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Protecting Red Oak Seedlings with Tree Shelters in Northwestern Pennsylvania

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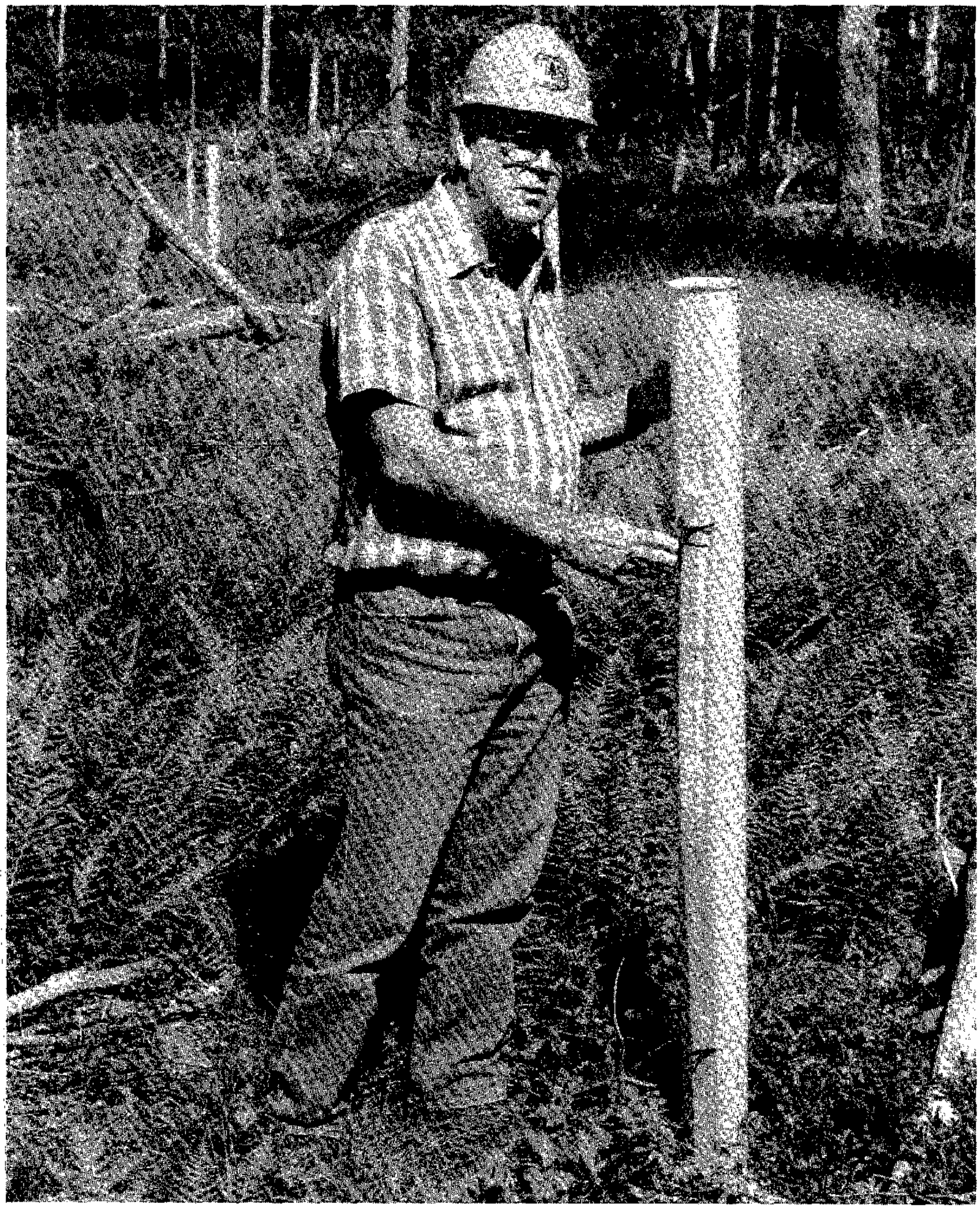

Abstract

Maintenance of oak species and a lack of oak regeneration are major silvicultural problems in many upland oak forests of the Eastern United States. Advance oak regeneration where present generally is small and lacks vigor. As a result, artificial regeneration is sometimes used, but planted oak seedlings usually do not grow well. Plastic tree shelters have been used to protect planted and natural oak seedlings from deer browsing and to promote seedling height growth and survival. This study examined the growth and survival of planted and natural red oak seedlings and seedlings from planted acorns within translucent tree shelters, fences, and unprotected controls with and without herbicide application under a shelterwood seed-cut stand. After 2 years, surviving control planted seedlings were significantly shorter than those protected by tree shelters and fences. The average height of seedlings planted within tree shelters and fences was 0.88 foot and was not significantly different. Planted control seedlings were shorter after the second year than the first, suggesting that these unprotected seedlings had been browsed by deer. The best survival of planted seedlings was inside the fences, with and without herbicide. Survival in shelters was 82 percent when herbicide was used and 40 percent without herbicide, probably due to low light intensity. Survival of planted control seedlings was unsatisfactory whether or not herbicide was applied, likely the result of browsing. Only 16 percent of the acorns planted within shelters produced seedlings and none grew outside of shelters. Small mammals destroyed most planted acorns. Natural seedlings grew little and their height inside and outside of shelters was not different from that of planted seedlings. Recommendations based on these results should improve results when tree shelters are used.

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Introduction

Maintenance of oak species, particularly on the higher quality sites, is a major problem throughout the upland oak forests of Eastern North America. Successful natural regeneration of even-age oak stands requires that an adequate amount of sturdy, well-developed advance oak reproduction be present at the time of final harvest. Most oak regeneration failures are attributed to the absence of adequate amounts of advance regeneration or to the inability of oak to outgrow competition when released.

The problem of inadequate advance tree regeneration under maturing hardwood forests is intensified in many areas by the presence of large populations of white-tailed deer, which have influenced forest vegetation development in northwestern Pennsylvania since the 1920's (Marquis and Brenneman 1981). As a result, understory vegetation is sparse in most uncut stands, and new seedlings appearing after cutting are browsed severely. New stand establishment after harvest cutting often is delayed or prevented entirely. Even where regeneration occurs, browsing results in shifts in woody species composition, reduced stocking, or extended rotations (Marquis and Brenneman 1981; Tilghman 1989).

Inadequate advance tree regeneration has assumed even greater significance in the oak stands on the Allegheny Plateau of northwestern Pennsylvania due to insect infestation and drought. In 1988, the Allegheny National Forest reported significant oak mortality (in excess of 30 percent) on more than 16,000 acres due to repeated gypsy moth defoliation between 1986 and 1988 followed by a severe drought in the summer of 1988. The weakened oaks were susceptible to attack by two secondary pathogens, the two-lined chestnut borer and the shoestring root rot fungus, which ultimately killed them.[1] A further consequence has been the accelerated shift in species composition from oak species. As overstory densities are reduced by mortality, the existing understory vegetation responds and captures the site. These understories are dominated by hayscented fern, striped maple, American beech root suckers, or, if tree seedlings are present, by black cherry, red maple, or sweet birch. There are few oak seedlings and these are not sufficiently vigorous to compete.

This situation has heightened interest in planting to increase the population of oak seedlings in a stand understory where they are lacking or few in number. However, hardwood planting is futile in northwestern Pennsylvania unless the planted seedlings are protected against browsing. Also, planted oak seedlings are notoriously slow growing (Russell 1971; Johnson et al. 1976; Hilt 1977; Wendel 1980). Thus, land managers must protect oak seedlings from browsing and help them compete with established vegetation. To accomplish this, it may be necessary to control the interfering vegetation to provide sufficient light for satisfactory development. Cutting, burning, and herbicide spraying all have been suggested, but none has proven consistently effective in oak regeneration programs (Nyland 1989).

Using tree shelters to overcome browsing is a growing technology first developed in 1979 in Great Britain. Tree shelters are translucent, plastic tubes 4 to 6 inches in diameter and 4 to 6 feet tall that are placed around individual seedlings. They are expected to provide protection from browsing for 5 to 8 years. Tree shelters are reported to stimulate height growth during the first 1 to 3 years after planting and help support the seedling for up to 5 years. Seedling height growth inside tree shelters is reported to increase above normal unbrowsed growth rates by two or threefold due to a "greenhouse effect" that is created inside the tubes. Tree shelters also can screen planted seedlings from herbicide during a directed spray application (Tuley 1983, 1985; Frearson and Weiss 1987; Potter 1988; Manchester et al. 1988).

The reported success of tree shelters in promoting the survival and stimulating early growth rates of planted oak seedlings elsewhere suggested that this technology might be useful in planting oak on the Allegheny Plateau. The purpose of this study was to evaluate survival and height growth of planted and natural northern red oak seedlings and acorns within tree shelters. A knowledge of how red oak seedlings perform within shelters will aid in assessing the possibility of adapting tree-shelter technology to forest conditions in northwestern Pennsylvania and adjacent areas.

Methods

Site Description

The study site located on the Allegheny Plateau in Warren County, Pennsylvania, is highly representative of a large proportion of upland forests in northwestern Pennsylvania. The elevation is about 1,900 feet and the site's medium-textured soils (Aquic Fragiudults) developed on broad plateaus not subjected to glacial action. Annual precipitation measures 43 inches and is distributed evenly throughout the year. Average rainfall is about 4 inches each month in April through September, so moisture deficits are rare during the growing season.

This study was installed in 1990 in a 75-year-old upland mixed oak stand that had received a shelterwood seed cut in 1984. When sampled in 1990, the residual overstory contained 98 square feet of basal area per acre with a relative stand density of 53 percent of the average maximum stocking expected in an undisturbed stand of similar size and species composition. Oak species made up 53 percent of the basal area; red maple, white ash, and black cherry accounted for most of the balance. There was a dense ground cover of hayscented fern over 60 percent of the area. Although the site contained about 14,000 seedlings of commercial species per acre, only about 200 were northern red oak. Three-quarters of the commercial seedlings and all of the

[1] U.S. Department of Agriculture, Forest Service. 1992. FY '91 monitoring and evaluation report. Warren, PA: U.S. Department of Agriculture, Forest Service, Allegheny National Forest.

oaks were less than 1 foot tall. Once they emerge from fern cover, seedlings are unable to grow taller because they are browsed continually by white-tailed deer (Marquis and Brennerman 1981).

Plantings

Seedlings and acorns were planted at 1/4-chain intervals in a check-row grid; that is, distances were measured carefully between rows and within rows to facilitate relocation. The planted seedlings were bareroot, 1-0 northern red oak grown in the Pennsylvania Bureau of Forestry's Penn Nursery from Pennsylvania acorns. At the time of planting in early May 1990, the seedlings were top-pruned at 6 inches and root-pruned at 8 inches. Their average root collar measured 0.25 (±0.05) inch. The study acorns were collected in the Moshannon State Forest in Clearfield County. To ensure soundness, they were separated by float testing and then by visual examination. All acorns were pregerminated and planted approximately 1 inch deep.

Three protection treatments for planted seedlings and acorns, with and without herbicide application, provided 12 treatment combinations. These treatments were applied in a complete random arrangement where the 12 treatments were assigned in a row at random. The same random arrangement was then repeated 50 times throughout the grid row by row to ensure that the treatments were scattered across the study site.

One protection treatment provided was by 6-foot-tall, tan tree shelters as described. Although white tree shelters are now available, only tan shelters were available for this study. A second protection treatment was small fences 5 feet tall by 1 foot in diameter made from 1-inch mesh chicken wire supported by two stakes. The third treatment was an unprotected control. The herbicide treatment was glyphosate applied as a directed spray to an area within a 3-foot radius of the seedling at the equivalent rate of 1 lb a.i. per acre. Spraying control in mid-August 1990; this was within the recommended period for adequate control of herbaceous weeds (Horsley 1981).

The three protection levels and two herbicide levels also were applied to natural northern red oak seedlings within the study-grid area. Half of these seedlings were top-clipped at 8 inches (to simulate top-clipping of the planted seedlings) while the other half were left unclipped. Again, these treatments were assigned at random with one random start and the same random arrangement then repeated. A total of 180 seedlings (15 for each treatment) were treated. The location of each treated natural seedling was then referenced to the check-row grid as described in order to relocate them.

Measurements of first-and second-year growth response for planted seedlings, planted acorns, and natural seedlings were taken in early October in 1990 and 1991. Each group was examined separately. Data were collected on seedling mortality, number of growth flushes, and height growth. Data on height growth were examined by analysis of variance with the Bonferroni procedure to test differences among treatment means. The herbicide treatment was not significant (P = 0.371). These data were then combined for the comparisons among the three protection treatment means. The 0.05 level of probability was accepted as significant. Survival data were compared against an assumed threshold level of satisfactory survival of 80 percent.

Results and Discussion

At the time of planting, the initial oak seedling caliper averaged 0.25 inch and ranged from .0.14 to 0.40 inch. Because the planted seedlings were top-clipped, initial heights were not measured. The average caliper was less than the minimum-size guideline of 0.354 inch (3/8 inch) recommended by Johnson and others (1976). In fact, only 5 of the 300 seedlings planted in this study met or exceeded that minimum diameter. However, because we did not have larger stock available, we decided to plant this stock.

There were significant differences among protection treatments each year (Table 1). The herbicide treatment did not have a significant influence during either year; therefore, the herbicide and no herbicide data were combined. After the first year, the average height of seedlings planted inside tree shelters was 0.85 foot. They were significantly taller than either the fenced or control seedlings at 0.78 and 0.76 foot, respectively. The following year, the average height of sheltered and fenced trees was 0.88 foot while the control seedlings were significantly shorter at 0.68 foot. We found no trees with more than one growth flush in either year.

Table 1. — First- and second-year mean heights (±S.E.) for northern red oak seedlings planted in 1990, by protection treatment

Year	Tree shelter	Fence	Control
		Feet	
1990	.88 ±.02 b	.78 ±.02 a	.76 ±.02 a
1991	.88 ±.03 a	.88 ±.02 a	.68 ±.02 b

Values in each row followed by the same letter are not significantly different ($P < 0.05$).

The first-year results seemed to indicate an expected trend. The seedlings planted in tree shelters were significantly taller, though by only a small amount, than either the fenced or control seedlings (Table 1). However, by the second year, the protected seedlings (tree shelter and fence) were the same height while the control seedlings were 0.2 foot shorter. The earlier trend of faster seedling growth inside the tree shelters had disappeared. The fence protection was not expected to influence seedling growth other than protection from browsing. Therefore, since the control seedlings are now shorter than those inside the fences, the controls likely were browed by the white-tailed deer. The overall second-year height across all treatments in this study is the

Table 2. — First- and second-year survival over 2 years for northern red oak seedlings planted in 1990, by herbicide and protection treatment

Year	Tree shelter		Fence		Control	
	Herbicide	No herbicide	Herbicide	No herbicide	Herbicide	No herbicide
	Percent					
1990	96.0	90.0	100.0	100.0	94.0	96.0
1991	82.0	40.0	90.0	94.0	72.0	70.0

same (0.82 foot) as that reported by Zastrow and Marty (1991) for two-year-old, 1-0 northern red oak seedlings planted in an old field. However, they also found that their seedlings inside tree shelters averaged 1.45 feet. Our sheltered seedlings did not grow better than the controls or fenced seedlings.

First-year survival across all treatments averaged 96 percent; the range among treatments was 90 to 100 percent (Table 2). Accepting 80 percent survival as the threshold of success, survival for all treatments was successful. Survival was poorest (90 percent) in the tree shelters without herbicide treatment. By the second year, survival changed drastically and chi-square tests revealed significant differences among treatments (range: 94 to 40 percent). Survival in half of the protection/herbicide treatment combinations still exceeded the success threshold: fence with and without herbicide at 90 and 94 percent, respectively, and tree shelter with herbicide at 82 percent. Survival was poorest (40 percent) for seedlings in tree shelters without herbicide.

The high survival rates observed at 1 year were not surprising. Early survival of planted red oak seedlings generally is good and these observations were made in the fall of 1990, before the dormant season when winter weather conditions can be harsh and deer browsing intense. The low survival of the control trees compared to those in fences (Table 2) is best explained by exposure to deer browsing. The fences were not expected to modify the seedlings' environment other than to exclude deer. However, the low survival rate for trees planted in tree shelters with no herbicide is best explained as a response to low light intensity. Being translucent, tree shelters reduced the amount of light reaching the seedling by two-thirds of that entering through the shelterwood canopy, hence, the reduced survival (82 percent) for seedlings in tree shelters with herbicide treatment. But where tree shelters also were shaded by fern and other understory vegetation (no herbicide), the light level inside was further reduced by half, resulting in unsatisfactory mortality. In an understory of similar composition, interference from hayscented fern with survival and growth of black cherry seedlings by altering the availability of light close to the forest floor has been reported (Horsley, in press).

The direct seeding of acorns was a failure regardless of treatment. After 2 years, there were no seedlings from acorns planted as controls or inside fences and only 16 percent of acorns planted inside tree shelters had produced seedlings (Table 3). The average height of these seedlings was 0.48 foot. After the first year (1990), 98 percent of the acorns without shelters and 62 percent of those inside shelters were missing. Every tree shelter from which the acorn was missing had a hole approximately 1 by 1.5 inch chewed in the side. The chewed hole always was near the bottom of the shelter where the lower support tie passes through shelter side and around the stake. The size of the hole and the size of the incisor marks suggest that they were made by a species of deer mouse attracted to the acorn inside.

Table 3. — Fate of planted acorns after two growing seasons, by protection treatment

Seedlings	Tree shelter	Fence	Control
	Percent		
Live	16.0	0.0	0.0
Dead	22.0	1.0	4.0
Missing (1990)	62.0	99.0	96.0

Table 4. — Second-year mean heights (±S.E.) and survival of top-clipped and unclipped natural red oak seedlings, by protection treatment

Item	Tree shelter	Fence	Control
Height			
Clipped (feet)	.50 ±.04	.50 ±.06	.43 ±.04
Unclipped (feet)	.59 ±.06	.53 ±.03	.56 ±.05
Survival			
Clipped (%)	56.7	75.9	61.3
Unclipped (%)	50.0	86.7	96.6

Second-year height of the natural seedlings observed in this study averaged 0.52 (±.02) foot across all treatments and ranged from 0.43 to 0.59 foot (Table 4). None of the differences among the protection, top-clipping, or herbicide treatment means were significant ($P < 0.05$). The overall treatment mean is not different from the pretreatment average height of 0.51 (±.01) foot for these seedlings. The mean height of the unclipped seedlings for all protection treatments was greater than for top-clipped seedlings. This difference, though small and not significant, is consistent across all treatments. However, the probability of this difference being due only to chance is small ($P = 0.055$), suggesting that top-clipping had a real effect on the top-clipped seedlings.

Of the natural seedlings observed in this study, only 71 percent are alive, and there are just as many surviving in the nonherbicide plots as in those herbicided. The survival range among the protection/top-clipping treatment combinations was 59 to 97 percent (Table 4). Only the unclipped control (97 percent) and unclipped fenced (87 percent) seedlings exceeded the 80-percent survival threshold. However, the top-clipped seedlings in all three of the protection treatments and those unclipped inside of tree shelters had survival rates below 80 percent. It is especially notable that only slightly more than half of the natural seedlings with tree shelters are still alive after 2 years. Wendel (1980) also reported that top-clipping resulted in lower survival rates and reduced height growth.

Oak advance seedlings are not uncommon in many eastern upland hardwoods and in some stand they are relatively abundant. However, these seedlings generally are small (less than 1 foot) and slow growing, and live only for a couple of years (Arend and Gysel 1951; Weitzman and Trimble 1957; McGee 1967; Sander 1972; Nyland et al. 1982). The height growth of oak seedlings is directly related to the number of growth flushes experienced in a season, and multiple flushing usually is attributed to the high availability of light (Phares 1971). The natural seedlings in this study fit this pattern. They were initially short (0.5 foot average) and did not increase in height in 2 years. They experienced no multiple growth flushing and many died. In fact, imposing the additional light restriction of a tree shelter is the likely cause of this high mortality and slow growth. If natural advance oak seedlings are to be a part of the next forest, they need help by release and browsing protection. But not all seedlings can respond; only those that are at least of average height or taller and whose previous-year's growth was at least average for their age class should be treated. Small, slow-growing seedlings are unable to respond (Walters 1963). This study also suggests that the light levels inside tan tree shelters under even a partial canopy of a shelterwood seed cut may be too limiting for oak seedlings to respond. The seedlings should not be top-clipped.

Management Implications

The failure to replace oak forests with oak forests is cause for concern over the net loss of oak-dominated forests and the loss of landscape biodiversity. The conditions and processes that led to the establishment of oak forests on our better sites are no longer operating. Thinning and shelterwood methods are not sufficient to maintain oak in the next stand and are stimulating northern hardwood advance regeneration. On the Allegheny Plateau of northwestern Pennsylvania, the result is virtually monospecific stands of black cherry because of its prolific seeding and the preference for other species by the high deer population (Marquis and Brenneman 1981; Tilghman 1989).

Interest by land managers in using tree shelters as a way of increasing the oak component in newly emerging forest stands has increased sharply. Not only do tree shelters protect natural and planted seedlings from browsing but they are reported to promote both survival and height growth. Although results are not conclusive and costs are high, averaging about $760 to plant 200 seedlings per acre (Crothers 1991), enrichment planting of oak seedlings in tree shelters has been used on the Allegheny National Forest for the past 3 years. With establishment costs of this magnitude, it is necessary to take every conceivable precaution to ensure success.

The results of this study are not encouraging but should not be considered as critical of the tree-shelter concept. Rather, this study serves as a reminder that tree shelters are not a cure all for the difficulties in planting or regenerating oaks. The following precautions based on observations from this study should improve the performance of oak in tree shelters:

1. Plant only large (> 3/8 inch diameter), 2-0, undercut seedlings as suggested by Johnson and others (1986). Our planting stock was small and did not perform well.

2. Do not plant seedings in tan tree shelters under a dense overstory. Oak seedlings do not grow well where light is limited. Johnson and others (1986) suggested a shelterwood overstory density no greater than 55 to 65 percent. The overstory density should be even less for planting with the three shelters.

3. Manufacturers recommend using white tree shelters when planting under a shelterwood because they transmit more light than tan shelters. White tree shelters have been used locally but their success has not been evaluated fully.

4. At least for the first year, controlling competing vegetation with herbicide within at least 2-foot radius of the tree shelter may be helpful.

5. If tree shelters are to be placed around natural seedlings, select only seedlings that are at least 1 foot tall. The natural seedlings in this study averaged only 0.6 foot and did not respond.

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Examines the growth and survival of planted and natural red oak seedlings and seedlings from planted acorns within translucent tan tree shelters, fences, and unprotected controls under a shelterwood seed-cut stand. Seedlings planted within tree shelters and fences were inside tree shelters. Natural seedlings grew very little and their height inside and outside of tree shelters did not differ. Recommendations based on these results should improve results from the use of tree shelters.

Keywords: artificial regeneration; seedling growth; *Quercus rubra*

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