DISKING EFFECTS ON FIFTH-YEAR VOLUME PRODUCTION OF FOUR EASTERN COTTONWOOD CLONES ESTABLISHED ON AN AFFORESTATION SITE, SHARKEY COUNTY, MISSISSIPPI

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Abstract-In spring 1995, an eastern cottonwood (*Populus deltoides*) plantation was established on a former agricultural field in Sharkey County, MS to evaluate the effects of clonal variety and mechanical weed control on aboveground biomass production. Four cottonwood clones, ST-66, ST-72, ST-75, and S7C-1 were planted on a 12 foot x 12 foot spacing and subjected to 2 mechanical weed control treatments (disking in year 1 versus disking in year 1 and 2). Survival in the plantation ranged from 96 percent for ST-66 and S7C-1 to 87 percent for ST-72. But, survival was not influenced by mechanical weed control as it averaged 93 percent for each treatment level. After the fifth growing season, mean cottonwood height ranged from 48.3 feet for ST-66 to 39.8 feet for the other three clones. Similarly, diameter of ST-66 averaged 5.5 inches, while diameter of the other clones averaged 4.8 inches. Two years of mechanical weed control did not improve tree growth as heights averaged 41.8 feet and diameters averaged 4.9 inches regardless of disking treatment. Clonal effects on volume production were obvious after 5 growing seasons, ranging from 1038 $feet^3$ $acre^{-1}$ outside bark for ST-66 to 574 $feet^3$ acre-' outside bark for ST-75. Volume inside bark ranged from 631 $feet^3$ $acre^{-1}$ for ST-66 to 279 $feet^3$ acre' for ST-75 Multiple years of mechanical weed control did not improve eastern cottonwood volume production five growing seasons after plantation establishment. Results indicate that eastern cottonwood plantations may be established to rapidly develop a forest structure on a wide range of afforestation sites in the Lower Mississippi River Alluvial Valley.

INTRODUCTION

Extensive deforestation in the Lower Mississippi River Alluvial Valley, driven primarily by land use conversion to agricultural production, reduced bottomland hardwood forest acreage by more than 75 percent in the region (Stanturf and others 2000, Sternitzke 1976). Recently, interest in restoring bottomland hardwood forests on marginally economical agricultural land has been spurred by several governmental incentive programs (Stanturf and others 1998). Although most afforestation projects in the Lower Mississippi River Alluvial Valley focus on establishing heavy mast species such as bottomland oaks (*Quercus* spp.) (King and Keeland 1999), some landowners have management objectives that require establishment of fast growing, intensively managed and economically sustainable hardwood plantations (Stanturf and Portwood 1999).

Eastern cottonwood (*Populus deltoides* Bar-tram ex Marshall), a native, pioneer species that thrives on alluvial soils throughout the central and eastern United States, has several attributes which make it an appealing selection for afforestation in the Lower Mississippi River Alluvial Valley (Cooper 1990). Relative to plantation establishment and development, eastern cottonwood can be propagated with vegetative cuttings, superior clones are available for a variety of site types, plantation cultural practices are well established, it exhibits extremely fast growth rates, and growth and yield models are available for the species (Cao and Durand 1991a, Krinard 1988, McKnight 1970). The suitability of this species to plantation culture has led to its establishment in fiber farms and biofuel plantations worldwide. As an example, more than 3.7 million acres of eastern cottonwood have been planted in China since its introduction in the 1970s (Cao and Conner 1999).

Although sustainable fiber production is often the driving force behind establishment of eastern cottonwood plantations, other environmental benefits can be derived through afforestation with this species. Gardiner and others (In Press) demonstrated that the understory of eastern cottonwood plantations may be suitable for facilitating establishment of other native bottomland tree species on afforestation sites. The importance of eastern cottonwood forests as habitat for game and non-game wildlife species has been established for several decades (Twedt and Portwood 1997, Wesley and others 1981, Wigley and others 1980). Thornton and others (1998) demonstrated that sediment loss in runoff from cottonwood plantations was substantially lower than runoff from fields under conventional

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Table l-Schedule of operations during establishment of an eastern cottonwood plantation, Sharkey County, MS (adapted from Schweitzer and Stanturf 1999)

Date	Activity
October 1994	• Site preparation: two-pass disking • Row establishment with liquid nitrogen applied in subsoil trenches at 100 pounds acre^{-1}
March 1995	• Planted eastern cottonwood cuttings • Herbicide application: 6 foot band application of oxyfluorofen at 80 ounces acre-’ + glyphosate at 24 ounces acre-’ over dormant cuttings
May 1995	• Mechanical weed control: one-pass disking and row cultivation followed by second pass at right angles 2 weeks later
June-July1995	• Herbicide application: basal application of oxyfluorofen in a 3 foot band at 32 ounces acre-’
August 1995	• Mechanical weed control: one-pass disking and row cultivation followed by second pass at right angles 2 weeks later
Summer 1995	-Pesticide application: carbanyl applied at 16 ounces acre-’ for cottonwood leaf beetle control
June 1996	-Pesticide application: carbanyl applied at 16 ounces acre.’ for cottonwood leaf beetle control
June-July1996	• Mechanical weed control: one-passdisking

agricultural production. Vose and others (2000) documented the potential of eastern cottonwood for phytoremediation of groundwater contaminants such as trichloroethylene. Thus, improvements in surface and ground water quality can result from rapid buildup of a litter layer and root system beneath the forest cover. Furthermore, the high productivity of eastern cottonwood makes the species attractive for carbon sequestration and biofuel purposes (Thornton and others 1998, Stanturf and others 2000).

Though cultural practices for establishment and management of eastern cottonwood plantations are well developed, there is a need to refine current management systems. This is particularly relevant to plantation establishment on former agricultural land, sites where eastern cottonwood productivity may be marginal. The purpose of this study was to evaluate effects of clonal variety and mechanical weed control on fifth-year growth and volume production of eastern cottonwood on an afforestation site in the Lower Mississippi River Alluvial Valley.

METHODS

Study Site

The study was conducted on a previously farmed site located in Sharkey County, MS (90° 44’ west latitude, 32” 58’ north longitude). The site is situated about 1.5 miles east of Anguilla, and immediately north of the Delta National Forest. Soil on the site was mapped as a Sharkey series (very-fine, smectitic, thermic chromic EPIAQUERTS). Annual rainfall in Sharkey County averages 52 inches, and mean temperatures range from 45” Fahrenheit in January to 82” Fahrenheit in July (Scott and Carter 1962). Cultivation of the study site for soybean (*Glycine max* [Linnaeus] Merrill) production ended in the fall of 1994.

Experimental Design

In March 1995, 3, 20-acre stands (blocks) of eastern cottonwood were established using plantation establishment procedures practiced by Crown Vantage, Incorporated (table 1). For each 20-acre stand, 4 cottonwood clones (ST-66, ST-75 ST-72, S7C-1) were planted in 5-acre plots on a 12 foot x 12 foot spacing. Each 5-acre plot was split and randomly assigned a mechanical weed control treatment level. Half of the split-plots received weed control by disking in 1995, and the other half received weed control by disking in 1995 and 1996.

In each split-plot, a 0.5-acre measurement plot was established to record survival, height and diameter growth of eastern cottonwood. Total height and diameter at breast height of surviving cottonwood stems were measured after the fifth growing season. Tree heights were measured to the nearest 0.1 foot with a Criterion 300 Survey Laser (Laser Technology, Incorporated, Englewood, CO 80112), while diameter at breast height was measured to the nearest 0.1 inch with calipers. When multiple stems originated from the same cutting, the largest stem was measured.

Data Analyses

Individual tree volume was calculated using equations developed by Krinard (1988). Total tree volume outside bark $= 0.06 + 0.002221 \times (\text{diameter}^2 \times \text{height})$, volume inside bark to a 3-inch top $= -0.86 + 0.001904 \times (\text{diameter}^2 \times \text{height})$. If diameter was less than 5.0 inches, equations published by Mohn and Krinard (1971) were substituted. Intercept and slope coefficients from Mohn and Krinard (1971) were 0.21 and 0.00221 for volume outside bark, and -0.62 and 0.00204 for volume inside bark. Volume per acre was calculated by multiplying mean survival for a clone by the mean volume inside bark or outside bark for individual

Table P-Analysis of variance sketch for a randomized block design with split-plots used to analyze fifth year survival, height, diameter, and volume production of 4 eastern cottonwood clones

Source	Degrees of Freedom
Total	23
Block	2
Cottonwood Clone	3
Error(Cottonwood Clone)	6
Disking	1
Cottonwood Clone X Disking	3
Error	8

stems of the given clone. Basal area per acre was determined in a similar fashion. That is, mean survival for a clone was multiplied by the mean basal area of individual stems of the given clone.

Treatment effects on response variables (survival, height, diameter, volume inside bark, volume outside bark) were analyzed according to a randomized complete block design with split-plots (table 2). The analysis of variance was conducted with SAS statistical software (SAS Institute Incorporated, Cary, NC 27513). Survival percentages were transformed with a square root transformation prior to analysis. Where significant treatment effects were identified ($\alpha = 0.05$), differences between means were calculated according to procedures outlined by Petersen (1985).

RESULTS AND DISCUSSION

Stem-Level

After 5 growing seasons, none of the response variables measured in the eastern cottonwood plantation were influenced by multiple years of mechanical weed control (table 3). Survival was exceptional throughout the plantation, averaging 93 percent for each disking regime. Surviving eastern cottonwood stems averaged 41.8 feet tall and 4.9 inches diameter at breast height. Across disking regimes, stem volume averaged more than 1.4 feet^3 inside bark and 2.6 feet^3 outside bark (table 3).

Table 3-Effects of 1 year and 2 years of weed control by disking on survival, height, diameter, and volume inside bark and outside bark for an eastern cottonwood plantation, 5 years after establishment, Sharkey County, MS

Variable	Disking 1995	Disking 1995-96
Survival (pct)[a,b]	93 ± 1.4 a	93 ± 1.4 a
Height (ft)	41.5 ± 7.2 a	42.2 ± 7.0 a
Diameter (in)	4.9 ± 0.69 a	5.0 ± 0.69 a
Volume inside bark (ft^3)	1.4 ± 0.70 a	1.5 ± 0.88 a
Volume outside bark (ft^3)	2.6 ± 0.97 a	2.7 ± 1.10 a

[a] For each variable, means in rows followed by the same letter are not significantly different at =0.05.
[b] Mean ± standard error.

An early recommendation by McKnight (1970) suggested that eastern cottonwood plantations should be maintained weed-free until they develop to crown closure. More recently, Stanturf and Portwood (1999) suggested that weed control is necessary when stems average less than 6 feet tall after the first growing season, and it is not necessary when stems average greater than 8 feet tall. Benefits of additional weed control are uncertain when first-year stem height ranges between 6 and 8 feet (Stanturf and Portwood 1999). First-year sapling height in this study was on the lower end of the range of uncertainty as it averaged 6.8 feet (data not presented). Our results indicate that the additional year of weed control was not necessary for improving survival or growth of eastern cottonwood. In fact, Schweitzer and Stanturf (1999) reported that third-year growth in the current plantation was reduced by 2 years of mechanical weed control. They attributed the growth reduction to root damage during the second year of disking. Results from this study indicate that factors in addition to tree height should be considered before prescribing weed control practices. Such factors may include competition level and site quality. For example, 6 feet of first-year height growth on a marginally productive soil, such as the Sharkey series in this study, may be comparable to 10 feet of height growth on a highly productive soil such as the Commerce series (Cao and Durand 1991 b). Eliminating mechanical weed control in the second year of plantation establishment could amount to savings of 10 dollars per acre.

Clonal effects on survival, height, diameter and volume production were apparent in the plantation by the end of the fifth growing season (table 4). ST-66 and S7C-1 showed 10 percent higher survival than ST-72. Survival of ST-75 was numerically intermediate, but did not differ from the other clones (table 4). On the Sharkey soil series of the study site, ST-66 outperformed all other clones in fifth year height and diameter. Average height of ST-66 was 21 percent taller than the average height of the 3 other clones. Likewise, diameter of ST-66 measured 14 percent higher than the average diameter of the 3 other clones (table 4). As expected, results on volume production by cottonwood clone tracked similar to height and diameter growth. Five years after stand establishment, ST-66 produced a greater stem volume, inside bark and outside bark, than all other clones.

Clonal effects on eastern cottonwood survival and growth are well established (Foster 1985). Results from this study indicate that early growth of ST-66 on a heavy clay soil was superior to the other tested clones. The superior performance of ST-66 would be beneficial on afforestation sites of similar soil where management objectives targeted fiber production, carbon sequestration, or development of vertical structure. However, a thorough consideration of management objectives for the afforestation site should be considered prior to clone selection. To illustrate, Goelz and Monroe (1995) presented findings from a 21-year-old eastern cottonwood clonal trial in the Lower Mississippi River Alluvial Valley. They observed that ST-66 performed well in a short rotation for fiber production, but was only average for the relatively long rotation sawtimber production. Conversely, ST-72, which exhibited average volume production in this study, was a favored sawtimber producer

Table 4-Mean survival, height, diameter, and volume inside bark and outside bark for 4 eastern cottonwood clones, 5 growing seasons after plantation establishment, Sharkey County, MS

Variable	Clone ST-66	S7C-1	ST-72	ST-75
Survival (pct)[a,b]	96 ± 0.58 a	96 ± 1.3 a	87 ± 0.98 b	93 ± 2.0 ab
Height (ft)	48.3 ± 2.1 a	41.8 ± 2.4 b	40.7 ± 2.7 b	36.8 ± 2.4 b
Diameter (in)	5.5 ± 0.21 a	4.8 ± 0.25 b	5.0 ± 0.28 b	4.7 ± 0.26 b
Volume inside bark (ft^3)	2.2 ± 0.36 a	1.3 ± 0.28 b	1.4 ± 0.28 b	1.0 ± 0.17 b
Volume outside bark (ft^3)	3.6 ± 0.42 a	2.5 ± 0.36 bc	2.6 ± 0.38 b	2.0 ± 0.28 c

[a]For each variable means within rows followed by the same letter are not significantly different at =0.05.

[b] Mean ± standard error.

Table 5—Fifth year stem density, basal area and volume outside bark of 4 eastern cottonwood clones planted on a 12 foot x 12 foot spacing at an afforestation site, Sharkey County, MS

Clone	Stem Density (stems/ac)	Basal Area (ft^2/ac)	Volume (ft^3/ac)
ST-66	290	48	1038
S7C-1	290	36	712
ST-72	263	36	680
ST-75	281	34	574

at age 21 (Goelz and Monroe 1995). Additionally, eastern cottonwood productivity can be improved by establishing appropriate clonal mixes (Foster and others 1998). Establishment of extensive, single clone stands where forest restoration objectives are a focus may be inappropriate.

Stand-Level

Estimates of stand development are of primary importance to land managers with forest restoration objectives. Through 5 years of development in the eastern cottonwood plantation, stand density averaged about 280 stems/acre, basal area averaged 38 $feet^2$/acre, and merchantable volume averaged 750 $feet^3$/acre (table 5). In correspondence with individual stem results, variation in stand density, basal area and volume production was observed among clonal stands (table 5). Stem density ranged about 10 percent, basal area ranged about 41 percent, and volume estimates ranged more than 80 percent between clonal stands.

Stand level basal area and volume estimates observed in this study were similar to results reported by Krinard and Kennedy (1980). The study reported by Krinard and Kennedy (1980) involved 4 cottonwood clones established on a former soybean field with soil mapped to the same series as this study. Survival averaged only 75 percent, but the plantation had an average basal area of 38 $feet^2$/acre and yielded a volume outside bark of 683 $feet^3$/acre at year 5. Though the Sharkey soil series is considered marginally productive for eastern cottonwood (McKnight 1970), results from this study confirm the observation of Krinard and Kennedy (1980) that its exceptional growth on these heavy clay soils is unmatched by any other bottomland hardwood species. Eastern cottonwood can be used by afforestation managers to rapidly develop a forest structure on a wide range of site types of the Lower Mississippi River Alluvial Valley.

LITERATURE CITED

Cao, F. L.; Conner, W. H. 1999. Selection of flood-tolerant *Populus deltoides* clones for reforestation projects in China. Forest Ecology and Management. 117: 211-220.

Cao, Q. V.; Durand, K. M. 1991a. A growth and yield model for improved eastern cottonwood plantations in the Lower Mississippi Delta. Southern Journal of Applied Forestry. 15: 213-216.

Cao, Q. V.; Durand, K. M. 1991b. Site index curves for eastern cottonwood plantations in the Lower Mississippi Delta. Southern Journal of Applied Forestry. 15: 28-30.

Cooper, **D. T.** 1990. *Populus deltoides* Bartr. ex Marsh. eastern cottonwood. In: Burns, R. M.; Honkala, B. H., tech. coords. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. U. S. Department of Agriculture, Forest Service, Washington, D. C. vol. 2, 877 p.

Foster, G. S. 1985. Provenance variation of eastern cottonwood in the lower Mississippi Valley. Silvae Genetica. 13:116-l 18.

Foster, G. S.; **Rousseau,** R. **J.; Nance, W. L.** 1998. Eastern cottonwood clonal mixing study: intergenotypic competition effects. Forest Ecology and Management. 112: 9-22.

Gardiner, E. S.; Schweitzer, C. J.; Stanturf, J. A. In Press. Photosynthesis of Nuttall oak (*Quercus nuttallii* Palm.) seedlings interplanted beneath an eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) nurse crop. Forest Ecology and Management.

Goelz, J. C. G.; Monroe, R. L. 1995. A clonal cottonwood trial after 21 years. In: Edwards, M. B., comp. Proceedings of the eighth biennial southern silvicultural research conference; 1994 November l-3; Auburn, AL. Gen. Tech. Rep. SRS-1. Asheville, NC; U. S. Department of Agriculture, Forest Service, Southern Research Station: 367-372.

King, S. L.; Keeland, B. D. 1999. Evaluation of reforestation in the Lower Mississippi River Alluvial Valley. Restoration Ecology. 7: 348-359.

Krinard, R. **M.** 1988. Volume equations for plantation cottonwood trees (*Populus deltoides*). Res. Note SO-347. New Orleans, LA: U. S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 4 p.

Krinard, R. M.; Kennedy, H. E. Jr. 1980. Five-year-old cottonwood plantation on a clay site: growth, yield and soil properties. Southern Journal of Applied Forestry. 4(2): 80-83.

McKnight, J. S. 1970. Planting cottonwood cuttings for timber production in the South. Res. Pap. SO-60. New Orleans: U. S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 17 p.

Mohn, C. A.; Krinard, R. R. 1971. Volume tables for small cottonwoods in plantations. Res. Note SO-113. New Orleans, LA: U. S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 4 p.

Petersen, R. G. 1985. Design and analysis of experiments. New York: Marcel Dekker, Inc. 429 p.

Schweitzer, C. J.; Stanturf, J. A. 1999. A comparison of large-scale reforestation techniques commonly used on abandoned fields in the Lower Mississippi Alluvial Valley. In: Haywood, J. D., ed. Proceedings of the tenth biennial southern silvicultural research conference; 1999 February 16-l 8; Shreveport, LA. Gen. Tech. Rep. SRS-30. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southern Research Station: 136-141.

Scott, F. T.; **Carter, R.** C. 1962. Soil survey of Sharkey County, Mississippi. U. S. Department of Agriculture, Soil Conservation Service, 36 p.

Stanturf, J. A.; Gardiner, E. S.; Hamel, P. B.; Devall, M. S.; Leininger, T. D.; Warren, M. E., Jr. 2000. Restoring bottomland hardwood ecosystems in the Lower Mississippi Alluvial Valley. Journal of Forestry. 98: 10-16.

Stanturf, J. A.; Portwood, C. J. 1999. Economics of afforestation with eastern cottonwood (*Populus deltoides*) on agriculture land in the Lower Mississippi Alluvial Valley. In: Haywood, J. D., ed. Proceedings of the tenth biennial southern silvicultural research conference; 1999 February 16-1 8; Shreveport, LA. Gen. Tech. Rep. SRS-30. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southern Research Station: 66-72.

Stanturf, J. A.; Schweitzer, C. J.; Gardiner, E. S. 1998. Afforestation of marginal agricultural land in the Lower Mississippi River Alluvial Valley, U.S.A. Silva Fennica. 32:281-297.

Sternitzke, H. S. 1976. Impact of changing land use on Delta hardwood forest. Journal of Forestry. 74: 25-27.

Thornton, F. C.; Joslin, J. D.; Bock, B. R.; Houston, A.; Green, T. H.; Schoenholtz, S.; Pettry, D.; Tyler, D. D. 1998. Environmental effects of growing woody crops on agricultural land: first year effects on erosion, and water quality. Biomass and Bioenergy. 15: 57-69.

Twedt, D. J.; Portwood, J. 1997. Bottomland hardwood reforestation for Neotropical migratory birds: are we missing the forest for the trees. Wildlife Society Bulletin. 25: 647-652.

Vose, J. M.; Swank, W. T.; Harvey, G. J.; Clinton, B. D.; Sobek, C. 2000. Leaf water relations and sapflow in eastern cottonwood (*Populus deltoides* Ban.) trees planted for phytoremediation of a groundwater pollutant. International Journal of Phytoremediation 2: 53-73.

Wesley, D. E.; Perkins, C. J.; Sullivan, A. D. 1981. Wildlife in cottonwood plantations. Southern Journal of Applied Forestry. 5: 37-42.

Wigley, T. B.; Wesley, D. E.; Perkins, C. J.; Sullivan, A. D. 1980. Use of a cottonwood monoculture by white-tailed deer. Journal of Wildlife Management. 44: 264-265.