to develop advanced regeneration when clearcutting is unlikely to produce desired results. Patch cutting may be used when aesthetics are a concern; however, it is the most costly of the three methods (Meadows and Hodges 1997).

Artificial Regeneration of Oaks

Natural regeneration of oaks is not always feasible or possible. Examples include retired agricultural lands, areas with insufficient or poorly distributed seed sources, or when a salvage operation following extensive damage is conducted before regeneration can be established. Factors that land manages need to be aware of when regenerating a stand include site quality, prior stand condition, site preparation, species-site suitability, planting stocks, seedling quality, quality of planting job and desired stand structure (Kennedy 1993, Baker and Broadfoot 1979, Stanturf et al. 2004, Dey et al. 2008).

Stands which cannot be regenerated using natural regeneration can be established either by direct seeding or by planting seedlings. Stands sown with acorns are generally more species diverse than those planted with seedlings (Allen 1990). If wildlife habitat is the primary goal of ownership, direct seeding may be a better option due to its inherit value to have a more diverse species composition (Haynes 2004). However, most landowners in the southern U.S. are more interested in timber production, and research shows that sites planted with seedlings typically exhibited greater survival and growth and better quality timber (Allen 1990, Lockhart et al. 2005). For which reason, artificial regeneration has become the almost exclusive choice for oak establishment in areas without advanced oak regeneration or well established hardwood stands (King and Keeland 1999, Schoenholtz et al. 2001, Haynes 2004).

Bareroot Seedlings

Bareroot seedlings have been the primary choice in artificial regeneration for bottomland hardwood regeneration for many years (King and Keeland 1999). They are less expensive to produce, which has made them the number one choice for most hardwood nurseries. A favorable feature of bareroot seedlings is that they can be either planted by hand or machine.

Bareroot seedlings are available in many different age classes and sizes but, the preferred bareroot seedling for bottomland hardwood regeneration is a high quality, seedling which has spent one year in a nursery bed and no time of years as a nursery outplant (i.e. 1-0 seedling). Characteristics of a high quality 1-0, bareroot seedling are a basal diameter between 6mm and 8mm, total height between 50cm and 70cm, and more than seven first order lateral roots (FOLR) (Kormanik et al. 1987, Allen et al. 2001, Dey et al. 2010). A tall seedling with a large diameter and more extensive lateral root system typically performs better than those with smaller diameters and less extensive root systems (Kormanik et al. 1995, Kormanik and Ruehle 1987, Teclaw and Isebrands 1993). To optimize survival and reduce planting shock, these trees need to be planted from January to mid-March to ensure seedlings are completely dormant (Stanturf et al. 1998). To reduce any harm to the seedling, extra measures are taken. Some of measures include proper storage, handling, and planting practices. All of these steps serve to decrease the effects of transplant shock and the amount of establishment time.

Bareroot seedling performance is largely dictated by precipitation and amount of competing vegetation in the early years of establishment. Allen (1990) provides one of the best examples to illustrate this point. He evaluated bareroot plantings on federally owned lands after an average of 7.5 years and observed variable survival ranging from 90% to 55% when minimal or no post-planting treatments were applied. Differences in survival rates were attributed to differences in soil moisture and competing vegetation among sites. The results of this study demonstrated that bareroot seedlings are a viable option for artificial regeneration, but it also highlighted their sensitivity to inadequate moisture and competing vegetation.

Some nurseries offer standard bareroot planting stock at a cheaper rate than high quality bareroot planting stock. However to improve survival and performance of bareroot seedlings, it is important to plant high quality bareroot seedlings (Gardiner et al. 2002). Quality is graded based on morphological attributes after lifting such as root collar diameter, stem height and FOLR numbers.

Conventional Containerized Seedlings

A need for containerized seedlings was recognized when inconsistencies arose with planting bareroot seedlings in 1970's (Stein et al. 1975). Nursery production of containerized seedlings provided a more consistent product and containerized seedlings can be more hardy and robust than bareroot seedlings because of their fibrous undisturbed root system. This can give them an advantage when planted outside of the dormant season and when poor environmental conditions exist (Allen et al. 2001). Conventional containerized seedlings are typically shorter than 1-0 bareroot stock and have less root volume and mass but, they offer the advantage of a more fibrous root system and thus, a more balanced root "to" shoot ratio (Burkett and Williams 1998, Humphrey 1994, Williams and Craft 1998). These characteristics better equip containerized seedlings to overcome transplant stress and harsh conditions during the first growing season. Handling malpractices are mitigated due to the root protection offered by the container and planting media. On average, containerized seedlings exhibited survival rates greater than 80% regardless of planting date (William and Craft 1998). However, they do need to be planted after freezing temperatures especially when planted in high shrink-swell clay soils. This is to avoid the seedling being "heaved" out of the ground from the soils expanding and shrinking (Stroupe and Williams 1999).

Greater survival and early growth advantages of containerized seedlings are well documented. Johnson et al. (1984) reported greater shoot growth, leaf area, and root elongation for containerized northern red oak (*Quercus rubra*) seedlings compared to both small and large 1-0 and 1-1 bareroot stock after one growing season. Williams and Stoupe (2002) reported that containerized water and willow oak (*Quercus phellos*) had over twice the height growth of 1-0 bareroot seedlings after one growing season. Wilson et al. (2007) reported 25% greater survival and positive height growth for container grown northern red oak seedlings compared to 1-0 bareroot seedlings which exhibited dieback overall. Williams and Craft (1998) reported similarly better survival and growth of containerized Nuttall oak (*Quercus nuttallii*) seedlings compared to 1-0 bareroot seedlings even when planted late in the growing season. These studies affirm the ability of containerized seedlings to overcome transplanting stress and induce height growth earlier than bareroot seedlings.

After a pre-emergent herbaceous weed control treatment was applied to both containerized and bareroot stock, Hollis (2011) found that both Nuttall and swamp chestnut oak 1-0 bareroot seedlings maintained a consistent survival and height advantage over containerized seedlings both during first and second growing seasons. Thus, the advantage of planting containerized seedlings may be decreased or eliminated when growing conditions are favorable for bareroot plantings.

Some studies have indicated that seedling performance may be improved by increasing the size of the container (Moorhead 1978, Howell and Harrington 2002). Self et al. (2010) observed similar patterns when comparing small containerized seedlings to larger potted seedling. Costs vary greatly in planting stock and the higher price of large potted seedlings may cause some land owners to avoid them as the added benefits may not be cost-effective.

Large Containerized Potted Seedlings

Conventional size containerized seedlings may potentially have early survival and growth advantages compared to bareroot seedlings, primarily because of the greater capacity of their roots to absorb water and nutrients. However, because of their small stature, they are subject to many of the same factors that inhibit early growth and survival of 1-0 bareroot seedlings such as competing vegetation, white-tailed deer herbivory, and flooding. To overcome these limitations, Forest Keeling Nursery in Elsberry, Missouri developed a nursery process, the Root Production Method™ (RPM™), to produce large containerized seedlings with well developed, fibrous root systems (Dey et al. 2004). In 2012 another growing technique was used to produce seedlings grown in a pot named EKO™ which is made by RootMaker®. These seedlings are often over 1.5m tall, and have substantially larger root systems than 1-0 bareroot seedlings (Dey et al. 2004, Dey et al. 2006).

Because of their height, it is thought that RPM™ and EKO™ seedlings may help reduce the impacts of shading from overhead competition, flooding, and occurrence of deer browsing of terminal buds (Dey et al. 2006). It is thought that because of their size and potting medium, transplant shock will be mitigated and eliminated.

Research conducted with RMP™ seedlings is limited, but most of the information originates from a long-term case study installed on two retired agricultural sites in Missouri (Dey et al. 2003, Dey et al. 2004, Dey et al. 2006, Kabrick et al. 2005, Shaw et al. 2003), comparing the performance of RPM™ and 1-0 bareroot seedlings. Further studies have been done in south Mississippi (Hollis 2011, Alkire 2011, Conrad 2013).

The major drawback to large container seedlings is cost per unit. EKO™ trees planted in this study cost $15 per seedling and an additional $5 per seedling planting cost. The additional planting cost is a result of the size of the seedling which makes it more difficult to plant (Stanturf et al. 2004). Compare this price to average cost of a bareroot seedling being \$0.25 - \$0.35 and potted seedlings lose their appeal to many landowners (Dey et al. 2006). Long term benefits may offset the increased initial costs for some managers whose primary objective is to provide mast for wildlife. Dey et al. (2006) contended that planting fewer larger containerized seedlings per area will allow the cost to be offset when compared to individual price of bareroot seedlings. Intensive management of these small stands of larger potted seedlings could lead to a better established oak dominated plantation and future overstory. Common agroforestry practices such as riparian buffers, wind breaks, alley cropping, or silvopasture give RPM™ a niche that they could utilize (Dey et al. 2003). Thus, the "role" of RPM™ seedlings may differ from that of smaller planting stocks in bottomland restoration efforts (Dey et al. 2006).

Herbaceous Weed Control

Competing vegetation is a common inhibitor for most land owners trying to regenerate oaks in bottomland sites. Woody and herbaceous vegetation limit moisture availability, direct sunlight, and growing space for the much slower growing oak seedlings. Moisture availability is often the limiting factor because of the aggressive and persistence of forbs and other herbaceous species (Ezell 2007). Many of the herbaceous and woody species can be controlled through proper application of herbicides (Haynes 2004). While many factors have contributed to the high frequency of plantation failures, studies show that chemical control of competition can drastically improve survival, especially herbaceous weed control in the initial years of establishment (Ezell et al. 2007). Research indicates that use of herbaceous weed control alone is an economically desirable alternative to the "plant and walk away" approach (Grebner et al. 2003) which is the suggested approach for operational planting of larger potted seedlings (RPM™ and EKO™).

Sulfometuron methyl (Oust® XP)

Sulfometuron methyl (active ingredient in Oust® XP) is a broad spectrum, soil active herbicide that provides effective control of many species of grasses and forbs. It is suitable for tank mixing and is commonly used for herbaceous weed control in oak seedling establishment. Post-plant and pre-emergent applications are effective with this herbicide. Pre-emergent applications are most effective and should be applied prior to bud-break to minimize crop damage to oaks (Ezell and Cachot 1998). At a rate of 140g/ha, Oust® XP is effective for controlling many problematic herbaceous species, but it is only moderately effective against goldenrod (*Solidago spp.*), dogfennel (*Eupatorium capillifolium*), broomsedge (*Andropogon spp.*) and johnsongrass (*Sorghum halepense*). It is ineffective at controlling woody species (Miller 1993). Site preparation tank mixes containing sulfometuron methyl used for pine establishment have been shown to have substantial residual effects on herbaceous weed establishment. Ezell (2002) observed 80% bareground in July in plots treated the preceding September with site preparation tank mixes containing 210 g/ha Oust® or 539g/ha of Oustar® compared to 15% for those in control plots.

Ezell and Cachot (1998) reported an average of 20-25% increase in survival for six oak species and green ash (*Fraxinus pennsylvanica*) treated with two rates of Oust® (140 and 281g/ha) compared to untreated areas which averaged 60-70% survival in a case investigating post-plant pre-emergent application for crop survival. The results of two other trials with cherrybark oak (*Quercus pagoda*) and Nuttall oak similarly showed increases in average survival (31-44%) greater than control areas in years when moisture availability decreased due to below average growing season precipitation (Ezell et al. 2007). In all three trials, a 75% average was achieved during the first growing season with application (Ezell et al. 2007). Results from these studies warrant the use of Oust® XP in oak establishment and provides a cost effective way to control undesirable vegetation.

CHAPTER III

MATERIALS AND METHODS

Site Description

Research was conducted on two privately owned sites located in southeast Mississippi. One site is located 16 km northwest of Hattiesburg and the other is 8 km southeast of Lucedale. The soil series represented in this study were Freest-Susquehanna-Prentiss and Lenoir silt loam, respectively. According to USDAwebsoilsurvey.com (2012) the Hattiesburg area receives an average of 57in of annual rainfall. The Lucedale area receives an average of 61in of annual rainfall.

The Malone site (31°23’47.93N”, -89°28’33.24”W) in Lamar County, has a Freest-Suspuehanna-Prentis soil series. Prior to Katrina, timber on this site was a mixed stand of loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*) and water oak. After Katrina, a salvage operation was performed. The site has been kept open by periodic mowing. The few remaining woody stems were injected with a 20% aqueous solution of Arsenal® AC (Imazapyr) to prepare for planting. A restrictive layer approximately 10 in. below ground was reported by the planting crews that may be a restrictive layer for the first years of growth.

The second site, the Welford site (30°49’27.27”N, -88°27’13.86”W) in George County, has a Lenoir silt loam soil series. Prior to Katrina the site also had a mixed stand of loblolly pine and hardwoods. A small drain in the center of the site contained several stems of pond cypress (*Taxodium ascendens*). According to the landowner, this site does flood during, wet winters and springs due to its close proximity to the Escatawapa River. After Katrina, a salvage operation was performed and remaining debris was piled. The site was then root-raked and has been mowed and cultivated every year for a wildlife food plot. Remaining stems were injected with a 20% aqueous solution of Aresenal® AC to prepare for planting.

Site Delineation

The Malone study area was established with 1,800 seedlings planted on a 3.05m by 3.05m spacing. The Welford study area was established with 1,800 seedlings planted on a 2.74m by 2.74m spacing. Spacing was altered for the Welford site due to limited land area. A compass and two 300 ft. surveryor's tapes were used to ensure row straightness and uniform tree spacing. Each study area was divided into three blocked replicates. Six plots containing 100 planting locations were randomly assigned to groups of adjacent rows within each replicate to represent each of the six species and planting stock combinations. Pin flags of different colors were used to distinguish species and planting stock combinations and mark planting locations. A piece of 1.2m rebar was placed at the beginning and ending of each planting row with an aluminum tag attached denoting the replicate, row number, species, and planting stock. Corners of each study area were marked with 3.0m pieces of polyvinyl chloride (PVC) pipe placed over a 1.2m piece of rebar to ensure no disturbance to the study area.

Seedling Establishment

Two oak species, water oak and swamp chestnut oak, and three planting stocks: high quality 1-0 bareroot, 240cm^3 conventional containerized, and EKOgrown™ seedlings grown in a Rootmaker® container were used for evaluation. Bareroot seedlings were purchased from the Rayonier nursery in Elberta, Alabama. Conventional containerized seedlings were purchased from Mossy Oak Native Nurseries™ in West Point, Mississippi. EKO™ seedlings were produced and purchased from RES Native Tree Nursery in Montegut, Louisiana.

A total of 3,600 seedlings were planted for this study. Each site had 1,800 seedlings planted representing 300 seedlings per species and planting stock combination. Mississippi State personnel planted bareroot seedlings and conventional containerized seedlings with planting shovels on the first weekend of February 2013. A commercial planting crew planted the EKO™ seedlings with planting shovels in late October 2012. Seedlings were planted next to a pre-marked pin flag to insure proper spacing for uniformity. Each planting job was monitored by a graduate research assistant to ensure planting quality.

Pre-Emergent Herbicide Application and Groundcover Evaluations

Bareroot and conventional containerized seedlings were treated with a post-plant, pre-bud break application of Oust® XP (140g/sprayed ha) in March of 2013 and 2014. An 11.4L Solo® diaphragm-pump backpack sprayer equipped with a TeeJet 8003 Visiflo® nozzle, specially designed to minimize wind drift, was used to apply the herbicide as a 1.5m 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. To evaluate effectiveness of the pre-emergent application, ocular estimates of percent vegetative groundcover (grass, broadleaf forb, vines, and shrub) were recorded monthly from March through September in 2013. Bareroot and conventional containerized seedlings represented treatment plots, whereas EKO™ plots were considered untreated checks.

Seedling Survival and Measurements

Survival was recorded monthly during the first growing season from March through September, 2013 to determine if planting shock, moisture stress, or depredation contributed to mortality. The cambium layer was nicked with thumbnail to affirm suspected mortality during each survival evaluation. Survival was also recorded November, 2013 and November, 2014.

Initial groundline diameter (GLD) and height measurements were recorded February 2, 2013. Height of bareroot, conventional containerized and EKO™ seedlings were measured to the nearest centimeter using a meter stick. GLD measurements were measured to the nearest tenth of a millimeter using Mititoyo® digital calipers. First year GLD and height measurements were recorded on November 2, 2013 for both sites. Final measurements were recorded on November 8 and 9, 2014. Only living portions of the dominant stem were measured in height and GLD measurements in the case that a seedling exhibited dieback completely and re-sprouted.

Rainfall Collection

A Rainwise™ tipping bucket rain gauge equipped with a HOBO™ Pendant data logger was installed at each site to record monthly precipitation. Data were uploaded into a computer with HOBOWare™ Plus software. Rainfall data were used as a factor to support conclusions about survival and growth.

Experimental Design and Data Analysis

A randomized complete block design with a factorial arrangement of treatments was used for this study. Three blocks were established on each site. Individual blocks were sub-divided into six rectangular plots. Each plot was a single replicate for a unique species and planting stock combination and contained 100 seedlings each. The plot was considered the experimental unit for survival, stem measurements, and groundcover evaluations. Data were analyzed using Statistical Analysis System (SAS) software version 9.3®.

PROC ANOVA was also used to analyze height growth and GLD data which were tested for differences between sites, between species, among planting stocks, and for interactions among these factors. Height growth and GLD data were analyzed excluding seedlings that had complete dieback and resprouting. Differences were considered significant at the 0.05 level.

CHAPTER IV

RESULTS AND DISCUSSION

Malone Site

Ground Coverage

Broadleaf coverage

A heavy colonization of partridge pea (*Chamaecrista fasciculate*) was present prior to establishment. The landowner had planted partridge pea earlier in the year to increase wildlife habitat. He mowed the partridge pea in late fall for site preparation. Partridge pea had already at this point made its seed and left an enormous seed bank after mowing. By the end of May, partridge pea had colonized the control plots by 67% (Table 4.1) and was at nearly 80% at the end of the first growing season. For the treated plots colonization did not begin to occur until late July (15%). However, the partridge pea near the treated plots began to top seedlings in June by hanging over into the vacant space and casting shade. By the end of the growing season the treatment bands were still visible but encroachment of outside partridge pea had topped nearly 10% of the treated area.

Grass coverage

Grasses were well established on the site after site preparation. Species included little blue stem (*Schizachyrium scoparium*), various panic grasses (*Panicum spp., Dicanthelium spp.*) and crabgrass (*Digitaria spp.*). At planting there was 88% (Table 4.1) grass coverage across the site. At the end of the first growing season, treatment bands were still visible but colonization of grasses had begun to occur in the treated areas during the month of June. Treated areas had 45% grass colonization at the end of the first growing season. In the control areas, heavy colonization of grasses flourished and increased to 90-99% ground cover by the end of May. At the end of the growing season, some of the panic grasses exceeded 1.5m in height. This heavy colonization began to affect seedlings in the control plots and it was noted that they appeared to be suffering from moisture stress and lack of sunlight by the end of April.

Vine coverage

Vine coverage was comprised of blackberry (*Rubus spp.*) and poison ivy (*Toxicodendron radicans*). Coverage in both control and treated plots was very sparse and was less than 1% in March (Table 4.1). Vine coverage increased to 34% in the control at the end of the growing season but did not increase to any recognizable amount in the treated plots. The main species that increased was blackberry.

Shrub Coverage

Few shrubs established on the site through the first growing season (15% in treated and 17% in control plots) (Table 4.1). There was not a large difference (≤ 3%) between treated and control plots. The main species present was sweetgum, red maple (*Acer rubrum*) and yaupon (*Ilex vomitoria*). When present in the control and treated plots these species were mostly found near the planted trees. This could be due to seeds germinating on newly exposed mineral soil where oak seedlings were planted. Oust®

XP's label indicates that it is not effective at controlling woody species. The colonization of woody shrubs was at an expected rate.

Table 4.1 Percent cover of ground cover types for first growing season for the Malone site (all replicates).

	---------------------------------Month---------------------------------						
	March	April	May	June	July	August	September
Ground Cover Type	~~~~~~~~~~~~~~~~~~~~~% Cover~~~~~~~~~~~~~~~~~~~~						
Broadleaf							
Treated	< 1	< 1	2	6	15	16	22
Untreated	< 1	25	67	71	75	78	80
Grass							
Treated	2	8	12	18	26	34	45
Untreated	88	90	94	95	95	96	99
Vine							
Treated	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Untreated	< 1	< 1	< 1	10	21	30	34
Shrub							
Treated	< 1	3	6	6	10	12	15
Untreated	< 1	2	5	8	10	15	17

Rainfall

During the first and second growing seasons, annual average rainfall was observed on the Malone site (Table 4.2). There were no droughts or uncommonly high levels of rainfall for both growing seasons. The second growing season's monthly rainfall was lower than the first.

Table 4.2 Rainfall during the first and second growing seasons for the Malone site.

Year	April	May	June	July	August	September	Total
	----------	----------	----------	in	----------	----------	----------
2013	6.5	6.2	4.8	5.9	4.0	5.1	32.5
2014	5.0	4.5	4.8	5.7	5.7	4.5	30.2

First Year Monthly Survival

Water Oak

Water oak survival remained stable from March (96.1%) through May (92.6%), but then declined in June (87.3%) (Table 4.3). This could possibly be caused from trees not being fully dormant when planted. In May, dense partridge pea colonization began to develop. Partridge pea had begun to top the seedlings by July and had completely overtaken 10% of the treated plots. Even though there was adequate rainfall throughout the growing season this heavy colonization of partridge pea and grasses in the control plots increased moisture competition. Partridge pea also limited light availability for some of the seedlings and survival declined to 82.2% in the month of August.

Table 4.3 Monthly survival of water oak for the first growing season at the Malone site (all planting stocks).

Species	March	April	May	June	July	August	September	October
	----------	----------	----------	----------	percent	----------	----------	----------
Water Oak	96.1	96.0	92.6	87.3	84.7	82.2	82.0	81.2

Among different planting stocks, EKO^{TM} had the lowest survival (71.3%) at the end of the first growing season. Bareroot planting stock had the second lowest survival (76.3%) and the conventional containerized seedlings had the best survival (96.0%).

EKO™ seedlings are thought to have suffered from moisture stress caused by competition from grasses and partridge pea.

Swamp Chestnut Oak

Swamp chestnut oak exhibited a similar survival pattern to water oak with a steady decline of about 2% between monthly checks (Table 4.4). As stated above, the heavy colonization of partridge pea and grasses is thought to have contributed to the steady decline.

Table 4.4 Monthly survival of swamp chestnut oak for the first growing season at the Malone site (all planting stocks).

Species	March	April	May	June	July	August	September	October
	----------------				percent			----------------
Swamp Chestnut Oak	96.3	93.8	93.1	90.6	88.7	88.7	88.7	88.6

Among the planting stocks, EKO™ had the lowest survival (73.0%) at the end of the first growing season. Bareroot planting stock exhibited a much higher survival (95.0%) and conventional containerized had very similar survival (98.0%). Higher survival of bareroot planting stock could be due to seedlings being dormant when planted compared to water oak bareroot planting stock that appeared not to be dormant.

Second Year Survival

Water Oak

Overall survival for water oak at the end of the second growing season declined nine percent from 81.2% to 72.2% (Table 4.5). There was a very similar amount of rainfall throughout the second growing season compared to the first growing season. The amount of partridge pea at the end of the second growing season was less than it was at the end of the first growing season. However, the seedlings that appeared to have suffered from moisture stress from year one may have contributed to the higher overall mortality at the end of the second growing season.

Table 4.5 Water oak second year survival compared to first year survival for the Malone site (all planting stocks).

Year	
	------percent------
2013	81.2
2014	72.2

After two growing seasons, EKO™ still had the lowest survival at 58.5% (Table 4.6). That is a 12.8% decrease from the end of the first growing season. Bareroot seedling survival was 62.8% which was a 13.5% decrease from the end of the first growing season. Conventional containerized seedlings had the highest survival at 95.4% which is a difference of 0.6% from the first growing season.

Table 4.6 Second year survival of water oak compared to first year survival among planting stocks for the Malone site.

	------year------	
	2013	2014
Planting Stock		
	~~percent~~	
Bareroot	76.3	62.8
Containerized	96.0	95.4
EKO™	71.3	58.5

Swamp Chestnut Oak

It is unlikely that planting shock was a major contributing factor to mortality. Bareroot and conventional containerized swamp chestnut oak planting stock appeared to be completely dormant when planted. It is believed that seedling dormancy at planting translated to less stress in the first growing season and a better mortality rate was less during the second growing season compared to water oak. Overall survival dropped only 5.5% from the end of the first growing season (Table 4.7).

Table 4.7 Second year survival of swamp chestnut oak compared to first year survival for the Malone site (all planting stocks).

Year	
	------percent------
2013	88.6
2014	83.1

EKO™ continued to have the lowest survival at 65.0% (Table 4.8) which was an 8% decrease from the end of the first growing season. Bareroot seedlings survival was 86.6% which was an 8.4% decrease from the end of the first growing season. Conventional containerized seedlings had the highest survival at 97.8% which is a difference of 0.2% from the first growing season.

Table 4.8 Second year survival of swamp chestnut oak compared to first year survival among planting stocks for the Malone site.

	---------------year---------------	
	2013	2014
Planting Stock		
	~~percent~~~~~~~~	
Bareroot	95.0	86.6
Containerized	98.0	97.8
EKO™	73.0	65.0

Malone Site Survival Summary and Discussion

This was the fourth study in a series of six similarly designed studies with similar objectives. This was the first time water oak was chosen for evaluation in this study series. Second year overall survival of water oak (72%) was not comparable to second year results from 2010 plantings (approximately 97.1%) of cherrybark (Alkire 2011). Goodman et al. (2009) suggested water oak, may have a greater tendency to exhibit transplant stress compared to other bottomland oaks seedlings due to being a semi-evergreen. Most land managers would consider ~72% survival to be marginally acceptable for artificial regeneration with the goal being timber production. Conrad (2013) stated that if wildlife habitat is the manager's goal than 72% survival may be acceptable.

Swamp chestnut oak had greater survival compared to water oak both years. Overall survival of swamp chestnut oak (83.3%) after two seasons was comparable to that reported in a similar trial (approximately 87.9%) (Hollis 2011). Survival in both studies was considered acceptable.

Conventional containerized planting stock exhibited the highest survival in both species. It is generally concluded that a more fibrous root system compared to bareroot seedlings enables containerized seedlings to be more resilient to moisture stress resulting from planting shock or competing vegetation. Previous studies have observed that increasing container size improves overall survival (Howell and Harrington 2002, Self et al. 2006), but this trend was not observed in this study. Conrad (2013), found that large potted seedlings had lower survival than the smaller containerized seedlings. This could be due to a shoot to root imbalance. Bareroot seedlings are more susceptible to planting shock and moisture stress which appeared to be the main causes of mortality in water oak seedlings. Heavy colonization by partridge pea increased moisture competition and caused additional stress to some seedlings with less direct sunlight reaching their foliage. Bareroot seedlings have been found to exhibit lower survival compared to containerized seedlings (Rathfon et al. 1995, Burkett 1996, Willams and Craft 1998, Allen et al. 2001, Howell 2002, Howell and Harrington 2002, Shaw et al. 2003, Dey et al. 2006, Dey et al. 2008, Self et al. 2010) due to being more susceptible to transplant stress (Burkett and Williams 1998). In contrast other studies have found bareroot seedling survival to be greater than containerized seedlings (Hollis 2011, Conrad 2013) when herbaceous weed control is applied.

First Year Height Growth

Water Oak

Initial planted heights were 131.0cm, 55.3cm, and 52.3cm respectively for EKO™, bareroot, and conventional containerized (Table 4.9). At the end of the first growing season, EKO™ seedlings exhibited severe dieback. These seedlings had negative overall average height growth of -18.31cm. Bareroot seedlings exhibited both dieback and intense deer browse. Their overall average height growth was -3.96cm. Conventional containerized seedlings averaged 1.90cm of height growth. There was a significant difference among all three planting stocks.

Table 4.9 Average initial height and height growth of water oak by planting stock for first year for the Malone site (all replicates).

	---heights---			
Planting Stock	Initial	November, 2013	First Year Growth	
	~~cm~~~			
Bareroot	55.30	51.34	-3.96	B[1]
Containerized	52.30	54.20	1.90	A
EKO™	131.00	112.70	-18.31	C

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

Swamp Chestnut Oak

Similar to water oak, EKO™ seedlings had the highest initial average height (104.0cm). Conventional containerized had a slightly higher initial average height (47.0cm) than bareroot seedlings (46.3cm) (Table 4.10). At the end of the first growing season, EKO™ seedlings exhibited severe dieback much like that observed in water oak EKO™ seedlings. These seedlings had a negative average change in height of -14.02cm. Bareroot seedlings and conventional containerized seedlings had positive average total growth of 0.68cm and 2.82cm. There was a significant difference among all three planting stocks.

Table 4.10 Average initial height and height growth of swamp chestnut oak by planting stock for first year for the Malone site (all replicates).

Planting Stock	Initial	November, 2013	First Year Growth	
	~~cm~~~			
Bareroot	46.30	46.98	0.68	B[1]
Containerized	47.00	49.82	2.82	A
EKO™	104.00	89.98	-14.02	C

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

Second Year Height Growth

Water Oak

Conventional containerized seedlings had the highest average height growth on average (21.49cm) at the end of the second growing season (Table 4.11). Bareroot seedlings had an average height growth of 15.27cm, and EKO™ seedlings continued to exhibit severe dieback with an average negative height change of -11.00cm. There was a significant difference among all three planting stocks.

Table 4.11 Average first year heights, second year heights, and second year height growth of water oak by planting stock for the Malone site (all replicates).

Planting Stock	November, 2013	November, 2014	Second Year Growth	
	~~cm~~~			
Bareroot	51.34	66.61	15.27	B[1]
Containerized	54.20	75.69	21.49	A
EKO™	112.70	101.70	-11.00	C

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

Conventional containerized seedlings had the greatest overall average height growth over the study with an average total growth of 23.39cm (Table 4.12). Bareroot seedlings had the second highest average total growth with 11.31cm, and EKO™ seedlings exhibited a negative average total change with -29.31cm. There was a significant difference among all three planting stocks.

Table 4.12 Average total height growth by planting stock of water oak for the Malone site at end of the second growing season (all replicates).

Planting Stock	-----heights----- ~~~~cm~~~~	
Bareroot	11.31	B[1]
Containerized	23.39	A
EKO™	-29.31	C

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

Swamp Chestnut Oak

Bareroot seedlings had the highest average second year height growth of 13.50cm (Table 4.13). Conventional containerized seedlings had the second highest average growth with 8.9cm, and EKO™ seedlings continued to exhibit negative growth in the form of severe dieback. They averaged a -15.20cm difference in height. There was not a significant difference between bareroot and conventional containerized seedlings but both were significantly different compared to EKO™ seedlings.

Table 4.13 Average first year heights, second year heights, and second year height growth of swamp chestnut oak by planting stock for the Malone site (all replicates).

Planting Stock	--heights-- November, 2013	November, 2014	Second Year Growth	
	~~cm~~			
Bareroot	46.98	60.48	13.50	A[1]
Containerized	49.82	58.72	8.90	A
EKO™	89.98	74.78	-15.20	B

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

Bareroot seedlings had the greatest overall average height growth of 14.18cm after two growing seasons (Table 4.14). Conventional containerized seedlings had the second highest overall growth of 11.72cm and EKO™ seedlings had a negative average overall change of -29.22cm. There was not a significant difference between bareroot and conventional containerized seedlings for overall height growth but both were significantly different compared to EKO™ seedlings.

Table 4.14 Average total height growth by planting stock of swamp chestnut oak for the Malone site at end of the second growing season (all replicates).

Planting Stock	-----heights----- ~~~~cm~~~~	
Bareroot	14.18	A[1]
Containerized	11.72	A
EKO™	-29.22	B

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

Height Growth Summary and Discussion

Water oak conventional containerized planting stock had the highest overall total growth. This may be attributed to the ability of these seedlings being able to mitigate planting shock with the inherent fibrous root system typical to this planting stock. Bareroot seedlings typically need a year to reestablish a root system before allocating resources to height growth. This is evident when comparing year one growth with year two growth. Some water oaks also exhibited high levels of deer browse. These seedlings appeared to be physiologically active when transplanted, which may explain the herbivory and could certainly lead to increased transplant shock, stress, dieback, and mortality. Once bareroot seedlings reestablished roots in the second growing season they added a greater amount of growth. EKO™ seedlings were planted in October which is typically one of the driest months for Mississippi. This factor, when compounded with a shoot to root ratio imbalance and lack of seedling dormancy when planted appeared to result in extreme dieback. The prescribed "plant and walk away" approach for these seedlings which precludes any additional treatment such as herbaceous weed control, may have also contributed to poor performance of these seedlings.

Swamp chestnut oak bareroot seedlings had greater average height growth compared to conventional containerized or EKO™ seedlings. Conventional containerized seedlings had significantly greater height growth in the first growing season than bareroot. Once bareroot seedlings had their roots established, height growth was almost doubled compared to conventional containerized seedling height growth in year two. After two growing seasons, there was no significant difference between bareroot and conventional containerized seedlings regarding average total height growth. EKO™

swamp chestnut oak seedlings appeared to suffer from the same problems as water oak EKO™ seedlings.

Results were comparable with other studies which observed greater first-year height growth of containerized seedlings compared to bareroot seedlings (Dixon et al. 1981, Johnson et al. 1984, Rathfon et al. 1995, Burket and Williams 1998, Sweeney et al. 2002, William and Stroupe 2002). This increased growth did not persist into the second growing season. Other studies have found this to be true as well. Mullins et al. (1997) and Conrad (2013) observed similar results. Research has shown greater first year height growth of larger potted seedlings when compared to bareroot or conventional containerized seedlings (Shaw et al. 2003, Alkire 2011). This was not supported by the results of this study. Severe dieback that was observed in the EKO™ is similar to that observed in a study by (Conrad 2013). Results support others who have shown that once bareroot overcome transplant stress, they can exceed or match containerized seedlings in growth (Mullins et al. 1997, Sweeny et al. 2002, Burkett et al. 2005, Henderson et al. 2009, Hollis 2011, Conrad 2013).

First Year GLD Growth

Water Oak

EKO™ seedlings had the highest initial average GLD (11.15mm) followed by bareroot seedlings (6.66mm) (Table 4.15). Conventional containerized seedlings had the smallest GLD (4.42mm) but this planting stock had the greatest GLD growth during the first growing season (2.32mm). This growth was significantly more than that exhibited by bareroot (0.01mm) and EKO™ (1.12mm) seedlings, which were not significantly different from each other.

Table 4.15 Average initial groundline diameter and groundline diameter growth of water oak by planting stock for first year for the Malone site (all replicates).

	---GLD---			
Planting Stock	Initial	November, 2013	First Year Growth	
	~~mm~~~			
Bareroot	6.66	6.67	0.01	B[1]
Containerized	4.42	6.74	2.32	A
EKO™	11.15	12.27	1.12	B

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

Swamp Chestnut Oak

Swamp chestnut oak planting stocks followed the same pattern as water oak planting stock. EKO™ seedlings had the largest initial average GLD (11.61mm) followed by bareroot seedlings (8.06mm) (Table 4.16). Conventional containerized seedlings had the smallest GLD (5.93mm). After the first year there were significant differences among all three planting stocks. Conventional containerized seedlings had the greatest average GLD growth (1.88mm) followed by bareroot seedlings (1.31mm), and EKO™ seedlings exhibited an overall negative change (-0.66mm).

Table 4.16 Average initial groundline diameter and groundline diameter growth of swamp chestnut oak by planting stock for first year for the Malone site (all replicates).

Planting Stock	GLD Initial	GLD November, 2013	GLD First Year Growth	
	~mm~	~mm~	~mm~	
Bareroot	8.06	9.37	1.31	B[1]
Containerized	5.93	7.81	1.88	A
EKO™	11.61	10.95	-0.66	C

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

Second Year GLD Growth

Water Oak

Conventional containerized seedlings had the greatest second year GLD growth on average (3.01mm), bareroot seedlings had an average GLD growth of 1.73mm, and EKO™ seedlings continued to exhibit a negative change (-0.90mm) (Table 4.17). There was a significant difference among all three planting stocks for second year GLD growth.

Table 4.17 Average first year groundline diameter, second year groundline diameter, and second year groundline diameter growth of water oak by planting stock for the Malone site (all replicates).

Planting Stock	GLD November, 2013	GLD November, 2014	GLD Second Year Growth	
	~mm~	~mm~	~mm~	
Bareroot	6.67	8.40	1.73	B[1]
Containerized	6.74	9.75	3.01	A
EKO™	12.27	11.37	-0.90	C

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

Conventional containerized seedlings had the greatest total GLD growth (5.33mm) at the end of the second year (Table 4.18). Bareroot seedlings had greater growth (1.74mm) than EKO™ seedlings (0.22mm) but it was not significantly different.

Table 4.18 Average total groundline diameter growth by planting stock for water oak for the Malone site at end of the second growing season (all replicates).

Planting Stock	-----GLD----- ~~~~mm~~~~	
Bareroot	1.74	B[1]
Containerized	5.33	A
EKO™	0.22	B

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

Swamp Chestnut Oak

Conventional containerized seedlings had the greatest second year average GLD growth (1.46mm) (Table 4.19). Bareroot seedlings had a greater average GLD growth (0.66mm) than EKO™ seedlings (0.07mm). Average growth for conventional containerized seedlings was significantly greater than values for either bareroot or EKO™ seedlings with values for the latter two not significantly different.

Table 4.19 Average first year groundline diameter, second year groundline diameter, and second year groundline diameter growth of swamp chestnut oak by planting stock for the Malone site (all replicates).

	----GLD----			
Planting Stock	November, 2013	November, 2014	Second Year Growth	
	~~mm~~~~			
Bareroot	9.37	10.03	0.66	A[1]
Containerized	7.81	9.27	1.46	A
EKO™	10.95	11.02	0.07	B

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

Conventional containerized seedlings had the greatest average total GLD growth (3.33mm) followed by bareroot seedlings (1.97mm) and EKO™ seedlings which exhibited a negative change (-0.59mm) (Table 4.20). There were significant differences among all three planting stocks.

Table 4.20 Average total groundline diameter growth by planting stock for swamp chestnut oak for the Malone site at end of the second growing season (all replicates).

Planting Stock	-----GLD----- ~~~~mm~~~~	
Bareroot	1.97	B[1]
Containerized	3.33	A
EKO™	-0.59	C

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

GLD Growth Summary and Discussion

Water oak bareroot and conventional containerized seedlings exhibited positive growth during both growing seasons. Conventional containerized seedlings had the greatest amount of GLD growth for both growing seasons, with this growth being significantly greater than the other two planting stocks. There was a significant difference between bareroot and EKO™ seedlings at the end of the second growing season. However, bareroot seedlings did not exhibit a significant difference for GLD total growth at the end of year two compared to EKO™ seedlings. EKO™ seedlings exhibited a negative change in GLD the end of the second growing season. The same factors that affected height growth and survival may have contributed to the lesser performance in bareroot and EKO™ seedlings.

Swamp chestnut oak had similar GLD growth to that observed in water oak. At the end of each growing season bareroot and conventional containerized seedlings exhibited positive growth. Conventional containerized seedlings had the greatest GLD growth for each growing season and the greatest amount of overall growth. This growth was significantly different from the other two planting stocks. Bareroot seedlings outperformed EKO™ seedlings during the first growing season. However, bareroot and EKO™ growth did not differ significantly at the end of the second growing season. For overall growth, the amount the bareroot seedlings grew during the first growing season was enough to make its total GLD growth significantly different from EKO™ seedlings. Based on direct observation, the commercial planting crew hired to plant these larger seedlings did not utilize proper seedling care and planting practices. Thus, EKO™ seedlings were possibly adversely affected.

Root growth is directly correlated with diameter growth (Dey and Parker 1997) and is a good indication of seedling acclimatization to a site. Containerized seedlings have been shown to be less susceptible to planting shock compared to bareroot seedlings (Johnson et al. 1984, Self et al. 2006, Wilson et al. 2007). This may explain why water oak conventional containerized seedlings had greater GLD growth for both growing seasons. Other studies have been similar growth for the other species (Johnson et al. 1984, Williams and Craft 1998, Wilson and Stroupe 2002, Wilson et al. 2007). EKO™ and bareroot seedlings exhibited similar GLD growth after two growing seasons which is similar to results found by other studies, Close et al. (2005) and Conrad (2013).

Welford Site

Ground Coverage

Broadleaf coverage

There was very little broadleaf coverage on the site during the first growing season. Common ragweed (*Ambrosia atemisifolia*) was the most prevalent species but represented less than 1% coverage in the treated plots and 3% in the control plots (Table 4.21). Site prep on this area was very extensive and included root raking. This activity when combined with previous cultivated for wildlife food plots, resulted in very little herbaceous competition at the time of planting.

Grass coverage

Very little grass coverage was present during the first part of the first growing season. Johnson grass (*Sorghum halpense*) and little blue stem were the primary species in the 2% grass coverage across the site at the time (Table 4.21). By the end of the growing season, grass cover increased to 6% in the treated band areas. Grass cover was 42% of the control areas by the end of the growing season. The seed bank may have been depleted by site preparation so grass colonization may have been new foreign fresh germinates.

Vine coverage

Vine coverage was minimal at establishment, with only 5% coverage in treatment plots (Table 4.21). At the end of the first growing season coverage only increased to for treated plots 8%. For the control area vine coverage increased to 18% at the end of the first growing season. The most common species were blackberry and poison ivy.

Shrub Coverage

Shrub species included yaupon, sweetgum, water oak, red maple and eastern baccharis (*Baccharis halimifolia*) (Table 4.21). There was less than 1% shrub coverage across the entire site at installation. However, by the end of the first growing season yaupon and eastern baccharis began to colonize both treated and control plots (45-60% coverage). None of the seedlings were overtopped by the yaupon or eastern baccharis which averaged 25cm height, but it was apparent that the colonization had encroached upon the seedlings. Colonization by these shrubs made some of treatment bands less visible. In control plots, colonization was more intense and may have limited moisture availability for these seedlings.

Table 4.21 Percent cover of ground cover types for first growing season for the Welford site (all replicates).

	----------------------------------Month----------------------------------						
	March	April	May	June	July	August	September
Ground Cover Type	~~~~~~~~~~~~~~~~~~~~~% Cover~~~~~~~~~~~~~~~~~~~~						
Broadleaf							
Treated	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Untreated	< 1	< 1	< 1	< 1	< 1	< 1	3
Grass							
Treated	< 1	< 1	< 1	< 1	< 1	2	2
Untreated	< 1	2	15	19	24	38	42
Vine							
Treated	< 1	< 1	5	6	6	8	8
Untreated	< 1	5	8	9	12	13	18
Shrub							
Treated	< 1	5	8	15	26	39	45
Untreated	< 1	5	18	28	49	58	60

Rainfall

Rainfall records for the first and second growing season at the Welford site are found in Table 4.22. During the second growing season in 2014 an abnormally high amount of rainfall fell during the month of April. This rainfall caused pools to form in small areas of the research site. Mortality was much higher in these areas which had water around, seedlings for the next six weeks. Some deeper pools persisted until the middle of June according to the landowner.

Table 4.22 Rainfall during the first and second growing season for the Welford site.

Year	April	May	June	July	August	September	Total
	--			in	--		
2013	6.3	8.0	6.1	9.8	9.9	4.6	44.7
2014	18.1	9.8	5.2	7.9	2.8	5.5	49.3

First Year Monthly Survival

Water Oak

Monthly survival checks were conducting during the first growing season in an effort to determine the impact of competing vegetation, transplant shock, and drought on survival. Water oak survival was 99.1% for March and declined little through July (93.7%). It then declined to 90.9% in August (Table 4.23) which fell within expected mortality rates. There were no major weather events that may have contributed to mortality for the first growing season.

Table 4.23 Monthly survival of water oak for the first growing season at the Welford site (all planting stocks).

Species	March	April	May	June	July	August	September	October
	----------------------------------percent---------------------------------------							
Water Oak	99.1	98.3	96.1	95.1	93.7	90.9	90.0	89.0

Among the planting stocks for water oak, bareroot had the lowest survival (81.7%) at the end of the first growing season. EKO™ planting stock had the second lowest survival (87.0%) and the conventional containerized seedlings had the best survival (99.3%).

Swamp Chestnut Oak

Swamp chestnut oak survival remained stable and within a suitable range of normal expected mortality for the first growing season (Table 4.24).

Table 4.24 Monthly survival of swamp chestnut oak for the first growing season at the Welford site (all planting stocks).

Species	March	April	May	June	July	August	September	October
	--------------------------------percent------------------------------------							
Swamp Chestnut Oak	99.0	98.8	96.4	95.0	95.0	94.2	94.0	94.0

Among swamp chestnut oak planting stocks for, EKO™ seedlings had the lowest survival (87.7%) at the end of the first growing season. Bareroot planting stock had the highest survival (99.0%) of the three planting stocks, and conventional containerized had very similar survival (95.0%).

Second Year Survival

Water Oak

Overall survival for water oak at the end of the second growing season declined only 5.1% (Table 4.25). It appeared that abnormal rainfall in the month of April contributed to the increase in mortality for the second growing season. Water oak seedlings also appeared to still be physiologically active when planted. If so, the planting shock was more severe and deer browse was also at an elevated amount compared to the dormant swamp chestnut oak seedlings.

Table 4.25 Water oak second year survival compared to first year survival for the Welford site (all planting stocks).

Year	
	------percent------
2013	89.0
2014	83.9

Among the planting stocks, EKO™ had the lowest survival at 75.5% (Table 4.26). That is an 11.3% decrease from the end of the first growing season. Bareroot seedlings had the second highest survival at 80.3%, and conventional containerized seedlings had the highest survival at 95.7%, which is a difference of 3.6% from year one.

Table 4.26 Second year survival of water oak compared to first year survival among planting stocks for the Welford site.

	------year------	
	2013	2014
Planting Stock		
	~~percent~~	
Bareroot	81.7	80.3
Containerized	99.3	95.7
EKO^{TM}	87.0	75.7

Swamp Chestnut Oak

Planting shock was not a major contributing factor to mortality for swamp chestnut oak seedlings. However, most of the seedlings located in the standing pools, observed by the landowner during the month of June were EKO^{TM} swamp chestnut oak based on the locations of the pools (Table 4.27). Standing water contributed to the 8.2% increase in mortality.

Table 4.27 Swamp chestnut oak second year survival compared to first year survival for the Welford site (all planting stocks).

Year	
	------percent------
2013	94.0
2014	85.8

Among the planting stocks, EKO^{TM} still had the lowest survival at 78.0% (Table 4.28). That is a 9.7% decrease from the end of the first growing season. Of the three planting stocks, EKO^{TM} seedlings were the most affected by the standing pools of water which appeared to be a contributing factor to the increased mortality. Conventional containerized seedlings had the second highest survival at 85.0% a 10.0% decrease from the end of the first growing season. Bareroot seedlings had the highest survival at 94.0%, is a 5.0% decrease from year one.

Table 4.28 Second year survival of swamp chestnut oak compared to first year survival among planting stocks for the Welford site.

	------year------	
	2013	2014
Planting Stock		
	~~percent~~	
Bareroot	99.0	94.0
Containerized	95.0	85.0
EKO™	87.7	78.0

Survival Summary and Discussion

Swamp chestnut oak had better overall survival at the end of both year one and year two compared to water oak. Once again, transplant shock appeared to be higher in the water oak due to the seedlings not being completely dormant when planted. This may have also contributed to the fact that deer browsed more heavily on water oaks seedlings due to them having green foliage during the months of February when food sources for deer are often at lowest levels. Swamp chestnut oak EKO™ seedlings were affected more by standing water on the site May-June which may have resulted in more stress and unfavorable growing conditions. However, it can be concluded that EKO™ seedlings were already stressed from improper seedling care from commercial planting crews before planting in October. Flooding may have compounded this issue.

Other studies have found similar results when comparing containerized and bareroot seedlings (Williams and Craft 1998, Howell and Harrington 2002, Shaw et al. 2003, Self et al. 2006, Dey et al. 2008). Swamp chestnut oak bareroot survival was higher than containerized. This agrees with what Rathon et al. (1995). The authors of that study observed that northern red oak bareroot stock out performed containerized seedlings in areas that underwent tillage treatment to control vegetation. Self et al. (2006) reported differently. The authors of that study observed greater survival in large containerized seedlings compared to conventional containerized and bareroot.

First Year Height Growth

Water Oak

EKO^{TM} had the greatest initial height (131.42cm) (Table 4.29). Bareroot seedlings had an initial height of 54.20cm followed by conventional containerized with an initial height of 52.81cm. At the end of the first growing season EKO^{TM} seedlings exhibited dieback. These seedlings exhibited an average change in height of -2.11cm. Bareroot seedlings also exhibited dieback and deer browse damage their average change in height was -0.50cm. Conventional containerized seedlings had an average height growth of 8.89cm. There was a significant difference among all three planting stocks.

Table 4.29 Average initial height and height growth of water oak by planting stock for first year for the Welford site (all replicates).

Planting Stock	-----------heights-----------			
	Initial	November, 2013	First Year Growth	
	~~cm~~~~~~~~~~~~			
Bareroot	54.20	53.70	-0.50	B[1]
Containerized	52.81	61.70	8.89	A
EKO^{TM}	131.42	129.31	-2.11	C

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

Swamp Chestnut Oak

Similar to water oak, EKO^{TM} seedlings had the greatest initial average height (96.72cm) (Table 4.30). Conventional containerized seedlings had a greater initial average height (49.63cm) than bareroot seedlings (45.35cm). At the end of the first growing season, EKO^{TM} seedlings exhibited severe dieback much like that observed with the water oak EKO^{TM} seedlings. These seedlings had a negative average height change of -6.89cm. Bareroot seedlings and conventional containerized seedlings had positive growth of 2.28cm and 4.26cm, respectively. There was not a significant difference between bareroot and conventional containerized seedlings which were both significantly greater than EKO^{TM} seedlings.

Table 4.30 Average initial height and height growth of swamp chestnut oak by planting stock for first year for the Welford site (all replicates).

Planting Stock	-------heights-------			
	Initial	November, 2013	First Year Growth	
	~~	cm	~~~~~~	
Bareroot	45.35	47.63	2.28	A[1]
Containerized	49.63	53.89	4.26	A
EKO^{TM}	96.72	89.83	-6.89	B

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

Second Year Height Growth

Water Oak

Conventional containerized seedlings had the greatest average height growth (8.96cm) during the second growing season (Table 4.31). Bareroot seedlings had an average height growth of 0.03cm and EKO^{TM} seedlings continued to exhibit severe dieback with an average change of -10.74cm. There was a significant difference among all three planting stocks.

Table 4.31 Average first year heights, second year heights, and second year height growth of water oak by planting stock for the Welford site (all replicates).

Planting Stock	------heights------ November, 2013	November, 2014	Second Year Growth	
	~~cm~~~			
Bareroot	53.12	53.15	0.03	B[1]
Containerized	61.77	70.73	8.96	A
EKO™	126.81	116.07	-10.74	C

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

The 17.85cm increase by conventional containerized seedlings was the greatest average total height growth during the study (Table 4.32). Bareroot seedlings had on average total change of -0.53cm, and EKO™ had a negative average total change of -12.85cm. There were significant differences among all three planting stocks.

Table 4.32 Average total height growth by planting stock of water oak for the Welford site at end of the second growing season (all replicates).

Planting Stock	-----heights-----	
	~~cm~~~~	
Bareroot	-0.53	B[1]
Containerized	17.85	A
EKO™	-12.85	C

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

Swamp Chestnut Oak

Bareroot seedlings had the greatest average height growth of 0.84cm (Table 4.33). Conventional containerized seedlings a negative average change of -0.87cm. Once again, EKO™ seedlings exhibited negative change in the form of severe dieback with an average change of -25.21cm. There was not a significant difference between bareroot and conventional containerized seedlings but both were significantly different from EKO™ seedlings.

Table 4.33 Average first year heights, second year heights, and second year height growth of swamp chestnut oak by planting stock for the Welford site (all replicates).

Planting Stock	--------heights--------			
	November, 2013	November, 2014	Second Year Growth	
	~~cm~~~~~~~~~~~~			
Bareroot	47.63	48.47	0.84	A[1]
Containerized	53.89	53.02	-0.87	A
EKO™	89.83	64.62	-25.21	B

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

Conventional containerized seedlings had the greatest overall average height growth of 3.39cm after the two growing seasons (Table 4.34). Bareroot seedlings had average overall growth of 3.12cm, and were not significantly different from the conventional containerized height growth. EKO™ seedlings had a negative average overall change of -32.10cm which was significantly different from bareroot and conventional containerized seedlings.

Table 4.34 Average total height growth by planting stock of swamp chestnut oak for the Welford site at end of the second growing season (all replicates).

Planting Stock	-----heights----- ~~~~cm~~~~	
Bareroot	3.12	A[1]
Containerized	3.39	A
EKO™	-32.10	B

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

Height Growth Summary and Discussion

Water oak conventional containerized planting stock had the greatest average total height growth. It is surmised that conventional containerized seedlings were better able to mitigate planting shock due to the fibrous root system inherent to containerized seedlings (Humphrey 1994, Burkett and Williams 1998, Williams and Craft 1998, Allen et al. 2001). Bareroot seedlings need a year to reestablish a root system after planting before resources are allocated to height growth. This is evident when comparing year one and year two growth. During the second growing season, bareroot seedlings exhibited positive height growth. Deer browse may have also contributed to poor height growth in bareroot seedlings. These factors resulted in bareroot seedlings being placed under increased stress which resulted in bareroot seedlings exhibiting dieback during the first growing season. Conrad (2013) observed similar effects from deer browse. EKO™ seedlings were planted in October, which is typically one of the driest months in Mississippi. Problems resulting from this early planting time were likely compounded with a shoot to root ratio imbalance ending with increased dieback. The "plant and walk away" approach, advertised for use with EKO™ stock, may have contributed to poor performance. Dieback has been observed in similar studies (Burkett et al. 2005, Dey et al.

2006, Conrad 2013). The commercial planting crew hired to plant these larger seedlings were observed using improper seedling care and planting practices.

Swamp chestnut oak conventional containerized seedlings exhibited greater overall height growth compared to bareroot seedlings or EKO™ seedlings. Conventional containerized seedling growth was not significantly different from bareroot seedlings total height growth. Both conventional containerized and bareroot seedlings had similar height growth for both growing seasons which does not agree with results from studies by Dey et al. (2006) and Self et al. (2006) but does agree with studies that found at the end of two years bareroot seedlings did not differ from containerized seedlings (Mullins et al. 1998, Sweeny et al. 2002, Burkett et al. 2005, Henderson et al. 2009, Hollis 2011, Conrad 2013). EKO™ swamp chestnut oak seedlings suffered from the same problems as water oak EKO™ seedlings. They were planted outside of the normal planting season, root to shoot ration imbalance and not being dormant when planted may have led to the onset of extreme dieback.

First Year GLD Growth

Water Oak

EKO™ seedlings had the highest initial average GLD (10.52mm) followed by bareroot seedlings (6.37mm) (Table 4.35). Conventional containerized seedlings had the smallest average GLD (4.80mm). After the first growing season, conventional containerized seedlings increased 4.88mm. There was not a significant difference between bareroot (2.36mm) and EKO™ (3.04mm) seedlings, but both were significantly less than growth of the conventional containerized seedlings.

Table 4.35 Average initial groundline diameter and groundline diameter growth of water oak by planting stock for first year for the Welford site (all replicates).

Planting Stock	Initial	November, 2013	First Year Growth	
	--------------------------------------GLD---------------------------------------			
	~~mm~~~~~~~~~~~~~~~~~~~~~~~~~			
Bareroot	6.37	8.73	2.36	B[1]
Containerized	4.80	9.68	4.88	A
EKO™	10.52	13.56	3.04	B

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

Swamp Chestnut Oak

Swamp chestnut oak planting stocks followed the same pattern as water oak. EKO™ seedlings had the largest initial average GLD (10.34mm) followed by bareroot seedlings (7.65mm) (Table 4.36). Conventional containerized seedlings had the smallest GLD (6.49mm). After the first year there was no significant difference among the three planting stocks, with growth ranging from 2.06mm to 2.18mm.

Table 4.36 Average initial groundline diameter and groundline diameter growth of swamp chestnut oak by planting stock for first year for the Welford site (all replicates).

Planting Stock	Initial	November, 2013	First Year Growth	
	--------------------------------------GLD---------------------------------------			
	~~mm~~~~~~~~~~~~~~~~~~~~~~~~~			
Bareroot	7.65	9.83	2.18	A[1]
Containerized	6.49	8.57	2.08	A
EKO™	10.34	12.40	2.06	A

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

Second Year GLD Growth

Water Oak

Conventional containerized seedlings had the greatest average second year GLD growth (0.88mm) (Table 4.37). Bareroot seedlings had an average change in GLD of -0.22mm and EKO™ seedlings exhibited a change of -0.67mm. GLD growth was significantly greater for conventional containerized seedlings as compared to the other planting stocks.

Table 4.37 Average first year groundline diameter, second year groundline diameter, and second year groundline diameter growth of water oak by planting stock for the Welford site (all replicates).

Planting Stock	--------GLD-------- November, 2013	November, 2014	Second Year Growth	
	~~mm~~~~~~~~			
Bareroot	8.73	8.51	-0.22	B[1]
Containerized	9.67	10.56	0.88	A
EKO™	13.56	12.89	-0.67	B

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

Conventional containerized seedlings had significantly greater average total GLD growth (5.76mm) at the end of the second growing season (Table 4.38) than the other two planting stocks. EKO™ seedlings had slightly greater growth (2.14mm) than bareroot seedlings (2.37mm) but they were not significantly different.

Table 4.38 Average total groundline diameter growth by planting stock for water oak for the Welford site at end of the second growing season (all replicates).

Planting Stock	-----GLD----- ~~~~mm~~~~	
Bareroot	2.14	B[1]
Containerized	5.76	A
EKO™	2.37	B

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

Swamp Chestnut Oak

Conventional containerized seedlings had the greatest average second year GLD growth (0.36mm) which was significantly greater than the other planting stocks (Table 4.39). Bareroot seedlings and EKO™ seedlings had a negative change in GLD during the second growing season. There was not a significant difference between these two planting stocks.

Table 4.39 Average first year groundline diameter, second year groundline diameter, and second year groundline diameter growth of swamp chestnut oak by planting stock for the Welford site (all replicates).

	-----GLD-----			
Planting Stock	November, 2013	November, 2014	Second Year Growth	
	~~mm~~~~			
Bareroot	9.83	9.53	-0.30	B[1]
Containerized	8.57	8.93	0.36	A
EKO™	12.40	11.76	-0.64	B

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

Conventional containerized seedlings had the greatest average total GLD growth (2.44mm) followed by bareroot seedlings (1.88mm) and EKO™ seedlings (1.42mm)

(Table 4.40). The average total GLD growth of conventional containerized seedlings was significantly different from the other planting stocks.

Table 4.40 Average total groundline diameter growth by planting stock for swamp chestnut oak for the Welford site at end of the second growing season (all replicates).

Planting Stock	-----GLD-----	
	~~mm~~~~	
Bareroot	1.88	B[1]
Containerized	2.44	A
EKO™	1.42	B

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

GLD Growth Summary and Discussion

Water oak seedlings had the same growth pattern for both growing seasons. The conventional containerized seedlings had a significantly greater average GLD growth than the other two planting stocks. Other studies support these same results (Johnson et al. 1984, Williams and Craft 1998, Wilson and Stroupe 2002, Wilson et al. 2007). Bareroot and EKO™ seedlings had positive growth at the end of the first growing season but had negative change at the end of the second growing season. There was not a significant difference for GLD growth among these planting stocks at the end of each growing season or for average total growth. These results do not agree with a previous study, Self et al. (2006). It does, however, agree with Close et al. (2004) and Conrad (2013) and the pattern of growth was most similar to that of observed at the Malone site.

Swamp chestnut oak seedlings performed differently than water oak. At the end of the first growing season there was not a significant difference among the three planting stocks. However, at the end of the second growing season conventional containerized seedlings GLD growth was significantly different from the other two planting stocks. Swamp chestnut oak bareroot and EKO^{TM} seedlings had negative GLD growth at the end of the second growing season. Conventional containerized seedlings had the greatest total GLD growth and differed significantly from the other two planting stocks.

CHAPTER V

CONCLUSIONS

Water oak and swamp chestnut oak conventional containerized and bareroot seedlings exhibited good survival and performed well on two sites in south Mississippi. Water oak bareroot seedlings did have lower survival and poorer height growth which could be explained by them appearing to be physiologically active when planted and having signs of deer browse.

Early research on oak establishment hinged upon the premise that seedling size and planting stock type would provide optimum growth (Dixon et al. 1981, Johnson et al. 1984, Kormanik et al 1995, Dey and Parker 1997, Dey et al. 2006). The "bigger is better" approach subscribed to the idea that larger seedlings would be able to overcome adversities with their morphological traits (Johnson et al. 1984, Kormanik et al. 1995, Dey and Parker 1997, Schultz and Thompson 1997). Despite EKO^{TM} seedlings being twice as large in both height and GLD compared to bareroot and conventional containerized seedlings they did not exhibit a clear advantage in survival, height growth, or GLD growth. The results of this are supported by others (Sweeney et al. 2002, Burkett et al. 2005, Hollis 2011, Conrad 2013), in demonstrating that bareroot and conventional containerized seedlings can produce comparable growth and greater survival.

Herbaceous weed control applied in the first year was shown to result in comparable first year growth and survival from bareroot and smaller containerized seedlings (Mullins et al. 1998, Ezell and Hodges 2002, Sweeny et al. 2002, Ezell et al. 2007, Hollis 2011, Conrad 2013). Conventional containerized seedlings may be a more suitable choice when droughty conditions may occur (Stanturf et al. 1998, Self et al. 2006, Conrad 2013). Cost effectiveness is typically a very important factor in reforestation efforts; therefore, high quality 1-0 bareroot seedlings are likely the preferred planting stock for large-scale reforestation operations as opposed to containerized seedlings.

Results of this study show that with proper site preparation, seedling care, quality planting job, and first year herbaceous weed control a land manager can properly reforest lands with a high quality 1-0, bareroot seedling at a much lower cost compared to using containerized planting stock. This study is applicable to land managers trying to regenerate these two oak species on marginal agricultural lands and areas where typical site preparation has been applied on similar soils and expected growing conditions.

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