Root-Collar Diameter and Third-Year Survival of Three Bottomland Hardwoods Planted on Former Agricultural Fields in the Lower Mississippi Alluvial Valley

Emile S. Gardiner, Douglass F. Jacobs, Ronald P. Overton, and George Hernandez

Emile S. Gardiner is Research Forester, USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research, PO Box 227, Stoneville, MS 38776; Tel: 765.496.6686; E-mail: egardiner@fs.fed.us. **Douglass F. Jacobs** is Associate Professor, Hardwood Tree Improvement and Regeneration Center, Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907; E-mail: djacobs@purdue.edu. **Ronald P. Overton** is Area Regeneration Specialist, Northeastern Area State and Private Forestry, USDA Forest Service, West Lafayette, IN 47907; E-mail: roverton@fs.fed.us. **George Hernandez** is Regeneration Specialist, Region 8, USDA Forest Service, Atlanta, GA 30367; E-mail: ghernandez@fs.fed.us.

Gardiner, E.S.; Jacobs, D.F.; Overton, R.P.; Hernandez, G. 2009. Root-collar diameter and third-year survival of three bottomland hardwoods planted on former agricultural fields in the lower Mississippi Alluvial Valley. In: Dumroese, R.K.; Riley, L.E., tech. coords. 2009. National Proceedings: Forest and Conservation Nursery Associations—2008. Proc. RMRS-P-58. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 85–89. Online: http://www.fs.fed.us/rm/pubs/rmrs_p058.html.

Abstract: Athough the Lower Mississippi Alluvial Valley (LMAV) has experienced substantial afforestation of former agricultural fields during the past 2 decades, seedling standards that support satisfactory outplanting performance of bottomland hardwood tree species are not available. A series of experimental plantations, established on three afforestation sites in the LMAV, provided an opportunity to examine relationships between initial root-collar diameter and the probability of third-year survival for Nuttall oak (*Quercus nuttallii*), sweet pecan (*Carya illinoensis*), and green ash (*Fraxinus pennsylvanica*). Three years after planting, the probability of survival for Nuttall oak and sweet pecan seedlings improved with increasing initial root-collar diameter. The probability of survival for Nuttall oak and sweet pecan seedlings increased 26% and 33%, respectively, over the range of initial root-collar diameters (2 to 18 mm [0.08 to 0.71 in]). Intensive vegetation control during the first growing season also increased the probability of survival for both species. In contrast, green ash seedlings maintained a third-year survival of 95% across the three study sites, and the probability of survival was not influenced by initial root-collar diameter or first-year vegetation control. These results suggest that morphological variables, such as root-collar diameter, can provide practical, species-specific indices of potential survival for bottomland hardwood seedlings outplanted on former agricultural fields in the LMAV.

Keywords: afforestation, seedling survival, *Quercus nuttallii*, *Carya illinoensis*, *Fraxinus pennsylvanica*

Introduction

For over 2 decades, government programs, including the Wetland Reserve Program (WRP) and Conservation Reserve Program (CRP), have promoted restoration of forest cover on previously farmed acreage in the Lower Mississippi Alluvial Valley (LMAV) (Kennedy 1990). Participation in these incentive programs has been enthusiastic as landowners target replacement of economically marginal farmland with forest cover capable of enhancing wildlife habitat, establishing timber production, improving water quality, and promoting other environmental objectives (Schoenholtz and others 2001). For a multitude of reasons, natural regeneration is often not a reliable practice for establishing forest cover on former agricultural land in the LMAV (Allen 1997; Stanturf and others 2001). Managers, therefore, typically practice afforestation to establish native tree species on enrolled acreage (Stanturf and others 1998). Accordingly, the extensive afforestation employed to establish forest cover in the LMAV has spiked the demand for bottomland hardwood tree seedlings.

Although state and private nurseries have increased production to meet demand, hardwood seedlings raised by various growers can differ substantially in morphological and physiological attributes that may influence seedling field performance (Jacobs and others 2005a; Gardiner and others 2007). Indeed, field observations in the LMAV indicate a wide range of outplanting performance for hardwood seedlings, and some of these differences may be attributed to cultural practices that affect morphological or physiological condition of lifted stock (Jacobs and others 2005a; Wilson and Jacobs 2006; Gardiner and others 2007). Although it is established that seedling morphology and physiology can determine outplanting performance, scientifically based standards for the production and grading of bottomland hardwood seedlings are currently unavailable. Furthermore, afforestation programs implemented throughout the LMAV often maintain seedling specification policies that differ from state to state. Clearly, there is a need to acquire additional knowledge on the factors that determine outplanting success of bottomland hardwood seedlings so that nursery growers can target specific seedling characteristics, and landowners can purchase quality planting stock. This study is part of a larger research effort designed to examine linkages between nursery practices, seedling morphology, and outplanting performance of several bottomland hardwood species commonly planted on afforestation sites in the LMAV. Knowledge gained from this effort could eventually be used to develop hardwood seedling standard recommendations for afforestation in the LMAV. The objective of this manuscript is to present preliminary analyses of the relationships between initial root-collar diameter and third-year survival of outplanted Nuttall oak (*Quercus nuttallii*), sweet pecan (*Carya illinoensis*), and green ash (*Fraxinus pennsylvanica*) seedlings.

Methods

Overview

In February 2003, a series of experimental plantations were established on former agricultural sites in the LMAV to examine bottomland hardwood seedling quality, as affected by nursery source and competition control, on outplanting performance. The chosen sites in Louisiana, Mississippi, and Arkansas were privately owned and enrolled in either the WRP or CRP, and site conditions were representative of other acreage recently enrolled in these conservation programs. Jacobs and others (2005a) and Gardiner and others (2007) provide comprehensive details on the design, establishment, and measurement of this bottomland hardwood seedling quality research. Methods presented in this manuscript are a subset from that larger research effort, and are restricted to those most relevant to our examination of the relationships between initial root-collar diameter and third-year survival of Nuttall oak, sweet pecan, and green ash seedlings.

Seedling Material and Laboratory Procedures

Nuttall oak, sweet pecan, and green ash seedlings were obtained from the Louisiana Department of Agriculture and Forestry Monroe Nursery in Monroe, the Mississippi Forestry Commission Winona Nursery in Winona, and the Arkansas Forestry Commission Baucum Nursery in North Little Rock. The 1+0 bareroot seedlings were lifted on 30-31 January 2003, then stored at 4 °C (39 °F) in refrigerated lockers located at the Center for Bottomland Hardwoods Research, Stoneville, MS, and the Theodore Roosevelt National Wildlife Refuge Complex, Hollandale, MS. Prior to outplanting, each seedling was tagged with a unique number referencing its nursery of origin and measured values for several morphological variables. Root-collar diameter, measured with calipers to the nearest 0.1 mm, was among the variables measured on each seedling in the laboratory.

Field Sites and Design

Three locations in the LMAV, scheduled to receive afforestation, were selected as experimental sites for this study. The sites were former agricultural fields in Madison Parish, LA (32° 26' N, 91° 25' W), Bolivar County, MS (33° 53' N, 91° 00' W), and Chicot County, AR (33° 03' N, 91° 22' W). On each site, a factorial arrangement of nursery (three levels—Louisiana, Mississippi, Arkansas) and weed control (two levels—no weed control, complete weed control) treatments were assigned within three blocks of six experimental plots established for each species. Treatment plots consisted of a 5 by 10 grid of planting spots spaced 1.8 m (6 ft) apart. Thus, a total of 900 seedlings for each species, 300 from each nursery, were planted on each of the three experimental sites (2,700 total seedlings for each species).

On each site, experimental plantations were delineated on soils suited for each species such that Nuttall oak and green ash were assigned to Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts) at the Madison Parish and Bolivar County sites, and Perry clay (very-fine, smectitic, thermic Chromic Epiaquerts) at the Chicot County site. Sweet pecan was assigned to the better drained Dundee loam (fine-silty, mixed, active, thermic Typic Endoaqualfs) at the Madison Parish site, Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) at the Bolivar County site, and Robinsonville loam (coarse-loamy, mixed, superactive, nonacidic, thermic Typic Udifluvents) at the Chicot County site.

Planting and Tending Practices

All three study sites were planted in February 2003. A professional planting crew was contracted to plant the Madison Parish and Chicot County sites, while the authors and forestry technicians planted the Bolivar County site. The experimental seedlings on all sites were hand-planted using hardwood planting shovels that had a 16.5 cm (6.5 in) wide x 25 cm (10 in) long blade. Vegetation control practices were initiated on designated plots immediately after planting to remove all competing vegetation through the first growing season (Corbin and others 2004). Herbicide applications included a pre-emergent broadcast application of Goal® 2XL (oxyfluorfen) applied at a rate of 4.7 L/ha (2 qt/ac) in early March 2003, broadcast applications of Select® 2EC (clethodim) applied as needed throughout the growing season at a rate of 0.6 or 0.9 L/ha (0.5 or 0.75 pt/ac), and directed applications of Derringer (glufosinate-ammonium) applied at a rate of 118 ml/L (4 oz/gal) of water as needed throughout the growing season. Additionally, mechanical weed control by mowing and hand-hoeing was employed as needed to aid in competition control.

Data Analysis

The experimental design as described above is structured for an "ANOVA-type" analysis of experimental factors. This design, however, also allows for exploration of relationships between seedling morphological characteristics and variables of outplanting performance. To meet the objectives of this manuscript, logistic regression was used to estimate the probability of seedling survival at year 3 from initial measurements of root-collar diameter. Third-year survival and initial root-collar diameter data from all three study sites were pooled, and the probability of seedling survival over the range of measured root-collar diameters was modeled as:

$$P = 1 / 1 + e^{-(a + b \cdot \text{initial root-collar diameter})}$$

In this model, e is the base of the natural logarithm (2.718), while a and b are estimated model parameters. The probability of survival (P) is unitless and can range between 0 and 1 such that probabilities near 0 indicate little chance of occurrence and probabilities near 1 indicate a high chance of occurrence. For each species, separate models were developed for seedlings receiving weed control and seedlings that did not receive weed control. Model significance was determined at $P = 0.05$.

Results and Discussion

Knowledgeable and conscientious afforestation foresters and planting crews operating on former agricultural fields in the LMAV have demonstrated success in establishing bottomland hardwood plantations that maintain relatively high survival rates. Plantation failures, however, are still frequent, particularly if adequate care is not taken to assure suitable species selections, site preparation, procurement of quality planting stock, and proper seedling storage, handling, and planting (Gardiner and others 2002). In this study, third-year survival of bareroot seedlings planted on former agricultural fields in the LMAV ranged from 95% for green ash to 67% for sweet pecan across all three study sites. Nuttall oak was intermediate with 85% survival across all sites. These percentages, particularly for Nuttall oak and green ash, are as good as, or higher than, other reported survival rates from the LMAV (Krinard and Kennedy 1987; Ozalp and others 1997; Michalek and others 2002; Patterson and Adams 2003). As in this study, green ash survival rates on afforestation sites are generally higher than other bottomland species, and it is not uncommon to observe less than 5% mortality of this species 3 years after outplanting in the LMAV (Krinard and Kennedy 1987; Groninger and Babassana 2002). This may be due, in part, to the ability of green ash to readily develop adventitious roots (Kennedy 1972). Less is known about the artificial establishment of sweet pecan on afforestation sites, but Krinard and Kennedy (1987) reported fourth-year survival of this species averaged 57% on a cleared forest site in the LMAV.

With recent advances in herbicide labeling and application technologies, practitioners in the LMAV are beginning to employ vegetation control practices during plantation establishment. Operational vegetation control practices are generally known to benefit bottomland hardwood seedling growth (Gardiner and others 2002; Groninger and others 2004), but improving seedling survival through vegetation control practices has not been consistently observed. Greatest gains in survival following vegetation control have perhaps been observed in establishment years of low rainfall (Ezell and Catchot 1997; Ezell and Hodges 2002). In this study, complete weed control during the first growing season reduced seedling mortality for Nuttall oak and sweet pecan. Ninety percent of the planted Nuttall oak seedlings survived 3 years when established in plots receiving weed control, whereas 80% survived the same period without weed control. Third-year survival for sweet pecan averaged 75% in plots that received first-year weed control as compared to 58% in plots that did not receive weed control. Removing unwanted vegetation did not benefit green ash survival, averaging 95% across all three study sites regardless of weed control treatment. The complete weed control practiced for the purpose of this experiment is not operationally feasible for large-scale plantations. Our results, however, do illustrate potential detriments of competing vegetation on survival of the three species examined.

While the plantation survival results described above contribute to our general knowledge of bottomland hardwood establishment on afforestation sites in the LMAV, exploring potential morphological indices of seedling survival is more important to the objective of this manuscript. Other authors working with various broadleaved species have identified variables such as root-collar diameter, root volume, and the number of first-order lateral roots as promising indices of some measures of hardwood seedling field performance (Dey and Parker 1997; Spetich and others 2002; Davis and Jacobs 2005; Jacobs and others 2005b). Our examination of the relationships between initial root-collar diameter and third-year seedling survival is revealing. Nuttall oak seedlings outplanted without receiving weed control showed third-year survival probabilities that ranged from 0.67 to 0.93 (fig. 1). The probabilities of survival were, in part, determined by initial root-collar diameter ($P >$ Chi Square < 0.001), as the lowest probabilities were associated with the smallest root-collar diameters and the greatest probabilities for survival were projected for seedlings with the largest root-collar diameters (fig. 1). Removing competing vegetation had a positive impact on the probabilities of survival for Nuttall oak, with the response curve shifting upwards to probabilities that ranged from 0.80 to 0.98 (fig. 1).

Plotting the response curve for probability of survival over initial root-collar diameter can be useful for identifying a target seedling size that corresponds to a threshold survival level. For example, to achieve an arbitrary 0.85 probability of survival 3 years after planting, a Nuttall oak seedling planted without receiving weed control would need a minimum root-collar diameter of about 11 mm (0.43 in) (fig. 1). Understandably, because competing vegetation reduced the probability of survival for Nuttall oak, the threshold root-collar diameter needed to achieve an 0.85 probability of survival is reduced to about 4 mm (0.15 in) if

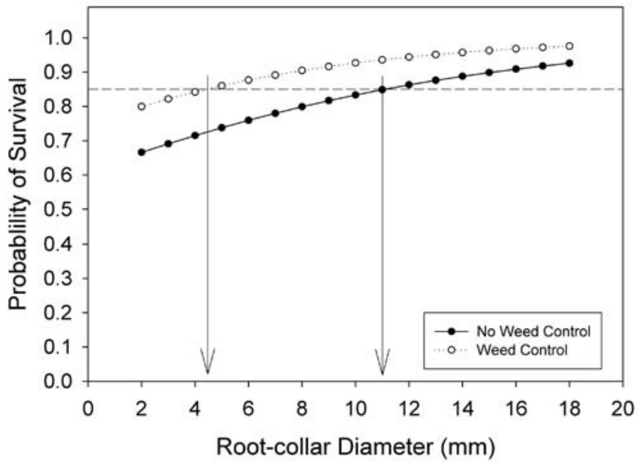

Figure 1. Third-year probability of survival for bareroot Nuttall oak seedlings established on three former agricultural fields in the LMAV. The dashed, horizontal line represents an arbitrary 0.85 probability of survival. Arrows indicate the minimum initial root-collar diameter that provides a 0.85 probability of survival.

complete weed control is practiced during the first growing season (fig. 1).

Third-year probabilities of survival for sweet pecan seedlings could be partially ascribed to initial root-collar diameter (P > Chi Square < 0.001). Survival probabilities ranged between 0.47 for seedlings with initial root-collar diameters of 2 mm (0.08 in) and 0.80 for seedlings with initial root-collar diameters of 18 mm (0.71 in) (fig. 2). The probabilities of survival for this species also responded to first-year weed control, that is, the response curve shifted upwards to a range of third-year survival probabilities from 0.66 to 0.90 (fig. 2). For sweet pecan, achieving an arbitrary 0.85 probability of survival appears unlikely without intensive control of competing vegetation (fig. 2). An initial

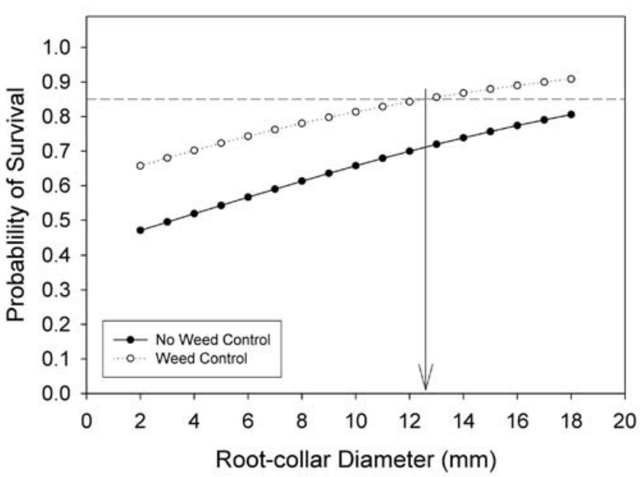

Figure 2. Third-year probability of survival for bareroot sweet pecan seedlings established on three former agricultural fields in the LMAV. The dashed, horizontal line represents an arbitrary 0.85 probability of survival. The arrow indicates the minimum initial root-collar diameter that provides a 0.85 probability of survival with competition control.

root-collar diameter of 13 mm (0.51 in), along with first-year weed control, would be needed to attain this probability of survival (fig. 2).

In contrast to the other species, the probabilities of survival for green ash seedlings could not be referenced to initial root-collar diameter (P > Chi Square = 0.77670). Third-year survival probabilities for this species were high across the entire range of initial root-collar diameters, indicating a large capacity for survival within a broad range of seedling morphology (fig. 3). Additionally, probabilities of survival for this species were not improved with first-year competition control (fig. 3).

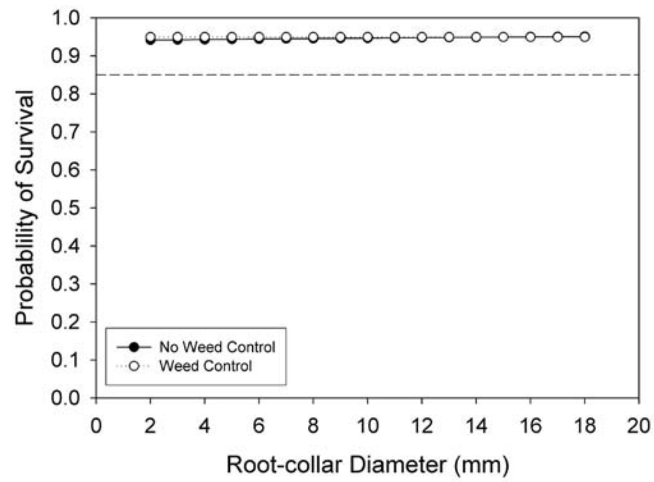

Figure 3. Third-year probability of survival for bareroot green ash seedlings established on three former agricultural fields in the LMAV. The dashed, horizontal line represents an arbitrary 0.85 probability of survival.

Conclusions

Bottomland hardwood tree seedlings have traditionally been raised, processed, planted, and tended with little regard for species-specific requirements. Lack of knowledge of bottomland hardwood seedling quality as it relates to outplanting success limits the implementation of species-specific standards. In this study, Nuttall oak, sweet pecan, and green ash exhibited differing abilities to survive outplanting on former agricultural fields in the LMAV. Three years after planting, the range in initial root-collar diameter was associated with differing probabilities of survival for Nuttall oak and sweet pecan seedlings. Survival probabilities for seedlings planted without weed control improved 26% for Nuttall oak and 33% for sweet pecan as initial root-collar diameter increased from 2 to 18 mm (0.08 to 0.71 in). The probability of survival for these species also responded to vegetation control, showing marked increases when seedlings were established in plots free of competing weeds. In contrast, the probability of survival for green ash seedlings showed little variation throughout the range of initial root-collar diameter. This species maintained a consistently high capacity for survival, even when planted with competing vegetation. These results suggest that seedling survival on afforestation sites in the LMAV could be improved through implementation of species-specific quality standards for planting stock. Morphological variables, such as root-collar diameter, can provide practical indices of potential survival for some bottomland hardwood species. Additionally, consideration of how the plantation will be managed, such as accounting for future vegetation control practices, during plantation establishment could lead to more informed decisions regarding seedling quality. The assessment of this seedling quality research will continue into the future, with more in-depth analyses of the relationships between seedling morphology and outplanting performance to support development of practical indices of bottomland hardwood seedling quality for afforestation sites on former agricultural fields in the LMAV.

References

Allen JA. 1997. Reforestation of bottomland hardwoods and the issue of woody species diversity. Restoration Ecology 5:125-134.

Corbin ME, Gardiner ES, Jacobs DF. 2004. Initial effects of complete weed control on survival and growth of two bottomland hardwood species established on former agricultural fields. Proceedings of the Southern Weed Science Society 57:192-197.

Davis AS, Jacobs DF. 2005. Quantifying root system quality of nursery seedlings and relationship to outplanting performance. New Forests 30:295-311.

Dey DC, Parker WC. 1997. Morphological indicators of stock quality and field performance of red oak (*Quercus rubra* L.) seedlings underplanted in a central Ontario shelterwood. New Forests 14:145-156.

Ezell AW, Catchot AL Jr. 1997. Competition control for hardwood plantation establishment. In: Waldrop TA, editor. Proceedings of the ninth biennial southern silvicultural research conference. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-20. p 42-43.

Ezell AW, Hodges JD. 2002. The importance of competition control for restoration of oaks in the southern United States. In: Frochot H, Collet C, Ballandier P, compilers. Popular summaries from the fourth international conference on forest vegetation management. Champenoux (France): Institut National de la Recherche Agronomique.

Gardiner ES, Russell DR, Oliver M, Dorris LC Jr. 2002. Bottomland hardwood afforestation: state of the art. In: Holland MM, Warren ML, Stanturf JA, editors. Proceedings of a conference on sustainability of wetlands and water resources: how well can riverine wetlands continue to support society into the 21st century? Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-50. p 75-86.

Gardiner ES, Salifu KF, Jacobs DF, Hernandez G, Overton RP. 2007. Field performance of Nuttall oak on former agricultural fields: initial effects of nursery source and competition control. In: Riley LE, Dumroese RK, Landis TD, technical coordinators. National proceedings, forest and conservation nursery associations—2006. Ogden (UT): USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Proceedings RMRS-P-50. p 120-125.

Groninger JW, Babassana DA. 2002. Accelerating planted green ash establishment on an abandoned soybean field. In: Outcalt KW, editor. Proceedings of the eleventh biennial southern silvicultural research conference. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-48. p 270-272.

Groninger JW, Baer SG, Babassana DA, Allen DH. 2004. Planted green ash (*Fraxinus pennsylvanica* Marsh.) and herbaceous vegetation responses to initial competition control during the first 3 years of afforestation. Forest Ecology and Management 189:161-170.

Jacobs DF, Gardiner ES, Salifu KF, Overton RP, Hernandez G, Corbin ME, Wightman KE, Selig MF. 2005a. Seedling quality standards for bottomland hardwood afforestation in the Lower Mississippi River Alluvial Valley: preliminary results. In: Dumroese RK, Riley LE, Landis TD, technical coordinators. National proceedings, forest and conservation nursery associations—2004. Ogden(UT): USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Proceedings RMRS-P-35. p 9-16.

Jacobs DF, Salifu KF, Seifert JR. 2005b. Relative contribution of initial root and shoot morphology in predicting field performance of hardwood seedlings. New Forests 30:235-251.

Kennedy HE Jr. 1972. Horizontal planting of green ash cuttings looks promising. New Orleans (LA): USDA Forest Service, Southern Forest Experiment Station. Research Note SO-147. 4 p.

Kennedy HE Jr. 1990. Hardwood reforestation in the South: landowners can benefit from Conservation Reserve Program incentives. New Orleans (LA): USDA Forest Service, Southern Forest Experiment Station. Research Note SO-364. 6 p.

Krinard RM, Kennedy HE Jr. 1987. Planted hardwood development on clay soil without weed control through 16 years. New Orleans (LA): USDA Forest Service, Southern Forest Experiment Station. Research Note SO-343. 4 p.

Michalek AJ, Lockhart BR, Dean TJ, Keeland BD, McCoy JW. 2002. Hand planting versus machine planting of bottomland red oaks on former agricultural fields in Louisiana's Mississippi Alluvial Plain: sixth-year results. In: Outcalt KW, editor. Proceedings of the eleventh biennial southern silvicultural research conference. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-48. p 352-357.

Ozalp M, Schoenholtz SH, Hodges JD, Miwa M. 1997. Influence of soil series and planting methods on fifth-year survival and growth of bottomland oak re-establishment in a farmed wetland. In: Waldrop TA, editor. Proceedings of the ninth biennial southern silvicultural research conference. Asheville (NC): USDA Forest Service, Southern Research Station. General Technical Report SRS-20. p 277-280.

Patterson WB, Adams JC. 2003. Soil, hydroperiod and bedding effects on restoring bottomland hardwoods on flood-prone agricultural lands in North Louisiana, USA. Forestry 76:181-188.

Schoenholtz SH, James JP, Kaminski RM, Leopold BD, Ezell AW. 2001. Afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley: status and trends. Wetlands 21:602-613.

Spetich MA, Dey DC, Johnson PS, Graney DL. 2002. Competitive capacity of *Quercus rubra* L. planted in Arkansas' Boston Mountains. Forest Science 48:504-517.

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

Stanturf JA, Schoenholtz SH, Schweitzer CJ, Shepard JP. 2001. Achieving restoration success: myths in bottomland hardwood forests. Restoration Ecology 9:189-200.

Wilson BC, Jacobs DF. 2006. Quality assessment of temperate zone deciduous hardwood seedlings. New Forests 31:417-433.

The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.