

Targeting Hardwoods

Douglass F Jacobs

Douglass F Jacobs is Associate Professor with the Hardwood Tree Improvement and Regeneration Center, Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907; Tel: 765.494.3608; E-mail: djacobs@purdue.edu

Jacobs DF. 2011. Targeting hardwoods. In: Riley LE, Haase DL, Pinto JR, technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2010. Proc. RMRS-P-65. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station: 115-120. Available at: http://www.fs.fed.us/rm/pubs/rmrs_p065.html

Abstract: Increasing demand for hardwood seedlings has prompted research to identify target seedling characteristics that promote hardwood plantation establishment. Operational establishment of hardwood plantations has typically emphasized seed collection from non-improved genetic sources, bareroot nursery seedling production, and spring planting using machine planters. The increasing diversity in objectives of hardwood planting projects, however, has led to identification of a wider range of management options to meet specific goals. Use of container hardwood seedlings may help to reduce transplant stress on harsh sites and improve seedling competitiveness; container production of hardwoods may be most effective using subirrigation. Greater use of genetically improved sources will help to promote hardwood plantations with better stem form, faster growth, and less incidence of disease or insect problems. On nutrient poor sites, exponential nursery nutrient loading may promote translocation of nutrients from reserves to new growth and improve establishment success. Fall outplanting may result in equivalent performance to spring outplanting, thereby extending the outplanting season. With use of larger stocktypes and alternative soil preparation treatments, hand planting may become increasingly common.

Keywords: seedling quality, stocktype, nursery fertilization, tree improvement, subirrigation

Introduction

This paper presents an overview of current initiatives led by the Hardwood Tree Improvement and Regeneration Center (HTIRC) at Purdue University and cooperators to identify target characteristics and improve the outplanting performance of hardwood forest seedlings. This current research initiative builds upon the extensive work of many scientists and practitioners that focused on seedling quality of conifer species, as well as some pioneering work done with hardwoods. Emphasis is on the Central Hardwood Forest Region of the US. This region differs from other forest regions in North America in that these forests are comprised almost exclusively of hardwood species (that is, oak [*Quercus* spp.], walnut [*Juglans* spp.], ash [*Fraxinus* spp.], cherry [*Prunus* spp.], hickory [*Carya* spp.], and so on) and are owned mainly by non-industrial private forest landowners. Commercial forest management focuses on development of high quality individual trees that may have value in excess of US\$ 10,000 (Figure 1).

Global production of conifer seedlings is much higher than that of hardwoods; therefore, relatively little attention has been given to seedling quality and grading research for hardwoods. Production of hardwoods, however, has increased in recent years to meet rising demand. Additionally, hardwood seedlings are generally larger and grown at wider spacing than conifer seedlings. They are usually more expensive to produce and may represent a significant portion of total nursery revenues in some regions (Wilson and Jacobs 2006). Additional research to improve quality and outplanting performance of hardwoods is justified.



Figure 1. High-value black walnut tree.

Objectives of Outplanting Project

Motivations for afforestation differ for many hardwood outplanting projects in the Central Hardwood Region compared to those for conifer plantations. Most reforestation operations in major planting zones in North America (that is, southern or Pacific Northwest US and Canada) focus on establishment of productive commercial plantations. Timber production, however, ranks lower as a justification for most hardwood plantation projects that usually emphasize conservation values and creating wildlife habitat. For example, a recent survey of Indiana landowners found that timber production ranked fourth among reasons for afforestation (Ross-Davis and others 2005). These landowners mainly emphasized the importance of establishing hardwood plantations for the benefit of future generations; this likely reflects differences in typical commercial rotation ages between hardwood (> 60 years) and conifer (15 to 60 years) plantations.

Type of Plant Material

Bareroot seedlings are, by far, the dominant stocktype produced by nurseries in the Central Hardwood Forest Region, representing greater than 95% of production (Jacobs

2003). A survey of operational plantation establishment success of afforestation hardwood plantations (ages 1 to 5 years) in Indiana reported 65% survival and <50% of seedlings deemed free-to-grow at age 5 (Jacobs and others 2004). This suggests that alternative stocktypes may provide new options to promote establishment success under specific site conditions.

During lifting of bareroot stock, disruption of root-soil contact and loss of fine roots may contribute to transplant shock (Figure 2). For instance, a study with three hardwood species on a well-managed outplanting site found that second-year growth of bareroot seedlings exceeded that of the initial year by 100% or more (Jacobs and others 2005), reflecting the time period required for root system re-establishment. Transplant shock may increase if shoot-to-root ratios become too high, emphasizing the need for proper root culturing and hardening in bareroot nurseries (Jacobs and others 2005).

Container seedlings offer an alternative to bareroot seedlings that may improve seedling establishment success under certain circumstances, such as harsh site conditions. Roots of container seedlings remain relatively undisturbed in medium at time of lifting and seedlings, and therefore, often show reduced transplant stress. For example, Wilson and others (2007) reported that although container northern red oak (*Quercus rubra*) seedlings were significantly smaller than that of bareroot seedlings at time of planting, they were statistically similar in size after one growing season.



Figure 2. Lifting of bareroot ash seedlings.

Despite the potential of container hardwood seedlings, some challenges have been identified in their production, mainly associated with the wide and spreading canopies characteristic of many hardwood species (for example, oaks; Figure 3). Traditional overhead watering under this circumstance often leads to poor uniformity, low water use efficiency, and foliar problems. Subirrigation (that is, delivering water from beneath the containers resulting in saturation of the plug via capillary rise) has been suggested as a method to overcome these limitations. This helps to keep foliage dry (thereby reducing risk of foliar disease), promotes high uniformity, and conserves water and fertilizer as irrigation is typically maintained in a closed-circuit system. A recent study with northern red oak reported equal or better performance of subirrigated seedlings versus those grown with overhead irrigation (Bumgarner and others 2008).



Figure 3. Canopy of container oak seedlings.

Genetic Considerations

In contrast to other important forest regions in North America, formal seed zones have not yet been developed in the Central Hardwood Forest Region. Typically, seed collection and transfer conforms mainly to state boundaries, although transfer between states occurs without regulation (Jacobs and Davis 2005). Only about 7% of hardwood stock in the eastern US originates from “genetically improved” sources (Jacobs and Davis 2005) and the majority of collection is done by nursery workers or people living adjacent to nurseries that prefer to collect from easily accessible trees with abundant seeds (that is, open-grown trees), or to collect from trees as they are harvested.

The tree improvement program at the HTIRC has helped to increase awareness and implementation of the benefits of using genetically improved sources in operation. Use of genetically improved black walnut (*Juglans nigra*) (that is, better stem form, fast growth, reduced anthracnose) has been shown to improve plantation productivity (Figure 4) and plantations of grafted black walnut have increased substantially in recent years. Additionally, HTIRC is now providing improved seeds of black walnut and other species to the Indiana Department of Natural Resources, and these are being sold directly to landowners. The HTIRC has also initiated programs to incorporate disease and insect resistance into threatened tree species, such as American chestnut (*Castanea dentata*), butternut (*Juglans cinerea*), and ash (Michler and others 2006; Jacobs 2007). It is expected that resistant sources of these species will be available for forest restoration in the future.



Figure 4. Plantation of genetically superior black walnut.

Limiting Factors on the Outplanting Site

On most typical afforestation sites in the Central Hardwood Region, mortality and slow growth are mainly a function of browsing damage and competing vegetation (Jacobs and others 2004). This emphasizes the need for improvement in hardwood nursery stock quality and silvicultural techniques on the outplanting site to overcome these limitations. Research on these sites has shown the importance of well-developed root systems and well balanced root-to-shoot ratios to promote early growth and drought resistance (Jacobs and others 2005; Jacobs and others 2009).

An estimated 20% of hardwood seedlings in Indiana are planted onto mine reclamation sites. These sites can be extremely difficult to regenerate successfully due to adverse soil conditions (that is, nutrient limitations, extreme pH), alternating wet/dry conditions, and soil compaction. Use of container seedlings significantly reduced plant moisture stress of newly planted northern red oak seedlings compared to bareroot stock on a mine reclamation site in southwestern Indiana (Davis and Jacobs 2004), suggesting potential of this stocktype to promote early growth and survival on mine reclamation plantings. Exponential nutrient loading, whereby luxury nutrient uptake is achieved by gradually increasing nursery fertilizer application rates, represents another technique to overcome low soil fertility on mine reclamation sites. While past research in this area has focused primarily on conifers, recent reports have shown the applicability of these systems to northern red oak and white oak (*Quercus alba*) (Birge and others 2006; Salifu and Jacobs 2006). Nursery nutrient loading has been demonstrated to promote retranslocation of stored nitrogen to fuel current growth, with responses most prominent on nutrient poor soils (Salifu and others 2008; Salifu and others 2009b). This may help promote hardwood seedling establishment on mine reclamation sites (Salifu and others 2009a).

Nearly all hardwood seedlings in the Central Hardwood Forest Region are outplanted onto afforestation sites; natural regeneration is usually relied upon for reforestation. Decreasing abundance of natural regeneration of desirable hardwood species (for example, oaks) associated with high deer populations and current management techniques (mainly involving single tree selection harvests) has prompted interest in artificial reforestation. Deer browsing and competing vegetation (especially from yellow-poplar [*Liriodendron tulipifera*]) are primary limiting factors on these sites. A recent study by Morrissey and others (2010) found that use of relatively large container seedlings (that is, 12 to 20 L [3 to 5 gal]) promoted competitiveness of northern red oak seedlings compared to bareroot seedlings after 5 years under a range of harvest openings. A major advantage to these large seedlings is that their height is nearly above the deer browse level at time of outplanting (Figure 5).

Timing of Outplanting Window

Nearly all hardwood outplantings in the Central Hardwood Forest Region are accomplished during spring after soil thaws. Fall outplanting has rarely been used mainly due to concerns that stock may not be sufficiently hardened

and because seedlings are then exposed to winter browsing. Fall outplanting, however, could be advantageous because seedlings may have an opportunity for root growth at two periods (fall and spring) when soil temperature and moisture are favorable. Additionally, fall outplanting may help to extend the outplanting period; this extended period is important because it is often logistically difficult to accomplish outplanting goals during only the spring period. Woolery and Jacobs (2011) reported that browsing during winter dormancy did not affect subsequent growth and development of northern red oak seedlings, while summer browsing was highly detrimental. Furthermore, a large-scale research trial with six hardwood species replicated over 2 years reported few differences in seedlings planted over a range of outplanting dates from November to July (Seifert and others 2006), further suggesting that the outplanting date for hardwoods can be extended beyond spring.

Outplanting Tool or Technique

The final consideration in targeting hardwoods is the type of planting tool or technique used to establish outplantings. In contrast to conifer production areas, about 90% of sites in the Central Hardwood Forest Region are machine planted (that is, tractor-hauled coulters with trencher and



Figure 5. Large container northern red oak seedling planted into gap opening.

packing wheels; Figure 6) (Jacobs and others 2004). This provides a relatively low-cost and efficient method to establish hardwoods on the flat and open afforestation sites most characteristic of this region. Under certain conditions, however, use of other options may be preferred or necessary. For example, trends toward increasing size of bareroot or container hardwoods that promote outplanting success on afforestation or reforestation sites (Jacobs and others 2005; Morrissey and others 2010) may necessitate use of hand planting with shovels or augers.

Mine reclamation sites represent another circumstance where outplanting operations may need to evolve toward

increasing use of hand planting. Recent research in soil replacement options initiated in the Appalachians (and now expanding to the Central Hardwood Forest Region) has shown that loose dumping may be preferable to standard graded plots for mine reclamation (Figure 7). Loose dumping, however, is not conducive to machine planting due to steep residual piles; this represents a potential source of resistance to operational use of loose grading because hand planting is generally more expensive and difficult to coordinate. This reflects a classic example of when the traditional outplanting tool or technique should not dictate other aspects of the regeneration operation.



Figure 6. Machine planting of afforestation site.



Figure 7. Replacement of soil after mining.

References

- Birge ZKD, Salifu KF, Jacobs DF. 2006. Modified exponential nitrogen loading to promote morphological quality and nutrient storage of bareroot-cultured *Quercus rubra* and *Quercus alba* seedlings. *Scandinavian Journal of Forest Research* 21:306-316.
- Bumgarner ML, Salifu KF, Jacobs DF. 2008. Subirrigation of *Quercus rubra* seedlings: nursery stock quality, media chemistry, and early field performance. *HortScience* 43:2179-2185.
- Davis AS, Jacobs DF. 2004. First-year survival and growth of northern red oak seedlings planted on former surface coal mines in Indiana. In: Barnhisel RI, editor. Proceedings of a joint conference of American Society of Mining and Reclamation 21st Annual National Conference and 25th West Virginia Surface Mining Drainage Task Force symposium; 2004 April 18-22; Morgantown, WV. Lexington (KY): American Society of Mining and Reclamation. p 480-502.
- Jacobs DF. 2003. Nursery production of hardwood seedlings. West Lafayette (IN): Purdue University Cooperative Extension Service. FNR-212. 8 p.
- Jacobs DF 2007. Toward development of silvical strategies for forest restoration of American chestnut (*Castanea dentata*) using blight-resistant hybrids. *Biological Conservation* 137:497-506.
- Jacobs DF, Davis AS. 2005. Genetic considerations in the operational production of hardwood nursery stock in the eastern USA. *Native Plants Journal* 6:4-13.
- Jacobs DF, Ross-Davis AL, Davis AS. 2004. Establishment success of conservation tree plantations in relation to silvicultural practices in Indiana, USA. *New Forests* 28:23-36.
- Jacobs DF, Salifu KF, Seifert JR. 2005. Relative contribution of initial root and shoot morphology in predicting field performance of hardwood seedlings. *New Forests* 30:295-311.
- Jacobs DF, Salifu KF, Davis AS. 2009. Drought susceptibility and recovery of transplanted *Quercus rubra* seedlings in relation to root system morphology. *Annals of Forest Science* 66:504.
- Michler CH, Pijut PM, Jacobs DF, Meilan R, Woeste KE, Ostry ME. 2006. Improving disease resistance of butternut (*Juglans cinerea*), a threatened fine hardwood: a case for single-tree selection through genetic improvement. *Tree Physiology* 26:121-128.
- Morrissey RC, Jacobs DF, Davis AS, Rathfon RA. 2010. Survival and competitiveness of *Quercus rubra* regeneration associated with planting stocktype and harvest opening intensity. *New Forests* 40:273-287.
- Ross-Davis AL, Broussard SR, Jacobs DF, Davis AS. 2005. Afforestation motivations of private landowners: an examination of hardwood tree plantings in Indiana. *Northern Journal of Applied Forestry* 22:149-153.
- Salifu KF, Jacobs DF. 2006. Characterizing fertility targets and multi-element interactions for exponential nutrient loading of *Quercus rubra* seedlings. *Annals of Forest Science* 63:231-237.
- Salifu KF, Apostol KG, Jacobs DF, Islam MA. 2008. Growth, physiology, and nutrient retranslocation in nitrogen-15 fertilized *Quercus rubra* seedlings. *Annals of Forest Science* 65:101.
- Salifu KF, Jacobs DF, Birge ZKD. 2009a. Nursery nitrogen loading improves field performance of bareroot oak seedlings planted on abandoned mine land. *Restoration Ecology* 17:339-349.
- Salifu KF, Islam MA, Jacobs DF. 2009b. Retranslocation, plant and soil recovery of nitrogen-15 applied to bareroot *Juglans nigra* seedlings. *Communications in Soil Science and Plant Analysis* 40:1408-1417.
- Seifert, J.R., D.F Jacobs, and M.F. Selig. 2006. Influence of seasonal planting date on field performance of six temperate deciduous forest tree species. *Forest Ecology and Management* 223:371-378.
- Wilson BC, Jacobs DF. 2006. Quality assessment of temperate zone deciduous hardwood seedlings. *New Forests* 31:417-433.
- Wilson ER, Vitols KC, Park A. 2007. Root characteristics and growth potential of container and bare-root seedlings of red oak (*Quercus rubra* L.) in Ontario, Canada. *New Forests* 34: 163-176.
- Woolery PO, Jacobs DF. 2011. Photosynthetic assimilation and carbohydrate allocation of *Quercus rubra* seedlings in response to simulated herbivory. *Annals of Forest Science* (Forthcoming)