EFFECTS OF TREE SHELTERS ON PLANTED RED OAKS AFTER SIX GROWING SEASONS

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Abstract: A 22 year-old shelterwood treatment that failed to regenerate oaks on an upland site in Michigan was clearcut in the fall of 1986 and planted with 2-0 northern red oak (*Quercus rubra* L.) seedlings the following spring. The four planting treatments included: control (clearcut harvest only), brush control only, 48 inch tree shelters only, and brush control plus tree shelters. After three years, 65 percent of sheltered northern red oak seedlings were at least 47 inches tall and on average 21 inches taller than unsheltered seedlings. After six years, a total of 92 percent of sheltered trees had reached a minimum height of 47 inches. By 1992, the height growth of sheltered trees made DBH measurements possible on 80 percent of sheltered trees (height $\geq$ 4.6 ft) compared to only 52 percent of unsheltered trees. Sheltered trees had significantly greater average diameters. Tree shelters have improved survival, diameter and total height growth over the first six growing seasons. The data showed however, that average tree height growth was comparable between sheltered and unsheltered trees for the past three growing seasons. The 19 inch total height advantage appears to be the result of accelerated growth during the first three growing seasons when trees were within the 48 inch tall shelters.

INTRODUCTION

The dramatic height growth results reported for sessile oak (*Quercus petraea* (Matt.)) in tree shelters in Great Britain (Tuley 1983), combined with the difficulty of regenerating northern red oak (*Quercus rubra* L.) in the United States (Lorimer 1989) contributed to the initial testing of tree shelters in the United States. The promise of improved survival and height growth for a wide variety of other species however, contributed to their widespread application by many public agencies, private industries and individuals before long-term research results were available. Early research results have indicated that tree shelters have some potential benefits under the right circumstances (Applegate and Bragg 1989, Burger and others 1992, Smith 1993).

Published research accounts on the impact of tree shelters on tree growth are limited for North American plant species. Potter (1991) wrote an excellent handbook summarizing the results of research for tree shelter use in Great Britain. Windell (1991) published an excellent compilation of information on tree shelters for use by researchers in the United States. He summarized current research and information on general use, economic feasibility, and materials and construction techniques. Early indications are that tree shelters protect planted seedlings from animal damage and increase early seedling survival and height growth (Lantagne and others 1990), however little information is available on the longevity of the benefits accrued by tree shelter use. The objective of this study is to evaluate the long-term effectiveness of tree shelters in establishing northern red oak. This paper presents 6-year results of a tree shelter study established in a Michigan clearcut.

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METHODS

The study is located in an oak-hickory forest at the W.K. Kellogg Experimental Forest in southern Michigan. Soils are predominantly sandy loam (Alfisols) that developed from stony glacial drift on a rolling, well drained site. An average northern red oak site index of 66 (base age 50) was measured for the site before harvest. The study area underwent a shelterwood seed cut in 1954 and a removal cut in 1964 as part of a previous oak regeneration study (Rudolph and Lemmien 1976). Before the study was established, all stems greater than 2 inches diameter at breast height (DBH) were removed in a whole-tree clearcut harvest in the fall of 1986. All remaining stems greater than 1 inch DBH were removed by hand.

A 2 X 2 factorial combination of treatments was replicated on 4 one acre blocks in a split-plot design. A 22 foot buffer zone was maintained between treatment blocks. Each acre block was split to accommodate brush control treatments (main plots). Each main plot was then split to accommodate tree shelter treatments (split plots). The four treatments were: control (no brush control, no shelters); brush control only; 48 inch shelters only, and brush control and shelters. All treatments were randomly applied within replications.

Brush control occurred as a prescribed burn and basal application of triclopyr and oil to non-oak species before harvest. Basal applications of triclopyr and oil with a backpack sprayer were also applied to non-oak species in the three years following harvest at an average cost of $40 to $45 per acre per year. The highest estimated average cost to treat each tree over a three year period was $0.38 per tree at the assigned planting density of 360 trees per acre.

Plastic shelters were constructed from 20 X 48 X 0.25 inch sheets of white corrugated polyethylene plastic. Each plastic sheet cost about $1.50 and stakes about $0.50 each. Individual sheets were formed into roughly 5- X 5-inch square shelters and stapled to 1- X 1-inch wooden stakes driven into the ground next to planted oak seedlings. The 48 inch tall shelters were placed close to the soil surface but were not sealed at the soil surface. Stakes were also driven into the ground next to all unsheltered seedlings. The stakes and shelters were checked and replaced as necessary each spring and fall in each year of the study. Maintenance costs in terms of labor used, averaged over 20 hours per acre per year for these shelters.

Northern red oak acorns collected from the study site in the fall of 1984 were float tested for viability. "Sinkers" were collected and 8 per square foot were sown in a prepared nursery bed. During the first lag phase of development during the second nursery season, seedlings were undercut in the nursery bed at 6 to 8 inches to encourage development of a fibrous root system (Hanson et al. 1986, Johnson et al. 1986). The 2-0 northern red oak seedlings were lifted in mid-April 1987, sorted to a minimum 3/8-inch root collar diameter (Johnson 1986), root pruned to 8 inches, wrapped and stored at 1 $^{\circ}$C until planting. Seedlings were planted over a two day period in late April 1987 with dibble bars at a 11- X 11-foot spacing for a total of 90 oak seedlings per treatment or 360 seedlings per block. After planting, seedlings were clipped 7 inches above the ground-line (Johnson et al. 1986). The 48 inch tree shelters were then installed. All work was completed by May 1, 1987.

Heights of all planted northern red oak seedlings were measured in the fall of 1992. The incidence of browse was not formally evaluated as surveys in previous years had found $<$ 10 percent of unprotected trees affected. DBH measurements were collected for the first time on all trees $\geq$ 4.6 feet in height after the 1992 growing season. Analysis of variance was used to test for significant differences among treatment means. The standard assumptions of analysis of variance were verified before data analysis. Percentages were transformed with the arcsine procedure (Little and Hills 1978). Chi-square analysis was used to test for differences in height class distributions and diameter class distributions for sheltered and unsheltered seedlings.

RESULTS

Over the first six years of the study, control of non-oak woody species has had no significant effect on the total height of planted red oak ($P = 0.24$), but survival and total height of sheltered and unsheltered trees have differed significantly (Table 1). There were no significant brush control X shelter interactions for any measured variable. Seedling survival and height for sheltered seedlings were significantly greater than for unsheltered seedlings (Table 2). Although sheltered trees have maintained a 19 inch total height advantage, the height growth of sheltered and unsheltered trees over the past three growing seasons has not differed (Table 2). Early growth gains resulted in 77 percent of the trees originally planted in shelters to average over 47 inches high after six growing seasons compared to only 50 percent of the unsheltered trees originally planted in the study ($P < 0.001$). Sixty-seven percent of the total number of sheltered trees originally planted were tall enough (≥ 4.6 ft) in 1992 to collect DBH measurements compared to a total of 38 percent of unsheltered trees ($P < 0.005$). Sheltered trees were also found to have significantly larger diameters than the measured unsheltered trees ($P < 0.0029$) (Table 2).

Table 1. Analysis of variance for total tree height for planted trees.

Factors	DF	Mean Square	F Ratio
Main Plots			
Replication (Rep)	3	877.05	
Brush Control (BC)	1	527.49	2.03
Rep X BC (Error a)	3	260.02	
Split Plots			
Shelters (S)	1	10257.48	34.03**
BC X S	1	533.80	1.77
Error	6	301.39	

** -- Significant ($p < 0.0011$)

Figure 1 illustrates the effect of shelters on seedling height class distribution after six years. Sheltered seedlings dominate every category above five feet. A Chi-square analysis indicated that the distributions were significantly different ($P < 0.0001$). A similar analysis of diameter distributions between sheltered and unsheltered trees also indicated a significant shift towards larger diameters for sheltered seedlings ($P < 0.0001$).

DISCUSSION

Tree shelters can improve the early survival and height growth of oak seedlings (Minter et al. 1992, Lantagne 1991, Tuley 1983). Survival differences between brush control and tree shelter treatments were not a major factor in this experiment. Over the first three growing seasons, survival averaged above 90 percent for all treatments. Results similar to these have been reported by Minter et al. (1992). After six growing seasons, survival was 10 percent greater in treatments receiving brush control or tree shelters as compared to the controls (Table 2). It appears that either brush control or tree shelter treatments are sufficient to maintain survival above 80 percent for the first six growing seasons after establishment. Therefore, tree shelters are not necessarily required to maintain acceptable survival rates for planted northern red oak on this site.

Table 2. Effect of shelters and brush control on survival and height of planted northern red oak seedlings after the sixth growing season.[1]

Treatments	Survival	Total Height	Height Increase[2]	DBH[3]
	-- (%) --	-- (in) --	-- (in) --	-- (in) --
Main Plots				
Brush Control	83a	75a	11a	0.5a
No Brush Control	73a	80a	12a	0.5a
Split Plots				
Shelter	84a[4]	87a[5]	11a	0.6a[6]
No Shelter	73b	68b	12a	0.5b

[1] Means within columns for main and split plots followed by the same letter are not significantly different at P<0.05 as found in the Analysis of Variance.
[2] Average yearly height increase was determined by subtracting 1989 total height from 1992 total height for each individually measured seedlings and dividing by three.
[3] DBH measurements for all trees ≥ 4.6 feet in height after six growing seasons.
[4] Survival percentages were significantly different at P<0.0042.
[5] Total height was significantly different at P<0.0011.
[6] DBH was significantly different at P<0.0029.

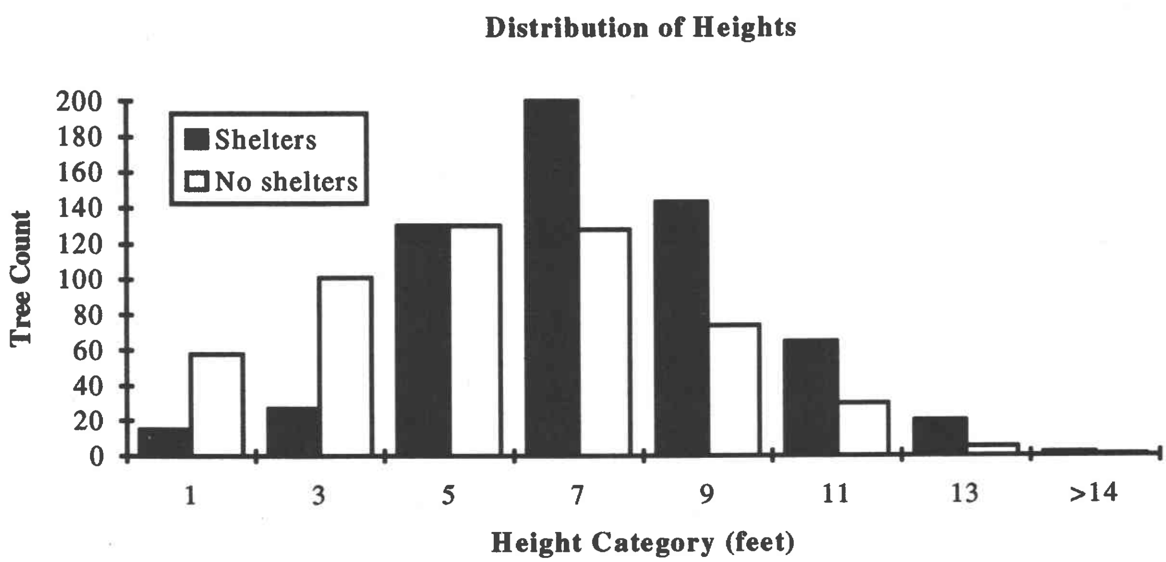

Figure 1: Height distributions of sheltered and unsheltered northern red oak seedlings after the sixth growing season. (The mid-range of each category is indicated on the x-axis. Distributions of the two classes of seedlings differ significantly based on Chi-square ($X^2 = 135$, $p < 0.0001$).

Although the analysis of the third year data affirmed the potential benefit of tree shelters on early growth and total tree height, sixth year results show no growth differences among treatments (Figure 2). Sheltered northern red oak seedlings have maintained an average height advantage of 19 inches, but growth rates between the treatments have stabilized. In the first three growing seasons, sheltered trees averaged over 11 in/year height growth, compared to less than 8 in/year height growth for unsheltered trees. In the last three years of the study, unsheltered trees grew over 11 in/year compared to less than 11 in/year for sheltered trees. In an earlier report on this study it was shown that increased linear stem elongation of the initial terminal flush was more important to total height growth than an increased number of flushes (Lantagne 1991). As would be expected, the latest results indicate that once these trees grew out of the shelter, overall terminal shoot growth slowed. This reduction in growth has been documented for northern red oak seedling sprouts that were clipped at ground level and placed in tree shelters (Kittredge et al. 1992). Tuley (1983) reported sessile oak height growth also slowed after year three in a tree shelter experiment in Great Britain. Potter (1991) did not report third year height growth decline for other tree shelter studies conducted in Great Britain. However, the maximum number of growing seasons for tree shelter research reported in the literature is five (Potter 1991). In this study, it appears that the apparent growth stimulus of tree shelters was lost over the last three growing seasons, similar to that found by Tuley (1983).

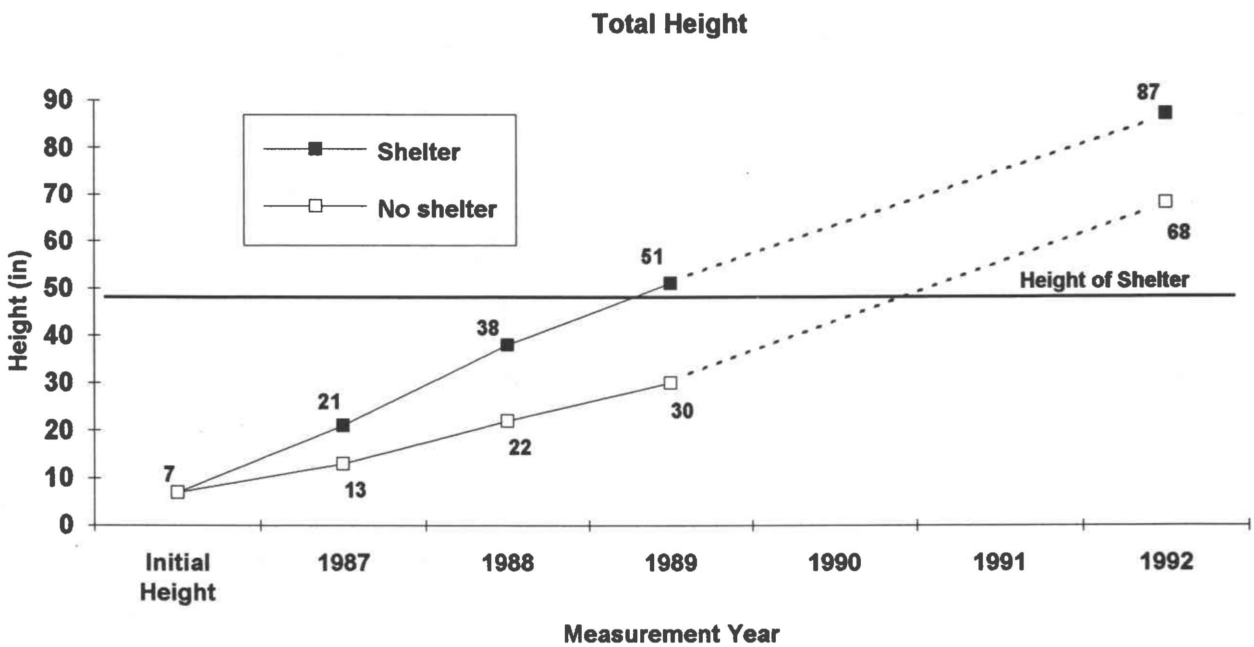

Figure 2: Mean Heights of surviving planted northern red oak seedlings. (All seedlings were top pruned at 7 inches above the groundline immediately following planting. Sheltered seedlings were significantly taller at the end of each growing season.)

The lack of a sheltered environment for the first flush may be the reason for reductions in average yearly height growth during the last three growing seasons. Tree shelters appear to increase the number of leaves available for photosynthesis (McNeel et al. 1993, Kittredge et al. 1992), and the length of time these leaves may remain active in producing photosynthate (Minter et al. 1992).

The interior of shelters have also been found to have elevated air temperatures, higher levels of CO^2 and a higher relative humidity which may contribute to the improved growth of sheltered seedlings (Minter et al. 1992, Potter 1991). In addition, trees protected from movement, as are seedlings in tree shelters, tend to grow taller and have smaller diameters (Rosenberg et al. 1983).

Although terminal shoot growth has slowed, the initial DBH measurements for sheltered trees were significantly greater than those measured for unsheltered trees. The early accelerated terminal shoot growth of sheltered seedlings did result in larger diameters after the trees exited the shelters. The reasons for this relationship are unclear but may be a result of being at DBH for a longer period combined with the stimulation of diameter growth in response to wind movement (Rosenberg et al. 1983).

SUMMARY

Many sheltered and unsheltered trees continue to maintain codominant crown positions with competing vegetation on the study site. The strong growth and development of unsheltered trees after six growing seasons may show the importance of using large, undercut and top clipped planting stock on the success of oak regeneration (Johnson et al. 1986). The cost of using and maintaining tree shelters, and the problem of plastic litter remaining in the forest, have to be evaluated considering the level of survival and growth response of unprotected trees in this study. The minimum cost for the tree shelter materials was over $2.00 per tree in this study. There were also additional costs associated with installation and maintenance that pushed the overall cost per tree higher. The cost of labor and material for controlling brush with herbicides for three years averaged less than $0.40 per tree. Even adding two additional years of brush control would only add $0.26 per tree for a total cost of less than $0.70 per tree over five years. Using high quality planting stock with brush control to increase the amount of northern red oak regeneration is less expensive then the use of tree shelters and may be sufficient in areas free of heavy browsing by rabbits and deer.

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