A COMPARISON OF LARGE-SCALE REFORESTATION TECHNIQUES COMMONLY USED ON ABANDONED FIELDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY[1]

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Abstract-Reforesting abandoned land in the lower Mississippi alluvial valley has attracted heightened attention. Currently, federal cost share programs, such as the Wetland Reserve Program and the Conservation Reserve Program, are enticing landowners to consider reforesting lands that are marginally productive for agriculture. This study examined four reforestation techniques commonly used in the area. These techniques were applied operationally, following methods used under federal reforestation programs. Four techniques were implemented on 8.1-ha blocks in a completely randomized design with three replications. The entire study site was prepared by disking following soybean harvest in the fall of 1994. The techniques tested were: (1) direct seeding Nuttall oak (*Quercus nuttallii* Palmer) acorns (2) planting 1-0 bareroot Nuttall oak seedlings (3) establishing a nurse crop of eastern cottonwood (*Populus deltoides* Marsh.) and then underplanting 1-O bareroot Nuttall oak seedlings (4) control (natural succession). All techniques were implemented by April 1995, except the underplanted oaks, which were planted following two growing seasons for the cottonwood (oak underplanted in March 1997). Results of this study are reported for 3 years of survival and growth of the seed germinants and seedlings, for cottonwood survival and growth, and interplanted oak survival and growth following 1 year. Natural invasion onto the site is also discussed. Comparisons are made among the four reforestation techniques, with ideas for incorporating this information into the administration of federal cost share reforestation programs.

INTRODUCTION

Large-scale reforestation of former agricultural lands in the lower Mississippi alluvial valley (LMAV) continues to attract interest. Lands that were cleared in the 1960's primarily for soybean production are undergoing a use shift again, this time back to trees. The decision by many landowners to reforest these lands has been aided, in part, by the increased availability of reforestation programs, such as the Wetland Reserve Program (WRP). This program provides the landowner with a one-time easement payment, technical expertise, and cost-share to cover part or all of the reforestation costs. Applying the information amassed for large-scale reforestation of hardwoods on former agricultural lands has been challenging. There are perhaps several reasons for this. Technology transfer outlets, such as written reports and other publications, may not be the most suitable methods of disseminating this information. Additionally, the target audience is diverse, and many of the practitioners are unknown.

Research continues on expanding our current reforestation knowledge base from a small to a larger scale. The basic techniques for introducing desirable hardwood species on former agricultural land have been worked out. However, much of the preliminary work has been done on a much smaller scale. Currently, large-scale reforestation is occurring on thousands of ha in the LMAV. Much of this work has been done under the Wetland Reserve Program, and seedling and acorn survival rates have been low. One objective of this study was to test four commonly used reforestation techniques and to monitor both growth and survival so that operational techniques can be adjusted accordingly.

In many reforestation projects in the LMAV, emphasis has been placed on hard-mast producing species such as the oaks. Typical reforestation on recently abandoned fields involves the establishment of one to three overstory species, usually oaks. Sowing of acorns is a conventional method for establishing new stands of oak even though failures often occur. Researchers have indicated that planting 1-O bareroot nursery stock or direct seeding acorns can work well for most bottomland hardwood species planted on a variety of sites in the LMAV (Allen 1990, Baker and Blackmon 1973, Johnson 1983, Johnson and Krinard 1985, Krinard and Kennedy 1987).

This project was designed to test one alternative reforestation technique which combines a faster growing species, cottonwood (*Populus deltoids* Marsh.) and a slower growing species, Nuttall oak (*Quercus nuttallii* Palmer), and to contrast this technique with more traditional approaches of planting bareroot seedlings or direct seeding of acorns of Nuttall oak. The control treatment for this study is to do nothing and allow natural field succession to occur.

Compared to other reforestation techniques, one advantage of using the cottonwood nurse crop may be the creation of a more favorable microclimate for oak growth and survival. Obviously, we cannot test this until later in the study. The early growth of cottonwood allows for the rapid establishment of a forest canopy. The advantage of this canopy is that it may lend itself to accelerating natural succession by attracting birds and small mammals that are vectors for dispersal of heavy seed.

The major disadvantage of pure cottonwood plantations to wildlife may be the paucity of hard mast. Although some may also feel that cultivation works against restoration goals, it has been found that wildlife importance values for all wildlife food plants in several cottonwood plantations studied peaked in the fourth, fifth and sixth growing seasons

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(Wesley and others 1981). The planting scheme under study here will provide for hard mast, and cultivation cessation after establishment will hopefully serve to promote plant establishment that would benefit wildlife and restoration in the later growing seasons.

In addition to providing wildlife habitat, the high survival rates and rapid growth of cottonwood will enable harvest in 10 years, generating income in a relatively short time period. Stanturf and others (1998) conducted a financial analysis for a private landowner of a cottonwood plantation and found that the cottonwood provided a cash flow over the rotation, with a positive internal rate of return. Data collected from the current study will allow for future costs analysis with the additional returns of the oak together with the cottonwood.

OVERVIEW AND METHODS

Four reforestation techniques have been installed on former agricultural land located in Sharkey County, Mississippi. The site is 2.5 km east of the community of Anguilla, approximately 1 km south of State Highway 14, and immediately north of the Delta National Forest. This land was transferred to the USDI Fish & Wildlife Service from the Farmers Home Administration in 1993, and is administered by personnel at the Yazoo National Wildlife Complex.

A recent soil survey of the tract conducted by the Natural Resources Conservation Service(NRCS) indicated that the soil is of the Sharkey series, a heavy clay with shrink-swell properties, described as a very fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts (Personal communication. Floyd Wood. 1995. Soil biologist, NRCS, 100 Capitol St., Jackson, MS 39289). The Sharkey series consists of poorly drained, clayey soils formed in fine textured sediment in slack water areas along the Mississippi River. The shrink-swell nature typical of clays with montmorillinitic mineralogies results in 2-10 cm wide cracks up to 1.5 m deep that form under dry conditions, and close upon wetting. The hydrologic and edaphic conditions of our study site typify most of the abandoned agricultural land available for and undergoing reforestation in this region.

The experimental design follows a randomized complete block design with three replicates located in different portions of the tract. Treatment plots are approximately rectangular in shape and 8.1 ha in size. Treatment plots were established in October 1994 (Blocks II and III) and February 1995 (Block I). The assignment of treatments to plots was done using a random numbers table, and is summarized in table 1.

Agricultural production on the study site ended in fall 1994. The entire study site was double disked (including the natural succession treatment) following soybean removal. Acorns were collected in the Delta National Forest, placed in water and non-viable acorns that floated were discarded. Acorns were then stored in ventilated polyethylene bag at 1.7 °C. The Fish & Wildlife Service conducted the planting/sowing using their standard equipment and techniques. In May 1995, acorns were machine sown at 1.1 m X 3.7 m spacing, with one acorn placed at each planting spot. Oak seedlings (1-0 stock) were obtained from Fratesi Nursery, Leland, MS (seed source Delta National Forest). Seedlings were machine planted in March 1995 at 3.7 m X 3.7 m spacing.

Table 1-Treatment plot assignment in each block

Treatment plot	Block I[a]	II	III
1	PLN	SOW	NUR
2	NAT	NAT	SOW
3	NUR	PLN	NAT
4	SOW	NUR	PLN

[a] PLN = Plant bare-root Nuttall oak seedlings (1-0 stock), NAT = natural old field succession, NUR = cottonwood/Nuttall oak intercrop, SOW = direct seeded Nuttall oak acorns.

Four cottonwood clones (ST-88, ST-72, ST-76, and S7C-1) were established using plantation establishment procedures practiced by Crown Vantage, Inc. in spring 1995 (table 2). Cottonwood cuttings were hand-planted in pure blocks at 3.7 m X 3.7 m spacing in March 1995. Each cottonwood clone area (2 ha per clone per block) was split, with one-half of the area (1 ha) receiving weed control by disking in 1995 only, and the other half receiving the same weed control in 1995 and 1996.

In March 1997, the underplanted Nuttall oak seedlings were planted underneath the cottonwood, in every other row (3.7 m X 7.4 m spacing). Additional seedlings were also planted in 0.4-ha blocks in the open fields adjacent to each cottonwood plot. Survival, height, and diameter data were collected in 1997, following one growing season.

Four permanent measurement plots were installed in each treatment plot in fall 1995. For the direct seeded and planted treatments, measurement plots were rectangular, approximately 0.2 ha in size. Sample measurement plots for cottonwood clones were also 0.2 ha and placed, by clone, in the 1995 and the 1995-96 disked areas. All cottonwood, planted and direct seeded spots were flagged in each treatment measurement plot. The control areas were sampled by installing 64 circular plots (6.45-m radius). This sample area equals 0.85 of the total ha sampled for each control treatment plot, which is comparable to the total area sampled in the direct seeded and planted measurement plots (0.2 ha X 4 quadrants). Height and diameter data have been collected for all woody stems in all treatments following the third growing season (1997).

Statistical analysis followed a Model I ANOVA. The SAS statistical package (SAS Institute, Inc. 1990) was used for data analysis, incorporating Duncan's New Multiple Range test for mean comparisons. All significant differences are reported at a $\leq$ 0.05.

RESULTS

Seedling and Acorn Germinant Plots

The seedling height and diameter growth increased significantly over 3 years (table 3). Seedling survival was 64 percent after 3 years, averaging 489 trees per ha.

Table P-Schedule of operations for cottonwood/Nuttall treatment

Dates	Activity
October 1994	Two-pass site preparation disking Row establishment and liquid nitrogen applied in trenches @ 112 kg N ha^{-1}
March 1995	Plant cottonwood
March 1995	Spray herbicide in band over dormant cuttings (oxyfuorfen @ 0.26 kg ha^{-1} + glyphosate @ 1.4 kg ha-‘)
May 1995	One-pass disking, followed 2 weeks later by second pass at right angle to first
June &July 1995	Basal application of oxyfluorofen @ 0.7 kg ha“
August 1995	One-pass disking, followed 2 weeks later by second pass at right angle to first
Summer 1995	Insect control for cottonwood leaf beetles (carbanyl @ 0.92 kg ha-‘)
June 1996	Insect control for cottonwood leaf beetles (carbanyl @ 0.92 kg ha”)
June & July 1996	One-pass disking
March 1997	Plant Nuttall oak seedlings at offset position from cottonwood
Winter 2004	Cottonwood pulpwood harvest

Table 3—Seedling and acorn germinant height, diameter, and survival comparisons among growing seasons

	Year		
Variable	1997[a]	1996	1995
Seedling height (cm)	73.8a	52.9b	1.3c
Seedling diameter (mm)	10.7a	6.2b	.lc
Seedling survival (percent)	64.2a	59.6a	62.8a
Germinant height (cm)	27.4a	18.4b	.5c
Germinant diameter (mm)	3.4a	2.5b	.lc
Germinant survival (percent)	16.0ab	10.6b	17.6a

[a] Different letters within rows indicate significant differences among means: average n = 1135 for seedlings: average n = 530 for germinants.

Acorn germinant survival was 16 percent, which was not significantly different from the 1995 or 1996 survival percentages (table 3). The 1995 acorn germinant survival was greater than that of 1996, and 1996 survival was less than 1997 survival. The most likely explanation for these discrepancies was sampling error. Acorn germinants averaged 225 stems per ha after 3 years. Height and diameter of germinants increased consistently over the three growing seasons.

Control Plots

In 1996, in a total of 0.85 ha sampled in each control plot, seven trees were found in Block 1 (five green ash *Fraxinus pennsylvanica* Marsh., two cedar elms *Ulmus* crassifolia **Nutt.),** five in Block 2 (four green ash, one cedar elm) and five in Block 3 (one green ash, four cedar elms). More volunteer trees were found in 1997 (table 4). In 1997, the average number of trees per ha was **195, 25** and 20 per block. The high number of swamp dogwoods (Comus foemina Mill.) found in Block 1 heavily weighted this average.

Cottonwood Plots

After three growing seasons, the clones displayed differences in growth, with ST-66 **> S7C-1 >ST-75 >** ST-72 for both height and diameter (table 5). Height and diameters were greater for those cottonwood clones that received 1 year of weed control compared to those that were **disked** in 1995 and 1996 (table 6). The results for survival among clones by weed control regime are given in table 7.

Cottonwood-Red Oak: Underplanted and Open-Grown Oaks

Following one field growing season, the underplanted oaks were significantly taller (48.2 cm for underplanted, 43.9 cm for open grown) and had greater average diameters (6.1 mm for underplanted, 7.7 mm for open grown) compared to those grown in the adjacent open fields. Survival for underplanted oaks averaged 57 percent after one growing season, while open-grown oaks had a 43 percent survival rate.

Table 4-Number and species of volunteer trees found on control plots, total of 0.85 ha sampled for each block; Sharkey Research Site, 1997

	Block		
Taxa	I	II	III
Fraxinus Pennsylvania Green ash	11	14	2
Ulmus crassifolia Cedar elm	16	5	5
Comus *stricta* Swamp dogwood	125	0	6
Diospyros Virginia Persimmon	7	0	0
Celtis laevigata Sugarberry’	8	2	52
Gleditsia triacanthos Honeylocust	0	0	1

Table 5—**Height,** diameter, and total number of sprout comparisons among cottonwood clones for 1997 data

Clone type	Diameter[a]	Height	Sprouts
	cm	*m*	*Number*
ST-66	10.1a	9.49a	1.2c
S7C-1	9.0b	8.71 b	1.3b
ST-75	8.7c	7.85c	1.5a
ST-72	8.1d	7.49d	1.4a

[a] Different letters within columns indicate significant differences among means; average n = 815.

Table 6—**Height,** diameter, total number of sprouts, and survival comparisons of means between 1 year (1995) and 2 years (199586) of weed control, by clone, following three growing seasons (1997 data)

Variable	Weed control	S7C-1[a]	ST-66	ST-72	ST-75
	Year(s)				
Height(m)	1995	6.9a	7.6a	5.9a	6.6a
	199596	5.8b	6.0b	5.5b	5.6b
Diameter (cm)	1995	7.1a	8.1a	6.1a	7.1a
	1995-96	5.8b	6.2b	5.6b	5.8b
Sprouts (no.)	1995	1.7a	1.6a	1.5a	1.7a
	1995-96	1.7a	1.5b	1.5a	1.6b
Survival (percent)	1995	97.6a	96.4b	88.6a	93.2a
	1995-96	94.4a	95.1a	82.2a	92.8a

[a] Different letters within columns, by clone, indicate significant differences between means.

Table 7-1997 cottonwood clone survival among clones by weed control regime-l year (1995) or 2 years (199596) of weed control

Clone	1995 weed control'	199596 weed control
	Percent	
S7C-1	97.6a	94.4ab
ST-66	96.4ab	95.1a
ST-72	88.6c	82.2b
ST-75	93.2b	92.8ab

[a] Different letters within columns indicate significant differences among means,

DISCUSSION

After three growing seasons, results from these four reforestation techniques are beginning to shed some light on expected reforestation on this site. It is understandable that the cottonwood growth and survival are superior to that of the oaks. Not only is cottonwood the fastest growing tree species in North America, but also the care and attention given to its establishment are displayed in the results. Seedling survival was approximately as expected for a large-scale operation. At an average of 489 trees per ha, seedling establishment would be deemed above adequate under guidelines set by NRCS for federal tree establishment programs, especially WRP. Under WRP, 308 hard mast stems per ha after three growing seasons meets the success criteria. Therefore, the 225 trees per ha for the acorn germinants would fall short of this goal.

Seedling survival, compared to other similarly reforested sites, was average to below average. Allen (1990) evaluated oak plantations established by the USDI Fish & Wildlife Service personnel on refuges in west-central Mississippi. Seven out of ten stands Allen assessed had over 489 trees per ha. Krinard and Kennedy (1987) observed survival rates of hardwood seedlings planted on Sharkey clay soil from 69 to 97 percent after 2 years, and 57 to 98 percent after 4 years. They found that Nuttall oak seedling survival was 85 percent (2 years) and 80 percent (4 years). Wittwer (1991) observed 78 percent survival of planted bottomland oaks after 3 years. Savage and others (1989) reported 370 trees per ha and a 64 percent survival rate for both seedlings and germinants on reforested bottoms in Louisiana.

To date, obtaining adequate stocking of oaks on good to poor sites has been difficult with either natural or artificial regeneration. It has been suggested that the inherent sluggish growth habitat of oak is the principal cause of regeneration failures. This slow growth rate combined with intensive vegetative competition and frequent animal browsing has plagued forest managers in their attempts to regenerate oaks. Based on research trials and our knowledge of direct seeding on public and private lands in recent years, the overall likelihood of regeneration success with oaks in a given year is somewhat less with direct seeding than with planting (Bullard and others 1992).

Before acorns germinate, predation from mammals and birds constitutes the major cause of loss (Harmer 1994a, b; Korstian 1927). A pilot small mammal trapping study (600 trap nights) conducted on a single plot of the direct seeded and the cottonwood treatments in October 1995 indicated that very dense small mammal populations were present on the direct seeded treatment (202 animals captured 216 times) compared to the cottonwood (2 animals captured 2 times). Sigrnodon *hispidus* was the most abundant of five species captured (Willis and others 1996). Therefore, rodent predation of acorns may have contributed to the lower survival rates and stocking in the direct seeded treatments, which had extensive weed cover compared to the bare soil conditions in the cottonwood treatments.

The expected survival of operationally direct seeded acorns has been reported at 35 percent (Johnson and Krinard 1985, Kennedy 1993). Theoretically, a large number of acorns should increase the possibility for some acorns to escape predation and germinate. Others have experienced this same problem and have addressed it by simply increasing the number of seeds sown. For example, Willoughby and others (1996) described results and recommendations from several studies designed to establish new woodlots by direct sowing. Their recommendation for acorns was to sown 10,000 per ha, with the aim of establishing 1,000 reasonably even-spaced vigorous trees by year 10. This figure allowed for losses from germination failure, predation, drought, herbicide damage, and weed competition. This planting density was also observed by the authors on State-run forests in Denmark, where the sowing and subsequent germination and growth of oak was so thick that it appeared almost like a shrub row.

The survival and stocking on these reforested sites must be viewed in the context of the landowners' objectives. If having a few widely spaced trees in fields dominated by herbaceous vegetation is the goal, it appears as if the current direct seeding or natural succession methods will work. However, if the objective is to restore these sites back to some level of a functional forested wetland, regardless of the function, more time and effort are needed to implement the techniques. The general knowledge of reforestation on old field sites exists; it now becomes a matter of using that information property to get the desired results. Perhaps the biggest challenge is not working out the individual aspects of large-scale reforestation but putting all those pieces together in one scheme. We can only continue to match species to sites, use proper seed and seedling handling, strive for good quality planting stock, perform site preparation, and perhaps most importantly, have on-site supervision to help make the pieces fit.

Plantations of fast growing tree species in short rotation cycles are going to play a vital role in meeting the rising demand for woody biomass production. *Populus* has shown promising growth and productivity, can be harvested in short periods, and has combined well, thus far, with the red oak intercropping system. Twedt and Portwood (1997) noted that in addition to production-related benefits, planting early-successional species can (1) promote rapid colonization by migrant birds (2) enhance plant species diversity (3) provide a more rapid financial return to landowners, and (4) enhance the public's perception of reforestation efforts. The ongoing research into physiological response of oaks established beneath cottonwood, as well as the possible changes in the edaphic and microclimate environment under the cottonwoods, will aid in our prognosis of implementing such a system.

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