Ten-Year Results of Tree Shelters on Survival and Growth of Planted Hardwoods

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ABSTRACT: *The performance of planted northern red oak (*Quercus rubra *L.), black walnut (*Juglans nigra *L.), and green ash (*Fraxinus pennsylvanica *Marsh.), with and without tree shelters, was evaluated 10 yr after planting. Northern red oak was planted in three harvested forest openings, and black walnut and green ash were planted in a cultivated field. Survival of northern red oak with tree shelters was significantly (*$P < 0.05$*) higher than northern red oak without shelters only for year 3. Survival differences between tree shelter treatments for black walnut and green ash were not significant. However, overall survival of green ash declined rapidly after year 5. Trees began to exit the 120-cm-tall shelters after 2 yr, but not in large numbers until the fourth year. Sheltered oaks were significantly taller than unsheltered oaks at year 10, and sheltered oaks had more height growth than unsheltered oaks at year 5, but not at year 10. Except for year 1, neither height nor height growth for black walnut was significantly different between tree shelter treatments. Green ash was taller and had more height growth with shelters than without shelters in year 1, but had more height growth without shelters than with shelters in year 5. Diameter growth at breast height did not differ between treatments for any of the three species. The greater height of sheltered northern red oaks compared to unsheltered northern red oaks could increase the opportunity of sheltered oaks to achieve dominant and codominant positions in the developing stands. North. J. Appl. For. 20(3):104–108.*

Key Words: Artificial regeneration, green ash, black walnut, northern red oak, tree tubes.

Tree shelters were developed in England in the late 1970s to help establish hardwood forests. Published success of tree shelters when used in the United States has ranged from exceptionally good to dismal. Tree shelters have been shown to protect young trees from browsing (Ward and Stephens 1995, Marquis 1977). They have also been associated with improved survival and growth (Potter 1988, Ponder 1995a), although in some cases the results have been mixed (Minter et al. 1992, Lantagne and Miller 1997). Tree shelters appear to be most effective in improving survival under difficult conditions, such as where deer or rabbit browsing is a major threat to successful regeneration. Tree shelters allow trees to become established quickly and to grow rapidly in height. The accelerated height growth can give the tree a head start over its competition and may mean fewer years of weed control. These benefits are believed to be associated with the better moisture and temperature levels inside shelters than outside them (Potter 1988, Ponder 1995a). In some cases tree shelters may influence nutrient uptake (Ponder 1995a).

The height growth advantage of tree shelters appears to be short-lived. Once seedlings emerge from tree shelters, growth rates appear to be similar to that for unsheltered seedlings (Lantagne 1995). The ability of tree seedlings to continue strong terminal growth after emergence from tree shelters appears to be dependent on the presence of competing vegetation as well as the species (Kays 1996). Tree shelters were used in this study to evaluate their effect on survival and growth of trees planted in forested openings and an old field 10 yr later.

Methods and Materials

The study included two plantings: one of northern red oak in forest openings and another of black walnut and green ash in an old field. The three northern red oak plantings were located on harvested (clearcut) openings on the Mark Twain National Forest near Salem, Missouri; two were in Reynolds County (CCC Camp and Crossville sites); and one was in Dent County (Scotia site). The sites were occupied primarily

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by black oak (*Q. velutina* Lam.) and scarlet oak (*Q. coccinea* Muenchh.) with lesser amounts of white oak and hickory (*Carya* spp.). The average age of trees in these mature stands was over 80 yr. The openings ranged in size from 12 ha for Scotia to 7 and 4 ha, respectively, for CCC Camp and Crossville. All sites were on northeasterly aspects with deep, well drained to somewhat excessively drained soils with gravel and some large rocks. The soils are of the Clarksville series (loamy-skeletal, siliceous, mesic Typic Paleudults). Slopes ranged from 5 to 14%. Plantings were located well within the interior of openings on areas that represented the dominant landscape and soil conditions. One year prior to the study, these areas had contained stands of mature trees of the upland oak- hickory timber type. Site index ranged from 74 to 80 for black oak at 50 yr (Hahn 1991). All trees, shrubs, and stems that had not been removed during the harvest were removed by hand from the sites before planting. Black walnut and green ash were established in separate 0.05 ha plantings containing three blocks each in an old field in Cedar County, near Stockton, Missouri. The nearly level field has moderately deep, well-drained, fine sandy loam soils. The soils are in the Helper series (fine-silty, mixed, thermic Udollic Ochraqualfs). The previously cultivated field, which had been fallow for more than 2 yr, was mowed in the fall prior to spring planting and received no other preparation.

In late March 1990, 1-0 northern red oak seedlings were planted in each of the three forest openings, and 1-0 black walnut and green ash seedlings were planted in each of the plots in the old field. Only seedlings with a basal diameter greater than 6 mm were planted. Root systems of all seedlings were clipped to a length of 20 cm. Red oak seedlings were planted on a 3 m^2 spacing by hand using a tree-planting shovel. Black walnut and green ash seedlings were planted using a tractor-drawn planter. Trees were 1.5 m apart within rows that were 3 m apart. The black walnut was thinned to 3 × 3 m spacing before the beginning of the sixth growing season.

Planted height and stem diameter at ground level were measured for all trees before tree shelters were installed around one-half of the trees. Sheltered trees in each planting were selected at random. Tree shelters were beige, 1.2 m tall, and ranged from 7.6 to 10.2 cm in diameter. Tree shelters were fastened with self-contained plastic tie-slips to 1.5 m sections of metal pipe that had been driven into the soil near each seedling. Weeds were controlled in the black walnut and green ash plantings with herbicide. Glyphosate was sprayed at the recommended rate in 61-cm-wide strips on both sides of rows soon after planting and annually thereafter in late spring through the fifth year. Weeds were not controlled in the oak plantings. Tree survival, live stem height, and basal diameter at 2.5 cm above the ground were recorded annually. Once trees were 135 cm tall or taller, measurements of diameter at breast height (dbh) were initiated, and basal diameter measurements were discontinued. To evaluate diameter growth at age 10, only trees having a dbh at age 5 were used. Trees within 1.5 m of each planted northern red oak were identified and their height measured to evaluate their competition with planted trees for space and light in year 5. Leaf samples from five planted trees in each treatment and block of the black walnut and green ash plantings and from each treatment of each oak planting were collected in year 5, oven-dried, ground in a Wiley mill containing a 20 mesh sieve, and sent to Custom Laboratory in Golden City, Missouri, for nutrient element analyses. More information on methods and materials can be found in previous reports (Ponder 1995a, Ponder 1995b).

The growth and leaf nutrient data were analyzed using a randomized complete block analysis of variance (SAS Institute, Inc. 1985). The mean for each treatment response (without and with tree shelters) was compared across locations for the northern red oak as three blocks and two treatments and three replicated blocks each for black walnut and green ash. Data were analyzed using the mean response of two treatments over three blocks (six observations). The analyses were repeated for each time period. Survival data were analyzed using the PROC LIFETEST procedure described in "Survival Analysis Using the SAS System" (Allison 1995). Annual tree survival data were coded according to tree status, 1 for live trees and 0 for dead trees, and subjected to an ANOVA. Survival differences among treatments were tested using the Wilcoxon test.

Results

Survival

After 10 yr, although overall survival of planted northern red oaks was better for trees with shelters than for trees without shelters, tree survival was significantly ($P < 0.05$) different between tree shelter treatments only for year 3 (Table 1). The greatest tree loss occurred between years 1 and 3 and between years 3 and 5.

Tree shelters did not significantly affect the survival of black walnut, but they did affect the survival of green ash by year 8 (Table 1). The mean survival across all treatments declined from 77 to 61% for black walnut by year 10 and from 85 to 55% for green ash after 8 yr. Compared to the oaks, more black walnut and green ash trees died in the first year of the study.

Height, Height Growth, and Diameter Growth

The mean heights for trees in all plantings were significantly ($P < 0.05$) greater for trees with tree shelters than for trees without tree shelters for year 1 (Table 2). But in years 5 and 10, the differences were significant only for the oaks. With few exceptions, height growth followed the same pattern as cumulative height (Table 3). For the oaks, height growth differences between tree shelter treatments were significant for years 1 and 5. For black walnut, height growth differences between treatments that were present at year 1 were not present in years 5 and 10. For green ash, height growth for tree with shelters was much greater than the height growth of trees without shelters at age 1, but at ages 5 and 8, trees in both tree shelter treatments averaged negative height growth.

Except for green ash in year 1, differences in basal diameter growth between treatments were not significant. The mean basal diameter growth was greater for green ash without shelters than with shelters.

Table 1. Mean survival for northern red oak planted in forest openings and for black walnut and green ash planted in an old field, with and without tree shelters.

Species	Tree shelter treatment	No. of seedlings	Year 1	Year 3	Year 5	Year 10*
			(%)			
Northern red oak	Without	169	92 ± 4a†	71 ± 4a	61 ± 4a	57 ± 4a
	With	149	97 ± 3a	87 ± 4b	67 ± 4a	62 ± 3a
Black walnut	Without	140	76 ± 5a	72 ± 6a	62 ± 5a	60 ± 6a
	With	80	78 ± 7a	66 ± 7a	63 ± 6a	62 ± 5a
Green ash	Without	140	81 ± 5a	68 ± 6a	52 ± 6a	49 ± 6a*
	With	80	89 ± 7a	71 ± 7a	68 ± 8a	61 ± 7b

* Data for green ash are for year 8. Measurements were not recorded after year 8.

† Values (mean ± standard error) for tree shelter treatments for a species in a column followed by different letters are statistically different at the 0.05 level by Wilcoxon test.

Table 2. Mean height for northern red oak planted in forest openings and for black walnut and green ash planted in an old field, with and without tree shelters.

Species	Tree shelter treatment	Year 1	Year 5	Year 10*
		[height (cm)]		
Northern red oak	Without	56.4 ± 14.4a†	167.3 ± 81.6a	282.2 ± 138.4a
	With	79.4 ± 27.4b	207.4 ± 74.4b	339.6 ± 125.8b
Black walnut	Without	26.0 ± 15.1a	271.0 ± 98.4a	724.8 ± 131.5a
	With	56.5 ± 27.4b	279.5 ± 107.9a	707.2 ± 151.5a
Green ash	Without	36.6 ± 13.2a	179.9 ± 78.9a	166.6 ± 94.7a*
	With	54.6 ± 22.7b	177.1 ± 59.3a	173.7 ± 76.3a

* Data for green ash are for year 8. Measurements were not recorded after year 8.

† Values (mean ± standard error and n = 6) for tree shelter treatments for a species in a column followed by different letters are statistically different at the 0.05 level by Tukey's HSD test.

Table 3. Mean height and diameter growth for 10-yr-old northern red oak planted in forest openings and for black walnut and green ash planted in an old field with and without tree shelters.

Species	Tree shelter treatment	Year 1	Year 5	Year 10*
		[height (cm)]		
Northern red oak	Without	6.4 ± 14.4a*	121.5 ± 80.1a	113.6 ± 70.4a
	With	30.5 ± 27.4b	159.1 ± 71.6b	128.1 ± 69.7a
Black walnut	Without	5.5 ± 15.9a	239.5 ± 84.3a	448.7 ± 85.6a
	With	26.7 ± 22.2b	249.5 ± 104.4a	418.5 ± 106.9a
Green ash	Without	–0.3 ± 13.9a	103.5 ± 73.4a	–22.8 ± 84.7a†
	With	18.9 ± 22.7b	64.0 ± 62.7b	–12.4 ± 62.4a
		Basal diameter growth†† (mm)	Dbh§(mm)	Dbh growth (mm)
Northern red oak	Without	0.4 ± 0.1a	10.7 ± 7.6a	7.1 ± 5.5a
	With	0.7 ± 0.8a	12.7 ± 6.9a	7.6 ± 5.9a
Black walnut	Without	0.8 ± 0.4a	54.3 ± 22.0a	51.9 ± 19.9a
	With	1.3 ± 1.2a	49.4 ± 21.8a	51.4 ± 16.0a
Green ash	Without	0.4 ± 0.2a	14.1 ± 12.1a	–2.8 ± 4.5a†
	With	0.2 ± 0.2b	11.4 ± 9.7a	1.0 ± 1.8a

* Values (mean ± standard error and n = 6) for tree shelter treatments for a species in a column followed by different letters are statistically different at the 0.05 level by Tukey's HSD test.

† Data for green ash are for 8 yr. Measurements were not recorded after year 8.

†† Basal diameter measured at 2.5 cm above the ground.

§ Diameter measured at breast height equivalent to 135 cm above the ground.

Trees began to emerge from the 120-cm-tall shelters after the second growing season, but not in large numbers until the fourth growing season. By the fifth year of the study, 96% of the sheltered walnuts were 135 cm tall compared to only 73% of those without shelters. By year 10, nearly all walnuts, regardless of treatment, had reached 135 cm in height (Table3). In contrast to walnut, only slightly more green ash with shelters had reached breast height than green ash without shelters. The number of green ash trees that had reached breast height declined by the eighth year. The number of northern red oak that were 135 cm tall more than doubled from year 5 to year 10, and more oaks with shelters were 135 cm tall than oaks without shelters. The mean height of natural regeneration within 1.5 m of planted northern red oaks with shelters ranged from 118 to 135 cm and 152 to 189 without shelters at age 5 (Table 4).

Discussion

Height growth response to tree shelters for oak plantings was apparent through year 5, with survival differences for year 3 only. Lantagne and Miller (1997) reported that survival and growth were poor for trees in a 3-yr-old northern red oak planting with and without tree shelters. They also reported that unsheltered trees had higher survival and better height growth than sheltered trees.

Field studies have consistently demonstrated the slow growth of planted oaks. For example, 1-0 white oak (*Q. alba* L.) seedlings planted in a clearcut in southern Missouri averaged about 3.1 m in height while dominant competitors averaged 6 m or more in height after 12 yr, depending on the site index (Johnson 1979). Similar results have been reported for northern red oak (Hilt 1977, Johnson 1976). On the average, for this study, oaks in shelters were 3.4 m tall, 0.6 m taller than oaks without shelters after 10 yr of growth. Some of the dominant competitors at year 5 had a mean height of 1.3 m near sheltered trees to 1.6 m near trees without shelters while sheltered and unsheltered trees at age 5 were 1.6 and 1.2 m tall, respectively (Tables 3 and 4). Also, the height range of natural regeneration was from 21 to sometimes over 300 cm for trees near sheltered trees and 13 to over 270 cm for trees near unsheltered trees. This suggests that sheltered oaks may have to compete more for light than unsheltered oaks in the developing stand, but the competition for light could encourage continual central leader growth. It is not known why natural regeneration near unsheltered trees tended to be taller than natural regeneration near sheltered trees.

Weeds were not controlled in oak plantings, but were controlled in black walnut and green ash plantings. Weed control is essential to the establishment and growth of black walnut (Krajicek 1975,Von Althen 1981, Ponder 1987). Depending on site conditions, controlling weeds may not improve oak seedling growth on forest sites (Wendel 1979, Lantagne 1991). However, sprouts that develop from stumps in harvested stands compete very aggressively with the planted trees for growing space.

The early height advantage of sheltered trees over unsheltered trees existed at age 10 for northern red oak, but not for black walnut. The height growth rate of sheltered trees declined after they exited the shelters. Also, since year 3, 8% more sheltered oaks have died than unsheltered oaks. The reverse was true for black walnut. The somewhat higher leaf concentrations of phosphorus, calcium, and manganese reported earlier for oaks (Ponder 1995a) did not exist at age 10 (data not shown). Thus, early advantages given by tree shelters that may enhance nutrition over unsheltered trees apparently disappear as the trees ages, diffusing nutrients in more biomass (Hoyle 1965).

Annual height measurements taken for green ash indicated considerable dieback, and measurements for green ash were terminated after year 8. The exact cause of the dieback and eventual mortality is not known, and there was no difference in the amount of dieback between treatments. Insects were a likely cause (Frank E. Doty, pers. comm., April 2001, nurseryman and commercial pesticide applicator, Highway 54, East, El Dorado Springs, MO 64744). The dieback usually occurred at the basal end of the shoot. When green ash resprouted, the new shoots never reached the height of the original shoots. Normally, resprouted shoots regained most of the height lost to dieback in one growing season because of the proportionately large root system from which the sprouts grow (Johnson 1976). It appears that root development might have been insufficient to support continued resprouting and shoot development. Also, it has been reported that voles and mice sometime chew holes in the bottom of shelters and girdle seedling roots (Wendell 1991). However, this kind of damage was not noticed in this study.

Several authors have estimated the cost of using tree shelters to establish hardwood trees (Smith 1993, Lantagne 1995). These authors agree that tree shelters can aid in tree establishment, but, because of their cost, alternatives should be investigated. These include planting fewer trees with tree shelters; investigating reuse of tree shelters; and not using tree shelters, but planting large diameter seedlings according to the prescription described by Johnson et al. (1986). The influence of tree shelters on height growth has been shown to enable trees to escape the risk of browsing and to be more competitive in the overstory (Ward and Stephens 1995). Animal browsing was not a problem in any of the plantings in this study. Except for the height of northern red oak, tree shelters had no effect on tree performance at year 10. Also, dieback and mortality of green ash made it impossible to evaluate the effect of tree shelters on its long-term performance.

Table 4. Mean height and height range of naturally regenerated woody plants within 1.5 m of planted northern red oak with and without tree shelters at age 5.

	Tree shelter		Tree shelter	
Species*	With	Without	With	Without
	.[mean height (cm)]		[height range (cm)]	
Sassafras	129	170	21–319	26–287
Maple	125	159	32–235	64–244
Northern red oak	122	168	21–319	39–252
White oak	118	162	32–260	21–268
Black oak	121	164	21–319	13–287
Dogwood	132	188	21–264	13–270
Black cherry	135	189	21–264	81–287
Hickory	132	152	32–262	21–270
Sumac	121	159	22–219	39–231

* Sassafras (*Sassafras albidum (*Nutt.) Nees), maple (*Acer* spp.), northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), black oak (*Q. velutina* Lam.), dogwood (*Cornus* spp.), black cherry (*Prunus serotina* Ehrh.), hickory (*Carya* spp.), sumac (*Rhus* spp.)

Management Implications

Tree shelters, in addition to protecting plants from animals, aid in the establishment and early accelerated height growth of planted hardwoods. Sheltered oaks were significantly taller than unsheltered oaks at year 10, and sheltered oaks had more height growth than unsheltered oaks at year 5, but not at year 10. Except for year 1, neither height nor height growth for black walnut was significantly different between tree shelter treatments. Green ash trees with shelters were taller than they were without shelters; however, by year 5, the reverse was true. Diameter growth at breast height did not differ between treatments for northern red oak, black walnut, or green ash. Tree shelters afforded black walnut a height and height growth advantage only for the first few years. However, 10 yr after planting, northern red oaks with shelters were 20% taller than northern red oaks without shelters, which may or may not make oaks more successful in reaching the overstory. Thus, the ability of tree shelters to maintain the height advantage of oaks as a long-term benefit is questionable.

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