NINE-YEAR PERFORMANCE OF FOUR HARDWOODS ON A HARVESTED SITE WITH AND WITHOUT FERTILIZER, TREE SHELTERS, AND WEED MATS IN SOUTHERN ILLINOIS

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Abstract.—Quality hardwood species often dominate stands on intermediate to high quality sites before regeneration. However, successfully regenerating these species after the harvest is rarely achieved on these sites. Hardwood species were planted on a high quality site in southern Illinois after clearcutting to study the effect of several cultural practices on the hardwoods' survival and growth. The performance of four hardwoods, black walnut (*Juglans nigra* L.), northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), and cherrybark oak (*Q. pagoda* Raf.), were significantly ($\alpha = 0.05$) affected by slow-release fertilization, tree shelters, and weed mats at age 9. Survival of all species was higher when treated with 10 g of slow-release fertilizer (16-6-8 NPK) in the planting hole than when not treated. Also, survival was better for trees enclosed in shelters than for trees not enclosed in shelters. Tree survival decreased with the use of weed mats. Tree shelters improved ninth-year height growth of northern red oak, white oak, and cherrybark oak, but not black walnut. The total height growth of black walnut, white oak, and cherrybark oak was greater with fertilizer at planting than without fertilizer packets. The height of red oak was less with fertilizer than without fertilizer. Trees with weed mats were shorter and had less height growth than trees without them.

INTRODUCTION

After decades of research describing techniques for successful regeneration of central hardwood forests, regenerating desirable hardwoods such as oaks after clearcutting continues to be a problem on many sites in the region. There have been various explanations why oaks are being replaced by less desirable species over much of the region (Heitzman and Grell 2003). Most silviculturists agree that, especially on more mesic sites, shade-tolerant non-oak species accumulate beneath undisturbed mature oak forests and eventually recruit into the overstory following disturbances such as timber harvesting (Johnson 1993, Johnson et al. 2009, Larsen and Johnson 1998).

However, even on sites with many desirable species including oak and black walnut in the understory, regeneration success after clearcutting can still be limited by stem size, vegetative competition, and site quality (Johnson 1993, Sander et al. 1984). A survey of 5- to 26-year-old clearcut oak stands found that on poor sites (oak site index 50-59) upland oaks became increasingly more abundant with stand age and accounted for 64 percent of all stems in all stands 15 years old and older. On medium sites (oak site index 60-69), the oaks obtained moderate importance after clearcutting and changed little with increasing stand age. On good sites (oak site index 70-80), dominant and codominant oaks decreased with time and accounted for only 11 percent of stems in stands 15 years old and older (Hilt 1985). Similar results were observed by Groninger and Long (2008) for sloping landscapes and differences in aspect. They found that the abundance of oaks increased from lower (moist) to upper (drier) slope positions and from cool (north-east) to hot (south-west) aspects.

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Planting nursery stock on harvested sites, especially on sites that lack adequate advance regeneration, and in small openings is an alternative (Demchik and Sharpe 1999, Heitzman and Grell 2003, Ponder 1995). The success of planted trees has been shown to be increased by competition control and proper site-species match. Results of studies incorporating tree shelters have been mixed; some indicated a positive influence on growth (Ponder 2003, Teclaw and Isebrands 1991) and others did not (Lantagne 1996, Teclaw and Zasada 1996). Because of vegetative competition, broadcast fertilization at the time of planting is usually discouraged.

An inventory of the understory in a southern Illinois stand scheduled to be clearcut showed that the vast majority of the reproduction consisted of hardwood species not considered desirable for timber or wildlife production. The site was rated as good (oak site index 80+) (Carmean and Hahn 1983), suggesting a difficulty in regenerating desirable overstory species given the limited number of advance regeneration stems present. The objective of this study was to compare the long-term survival and growth of planted black walnut (*Juglan nigra* L.), northern red oak (*Quercus rubra* L.), white oak *Q. alba* L.), and cherrybark oak (*Q. pagoda* Raf.) subject to fertilization, tree shelter, and weed mat treatments.

STUDY AREA

The study site is located on a gently rolling landform with slopes less than 8 percent and dissected by intermittent drainage channels. Current land conservation measures minimize water movement over the study area. The soil is a deep (solum thickness > 160 cm), well-drained Alford silt loam (fine-silty, mixed mesic Typic Hapludalfs) with a surface pH of 6.2, and P, K, Ca, and Mg in amounts of 55, 151, 1850, and 168 mg kg^{-1}, respectively. Before the stand was clearcut, maple (*Acer saccharum* Marsh.) and beech (*Fagus grandifolia* Ehrh.) were the most prevalent species based on basal area, together occupying 55 percent of the basal area. Hickory (*Carya* spp.), black walnut, and sweetgum (*Liquidambar styraciflua* L.) combined occupied 35 percent and oaks including northern red oak, white oak, and black oak (*Q. velutina* Lam.) occupied 10 percent of the basal area.

METHODS

Following the timber harvest in spring 1992, all remaining vegetation including trees, tree tops and branches, shrubs, and grapevines (*Vitis* spp.) were removed manually. Vegetation was cut with a chain saw or long-handle pruner and carried off plots by hand. Stumps were not sprayed to prevent sprouting. No other site preparation was done until 4 years later when the forest floor vegetation was sufficient to support a prescribed fire to reduce undesirable woody competition (Miller 1993). No estimate of species present was made before burning. Following the midday spring burn, the site was planted manually to 1-year-old nursery-grown black walnut, northern red oak, white oak, and cherrybark oak seedlings from the George O. White State Nursery in Licking, MO. Before planting, all seedlings less than 6 mm in diameter at root collar were culled from the planting stock. Root systems were clipped to 20 cm. Seedlings were planted in rows 2.4 m apart and 1.8 m apart within rows. Treatments included (1) two levels of fertilization, with and without prepackaged slow-release fertilizer; (2) two levels of tree shelters, with and without tree shelter; and (3) two levels of weed mats, with and without weed mats. Treatments were arranged in a randomized block design. Each of three blocks consisted of four tree species x eight treatments x 8 to 10 seedlings in row plots. At the time of planting, the slow-release fertilizer (16N-6P-8K) packet (Right Start®, TREESSENTIALS, St. Paul,

Table 1.—Ninth-year survival of four hardwood tree species planted in a southern Illinois clearcut forest in treatments at time of planting consisting of with and without slow-release fertilizer applied to the planting hole, with and without tree shelters, and with and without weed mat placed around seedlings

Treatment	Tree species			
	Black walnut	Red oak†	White oak	Cherrybark oak
	Percent survival			
Fertilizer				
With	61a±	60a	61a	73a
Without	67a	46b	47b	66a
Tree shelter				
With	65a	68a	64a	89a
Without	58a	51b	48b	59b
Weed mat				
With	57a	40a	48a	59a
Without	74b	65b	59b	72b

†Northern red oak

±Numbers with the same letter for different levels of a treatment for a tree species are not significantly different at $P \leq 0.05$.

MN) was placed in the bottom of the planting hole before the seedlings. Vispore® weed mats, a light weight, black polyethylene plastic, 0.9 x 0.9 m in size, were placed around seedlings receiving the treatment and anchored with soil and 15-cm-long metal pins. Tree shelters (TREESSENTIALS, St. Paul, MN) were 1.2 m tall and ranged from 7.6 to 10.2 cm in diameter. They were attached to 1.3-cm-diameter metal conduit placed near seedlings and held in place with plastic tie bands. For the first 2 years after planting, 61-cm-wide strips on both sides of rows were sprayed in the spring with a mixture of glyphosate (227 ml) and simazine (100 g) in 11 L of water using a backpack sprayer to control weeds in all treatments. Stump sprouts between rows were also sprayed with this herbicide mixture.

Over 9 years, tree survival and growth were measured periodically and at age 9. The experiment was analyzed as a randomized complete block design. Survival was analyzed using the PROC LIFETEST procedure (Allison 1995). Growth data were analyzed using analysis of variance with the PROC GLM procedures in SAS Version 8.2 (SAS Institute, Cary, NC). All statistical tests were performed at the $\alpha = 0.05$ level of significance.

RESULTS

After 9 years, survival of northern red oak and white oak was better with slow-release fertilization at planting than without it (Table 1). Survival for all oaks was better with tree shelters than without tree shelters. Weed mats tended to lower survival for all species, reducing survival to less than half for red and white oaks and more than two-thirds for black walnut and cherrybark oak (Table 1).

Except for northern red oak, fertilized trees had more height growth than unfertilized trees with differences of 1.5, 0.7, and 0.6 m for black walnut, white oak, and cherrybark oak, respectively (Table 2). Fertilizer was negatively correlated with northern red oak height growth with fertilized trees averaging less than 0.6 m in height growth over 9 years. Only the height growth of northern red oak and cherrybark oak were better with tree shelters than without tree shelters. Weed mats decreased height growth significantly only for white oak.

Table 2.—Total height growth for four hardwoods in southern Illinois planted in an upland forest clearcut after 9 years with and without slow-release fertilizer, tree shelter, and weed mat at planting

Treatment	Black Walnut	Red oak[†]	White oak	Cherrybark oak
	Meters			
Fertilizer				
With	8.25a[±]	2.98a	2.59a	4.42a
Without	6.76b	3.61b	1.94b	3.87b
Tree shelter				
With	7.44a	4.02a	2.72a	4.72a
Without	7.13a	3.30b	1.96a	3.86b
Weed mat				
With	6.75a	3.17a	1.74a	3.80a
Without	7.56a	3.45a	2.71b	4.32a

[†]Northern red oak

[±]Values with different letter for a treatment are significantly different according to Tukey multiple range test.

DISCUSSION

After 9 years, slow-release fertilization at the time of planting increased survival for all three oak species, but it did not increase the survival of black walnut (Table 1). Because newly planted bareroot seedlings do not have well-established root systems, they generally undergo moisture and nutrient stress before they become established. Apparently, *Quercus* species are more tolerant of moisture stress (Leuschner et al. 2001) than black walnut. Fertilization, on the other hand, may have reduced nutrient stress associated with bareroot seedlings by stimulating root development and initiating shoot growth sooner (Burdett et al. 1984) thus increasing survival and reducing the establishment period (Brockley 1988). Earlier, Burdett et al. (1984) reported that an application of slow release N, P, and K fertilizer at planting improved shoot growth of bareroot spruce (*Picea glauca* (Moench) Voss) trees more in the second season than in the first, while container-grown stock made large shoot growth responses during the first and second seasons. In contrast to the oaks, although not significantly different between treatments, fewer black walnuts survived with fertilization than without it. Williams (1974) reported that the addition of 28 g of conventional 8N-32P-8K analysis fertilizer at planting and an additional 57 g broadcast in a cultivated circle around each tree 1 month later reduced survival and growth of black walnut. The author (Williams 1974) attributed the negative effect to not controlling the overtopping vegetation that was vigorously stimulated by fertilizer or to damage to seedling roots by coming in contact with fertilizer in the planting hole. In another black walnut fertilization study using slow-release fertilizer, Jacobs et al. (2005) reported that survival was not affected and remained above 85 percent for treatments with and without fertilization 2 years after planting.

The height growth response of trees to fertilization was inconsistent among the oaks (Table 2). Although height growth for black walnut, white oak, and cherrybark oak increased with fertilization, it was the opposite for fertilized northern red oak. Reports in the literature indicate the inconsistent response of young black walnut to fertilization (Jacobs et al. 2005, Nicodemus 2008, Ponder 1994, Williams 1974), but much less information is available on young oaks. One reason may be that fewer oak plantations are being established in old fields compared to black walnut. Most forest soils, while probably not optimal in nutrient composition for tree growth, do have nutrient capital to support tree growth at some acceptable rate, with the greatest gains in growth coming from weed control (Johnson et al. 2009). However, the reason for the lower height growth of fertilized red oaks compared to the better height growth for unfertilized trees is not known.

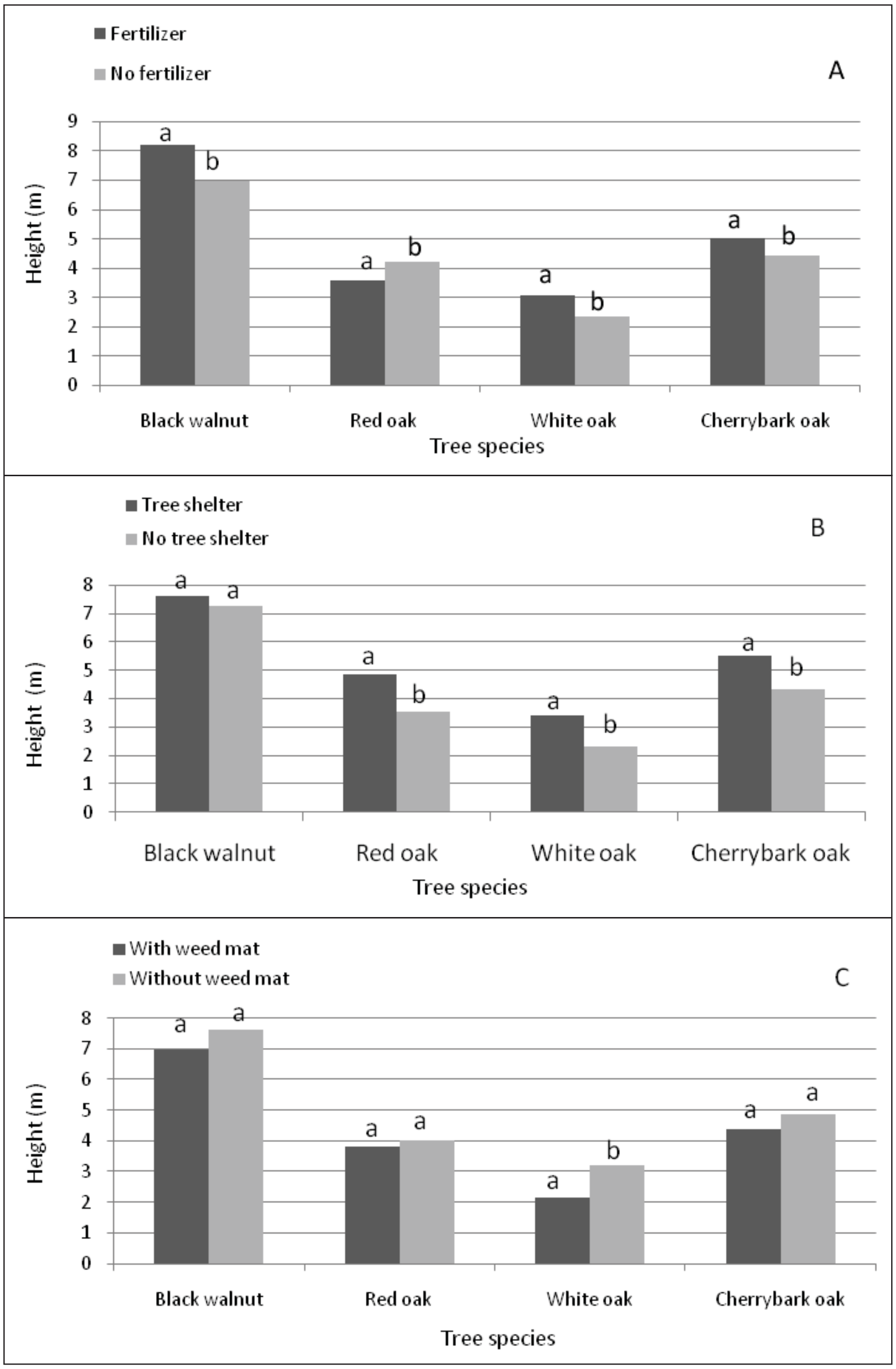

Figure 1.—Nine year height of black walnut, northern red oak, white oak, and cherrybark oak (A) with and without slow-release fertilizer, (B) with and without tree shelter, and (C) with and without weed mat. Values with different letter for a treatment are significantly different according to Tukey's multiple range test.

Both height and height growth of all species of seedlings benefited from the use of tree shelters (Table 2, Fig. 1). But differences were not significant for black walnut and white oak. Better height and height growth with tree shelters than without them as demonstrated by northern red oak and cherrybark oak is not unusual (Bardon and Countryman 1993, Gillespie et al. 1996). Neither is the insignificant height growth response in black walnut and white oak (Lantagne 1996, Lantagne and Miller 1997). Mechanisms for these responses are not fully understood. Aside from protecting trees from animals and mechanical dangers, growth enhancement attributed to tree shelters is likely due to increased air temperature, CO_2, and reduced wind inside the shelter (Puértolas et al. 2010). These enhanced conditions tend to favor seedling survival and growth.

Weed mats were not beneficial for tree survival or tree growth (Table 2). The reason for the poor performance of weed mats on tree growth is not known. It may be due to rodent damage as they may live, feed, and nest beneath mats, thus causing death and damage to seedlings (http://www.cacaponinstitute.org/WVPTS/deerfence.htm). Although weed barriers were not effective in this study, they have many positive attributes including increasing soil temperatures in the spring, reducing evaporative soil moisture loss during dry periods, controlling herbaceous competition, and increasing survival and growth of young hardwood trees (Geyer 2003).

Two years of weed control likely influenced what plant species inhabited plots and reduced the number of some species that can regenerate by sprouting, increasing the opportunity for regeneration from seeds. Regenerating vegetation was not inventoried, but visually a major component of the regeneration consisted of yellow-poplar (*Liriodendron tulipifera* L.). It was not uncommon for planted trees and natural regeneration including yellow-poplar to be nearly the same height. However, the lack of post-treatment data on the composition of understory species and height keeps us from better understanding how treatment trees compete with trees from natural origin on this site.

In summary, slow-release fertilizer packets placed in the planting hole increased tree survival for two of the oak species but not for black walnut, while increasing height growth for all species except northern red oak. Tree shelters increased survival for all oaks, but height growth only for northern red oak and cherrybark oak. The use of weed mats reduced survival for all species and white oak height growth. Except for northern red oak in the weed mat treatment, survival at age 9 for the remaining species and treatments was 50 percent or higher, suggesting that a significant number of these species are continuing to be a part of the regenerating stand.

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