A PRELIMINARY SYNTHESIS OF GROWTH DATA FOR BOTTOMLAND HARDWOOD SPECIES COMMONLY PLANTED IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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Abstract—This study synthesizes published height growth measurements for a range of bottomland hardwood species commonly used in afforestation efforts in the Lower Mississippi Alluvial Valley (LMAV), including a variety of oak and non-oak species, from establishment up to 20–30 years of age. Over this time period, cottonwood outperforms all species, while red oaks (cherrybark, Nuttall, water, and willow), sweetgum, and sycamore show intermediate growth trends. Green ash and swamp chestnut oak show lower growth over the same period. In terms of site quality effects, heavier textured clay soils tend to produce lower growth rates for most species, while higher quality loam soils produce the highest growth. Nonetheless, the lack of published data suggests that an increased sampling effort is needed to improve our knowledge of growth patterns of trees commonly used in afforestation in the LMAV and assist landowners and managers in anticipating stand development and silvicultural treatments.

INTRODUCTION

In recent decades, restoration efforts have established hundreds of thousands of acres of planted hardwood stands throughout the Southeastern United States in an effort to restore bottomland hardwood (BLH) forests on marginal farmland (Allen 1997, Twedt 2004). These efforts have been largely supported by Federal incentive programs that began in the 1980s, particularly the Wetland Reserve Program (WRP) and Conservation Reserve Program (CRP) (Gardiner and others 2004, Schoenholtz 2001, Twedt 2004). The reestablishment of BLH forest cover is meant to reverse many decades of forest loss to agricultural conversion and restore ecosystem services that these forests provide. The intended benefits include improvement in soil and water quality, enhancement of wildlife habitat, and sequestration of carbon, in addition to forest production for biomass or timber (Stanturf and others 2001).

In the Lower Mississippi Alluvial Valley (LMAV), much research has focused on planting approaches and early growth and survival, thereby contributing to more effective establishment methods (Stoll and Frey 2016). Several studies have also reviewed the challenges of afforestation and restoration of BLH forests (e.g., Dey and others 2010, Groninger 2005, Stanturf and others 2001). While at least one study has quantitatively assessed trends in species and establishment approaches used in hardwood afforestation programs (Schoenholtz and others 2001), to our knowledge no studies have attempted to synthesize published growth data for the wide variety of species used in afforestation efforts, especially across varying site conditions. This represents a particular knowledge gap given that many of the earlier plantings are approaching stand closure and stem exclusion and may benefit from silvicultural treatment. Better growth data, particularly height data, are also needed for modeling carbon storage (Duncanson and others 2015, Shoch and others 2009).

The objectives for this study were to (1) evaluate the availability of measurement data for different bottomland hardwood species and plantation ages, (2) evaluate height growth trends among bottomland hardwood plantation species, and (3) evaluate growth patterns among soil types. These data should be of value for landowners and managers for anticipating stand development, growth and yield, and silvicultural treatments.

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Kirschman, Julia E., comp. 2018. Proceedings of the 19th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-234. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 444 p.

METHODS

For purposes of this study, we gathered data from published, peer-reviewed literature. We performed searches in Scopus and Google Scholar using combinations of search terms that included "bottomland," "hardwood," "plantation," "Mississippi," "afforestation," and also the names of BLH species. We also evaluated proceedings of the Biennial Southern Silviculture Research Conference, U.S. Forest Service publications, and related technical reports. Studies selected for the analysis (1) were located in the LMAV or on bottomland sites in areas adjacent to the LMAV (fig. 1) and (2) reported height growth data at a specific age. While a large number of species were identified, we focused primarily on several commonly planted oak species and non-oak species for which there were adequate data. The most common oak species included cherrybark oak (*Quercus pagoda* Raf.), Nuttall oak (*Q. texana* Buckley), water oak (*Q. nigra* L.), willow oak (*Q. phellos* L.), and swamp chestnut oak (*Q michauxii* Nutt.). The common non-oak species included cottonwood (*Populus deltoides* Bartram ex Marshall), green ash (*Fraxinus pennsylvanica* Marshall), sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.).

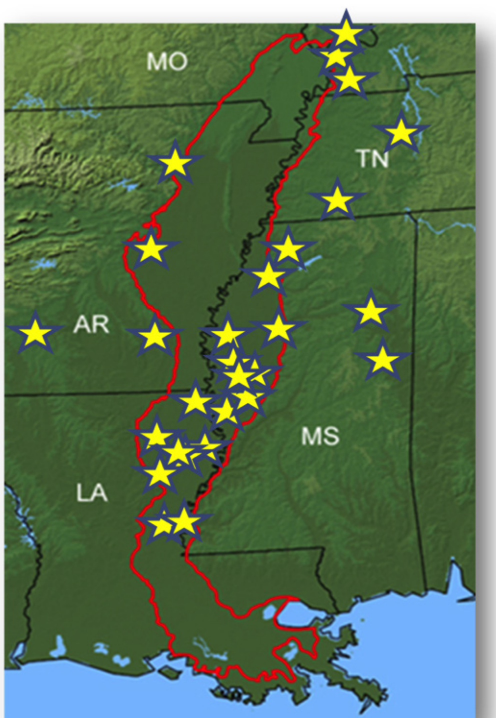

Figure 1—Approximate locations of study sites synthesized from published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley. Source: www.lmvsci.gov.

Datapoints were extracted directly from tables where available, and where data were presented in graphical form, datapoints were extracted using DataThief software (Tummers 2006). For purposes of this analysis, individual datapoints were taken directly from plot or replicate means of height or diameter for a given species at a specific age as presented in the individual studies. Studies supplied widely different amounts of usable data. Some studies reported replicate means for multiple species, measured over multiple years, thus providing a large number of datapoints, whereas other studies reported only mean growth values for a limited number of species or ages. In addition to species-age growth data, soil type, site preparation, planting stock, planting density, competition control, and intermediate treatments were also included as available. For the purposes of this paper, a preliminary assessment of age-growth data by species was performed. In addition, height performance across soil types was assessed for a subset of oak species (cherrybark, Nuttall, and water) and non-oak species (green ash, sweetgum, and sycamore) for which sufficient published data were available.

RESULTS AND DISCUSSION

We identified 38 studies that provide quantitative data on height growth performance of woody BLH species that have been assessed in the LMAV or adjacent areas (fig. 1, table 1). There were 13 species that were encountered in this set of studies (fig. 2). However, a subset of species comprised the bulk of the measurements. By far the most frequently measured species in this dataset were several oak species (Nuttall, water, and cherrybark oak) followed by several non-oak species (green ash, sweetgum, sycamore, and cottonwood). These species comprised more than 90 percent of measurements. Other oak species such as Shumard oak (*Quercus shumardii* Buckley var. *shumardii*), willow oak, pin oak (*Q. palustris* Münchh.), swamp chestnut oak, and white oak (*Q. alba*) were less frequent, as was sweet pecan [*Carya illinoinensis* (Wangenh.) K. Koch]. Perhaps not surprisingly, the vast majority of measurements have been made on shade-intolerant species, which have been favored because of their rapid growth in open environments (e.g., cottonwood) and/or their wildlife benefits (e.g., red oaks to improve availability of hard mast) (Krinard and Johnson 1980, Lockhart and others 2008). Mid-tolerant to shade-tolerant species were represented principally by green ash and swamp chestnut oak.

Most published height and diameter measurements have been made on stands 10 years age or less (fig. 3). Far fewer measurements have been made in stands of 10–20 years of age, and an even lower number of

Table 1—List of studies providing height growth data for bottomland hardwood species in and around the Lower Mississippi Alluvial Valley

Studies		
Adams and others 2007	Kennedy and others 1987	Miwa 1995
Allen 1990	Krinard 1985	Ozalp and others 1997
Burkett and others 2005	Krinard and Johnson 1975	Patterson and Adams 2003
Carlson and Goelz 1998	Krinard and Johnson 1980	Roth and others 1993
Clatterbuck 2002	Krinard and Johnson 1984	Rousseau 2008
Devine and others 2000	Krinard and Johnson 1988	Self and others 2006
Ezell and Shankle 2004	Krinard and Kennedy 1981	Self and others 2010
Gardiner and others 2004	Krinard and Kennedy 1983	Self and others 2011
Goelz 2001	Krinard and Kennedy 1987	Self and others 2013
Groninger and others 2004	Lockhart and others 2006	Stanturf and others 2009
Gwaze and others 2003	Meadows and Goelz 1993	Stine and others 1994
Jeffreys and others 2010	Meadows and Goelz 2001	Twedt and Wilson 2002
Johnson 1981	Michalek and others 2002	

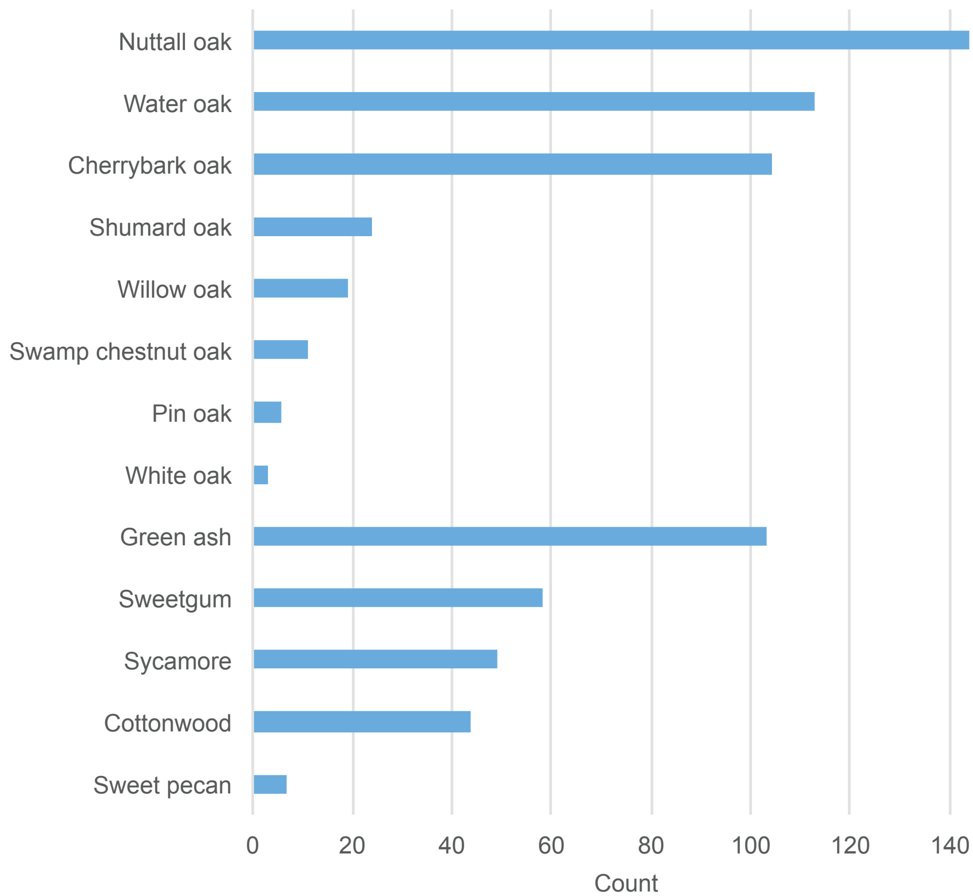

Figure 2—Counts of measurements for different oak and non-oak species synthesized from published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley.

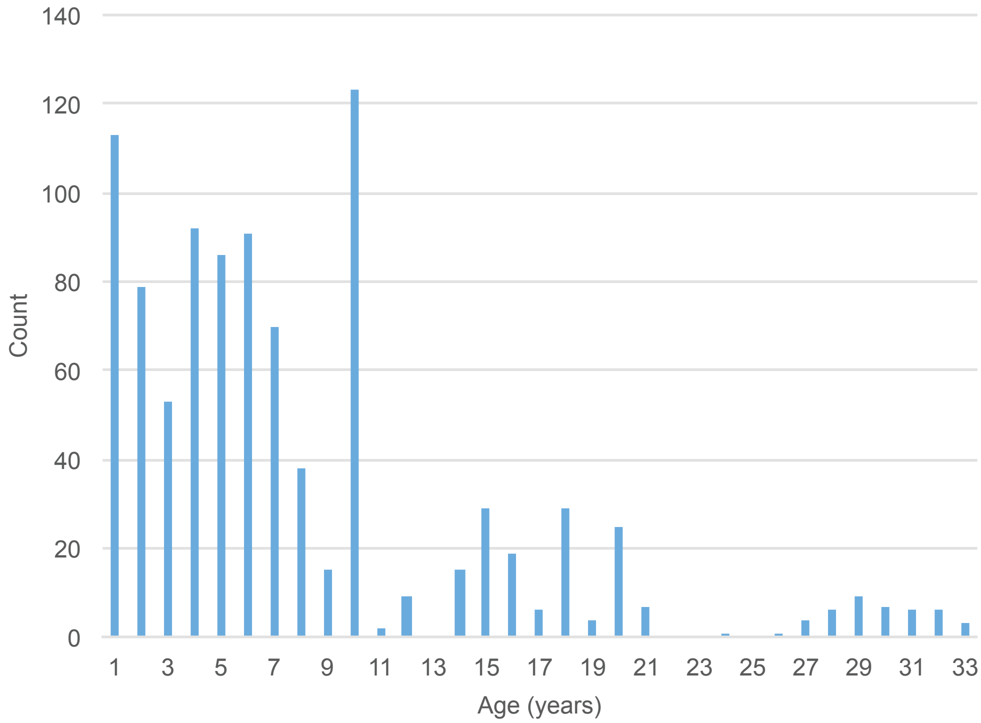

Figure 3—Counts of measurements by age based on published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley.

measurements have been made in stands older than 20 years of age. This reflects in part the short history of large-scale planting programs (~30 years), but also the lack of monitoring and measurement of stands beyond the initial years of establishment (Stoll and Frey 2016). Clearly, most studies have focused on establishment and early growth.

Based on linear height growth trends (fig. 4), cottonwood outperforms other BLH plantation species, approaching or exceeding 100 feet by age 20. In contrast, swamp chestnut oak exhibited the lowest height growth, approaching only 30 feet at age 20. Intermediate growth was exhibited by the red oak species (cherrybark, Nuttall, water, willow), sweetgum, and sycamore which approached between 40–50 feet plus at age 20. More specifically, cherrybark oak, sweetgum, and sycamore performed similarly and trended slightly higher than Nuttall, water, and willow oak. Green ash performance was lower than all but swamp chestnut oak, approaching 35 feet by age 20. Outside of cottonwood, the most rapid initial growth was evidenced in sycamore and green ash; however this advantage was not sustained, especially for green ash.

Height growth differences were also evaluated across different soil types for a subset of species for which there were adequate data. Of the soil types evaluated, generally the Falaya and Collins silt loams have higher site quality (as measured by site index) for bottomland hardwood species, with Arkabutla loam soils of moderate to high site quality, and heavy clay Sharkey soils (a dominant soil type of marginal agricultural land) of lower site quality. Height growth differences were evident when comparing growth of individual species across these different soil types.

Nuttall oak height growth (fig. 5A) was highest in the Falaya silt loam, achieving 55 feet by age 20, which was approximately 25 percent higher growth than in either the Arkabutla loam or Sharkey clay soils beyond age 15. Likewise, water oak height growth (fig. 5B) was also highest in the Falaya silt loam, with height exceeding 60 feet by age 20. Water oak height growth was intermediate in the Arkabutla loam, achieving 45 feet by age 20, while heights were substantially lower in Sharkey clay soils (just above 20 feet by age 18). Cherrybark oak height growth (fig. 5C) was highest in the Falaya silt loam, reaching 60 feet by age 20. Growth was lower in the Arkabutla loam, achieving 47 feet by age 20. Performance of cherrybark oak in Sharkey clay or other heavy clay soils was unavailable, likely because these soils are not considered suitable sites for planting cherrybark oak.

Green ash height growth performance (fig. 6A) was lower than in the oaks, and differed relative to the oak species, showing greater height growth in the Sharkey clay soil, followed by the Collins silt loam, and the Arkabutla loam. Green ash achieved 35 feet in 15 years in the Sharkey soil, but required 18 years in the Collins soil and 20 years in the Arkabutla soil. The lower growth

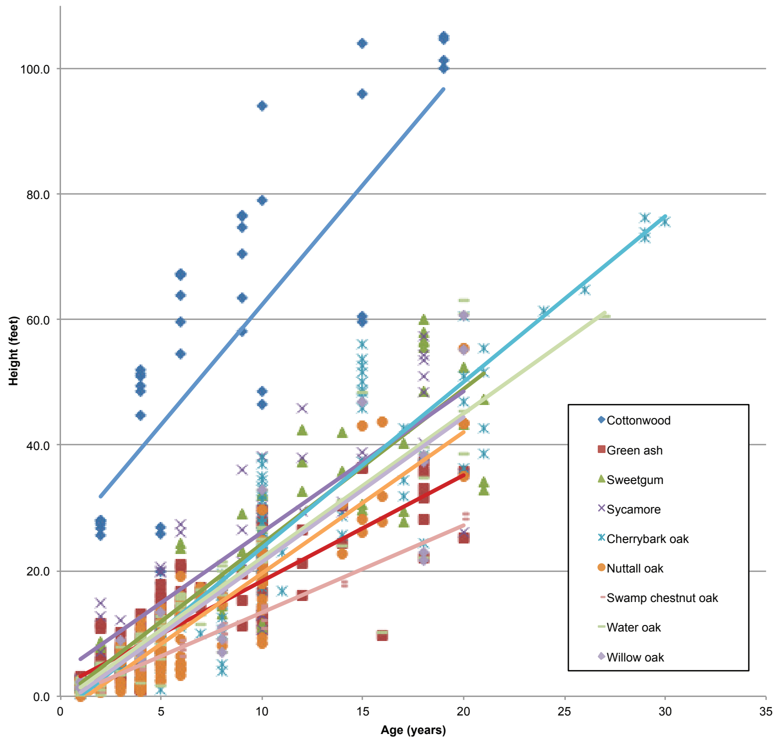

Figure 4—Growth of cherrybark oak, Nuttall oak, water oak, willow oak, swamp chestnut oak, cottonwood, green ash, sweetgum, and sycamore based on published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley.

performance in the Arkabutla soil type was notable, given that height performance was more rapid initially (>10 feet versus 5 feet in the other soil types at age 2). Sweetgum height growth (fig. 6B) also diverged among soil types, achieving 60 feet by age 18 in the Collins silt loam, followed by intermediate performance in the Arkabutla loam (>50 feet by age 20) and lower growth in the Sharkey clay soil (30 feet by age 15). As with green ash, sweetgum showed better initial performance in the Arkabutla soil, but this advantage was not sustained. Sycamore height performance (fig. 6C) also diverged with higher growth in the Collins soil (58 feet by age 18), intermediate growth in the Sharkey clay soil (approaching 40 feet by age 15), and lower growth in the Arkabutla soil (~35 feet by age 20). As in both green ash and sweetgum, performance in the Arkabutla soil was higher initially (age 2) but was lower beyond age 10.

CONCLUSIONS

This assessment of published height growth data for bottomland hardwood species used in afforestation efforts in the LMAV yielded several pieces of information. First, measurement data are primarily available for stands less than 10 years of age, with data increasingly limited beyond age 10. Second, while the growth of at least 13 species has been evaluated at some level, most published measurements have been concentrated on a small group of species that includes cherrybark, Nuttall, and water oak, and cottonwood, green ash, sweetgum, and sycamore. Notably few shade-tolerant to mid-tolerant species have been assessed. Third, based on available data there is varying growth potential among the species. Cottonwood outperforms all species; the red oaks (cherrybark, Nuttall, water, and willow), sweetgum, and sycamore show intermediate growth trends; and green ash and swamp chestnut oak show lower growth over the same period. Growth varies by soil type; heavier textured clay soils generally produce lower growth rates for most species, while higher quality loam soils produce higher growth. Furthermore, growth trajectories differ among species and soil types over time (e.g., rapid initial growth in sycamore and green ash), supporting the need for ongoing measurement. Future research should attempt to increase measurement of stands greater than 10 years of age and across a wider range of species to improve our knowledge of growth patterns of trees commonly used in afforestation in the LMAV. This will be valuable to landowners and managers in anticipating stand development and silvicultural treatments.

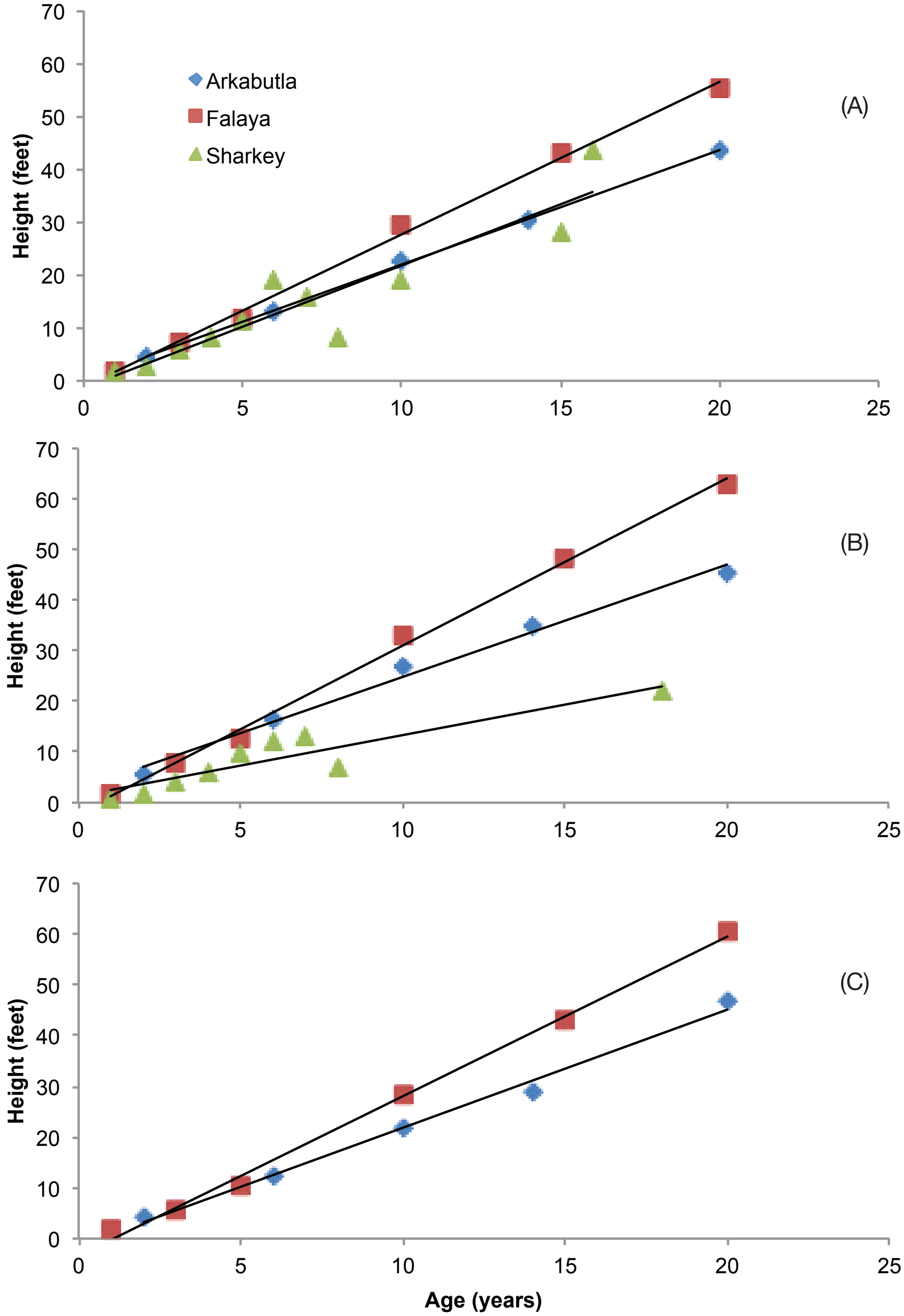

Figure 5—Growth of (A) cherrybark oak, (B) Nuttall oak, and (C) water oak across different soil types based on published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley.

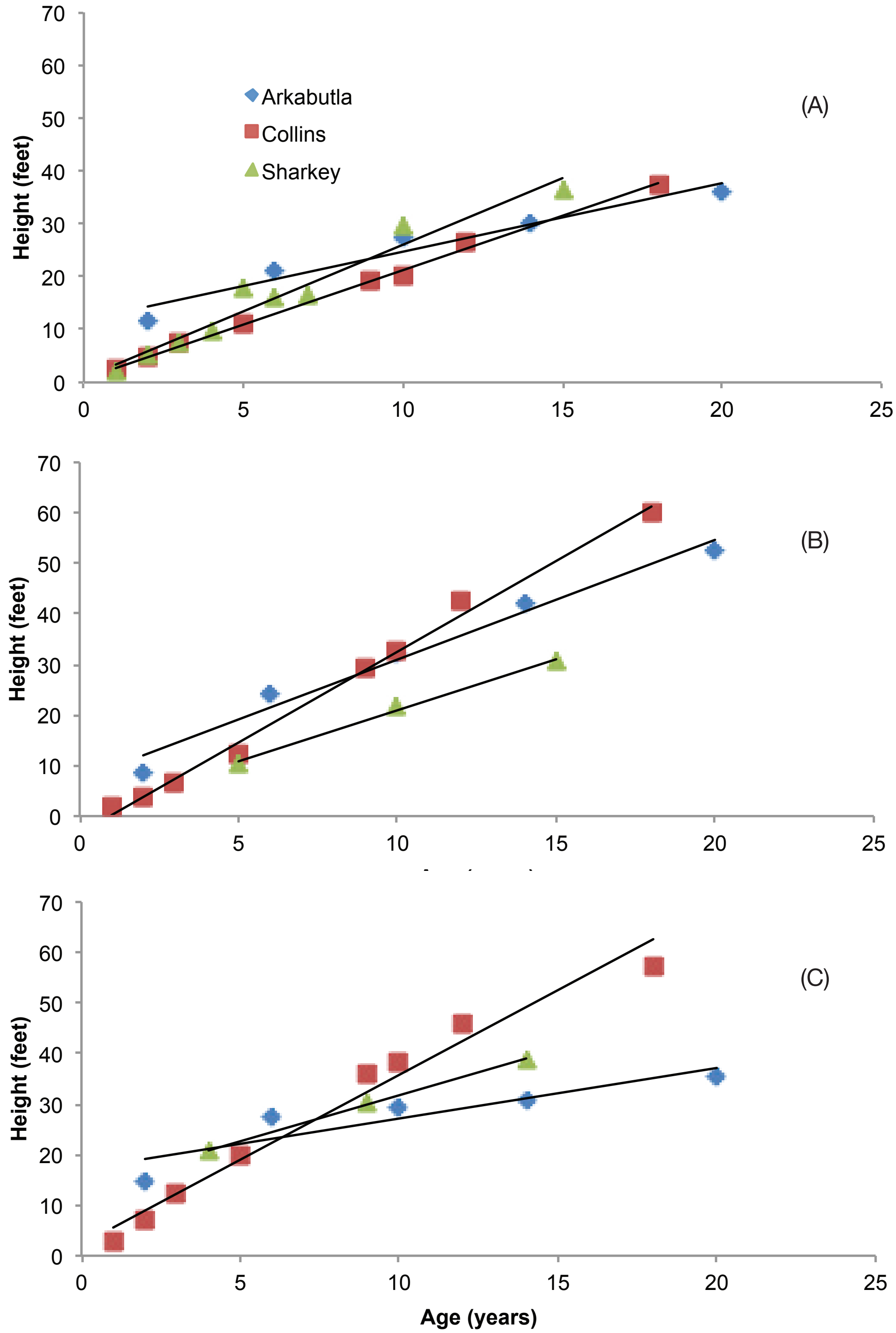

Figure 6—Growth of (A) green ash, (B) sweetgum, and (C) sycamore across different soil types based on published growth data of bottomland hardwood plantation species used in and around the Lower Mississippi Alluvial Valley.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture under Project No. MISZ-621020.. We also acknowledge support from the Forest and Wildlife Research Center, the College of Forest Resources, and the Department of Forestry at Mississippi State University.

LITERATURE CITED

Adams, J.P.; Rousseau, R.J.; Adams, J.C. 2007. Genetic performance and maximizing genetic gain through direct and indirect selection in cherrybark oak. Silvae Genetica. 56: 80–87.

Allen, J.A. 1990. Establishment of bottomland oak plantations on the Yazoo National Wildlife Refuge Complex. Southern Journal of Applied Forestry. 14: 206–210.

Allen, J.A. 1997. Reforestation of bottomland hardwoods and the issue of woody species diversity. Restoration Ecology. 5: 125–134.

Burkett, V.R.; Draugelis-Dale, R.O.; Williams, H.M.; Schoenholtz, S.H. 2005. Effects of flooding regime and seedling treatment on early survival and growth of Nuttall oak. Restoration Ecology. 13: 471–479.

Carlson, D.W.; Goelz, J.C.G. 1998. Hardwood plantations after 20 years on a minor stream bottom in southeast Arkansas: survival, growth, and volunteer ingrowth. In: Waldrop, T.A., ed. 1998. Proceedings of the ninth biennial southern silviculture research conference. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 555–559.

Clatterbuck, W.K. 2002. Growth of a 30-year cherrybark oak plantation 6 years after thinning. In: Outcalt, K.W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 189–192.

Devine, W.D.; Houston, A.E.; Tyler, D.D. 2000. Growth of three hardwood species through 18 years on a former agricultural bottomland. Southern Journal of Applied Forestry. 24: 159–165.

Dey, D.C.; Gardiner, E.S.; Kabrick, J.M. [and others]. 2010. Innovations in afforestation of agricultural bottomlands to restore native forests in the eastern USA. Scandinavian Journal of Forest Research. 25: 31–42.

Duncanson, L.; Rourke, O.; Dubayah, R. 2015. Small sample sizes yield biased allometric equations in temperate forests. Scientific Reports. 5: 17153.

Ezell, A.W.; Shankle, M.W. 2004. Effects of subsoiling and competition control on first year survival and growth of four hardwood species. In: Connor, K.F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 571-573.

Gardiner, E. S.; Stanturf, J. A.; Schweitzer, C. J. 2004. An afforestation system for restoring bottomland hardwood forests: biomass accumulation of Nuttall oak seedlings interplanted beneath eastern cottonwood. Restoration Ecology. 12: 525–532.

Goelz, J.C.G. 2001. Survival and growth of individual trees in mixed species plantations of bottomland hardwoods on 2 Mississippi Delta soil types. Native Plants Journal. 2: 98–104.

Groninger, J.W. 2005. Increasing the impact of bottomland hardwood afforestation. Journal of Forestry. 103: 184–188.

Groninger, J.W.; Baer, S.G.; Babassana, D.A.; Allen, D.H. 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.

Gwaze, D.P.; Byram, T.D.; Raley, E.M. 2003. Performance of Nuttall oak (*Quercus texana* Buckl.) provenances in the western gulf region. In: Mckinley, C.R., ed. Proceedings of the 27th southern forest tree improvement conference. Springfield, VA: National Technical Information Service: 126–137.

Jeffreys, J.P.; Schultz, E.B.; Matney, T.G. [and others]. 2010. Effects of disking, bedding, and subsoiling on survival and growth of three oak species in central Mississippi. In: Stanturf, J.A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep.SRS-121. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 151–155.

Johnson, R.L. 1981. Oak seeding--it can work. Southern Journal of Applied Forestry. 5: 28–33.

Kennedy, H.E.; Krinard, R.M.; Schlaegel, B.E. 1987. Growth and development of four oaks through age 10 planted at five spacings in a minor stream bottom. In: Proceedings of the ninth annual southern forest biomass workshop. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 81–91.

Krinard, R.M. 1985. Cottonwood development through 19 years in a Nelder's design. Forest Service Research Note SO-322. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4p.

Krinard, R.M.; Johnson, R.L. 1975. Ten-year results in a cottonwood plantation spacing study. Forest Service Research Paper SO-106. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 12p.

Krinard, R.M.; Johnson, R.L. 1980. Fifteen years of cottonwood plantation growth and yield. Southern Journal of Applied Forestry. 4: 180–185.

Krinard, R.M.; Johnson, R.L. 1984. Cottonwood plantation growth through 20 years. Forest Service Research Paper SO-212. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 16p.

Krinard, R.M.; Johnson, R.L. 1988. Stand parameters of a 27-year-old water oak plantation on old field loessial soils. Res. Note SO-348. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4 p.

Krinard, R.M.; Kennedy, H.E., Jr. 1981. Growth and yields of 5-year-old planted hardwoods on Sharkey clay soil. Forest Service Research Note SO-271. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 3p.

Krinard, R.M.; Kennedy, H.E., Jr. 1983. Ten-year growth of five planted hardwood species with mechanical weed control on Sharkey clay soil. Res. Note SO-303. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4p.

Krinard, R.M.; Kennedy, H.E., Jr. 1987. Fifteen-year growth of six planted hardwood species on Sharkey clay soil. Res. Note SO-336. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4p.

Lockhart, B.R.; Ezell, A.W.; Hodges, J.D.; Clatterbuck, W.K. 2006. Using natural stand development patterns in artificial mixtures: a case study with cherrybark oak and sweetgum in east-central Mississippi, USA. Forest Ecology and Management. 222: 202–210.

Lockhart, B.R.; Gardiner, E.; Leininger, T.; Stanturf, J. 2008. A stand-development approach to oak afforestation in the Lower Mississippi Alluvial Valley. Southern Journal of Applied Forestry, 32: 120–129.

Meadows, J.S.; Goelz, J.C.G. 1993. Thinning in a 28-year-old water oak plantation in north Louisiana: four-year results. In: Brissette, J.C., ed. Proceedings of the seventh biennial southern silvicultural research conference. Gen. Tech. Rep. SO-93. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 501–508.

Meadows, J.S.; Goelz, J.C.G. 2001. Fifth-year response to thinning in a water oak plantation in north Louisiana. Southern Journal of Applied Forestry. 25: 31–39.

Michalek, A.J.; Lockhart, B.R.; Dean, T.J. [and others]. 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, K.W., ed. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 352–357.

Miwa, M. 1995. Reestablishment of bottomland oak species in Lower Mississippi Valley alluvial soils. Wetlands Research Program Technical Report WRP-RE-14. U.S. Army Corp of Engineers. 52p.

Ozalp, M.; Schoenholtz, S.H.; Hodges, J.D.; 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, T.A., ed. Proceedings of the ninth biennial southern silviculture research conference. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 25–27.

Patterson, W.B.; Adams, J.C. 2003. Soil, hydroperiod and bedding effects on restoring bottomland hardwoods on flood-prone agricultural lands in North Louisiana, USA. Forestry. 76: 181–188.

Roth, F.A.; Wheeler, G.L.; Colvin, R.J. 1993. Growth of a cherrybark oak plantation after 29 years on a Coastal Plain creek-bottom site. In: Brissette, J.C., ed. Proceedings of the seventh biennial southern silvicultural research conference. Gen. Tech. Rep. SO-93. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station: 479–483.

Rousseau, R.J. 2008 Twenty-year results from a bottomland oak species comparison trial in western Kentucky. In: Jacobs, D.F.; Michler, C.H., eds. Proceedings of the 16th central hardwood forest conference. Gen. Tech. Rep. NRS-P-24. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station: 223–232.

Schoenholtz, S.H.; James, J.P.; Kaminski, R.M. [and others]. 2001. Afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley: status and trends. Wetlands. 21: 602–613.

Self, A.B.; Ezell, A.W.; Guttery, M.R. 2006. First-year survival and growth of bottomland oak species following intensive establishment procedures. In: Connor, K.F., ed. Proceedings of the thirteenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 209–211.

Self, A.B.; Ezell, A.W.; Hollis, D.B.; Alkire, D. 2011. Effect of mechanical site preparation treatments on oak survival in a retired field afforestation effort--first-year results. In: Fei, S.; Lhotka, J.M.; Stringer, J.W. [and others], eds. Proceedings of the 17th central hardwood forest conference. Gen. Tech. Rep. NRS-P-78. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station: 314–322.

Self, A.B.; Ezell, A.W.; Londo, A.J.; Hodges, J.D. 2010. Evaluation of Nuttall oak and cherrybark oak survival by planting stock and site preparation treatment type in a WRP planting on a retired agricultural site. In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 159–163.

Self, A.B.; Ezell, A.W.; Moree, J.L.; Thornton, R. 2013. Effect of directed-spray glyphosate applications on survival and growth of planted oaks after three growing seasons. In: Guldin, J.M., ed. Proceedings of the 15th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-175. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 295–298.

Shoch, D.T.; Kaster, G.; Hohl, A.; Souter, R. 2009. Carbon storage of bottomland hardwood afforestation in the Lower Mississippi Valley, USA. Wetlands. 29: 535–542.

Stanturf, J.A.; Gardiner, E.S.; Shepard, J.P. [and others]. 2009. Restoration of bottomland hardwood forests across a treatment intensity gradient. Forest Ecology and Management. 257: 1803–1814.

Stanturf, J.A.; Schoenholtz, S.H.; Schweitzer, C.J.; Shepard, J.P. 2001. Achieving restoration success: myths in bottomland hardwood forests. Restoration Ecology. 9:189–200.

Stine, M.; Chambers, J.L.; Wilson, M.; Ribbeck, K. 1994. Twenty-year survival and growth of six bottomland hardwood species. In Edwards, M.B., ed. 1995. Proceedings of the eighth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 1–3.

Stoll, J.; Frey, B.R. 2016. Stand development patterns for young planted oak stands on bottomland hardwood restoration sites. In: Schweitzer, C.J.; Clatterbuck, W.K.; Oswalt, C.M., eds. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS-212. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 369–376.

Tummers, B. 2006. DataThief III. http://datathief.org/. [Date accessed May 29, 2015].

Twedt, D.J. 2004. Stand development on reforested bottomlands in the Mississippi Alluvial Valley. Plant Ecology. 172: 251–263.

Twedt, D.J.; Wilson, R.R. 2002. Development of oak plantations established for wildlife. Forest Ecology and Management. 162: 287–298.