THE EFFECTS OF SEEDLING STOCK-TYPE AND DIRECT-SEEDING ON THE EARLY FIELD SURVIVAL OF NUTTALL OAK PLANTED ON AGRICULTURAL LAND[1]

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ABSTRACT-First-year results are presented for two studies designed to compare the effects of seedling stock-type and direct seeding on survival and stem height of Nuttall oak (*Quercus texana*) planted on former agricultural land. Bareroot and container seedlings were observed to have good survival when flooding or long-term soil saturation was not present. Container seedlings appear to survive flooding better than bareroot seedlings. Also, container seedlings were successfully established in the late spring after the floodwaters receded. The bareroot seedlings, which had to remain in cold storage while the site was flooded, had poor survival when planted in late spring. Direct seeding does not appear to be a viable reforestation option on sites which flood frequently. The bareroot and container seedlings were observed to have a notable amount of stem dieback during the first year after planting.

INTRODUCTION

Federal programs and regulations such as the Wetlands Reserve Program (WRP), the 1985 Food Security Act, and Section 404 of the Clean Water Act have been the driving forces for the recent increase in the hardwood reforestation of flood-prone agricultural lands. Unfortunately, the flooding which made farming difficult also hampers reforestation efforts. Seedlings of flood tolerant species are generally more sensitive to long durations of flooding than mature trees (Kozlowski and others 1991). When complete inundation occurs after bud break, significant amounts of stem dieback and lower survival can occur (Baker 1977, Whitlow and Harris 1979). As one might expect, the negative impacts of spring flooding appears to be most severe on seedlings of moderately flood tolerant and flood intolerant bottomland hardwood species. Day and others (1998) reported that spring flooding greatly reduced first-year survival of willow oak (*Quercus phellos*) bareroot seedlings planted in December. First-year survival of cherrybark oak (*Ouercus* pagoda) bareroot seedlings dropped from 90 percent on a nonhydric soil to about 50 percent on a hydric soil that was saturated during the late-winter and early spring (Williams and others 1993).

At locations where flooding is minimal, research results indicate that seedling establishment can be successful. Allen (1990) observed adequate bottomland hardwood oak stocking for five planted seedling stands (266 trees/ac) and five direct seeded stands (293 trees/ac) about 6 years after establishment. Miwa (1995) observed first-year seedling survival greater than 70 percent for four bottomland hardwood species planted on hydric and non-hydric soils which no longer experience significant flooding. Five years after planting, seedling survival was still greater than 60 percent (Ozalp and others 1998). Stanturf and Kennedy (1996) observed survival exceeding 60 percent after 5 years for 2-O cherrybark oak seedlings planted in a floodplain clearcut.

The use of container-grown hardwood seedlings instead of bareroot seedlings may be a potential option for the reforestation of flood-prone sites. White and others (1970) presented the possible advantages of using container hardwood planting stock. Advantages that may be especially important to a wetland reforestation planner are the ability to extend the planting season and the higher survival usually observed on adverse sites. For example, container seedlings could be planted after the flood waters recede in early summer. While bareroot seedlings that are typically lifted from the nursery during the winter must spend an extended period of time in cold storage prior to planting. Since hardwood seedlings are sometimes packed in bundles or bags which cannot be completely sealed, there is a risk of seedling dessication during unplanned, long-term cold storage. Results are presented from two studies that compared the early field survival and growth between 1-O bareroot seedlings and container Nuttall oak seedlings. Study A also included a direct seeding treatment.

METHODS

Study A

Container seedlings were grown in 164 cm^3 plastic cone containers filled with a 1:1 mix of peat moss and commercial grade vermiculite. The seed used were from a Mississippi Delta seed source. The seed were artificially stratified prior to sowing (Olson 1974). Seed were sown in the containers on May 26, 1992. The containers were placed at a density of 24 seedlings/ft^2. The container seedlings were grown in a shadehouse covered with a 50 percent shade cloth. The shadehouse was located at the US. Army Engineer Waterways Experiment Station, Vicksburg, MS. The seedlings were watered and fertilized as needed. The container seedlings remained outdoors until transported to the study site. The bareroot seedlings were obtained from a commercial forest tree nursery in early January 1993. The seedlings were packed in kraft storage bags, transported to

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Waterways Experiment Station and placed in cold storage until planted. While the seed for the bareroot seedlings were from a Mississippi Delta seed source, they were not from the same seed lot as the seed used for the container seedlings. The seed used for the direct seeding treatment were from the same seed lot as the seed for the container seedlings. Prior to sowing at the study site, the seed were artificially stratified.

The study site is located at the U.S. Army Engineer Lake George Wildlife/Wetland Restoration Project, Yazoo County, Missisippi. The soil type is a Sharkey clay (very fine, montmorillonitic, nonacidic, thermic, Vertic Haplaquept). The study site was farmed for soybeans during the growing season prior to initiating the study. The specific location was chosen because, based on observations, the site received backwater flooding from the Yazoo and Big Sunflower Rivers during the late winter and early spring almost every year. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on four dates: January 22, 1993, February 16, 1993, March 16, 1993, and June 6, 1993. Prior to each planting date, 40 bareroot and container seedlings were randomly sampled to measure stem height, root collar diameter, shoot oven-dry weight, and root oven-dry weight. For the direct seeding treatment, two seed were sown for each position on each date. Seed positions were on a 1.5 m by 1.5 m spacing and the seed were sown at a depth of about 5 cm. The experimental design is a randomized complete block split plot design with four replications. The whole plots are the planting dates. The bareroot seedlings, container seedlings, and the direct seeding are the sub-plots. T-tests were used to test for biomass differences. Analysis of variance was used to test for treatment differences regarding first-year survival, stem height and growth. As anticipated, the study site flooded for a period beginning in late March and ending in late May. The seedlings planted and the seed sown in January, February and March were completely inundated for almost eight weeks.

Study B

Container seedlings were grown in 164 cm^3 plastic cone containers filled with a 1 :1 mix of peat moss and commercial grade vermiculite. Seed were from a Mississippi Delta seed source. The seed were artificially stratified prior to sowing (Olson 1974). Seed were sown on May 26, 1994 and seedlings grown at a shadehouse facility (50 percent shade) located at the Arthur Temple College of Forestry, Stephen F. Austin State University. Container density was 24 seedlings/ft^2. Seedlings were irrigated and fertilized as needed. An additional treatment imposed on the container seedlings was a mycorrhizal inoculation conducted on July 6, August 30, and December 21. The inoculum used was from a commercially available kit of *Pisolithus tinctorus* mycelium. The same one-half of the container seedling population received a drench of the fungus solution, prepared according to manufacturers recommendations, on each date. Bareroot seedlings were purchased from a commercial hardwood nursery. The seed source and seed lot were the same for both the container and bareroot seedlings. Only bareroot seedlings taller than 46 cm were used in this study.

Seedling morphology was compared by randomly selecting 50 seedlings from each stocktype. Stem height, root collar diameter, stem oven-dry weight, root oven-dry weight, root volume, and the number of primary lateral roots were measured for each seedling. A one-way analysis of variance was used to test for differences in morphology between bareroot, container, and container-inoculated seedlings.

The bareroot and container Nuttall oak seedlings were planted on three former agricultural sites located in Mississippi, Louisiana and Texas. In Mississippi, the study site is located on the Yazoo National Wildlife Refuge, Sharkey County. The soil type at this site is a Sharkey clay. The seedlings were planted at three different elevations representing three different levels of flooding. Precise elevations were determined by using standard surveying techniques. At the lowest elevation, flooding should be deeper and of longer duration than at the highest elevation which should receive no flooding. The bareroot seedlings were lifted from the nursery beds on January 9, packed in kraft storage bags and transported to the study site on January 10. The container seedlings remained outdoors until transported to the study site on January 10. The bareroot and container seedlings were hand-planted on a 1.5 m by 1.5 m spacing. The experimental design is a randomized complete block split-plot design with 4 replications. The whole plots are the elevations while the subplots are the stock-types. Analysis of variance was used to test for treatment differences for percent survival and stem height.

In Louisiana, the study site is located on the Bayou Macon Wildlife Management Area, East Carroll Parish. The soil type is a Sharkey clay. For this site, only the stock-type treatment effects on percent survival and stem height were tested. The study design is a 3 X 3 Latin Square. While the planting location appeared to be flat, the Latin Square design was chosen to account for subtle changes in elevation which could have led to differences in soil moisture levels. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on February 14, 1995. The bareroot seedlings were a subset of a general population obtained from the nursery on January 3 and placed in cold storage at Stephen F. Austin State University until planted. The container seedlings remained outdoors until transported to the planting site.

In Texas, the study site was located on the Alazan Bayou Wildlife Management Area, Nacogdoches County. The soil type is a Mantachie sandy loam (fine-loamy, silicious, acid thermic Aeric Fluvaquent). The study design and analysis were similar to that used for the Bayou Macon site. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on February 9, 1995. The bareroot seedlings were a subset of the general population obtained from the commercial nursery on January 3 and placed in cold storage at Stephen F. Austin State University until planted. The container seedlings remained outdoors until transported to the planting site.

RESULTS AND DISCUSSION

Seedling Biomass

For both studies, the container seedlings were smaller than the bareroot seedlings (tables 1 and 3). The minimum size recommendations for bottomland oak bareroot planting stock are a stem height of 46 cm, root collar diameter of 10 mm, and a tap root length of 20 cm (Kennedy 1992). For study A, the average root collar diameters for both bareroot and container seedlings were smaller than recommended.

The average root collar diameter for bareroot seedlings used in study B exceeded the recommendation. Several early studies with hardwood species other than oaks suggested that the minimum root collar diameter for planting stock should be at least 6 mm (Belanger and McAlpine 1975, Klawitter 1961, Rodenback and Olson 1960, Williams 1965). Equal or greater survival was observed for planting stock with root collar diameters larger than 6 mm. McKevlin (1992) also recommends that the

Table l-Average morphological characteristics (N=40) of Nuttall oak seedlings planted for study A

Variables	1993 Planting date							
	January		February		March		June	
	BR	CO	BR	CO	BR	CO	BR	CO'
Height (cm)	63	47*[2]	52	46*	53	39	56	54
Root collar diameter (mm)	7.4	6.1*	7.0	6.6	6.3	5.5	7.3	6.5
Shoot dry weight (g)	9.2	4.9*	5.4	6.1	5.7	3.5*	6.5	5.0*
Root dry weight (g)	6.7	4.5*	5.9	4.1	5.1	3.3*	5.3	3.2*

[1]BR = 1-0 bareroot seedlings; CO = seedlings grown in 164cm³ plastic cone containers.
[2] For each planting date, means in a row followed by an asterisk are significantly different at the P=0.05.

Table 2—Average first-year height, height growth, and percent survival for the Nuttall oak seedlings planted in 1993 for study A. Values are determined by averaging the values from four subplots. There are 25 samples in each subplot

Planting date and stock-type'	Height	Height growth	Survival
	— — — — — cm	— — — — —	—— % ——
January			
Bareroot	35	-12	59
Container	44	4	84
Direct seedling	14	14	44
February			
Bareroot	39	-14	56
Container	46	3	80
Direct seeding	14	14	39
March			
Bareroot	37	-21	32
Container	48	4	75
Direct seeding	16	16	28
June			
Bareroot	22	-31	4
Container	48	3	95
Direct seeding	17	17	9
Root MSE[2]	5	7	14

[1]The interaction between planting date and stock-type is statisically significant at the P=0.05.
[2]Root MSE = Root Mean Square Error.

minimum root collar diameter for bottomland hardwood planting stock should be at least 6 mm. For both studies, an important distinction between the stocktypes may be in their root characteristics. The bareroot seedling roots consisted primarily of a large tap root and a few primary and secondary laterals. The container seedling roots were fibrous consisting of a tap root and many higher order lateral roots. Container seedling production typically promotes fibrous root system development and protects these roots until planting (Landis and others 1990). For study B, the container seedlings had a significantly higher number of primary lateral roots than the bareroot seedlings (table 3). Mycorrhizal inoculation appeared to have little effect on container seedling morphology.

Survival and Stem Height

For study A, survival was highest when the seedlings and seed were planted in January and February (table 2). Survival was reduced significantly if the planting occurred in March or June. Overall, container seedlings had the best first-year survival while direct seeding had the worst. Direct-seeding bottomland oak species can be a low-cost and effective means of reforesting agricultural lands (Bullard and others 1992, Stanturf and Kennedy 1996, Wittwer 1991), however, adequate stocking by direct-seeding may not be achieved because of seed predation, flooding, or drought (Johnson and Krinard 1967). Since two seeds were placed at each position, actual stocking by direct seeding is one-half what is presented in table 2. Seedling stocking could have been higher. Many of the acorns sown prior to the flood were found on the soil surface or exposed in the soil cracks in June. The high shrink characteristic of the Sharkey clay soil during rapid drying may have caused the seed exposure. Sowing seed deeper than 5 cm may be necessary for clay soils (Johnson and Krinard 1987). For reforestation projects initiated by Federal programs or regulation, adequate seedling survival usually must be guaranteed. The required seedling survival can range from 50-90 percent. Consequently, direct-seeding, although relatively inexpensive, may be too risky for many bottomland hardwood wetland restoration projects.

Excellent survival can be achieved by planting bareroot seedlings, especially when environmental conditions are

Table 3 -Average (N=50) morphological characteristics of the Nuttall oak seedlings planted in Study B

Variable	Bareroot	Container	Container w/ inoculation
Height (cm)	70.0a	60.0b	66.0b
Root collar diameter (mm)	13.0a	9.0b	9.0b
Stem dry weight (g)	13.0a	4.5b	4.6b
Root dry weight (g)	11.3a	7.5b	7.4b
Root volume (ml)	11.6a	3.5b	3.7b
No. primary lateral Roots > 0.5 mm	16.0c	30.0b	35.0a

Means within a row followed by the same letter are not significantly different at the P=0.05.

Table 4-Average height and survival for the Nuttall oak seedlings planted on three different sites for study B for the Sharkey Site averages were determined by averaging the values from 4 subplots, 30 seedlings in each subplot. For Alazan Bayou and Bayou Macon, the averages were determined by averaging the values from 3 plots, 30 seedlings in each plot

Stock-type	Sharkey Site, MS[1]		Alazan Bayou WMA, TX		Bayou Macon WMA, LA	
	Survival					
	Not flooded	Flooded	Height	Survival	Height	Survival
	- - - - - % - - - - -		- - cm - -	- - % - -	- - cm - -	- - % - -
Bareroot	20	36	57b	94	33c	79b[2]
Container	7	43	72a	97	49b	88b
Container with inoculation	3	28	66ab	97	59a	97a

[1] For the Sharkey Site, the numbers represent second-year survival. For Alazan Bayou and Bayou Macon, the numbers represent first-year survival and height.
[2] For each site, numbers in a column followed by the same letter are not significantly different at the P=0.05.

optimum (Allen 1990, Miwa 1995). For study A, the reduced survival for **bareroot** seedlings planted in March and June may partially be explained by the reduction in seedling viability during long-term cold storage (table 2). The original experimental design called for plantings to occur in January, February, March, April and May. The unplanned delay in planting was necessary because of the flooding which occurred in March, April and May. For study B, **bareroot** and container seedlings planted at Alazan Bayou and Bayou Macon had first-year survival greater than 80 percent (table 4). These sites did not experience long-term flooding or soil saturation. Survival was difficult to ascertain at the Sharkey Site. First-year survival and height was impossible to measure because of severe stem **dieback** and rodent hervibory. Flooding did occur following planting during the late winter and early spring at the lowest elevations. Second-year survival was observed to be highter at the lowest elevations. This observation is difficult to explain, in part, because of the high amounts of **herbivory occuring** at the Sharkey Site.

For study A, flooding appeared to have less adverse effect of container seedling survival. Container seedling survival was higher than **bareroot** seedling survival when the planting occurred in January or February. In addition, the high June survival for container seedlings suggests that they can be kept in the containers and successfully established after the flood waters recede. The successful establishment of the June-planted container seedlings was achieved even though the buds were not dormant and evapo-transpirational demand on the site was high. Graber (1978) reported the successful establishment of container seedlings of several northern hardwood species that were planted during the summer.

For study A, it was anticipated that the direct-seeded seedlings would be smaller than container or **bareroot** seedlings. However, for study A and B the amount of stem **dieback** observed for the container and **bareroot** seedlings was great. **Bareroot** seedlings were shorter after the first year in the field than when planted. Container seedlings were about as tall as when they were planted. Adequate survival is usually more important than rapid height and diameter growth for most bottomland hardwood wetland restoration projects. However, the detrimental effects of complete inundation on seedling survival suggests that rapid height growth after planting on flood-prone sites is desirable.

REFERENCES

Allen, J.A. 1990. Establishment of bottomland oak plantations on **the Yazoo** National Wildlife Refuge complex. Southern Journal of Applied Forestry. **14(4):** 206-210.

Baker, J.B. 1977. Tolerance of hardwoods to spring flooding. Southern Journal of Applied Forestry. l(3): 23-25.

Belanger, R.P.; McAlpine, R.G. 1975. Survival and early growth of planted **sweetgum** related to root-collar diameter. Tree Planters' Notes. **26(4): 1, 21.**

Bullard, S.; Hodges, J.D.; Johnson, R.L.; Straka, T. 1992. Economics of direct seeding and planting for establishing oak stands on old-field sites in the South. Southern Journal of Applied Forestry. **16(1):** 34-40.

Day III, C.P.; Hodges, J.D.; Schoenholtz, S.H.; Belli, K.L. 1998. Influence of hydrology on artificial regeneration of oaks in the Mississippi Delta. In: Proceedings of the 9th biennial southern silvicultural research conference; 1997 February 25-27; Clemson, SC. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of **Agriculture,** Forest Service, Southern Research Station: **295-299.**

Graber, R. 1978. Summer planting of container-grown northern hardwoods. Res. No. NE-263. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 5 p.

Johnson, R.L.; Krlnard, R.M. 1987. Direct-seeding of southern oaks---progress report. In: Proceedings 15th annual hardwood symposium of the hardwood research council: applying the latest research to hardwood problems; 1987 May 10-12; Memphis, TN. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry: 1 O-1 6.

Kennedy, H.E., Jr. 1992. Artificial regeneration of bottomland oaks. In: **Loftis,** David L.; McGee, Charles E., eds. Symposium proceedings, oak regeneration: serious problems, practical recommendations; 1992 September E-10; Knoxville, TN. Gen Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: **241-**249.

Klawitter, R.A. 1961. Seedling size affects early survival and height growth of planted cypress. Res. Note. 155. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Kozlowski, T.T.; Kramer, P.J.; Pallardy, S.G. 1991. The physiological ecology of woody plants. New York: Academic Press. 657 p.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1990. Containers and growing media. The container tree nursery manual. Agric. Handb. 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 88 p. Vol. 2.

McKevlin, M.A. 1992. Guide to regeneration of bottomland hardwoods. Gen. Tech. Rep. SE-76. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 35 p.

Miwa, M. 1995. Reestablishment of bottomland oak species in lower Mississippi Valley alluvial soils. Tech. Rep. WRP-RE-14. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Olson, D.F., Jr. 1974. *Ouercus* L. oak. In: Seeds of woody plants in the United States. **Agric.** Handb. 450. U.S. Department of Agriculture, Forest Service: 692-703.

Ozalp, M.; Schoenholtz, S.H.; Hodges, J.D.; Mlwa, M. 1998. Influence of soil series and planting methods on fifth-year survival and growth of bottomland oak reestablishment in a farmed wetland. In: Proceedings of the 9th biennial southern silvicultural research conference; 1997 February 25-27; Clemson, SC. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 277-280.

Rodenbach, R.C.; **Olson, D.F., Jr.** 1960. Grading yellow-poplar planting stock is important. Res. Note 147. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Stanturf, J.A.; Kennedy, H.E., Jr. 1996. Survival and growth of planted and direct seeded cherrybark oak in South Carolina. Southern Journal of Applied Forestry. **20(4):** 194-196.

White, D.P.; Schneider, G.; Lemmlen, W. 1970. Hardwood plantation establishment using container grown stock. Tree Planters' Notes. **21(2): 20-25.**

Whitlow, T.H.; Harris, R.W. 1979. Flood tolerance in plants: a state of the art review. U.S. Army Engineer Waterways Experiment Station Tech. Rep. E-72-2. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Williams, H.M.; Klelss, B.M.; Humphrey, N.; Kllmas, C.V. 1993. First-year field performance of oak species with varying flood tolerance planted on hydric and nonhydric soils. In: Proceedings of the 7th biennial southern silvicultural research conference; 1992 November 17-19; Mobile, AL. Gen. Tech. Rep. SO-93. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 409-414.

Williams, R.D. 1965. Plant large black walnut seedlings for best survival and growth. Res. Note CS-38. Columbus, OH: U.S. Department of Agriculture, Forest Service, Central States Forest Experiment Station.

Wittwer, R.F. 1991. Direct seeding bottomland oaks in Oklahoma. Southern Journal of Applied Forestry. **15(1):** 17-22.