PROTECTION OF TREE SEEDLINGS FROM DEER BROWSING

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Abstract: Browsing by large deer herds has seriously impaired successful regeneration on some Connecticut forests. Six plots were established in 1990 to examine the effectiveness of 5 deer browsing protection devices for 5 tree species. Protective devices included plastic mesh sleeves (60-cm), Reemay (spunbonded polypropylene) sleeves (60-cm), Tubex tree shelters (120 and 180-cm), and Corrulite tree shelters (120-cm) to be compared to unprotected controls. Species included eastern white pine, eastern hemlock, Norway spruce, northern red oak, and black walnut. After 3 growing seasons, seedlings within tree shelters were significantly taller than seedlings protected by plastic mesh and Reemay sleeves, except for eastern hemlock. Tree shelters stimulated growth of hardwood seedlings more than conifer seedlings. Mortality was lower for seedlings protected by tree shelters than for other treatments. Unprotected black walnut seedlings were actually shorter after 3 yr than when planted because of browsing. The Reemay sleeves and plastic mesh were not durable; most were damaged by weather or animals. The mesh caps placed over tree shelters to prevent bird mortality distorted many trees emerging from tree shelters. Browse damage was observed on trees growing out of 120-cm tree shelters.

INTRODUCTION

Heavy browsing by large deer herds has seriously impaired natural regeneration on some forests in Connecticut. The deer herd in Connecticut has increased from an estimated 19,000 in the mid-1970s (Anderson 1984) to over 50,000 in 1993 (Kilpatrick 1993). Deer browsing has become a problem throughout much of the central hardwood region (Marquis 1977, Kelty and Nyland 1983, Kittredge and others 1992). Deer browsing is especially acute in parks and natural areas where hunting is prohibited and herd sizes are artificially high because of the lack of natural predators (Miller and others 1992, Girard and others 1993).

Early work showed that hardwood growth was increased by protection from deer browsing using mesh tubes (Marquis 1977). Tree shelters (solid plastic tubes) increase hardwood tree growth by providing protection from browsing and providing favorable growing conditions. Tuley (1985, cited from Potter 1988) discovered that early oak height growth in England was dramatically increased by using plastic tubes. Tree shelters have increased height growth of northern red oak (Lantagne and others 1990, Lantagne 1991, Minter and others 1992, Kittredge and others 1992, Smith 1993, Walters 1993), and black walnut (Ponder 1991).

Alternatives to tree shelters include fencing the planting area and repellents. Deer fences are effective in reducing browse damage (McCormick and others 1993, George and others 1991), but may require frequent maintenance inspections (George and others 1991) and also increase growth of less desired species such as red maple (McCormick and others 1993). Although repellents have reduced deer browsing of orchards (Conover and Kania 1988, Swihart and Conover 1988, Byers and Scanlon 1987), nurseries (Conover 1984), and Christmas tree plantations (Raymond[2]); control is inconsistent (Conover 1984, Swihart and Conover 1988) and needs to be applied several times a year (Conover 1987, Raymond[2]). Clearly, repellents are inadequate for forest plantations. This report will examine how various browsing protection methods affect growth and survival of seedlings.

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METHODS

In spring 1990 six study sites were established: 3 at Mohawk State Forest and 3 at Lake Gaillard. Both forests are actively managed for timber and hunting is prohibited. Consequently, large deer herds have developed which prevent natural regeneration and destroy artificial forest plantations. Study sites on Mohawk State Forest were recent red pine clearcuts. Two Lake Gaillard study sites were former pasture with scattered woody regeneration, the other was a newly abandoned corn field. All plots were cleaned with chainsaw and machete prior to planting and 2 years later.

Northern red oak (*Quercus rubra*), eastern white pine (*Pinus strobus*), and Norway spruce (*Picea abies*) were planted at both forests. Additionally, eastern hemlock (*Tsuga canadensis*) was planted at Mohawk State Forest and black walnut (*Juglans nigra*) was planted at Lake Gaillard. Seedling height (cm) and root collar diameter (mm) were measured prior to planting. Mean root collar diameters were: black walnut-7.1 mm, northern red oak-5.8 mm, eastern white pine-5.7 mm, Norway spruce-3.6 mm, and eastern hemlock 2.6 mm. Seedlings were stratified by root collar diameter before assignment to treatments. At each of the six sites 8-20 seedlings received each treatment.

The 6 treatments included: 60 cm high plastic mesh sleeve supported by a bamboo stake, 60 cm high spunbonded polypropylene (Reemay[3]) sleeve supported by a bamboo stake, 120 cm Tubex[3] tree shelter, 180 cm Tubex[3] tree shelter, 120 cm Corrulite[3] tree shelter, and an unprotected control. Both bamboo and wood stakes were untreated. Mesh caps provided were placed over all tree shelters to prevent songbird entry into the tubes.

Tree heights (nearest cm), browse damage, and any distortions of the terminal leader were measured at the end of each growing season (~15 September). Browse damage was noted at the beginning (~1 December), middle (~15 February), and end of winter (~1 April). Damage to protective devices was noted during each field check. Failure of protective device was defined as a fallen tree shelter or sleeve, removal of mesh or Reemay sleeve by animals, or disintegration of sleeve to degree that terminal leader was not covered.

Deer density was estimated by the pellet-group count technique (Neff 1964) in 1991 at both forests and 1992 at Lake Gaillard. Five of the study sites were separated by at least 5 km to increase probability that each study area was browsed by distinct deer herds. There was a single pellet-group survey for the 2 study areas at Mohawk State Forest which were only 1 km apart. At each study site 37 to 50 1/247 ha circular plots were randomly located within 1 km of each plot center. Rabbit pellet groups were also counted.

Tukey's HSD test (SYSTAT 1992) was used to test differences in height growth among treatments by size class and year. Chi-square statistics were used to determine whether cumulative browse differed among treatments and whether cumulative browse of unprotected seedlings differed among species. Chi-square statistics were used to determine whether mortality and cumulative failure differed among treatments by species. Preliminary analysis found no difference in growth, mortality, browse, or failure among tree shelter types. Therefore, data for the 3 tree shelter types were combined. Differences were considered significant at $P \leq 0.05$.

RESULTS

Deer density was estimated to be 18/km^2 at both Mohawk State Forest study areas in 1991. Estimates of deer density at Lake Gaillard ranged from 17-31/km^2 in 1991 (mean 24/km^2) and from 13-24/km^2 in 1992 (mean 18/km^2). At least one pellet-group was found on 62% of sample plots in 1991 at Lake Gaillard; 17% of sample plots had at least one rabbit pellet-group. At Mohawk State Forest, 49% and 26% of sample plots had at least one deer and rabbit pellet-group, respectively. The 1992 survey found deer pellet-groups on 47% of plots and rabbit pellet-groups on 12% of plots.

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[3] Use of tradenames does imply endorsement by the Connecticut Agricultural Experiment Station.

Heights of all species, except eastern hemlock, were significantly greater after 3 growing seasons when protected by tree shelters than when unprotected or protected by sleeves (Table 1). The increased height of seedlings protected by tree shelters was significant after 1 growing season. Unprotected black walnuts were actually smaller after 3 growing seasons than when planted. Seedlings protected by sleeves were not significantly taller than unprotected seedlings after 3 growing seasons, except for black walnut protected by mesh sleeves. Hardwoods clearly responded better to tree shelters than conifers. Relative to unprotected controls, trees in tree shelters were taller; black walnut, 215%; northern red oak, 145%; white pine, 70%; Norway spruce, 30%; and hemlock, 20%.

Table 1. Seedling height (cm) at end of growing season by species, treatment, and years since planting.

	Initial	Years since planting 1st	2nd	3rd
Northern red oak				
Control	31.1 a[a]	28.9 a	32.6 a	45.1 a
Mesh	30.3 a	32.0 a	41.2 a	50.5 a
Reemay	31.8 a	31.2 a	38.1 a	50.2 a
Tubes	30.2 a	37.4 b	71.2 b	110.6 b
Black walnut				
Control	34.0 a	38.3 a	38.8 a	28.2 a
Mesh	35.4 a	41.9 a	45.6 b	48.3 b
Reemay	34.1 a	39.7 a	42.0 ab	40.1 ab
Tubes	36.1 a	46.8 b	65.5 c	89.0 c
Eastern white pine				
Control	21.5 a	23.0 a	31.0 a	51.8 a
Mesh	22.1 a	23.9 ab	38.2 b	57.8 a
Reemay	21.8 a	23.6 a	37.4 b	57.4 a
Tubes	21.5 a	25.6 b	51.0 c	88.3 b
Eastern hemlock				
Control	19.6 a	18.3 ab	21.8 ab	40.4 ab
Mesh	19.6 a	17.2 a	28.0 b	35.9 a
Reemay	18.9 a	17.5 a	18.0 a	28.1 a
Tubes	19.1 a	20.2 b	34.7 c	48.5 b
Norway spruce				
Control	21.6 a	25.2 ab	29.9 a	47.2 a
Mesh	22.3 a	24.1 a	31.3 a	46.7 a
Reemay	22.6 a	24.9 ab	31.0 a	45.8 a
Tubes	22.4 a	26.3 b	40.6 b	61.4 b

[a] Column values for each species followed by the same letter do not differ significantly at $P \leq 0.05$.

Table 2. Cumulative mortality[a] (%) by species, treatment, and years since planting and original sample size in 1989.

	Years since planting			Sample
	1st	2nd	3rd	size
Northern red oak				
Control	6	12	8[a]	36
Mesh	7	8	14	72
Reemay	3	3	8	72
Tubes	0	8	2	108
Black walnut				
Control	0	0	8	24
Mesh	0	0	0	48
Reemay	2	4	6	48
Tubes	0	12	0	72
Eastern white pine				
Control	28	32	37	60
Mesh	29	36	38	120
Reemay	23	32	35	120
Tubes	24	26	28	180
Eastern hemlock				
Control	30	50	57	30
Mesh	27	47	44	60
Reemay	28	27	40	60
Tubes	4	19	21	90
Norway spruce				
Control	8	30	34	50
Mesh	17	28	29	100
Reemay	11	32	36	100
Tubes	10	25	27	150

[a] Cumulative mortality may decrease because some trees resprouted following aboveground dieback.

Total mortality after 3 growing seasons was not independent of treatment for all species (Table 2). Mortality of seedlings protected by tree shelters was much lower than other treatments. Again, there was a difference between hardwoods and conifers. Mortality of conifers protected tree shelters was reduced by about one-third compared with other treatments. In contrast, northern red oak mortality was reduced by at least 75% and there was no mortality of black walnut protected by tree shelters.

Browse of terminal buds was not independent of treatment ($\chi^2 = 302.3$, d.f.= 3, $P \leq 0.001$). Cumulative browse of seedlings protected by tree shelters was 75-89% lower than for other treatments (Table 3). Sleeves reduced browsing by 34-56% relative to unprotected seedlings. Browse of seedlings within tree shelters was caused by either mice gnawing through tubes and then on seedlings or deer browsing on seedlings which had grown out of 120-cm tree shelters.

There was a significant difference among species in the percentage of unprotected seedlings which were browsed ($\chi^2 = 27.7$, d.f.= 4, $P \leq 0.001$). Terminal buds of hardwoods were browsed much more frequently than conifers. Ninety-two percent of both unprotected northern red oak and black walnut were browsed compared with 57% of white pine, 54% of Norway spruce, and 47% of eastern hemlock.

The principal reason for higher browse levels of seedlings protected by mesh and Reemay sleeves was a higher failure level compared with tree shelters (Table 4). There was a significant difference of failure rate among protection devices ($\chi^2 = 213.4$, d.f.= 2, $P \leq 0.001$). By the end of the winter after the 3rd growing season fewer than half of seedlings protected by sleeves were still protected, compared with 75% of seedlings protected with tree shelters.

Distorted terminal growth of unprotected seedlings was rare, only 1.5% of total (Table 5). The proportion of seedlings (combined species) with distorted tops was not independent of treatment ($\chi^2 = 68.1$, d.f.= 2, $P \leq 0.001$). The proportion of seedlings with distorted tops was not independent of treatment for all species except black walnut. Distortion rates were approximately 3 times higher for seedling protected by sleeves than by tree shelters. Reemay sleeves caused more distortions than mesh sleeves for all species except Norway spruce.

Table 3. Annual browse of terminal bud (%) and cumulative browse (1989-1992) by treatment and years since planting.

	Years since planting			Cumulative	Sample
Treatment	1st	2nd	3rd	browse (%)	size
Control	47.5	31.0	25.5	65.0	200
Mesh sleeves	5.0	12.8	18.8	28.5	400
Reemay sleeves	6.5	24.8	25.8	43.0	400
Tubes	0.0	5.8	2.5	7.3	600
Combined	8.8	15.4	15.3	28.8	1600

Table 4. Failure of browsing protection devices (%) by treatment and years since planting. See text for description of types of failure. Percentages may not add because of rounding error.

	Years since planting			Cumulative	Sample
Treatment	1st	2nd	3rd	failure (%)	size
Reemay	0.0	44.5	26.0	70.5	400
Mesh	0.3	27.8	27.5	55.5	400
Tubes	0.0	8.0	17.3	25.3	600

Table 5. Percent of seedlings with distorted top growth by the end of the 3rd growing season by species and protection device.

Treatment	Northern red oak	Black walnut	Eastern white pine	Norway spruce	Eastern hemlock	Combined species
Control	5.6	0.0	1.7	0.0	0.0	1.5
Mesh	22.2	14.6	10.0	47.0	15.0	22.8
Reemay	43.1	22.9	24.2	17.0	28.3	26.3
Tubes	22.2	8.3	4.4	4.7	2.2	7.8

DISCUSSION

Study sites for this research were selected because natural regeneration was inadequate and browsing damage was heavy in recent plantations. Regeneration was dominated by browse resistant species such as *Carpinus caroliniana*, *Ostrya virginiana*, *Acer pensylvanicum*, *Berberis* spp., and ferns. Earlier studies have established that natural regeneration may be inadequate when deer densities exceed 7-8 deer/km² (Behrend 1970, Anderson 1984, Tilghmann 1989). The lowest deer density observed in this study, 13 deer/km², was clearly too high to obtain sufficient natural regeneration. A browse line has developed in the areas with more than 20 deer/km². It should be noted that pellet-group counting has been criticized as unreliable (Fuller 1991), although studies have reported good correlations with track counts (Mooty and Karns 1984) and drive-line census (deCalesta and Witmer 1990). Therefore, deer densities reported here should only be considered as approximations.

Compared with unprotected seedlings and seedlings protected with sleeves, hardwood seedlings protected by tree shelters have grown taller, lower mortality rates, lower percentage of distorted terminal leaders, and lower browse pressure. This research concurs with earlier studies that tree shelters increase growth of individual hardwood seedlings (Lantagne and others 1990, Lantagne 1991, Ponder 1991, Minter and others 1992, Kittredge and others 1992, Walters 1993, Smith 1993). Tree shelters have the added benefit of reducing browse damage (Table 3).

Tree shelters are not a plant and walk away alternative (Smith 1993). Tree shelters failed not only because of rotting stakes, which we expected, but also because of buck rubbing and wind rocking in wet soils. It is difficult to properly set stakes in rocky and shallow soils. There were 3 causes of distorted terminals for trees within tubes. Wasps nests in tube interiors formed a physical barrier for terminal expansion, especially second flush growth. Emerging terminal leaders often snagged on the mesh placed over tubes to bird entry. Snagged terminals spiraled until penetrated the mesh. Lastly some trees gradually spiraled against tube interiors until emerging.

It is still too early to determine if tree shelters are suitable for conifer species. Although height of eastern white pine and Norway spruce protected by tree shelters was higher than for other treatments, the increased height was only equivalent to one year's growth (Table 1).

Both types of sleeves were unsuitable for newly planted seedlings due to high failure and terminal distortion rates. Consequently, seedlings protected by sleeves were not taller than unprotected seedlings after 3 growing seasons . High failure rates resulted in unacceptable levels of terminal buds browsing, especially of hardwoods. The most common cause of sleeve failure was disintegration of sleeve to degree that the terminal leader was not covered. Other causes were removal by deer pulling sleeves off seedlings and animal gnawing of sleeves. Reemay sleeves gradually fray and the sleeve interior can become a dense fiber web which snags and distorts expanding terminal growth. Most distortions associated with mesh sleeves occurred when sleeve alignment deviated from vertical and expanding terminals became snagged. Sleeves were pulled from vertical alignment by animals, competing vegetation, wind, and rain, ice, and snow loads.

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LITERATURE CITED

Anderson, J.P. Jr. 1984. Deer damage in Connecticut. The Connecticut Conservation Reporter. **10**: 1-11.

Behrend, D.F., G.F. Mattfeld, W.C. Tierson, and J.E. Wiley III. 1970. Deer density control for comprehensive forest management. J. For. **68**: 695-700.

Byers, R.E., and Scanlon, P.F. 1987. Keep deer away with soap. Amer. Fruit Grower. **107**: 8.

Conover, M.R. 1984. Effectiveness of repellents in reducing deer damage in nurseries. Wildl. Soc. Bull. **12**: 399-404.

Conover, M.R. 1987. Comparison of two repellents for reducing deer damage to Japanese yews during winter. Wildl. Soc. Bull. **15**: 265-268.

Conover, M.R., and G.S. Kania. 1988. Effectiveness of human hair, BGR, and a mixture of blood meal and peppercorns in reducing deer damage to young apple trees. Eastern Wildl. Damage Control Conf. **3**: 97-101.

deCalesta, D.S., and G.W. Witmer. 1990. Drive-line census for deer within fenced enclosures. USDA For. Serv. Res. Pap. **NE-643**. 4 p.

Fuller, T.K. 1991. Do pellet counts index white-tailed deer numbers and population change? J. Wildl. Manage. **55**: 393-396.

George, D.W., T.W. Bowersox, and L.H. McCormick. 1991. Effectiveness of electric deer fences to protect planted seedlings in Pennsylvania. Pages 395-401 *in* 8th Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. **NE-148**.

Girard, G.T., B.D. Anderson, and T.A. DeLaney. 1993. Managing conflicts with animal activists: white-tailed deer and Illinois nature preserves. Nat. Areas J. **13**: 10-17.

Kelty, D.B., and R.D. Nyland. 1983. Hardwood browse production following shelterwood cutting. J. Wildl. Manage. **47**: 1216-1220.

Kittredge, D.B., M.J. Kelty, and P.M.S. Ashton. 1992. The use of tree shelters with northern red oak natural regeneration in southern New England. North. J. Appl. For. **9**: 141-145.

Kilpatrick, H.J. 1993. Conn. Federal Aid Report **W-49-R-18**. Wildl. Div., Conn. Dept. Envir. Protec. 4 p.

Lantagne, D.O. 1991. Tree shelters increase heights of planted northern red oaks. Pages 291-298 *in* . 8th Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. **NE-148**.

Lantagne, D.O., C.W. Ramm, and D.I. Dickmann. 1990. Tree shelters increase heights of planted oaks seedlings in a Michigan clearcut site. North. J. Appl. For. **7**: 24-26.

Marquis, D.A. 1977. Devices to protect seedlings from deer browsing. USDA For. Serv. Res. Note **NE-243**. 7 p.

McCormick, L.H., J.W.Groninger, K.A.Penrod, and T.E.Ristau. 1993. Deer exclusion effects on understory development following partial cutting in a Pennsylvania oak stand. Pages 418-427 *in* 9th Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. **NC-161**.

Miller, S.G., S.P. Bratton, and J. Hadidian. 1992. Impacts of white-tailed deer on endangered and threatened vascular plants. Nat. Areas. J. **12**: 67-74.

Minter, W.F., R.K. Myers, and B.C. Fischer. 1992. Effects of tree shelters on northern red oak seedlings planted in harvested forest openings. North. J. Appl. For. **9**: 58-63.

Mooty, J.J., and P.D. Karns. 1984. The relationship between white-tailed deer track counts and pellet-group surveys. J. Wildl. Manage. **48**: 275-279.

Neff, D.J. 1964. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. **32**: 597-614.

Ponder, F. 1991. Growth of black walnut seedlings protected by treeshelters. Ann. Rep. North. Nut Growers. Assoc. **82**: 170-174.

Potter, M.J. 1988. Treeshelters improve survival and increases early growth rates. J. For. **86**: 39-41.

Smith, H.C. 1993.Development of red oak seedlings using plastic shelters on hardwood sites in West Virginia. USDA For. Serv. Res. Pap. **NE-672**. 7 p

SYSTAT, Inc. 1992. SYSTAT for Windows: Statistics, Version 5th ed. 750 p.

Swihart, R.K. and M.R. Conover. 1988. Strategies for reducing wildlife damage in orchards. Bulletin **855**, The Connecticut Agricultural Experiment Station. New Haven, CT. 14 p.

Tilghmann, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. J.Wildl. Manage. **53**: 524-532

Tuley, G. 1985. The growth of young oak trees in shelters. Forestry **58**: 181-195. Original not seen. Cited from Potter (1988).

Walters, R.S. 1993. Protecting red oak seedlings with tree shelters in northwestern Pennsylvania. USDA For. Serv. Res. Pap. **NE-679**. 5p