ANIMAL DAMAGE TO HARDWOOD REGENERATION AND ITS PREVENTION IN PLANTATIONS AND WOODLOTS OF SOUTHERN ONTARIO

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ABSTRACT

Damage to natural and artificial regeneration caused by mice (**Microtus pennsylvanicus**), squirrels (**Sciurus carolinensis**), rabbits (**Sylvilagus floridanus**), snowshoe hares (**Lepus americanus**), European hares (**Lepus europaeus**), groundhogs (**Marmota monax**), deer (**Odocoileus virginianus**), and cattle (**Bos taurus**) in hardwood plantations and woodlots in southern Ontario is discussed. Possible control methods and their relative effectiveness are described and estimates are provided on the cost of the most promising controls.

RÉSUMÉ

On examine les dommages causés par les campagnols (**Microtus pennsylvanicus**), les écureuils (**Sciurus carolinensis**), les lapins (**Sylvilagus floridanus**), les lièvres d'Amérique (**Lepus americanus**), les lièvres d'Europe (**Lepus europaeus**), les marmottes (**Marmota monax**), les cerfs (**Odocoileus virginianus**) et les bovins (**Bos taurus**) à la régénération naturelle et artificielle dans les plantations et des boisés de feuillus du sud de l'Ontario. On présente des moyens possibles de répression et leur efficacité relative, ainsi que des estimations de coûts pour les moyens les plus prometteurs.

Frontispiece: Six-year-old white ash girdled by mice.

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INTRODUCTION

Animals can cause serious damage in hardwood woodlots and plantations. Squirrels **(Sciurus carolinensis)** pilfer black walnut **(Juglans nigra** L.) seeds and strip the bark of sugar maple **(Acer saccharum** Marsh.) trees. Meadow voles **(Microtus pennsylvanicus)**, cottontail rabbits **(Sylvilagus floridanus)**, European hares **(Lepus europaeus)** and groundhogs (**Marmota monax)** gnaw the bark of stems, while cottontail rabbits, snowshoe hares **(Lepus americanus)**, whitetail deer **(Odocoileus virginianus)** and cattle **(Bos taurus)** browse shoots and twigs. Intensive or repeated attacks may kill young hardwood trees, although more often the trees will survive by their ability to sprout. But growth may be stunted and tree form seriously degraded. Since most hardwood species are grown for high-quality timber production, landscape or aesthetic values, damaged, slow-growing, or misshaped trees have little value.

This report discusses the most common animal damage encountered in hardwood woodlots and plantations and outlines various approaches to control or minimize the damage.

PILFERAGE OF BLACK WALNUT SEEDS BY SQUIRRELS

The Problem

Natural regeneration of black walnut is inadequate in most woodlots of southern Ontario because the extraordinarily high value of large-diameter logs has resulted in serious depletion of trees of nut-bearing age. In addition, natural walnut regeneration has never been very plentiful because squirrels consume large quantities of nuts each year and young seedlings are very intolerant of shade and competition.

Artificial regeneration, therefore, appears to be the only method of reintroducing walnut trees into woodlots that are currently void of seed trees, or of increasing the number of walnut trees in other woodlots.

Walnuts may be regenerated either by direct seeding or by planting nursery-grown seedlings. Direct seeding is preferred by many woodlot owners since it is easier, cheaper and prevents root damage and transplant shock which are unavoidable in the planting of nursery-grown seedlings. Unfortunately, in most woodlots, consumption of nuts by squirrels can make successful seeding nearly impossible or at least more expensive than the planting of nursery-grown seedlings.

Possible Solutions

Many trials have been carried out to find effective methods for protecting seeds from squirrels. For example, the dumping of large quantities of nuts in the woodlot has been tried on the theory that when more nuts are available than can be eaten by the squirrels, the extra nuts will be buried by the squirrels for later consumption. Many of these nuts will not be found again, will germinate, and will grow into trees. In practice, this method has proven to be very wasteful of seed and results have been disappointing.

An attempt has also been made to hide the nuts from squirrels by seeding at depths of 5, 15 and 25 cm below the soil surface (von Althen 1969). However, over 60% of the sown nuts were dug up and eaten by squirrels within four weeks of seeding. Total emergence was less than 6% for all treatments, with no significant difference between treatments.

In another experiment the survival and growth of seeded black walnut, protected against squirrel pilferage by various methods, was compared with the survival and growth of planted nursery-grown seedlings (von Althen 1969). The two-year results show that the protection of seed spots with wire screens and the planting of nursery-grown seedlings resulted in five and six times as many stocked spots, respectively, as the unprotected control (Table 1). Sowing the nuts in tin cans (Fig. 1) was not as successful as protection of the seed spots with wire screens, although the success rate was more than double that achieved by dipping the nuts in Arasan 42S or spraying Arasan 42S on the soil surface.

Table 1. Percentage of seed spots stocked and average growth of seedlings, by treatment, after two growing seasons.

Treatment	Seed spots stocked (%)	Two-year height (cm)
Control, two seeds per spot without protection	16	22
Two seeds per spot protected by a wire screen 60 cm high and 76 cm in circumference	80	27
Two seeds per spot coated with Arasan 42S	25	26
Two seeds per spot; Arasan 42S sprayed over the soil surface of the seed spot	21	25
One seed planted in a 280-ml tin can with the lower lid removed and two slits cut at right angles across the upper lid and the corners raised to an upright position	56	24
One nursery-grown 1+0 seedling planted without protection	94	46

Nielsen (1973) reported that pilferage could be greatly reduced by thorough removal of the hulls because the squirrels were attracted by the smell of the decaying hulls. However, when Williams et al. (1977) tested this method, they found that squirrels took 93% of normally hulled nuts, 93% of hulled and cleaned nuts and 92% of hulled, cleaned and hydrogen-peroxide-dipped nuts. These researchers also found that the squirrels preferred the nuts of certain trees. They dug up most of the nuts from the preferred trees before digging up those from the remaining trees. Unfortunately, in the end, over 90% of all seeds from all trees were eaten, so it appears unlikely that a squirrel-proof seed source will be discovered.

Figure 1. Black walnut seeded in tin can with lower lid removed, two slits cut at right angles across the upper lid, and the corner raised to an upright position.

To assess the relative value of different protection methods in reducing seed pilferage by squirrels, Williams et al. (1977) tested large numbers of mechanical devices and repellents. Treatments included:

1. control, no protection
2. cracked shell parts from the same tree as the sown nuts mixed in the cover soil
3. cracked shell parts from several seed sources mixed in the cover soil
4. about 60 g of broken glass mixed with cover soil
5. mothballs pressed into the soil 2.5 cm from nut
6. mothballs pressed into the soil 5 cm from nut
7. mothballs pressed into the soil 10 cm from nut
8. mothballs pressed into the soil 15 cm from nut
9. dry cow manure (collected from a pasture) placed over seed spot
10. fresh cow manure (collected from a barn) placed over seed spot
11. seed spot sprinkled with kerosene
12. seed spot sprinkled with terpentine
13. seed spot sprinkled with sulphur
14. seed spot sprinkled with camphor
15. seed spot sprinkled with cayenne (red) pepper
16. nut dipped in kerosene
17. nut painted with pine tar

18. nut dipped in camphor
19. nut dipped in commercial repellent
20. nut dipped in one part commercial repellent and 10 parts latex stickers
21. nut encased in polymer mixed with water, peat, and sand before sowing
22. nut planted in tin can with hole in upper end
23. nut wrapped in chicken wire
24. chicken wire stacked down over seed spot
25. flat rock (about 40 cm^2) placed over seed spot

The only treatments which were more effective than the control were: broken glass (4), fresh manure (10), tin can (22), wire wrap (23) and flat rock (25). Moth-balls were effective in a preliminary study but failed to prevent pilferage in the final test. Dry manure did not work. The effective manure, taken from a cattle barn, was placed over the seed spot in rather generous portions (Williams and Funk 1979). The flat rock had to be removed before the seed started to germinate. The repellents with strong odors such as kerosene, terpentine, etc., actually attracted squirrels rather than repelled them. Although some methods worked, all were more time consuming than the planting of nursery-grown seedlings.

Where the costs of labor and material are less important than the establishment of black walnut regeneration by seeding, it is recommended that each seed spot be protected with a wire sleeve approximately 60 cm high and 20 cm in diameter (65 cm circumference) held in place by either stakes or wire pins. If the wire mesh of the sleeve is less than 1.25 cm in diameter the sleeve will also protect the young seedling from stem girdling by mice. The sleeve is also useful in protecting young seedlings from browsing by rabbits and deer.

Nut pilferage may also be prevented by the elimination of squirrels through intensive hunting or live trapping. However, this method has generally proven unsatisfactory since it is nearly impossible to eliminate all squirrels, and many woodlot owners rather enjoy the presence of squirrels in the woodlot.

BARK STRIPPING BY SQUIRRELS

The Problem

In late winter and early spring when the sap rises, grey squirrels sometimes feed on the inner bark of sugar maple and other hardwood trees. The preferred trees appear to be small- to medium-sized sugar maple growing in an open stand or along the edge of plantations or woodlots. The squirrels pull off the outer bark and eat the soft inner tissues. Bark may be removed in small patches or over large areas (Fig. 2). Some stems are completely girdled, and this results in the death of the whole tree or of all parts above the girdled area. Kenward (1982) who studied bark stripping by grey squirrels in Great Britain concluded that food shortage was probably the main cause, but that agonistic behavior and variation in the quality of the sap could not be ruled out.

Possible Solutions

The most reliable method of protection is a reduction in the number of squirrels by trapping or shooting (Rowe 1973). It has also been suggested that the provision of feed may deter the squirrels from bark stripping. However, no information is available on the success of this method.

STEM GIRDLING BY MICE

The Problem

Stem girdling by mice is a serious problem in the establishment of hardwood plantations in southern Ontario (von Althen 1971). Although several species of mice feed on the bark of hardwood trees and shrubs, the most common and most destructive species is the meadow vole. It is a medium-sized mouse with dark brown, rather long hair, inconspicuous ears and a short tail (Eadie 1954). It lives in fields and pastures and is especially abundant in areas with a dense cover of weeds and grasses (Eadie 1953). It constructs an irregular system of tunnels through the surface litter and just below the surface layer of dead stems and leaves. The remains of food material, such as bits of grass, stems and seeds, and numerous droppings, can generally be seen in the tunnels. Nests are built in burrows below the surface or above ground in the shelter of tufts of grass or dead vegetation. The nests are made of fine grass stems, leaves or other vegetable fibres, woven into a hollow ball with an entrance on one side. These nests can frequently be seen in spring after snow melt.

Meadow voles have a prodigious rate of reproduction. Under natural conditions five to ten litters are produced per year, each averaging five young (Eadie 1954). Population levels are believed to vary in cycles with peaks occurring at roughly four-year intervals. During peak periods damage is always extensive, but even when population levels are low considerable damage may occur as a result of unusual conditions such as food scarcity or a snow cover which persists for an extended period.

Meadow voles feed on a variety of foods including grasses, herbs, seeds, fruit, roots and the bark of trees and shrubs (Jokela and Lorenz 1959, Thompson 1965). During the spring and summer when food is plentiful populations of meadow voles may reach 2000 or more animals per hectare (Radvanyi 1974a, b). In August when the natural food supply of grasses, herbs and seeds becomes exhausted, the voles start to eat the bark of young trees and shrubs, and continue to do so during the winter when the snow provides good protection from natural predators (Fig. 3).

Meadow voles appear to have a definite preference for the bark of different species of trees and shrubs. The favored barks are those of young sugar maple, white ash **(Fraxinus americana** L.) (Fig. 4) and Manitoba maple **(Acer negundo** L.), followed by those of poplars **(Poplar** spp.) (Bowersox 1973) (Fig. 5), basswood **(Tilia americana** L.), silver maple **(Acer saccharinum** L.), catalpa **(Catalpa speciosa** Ward.), red oak **(Quercus rubra** L.), and autumn olive **(Elaeagnus umbellata** Thunb.) (Fig. 6). The barks of black walnut and butternut **(Juglans cinerea** L.) are least popular and generally are eaten only after all other food supplies have been exhausted (Fig. 7).

Figure 2. Sugar maple bark stripped by grey squirrels.

Figure 3. Stem of six-year-old white ash girdled by mice. A new shoot may develop but all growth to date has been lost.

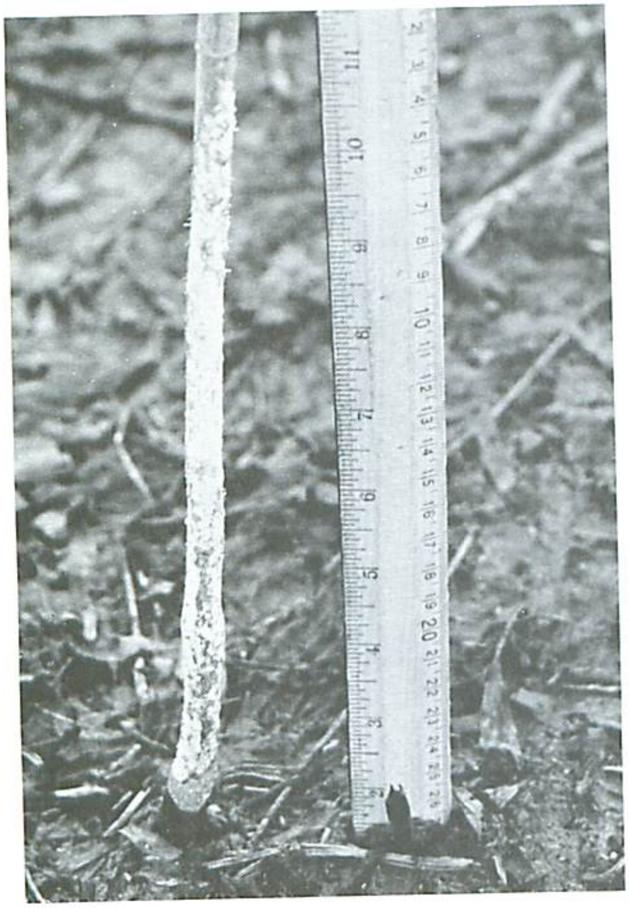

Figure 4. Recently planted white ash seedling girdled by mice. A new shoot will develop from the root collar, but growth has been lost and new shoots will require pruning.

Figure 5. Bark of hybrid poplar gnawed by mice.

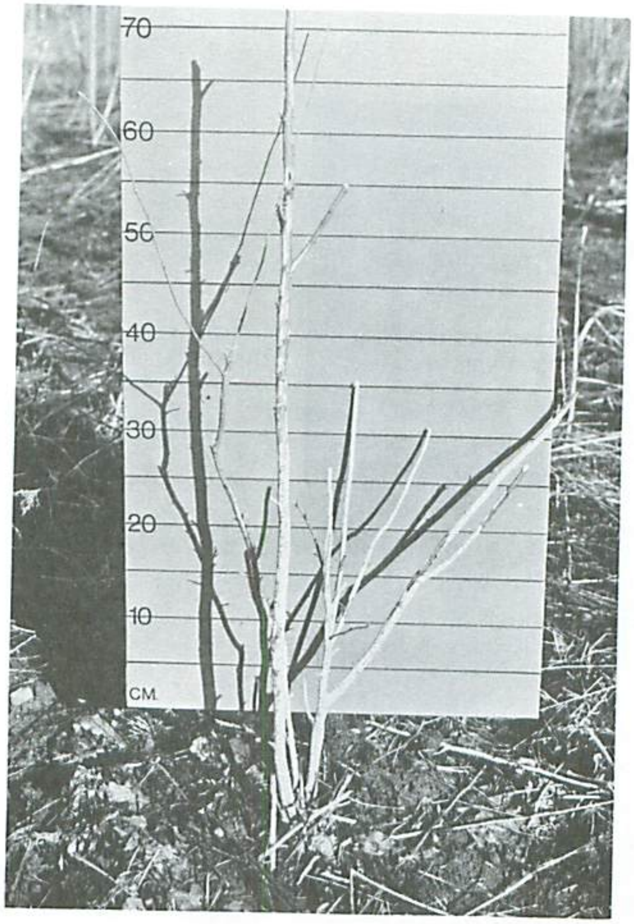

Figure 6. Protected from predators by deep snow, the mice have eaten the bark of this autumn olive to a height of 65 cm above ground.

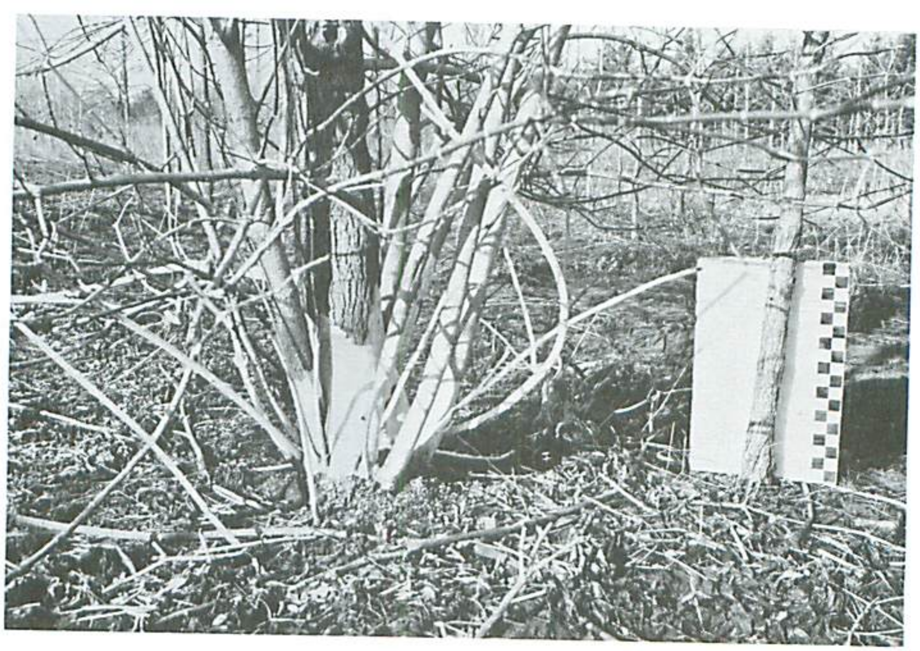

Figure 7. Manitoba maple in centre has been completely girdled while black walnut on right has not been touched.

The extent of damage is often difficult to assess because partially girdled trees may appear healthy, and trees with stems completely girdled during the winter may leaf out the following spring. Totally girdled stems (all outer tissues eaten to the xylem around the circumference of the stem) (Fig. 3), may continue to draw up water and nutrients which are transported through the inner xylem tissue of the stem. However, because the phloem tissues have been eaten, food manufactured in the leaves cannot reach the roots, and the tree slowly starves. Partially girdled stems, with bridges of phloem tissue left undamaged, can remain alive until callus tissue has closed the wound, but height and diameter growth of damaged trees are always reduced (Fig. 8). A wound caused by gnawing provides easy access for disease organisms, and a tree weakened by stem gnawing is highly susceptible to secondary attacks by insects and disease organisms.

Death of the main stem of most hardwood species does not necessarily result in the death of the total tree as it does in conifers. Hardwoods have the ability to sprout from the root collar or from adventitious buds along the stem. When the main stem dies, following girdling, many sprouts are produced from the living tissue between the root and the lower edge of the wound (Fig. 9). Should these sprouts be girdled again, new shoots are produced (Fig. 10). This frequently results in a large number of sprouts, all competing for dominance. To produce a tree with a single stem, it is therefore necessary to reduce the number of sprouts manually. For best results this must be done in successive operations. To ensure that sprouts are windfirm, a clump must first be reduced to two or three of the strongest sprouts. One or two years later all sprouts but the best one are cut.

Although thinning of clumps is necessary to produce trees of acceptable size and form, it is both labor intensive and expensive. In addition to the loss of growth of the original stem, the mortality of some trees, and the necessity of control methods to protect the remaining trees, girdling damage by meadow voles greatly increases the cost of regeneration.

Possible Solutions

A very effective method of preventing girdling damage is the elmination of the weed cover. This deprives the animals of shelter and food and makes the plantation a hostile environment for rodent survival and reproduction. Also, the elimination of weed competition increases the growth of the planted trees and fast-growing trees are less vulnerable to rodent damage because the bark of larger trees is less palatable than that of small stems with succulent bark.

An established weed cover can be most effectively and economically eliminated by mechanical or chemical site preparation before the trees are planted (Table 2). Once trees have been planted, the choice of treatments is largely restricted because the trees interfere with the free movement of machinery and the most efficient application of herbicides (von Althen 1979). To prevent the regrowth of weeds the prepared area must be kept relatively weed-free by disking or rototilling, by applications of herbicides or by a combination of these treatments. Excellent weed control can be maintained by disking or rototilling between the rows of trees and spraying Roundup on the unwanted vegetation within the rows. Another efficient control method is an annual application of the pre-emergence herbicide Princep (Fig. 11).

Figure 8. With mainly the outer bark layers eaten by mice, this white ash seedling will survive but height and diameter growth will be reduced.

Figure 9. Multiple shoots growing from the root collar of a previously girdled basswood stem.

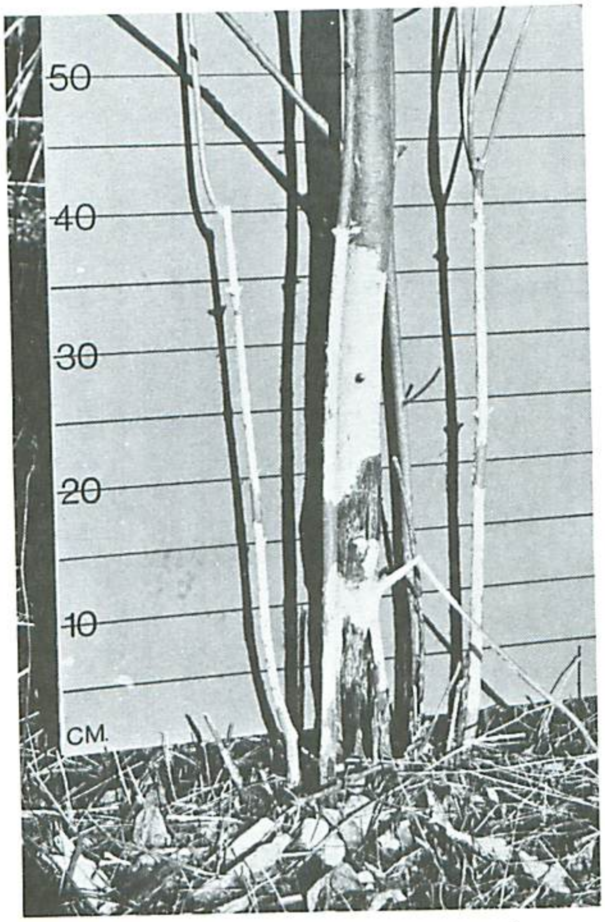

Figure 10. When this white ash was partially girdled (old scars) new sprouts grew. Recently the original stem and the sprouts were girdled again.

Figure 11. Total area plowed and disked before planting followed by one broadcast application of 4.5 kg/ha of Princep Nine-T.

Table 2. Estimated costs of different methods of protecting hardwood seedlings from stem girdling by voles.

Treatment	Equipment required	Material ($)	Machine $50.00/hr ($)	Labor $6.00/hr ($)	Total ($)	Remarks
1. Elimination of the weed cover on 1 ha of plantation by spraying 4.5 kg/ha of Princep Nine-T between the rows of trees	Tractor-mounted sprayer	61/ha	125/ha	-	186/ha	must be repeated annually but weed control will greatly improve tree growth
2. Elimination of the weed cover on 1 ha of plantation by rototilling between rows and spraying 4.5 kg/ha of Roundup on weeds growing between the trees	Tractor-mounted rototiller; backpack sprayer	28/ha	125/ha	24/ha	177/ha	must be repeated annually but weed control will greatly improve tree growth
3. Wrapping a 30-cm-high plastic tree guard around stem	-	0.35/tree	-	0.05/tree	0.40/tree	Guards may be reused. Without weed control tree growth will be slow.
4. Installation of 25 stations on 1 ha to dispense poisoned grain	-	Stations - 300/ha Bait - 125/ha	- -	48/ha 48/ha	521/ha	Station may be reused. Bait must be replenished four times a year. Without weed control tree growth will be slow.
5. Painting repellent on stem	-	0.03/tree	-	0.04/tree	0.07/tree	must be repeated annually. Without weed control tree growth will be slow.

In older plantations or on land where mechanical or chemical weed control are not feasible or desirable, vole populations may be kept in check by applications of poison bait (Hood 1972). The most common rodenticide is zinc phosphide. Grain or cracked corn treated with zinc phosphide is available in most agricultural supply stores. In the past, poisoned grain was broadcast over the total plantation area. Although this method was effective in decreasing the number of voles, the relief was only temporary because migration into the area from adjacent, untreated fields soon restored the pretreatment population levels. Furthermore, the exposed poisoned grain was either subject to rapid deterioration or available to non-target animals and birds. To overcome these problems Radvanyi of the Canadian Wildlife Service developed a poison-bait feeder which keeps the poisoned grain out of the reach of non-target animals and at the same time makes the grain available to mice on a continuous basis (Radvanyi 1974a, 1980). The feeder station consists of two 60-cm lengths of tubing, 5 cm in diameter, put together to form an inverted "T" (Fig. 12). The first feeding stations were made of galvanized metal drainpipes soldered together. Newer stations have been made from plastic pipe pressed or glued into a plastic Tee connector. The feeder is supported by being tied to a small stake. The vertical tube holds approximately 800 g of poisoned grain. A 280 g soft drink or soup can with one lid removed serves as a lid when placed over the vertical section of the station. It is recommended that at least 25 stations per ha be used. The stations must be inspected at approximately two-month intervals, cleaned and refilled with grain if they are to remain operational (Martell and Radvanyi 1976).

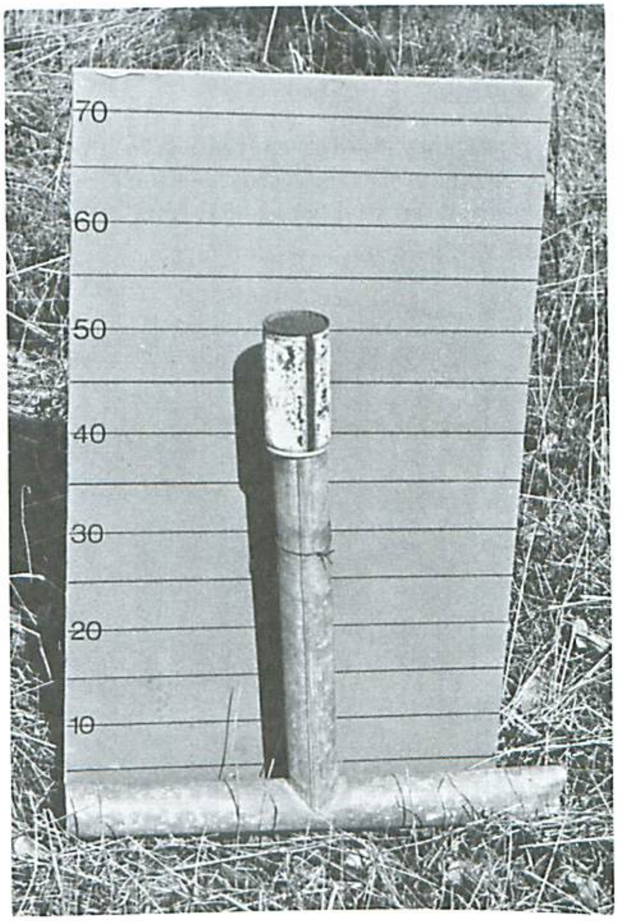

Figure 12. Feeder station to dispense poisoned grain.

One of the limitations on the effectiveness of poison bait is the problem of bait acceptance (Myllymaki 1975). Experiments have shown that most baits cannot compete with naturally occurring food items and that acceptability is lowered still further by the addition of the more or less unpalatable poison substance. This might explain why poison bait is successful in reducing large populations which are on the verge of starvation but cannot significantly reduce relatively small populations with a near-adequate food supply.

Sleeves of fine mesh hardware cloth or wire and plastic collars have proven highly effective in providing long-lasting protection against vole damage but the cost of placing sleeves around all trees in a plantation is prohibitive. Wrapping tree trunks in aluminum foil is cheaper. However, there is a report from Finland that grafted trees, protected by foil, suffered injury which may be attributed to improper aeration inside the collar (Myllymaki 1975). Aluminum foil wrapped around the trunks of planted white ash in southern Ontario provided good protection against vole damage during two winters of average population levels. After two years, many sleeves had to be replaced because they had either blown off, were ripped or were otherwise damaged. No injury to the tree trunks was observed from lack of aeration or other causes.

A traditional protection method in Finnish orchards has been the packing of snow around the stems of fruit trees. This method has proven marginally effective because the icy snow prevents the vole from reaching the stems through the snow. Voles do not like to be exposed on top of the snow while gnawing the bark. It has also been suggested that vole movement under the snow may be prevented by compacting the snow with a tractor or snowmobile (R. Boostra, pers. comm.). However, no information is available on the effectiveness of this method.

Numerous chemical repellents have been tested in the laboratory and in field trials (Lund 1975, Green 1978) but none has provided sufficient protection from small mammal damage to merit recommendation (Myllymaki 1975).

STEM GNAWING AND BROWSING BY RABBITS AND HARES

The Problem

Cottontail rabbits and snowshoe hares can cause serious damage in hardwood woodlots and plantations by gnawing the bark of stems or browsing the shoots and twigs of young trees. The problem is especially serious in plantations where hardwood trees have been interplanted with conifers and in peripheral areas where hardwood plantations border coniferous forests, bogs or other cover which provides shelter for rabbits and hares.

Extensive gnawing of the stem bark generally results in the death of all parts of the tree above the point of injury. However, because most hardwood trees are able to sprout from the root collar or from adventitious buds along the stem, few trees die. Severe bark gnawing may cause the loss of several years' growth and poor stem form, and may facilitate the entrance of disease organisms which, in years to come, could adversely affect the health of the tree (Fig. 13).

Rabbits and hares appear to have a definite preference for the bark of different tree species and shrubs. They favor the bark of young sugar maple, red oak and white oak (**Quercus alba** L.), basswood, thornless locust (**Gleditsia triacanthos inermis** L.) (Fig. 14), hybrid poplars and autumn olive (Dickmann 1978). Much less often selected are the barks of black walnut, butternut, silver maple and Russian olive (**Elaeagnus angustifolia** L.). Rabbits prefer the bark of young trees to that of older trees. Sprouts of previously girdled trees are therefore gnawed much more readily than is the bark of trees 10 cm or more in diameter. Plantations attacked by rabbits often contain large trees which have escaped gnawing at an early age and have now outgrown the damage, while clumps of sprouts, originating from the stumps of previously girdled trees, continued to be attacked.

Browsing of shoots and twigs can also cause severe damage. While occasional browsing will reduce growth and adversely affect tree form, extensive and, especially, repeated browsing can result in complete regeneration failure (Eadie 1954, Stroempl 1980).

Possible Solutions

In accessible areas intensive hunting can be very effective in keeping rabbit and hare populations at acceptable levels. However, hunting may not be permitted, feasible or sufficiently successful to protect individual, high-value trees, plantations or natural regeneration from some browsing damage.

Attempts to reduce hare populations by broadcasting apples treated with strychnine, by applying a strychnine-adhesive spray to seedlings or by setting out strychnine salt blocks have either failed to give adequate protection to seedlings or have constituted a hazard for non-target animals (Kelly 1957, Hartwell 1968).

Figure 13. Stem of four-year-old sugar maple gnawed by rabbits above plastic tree guard.

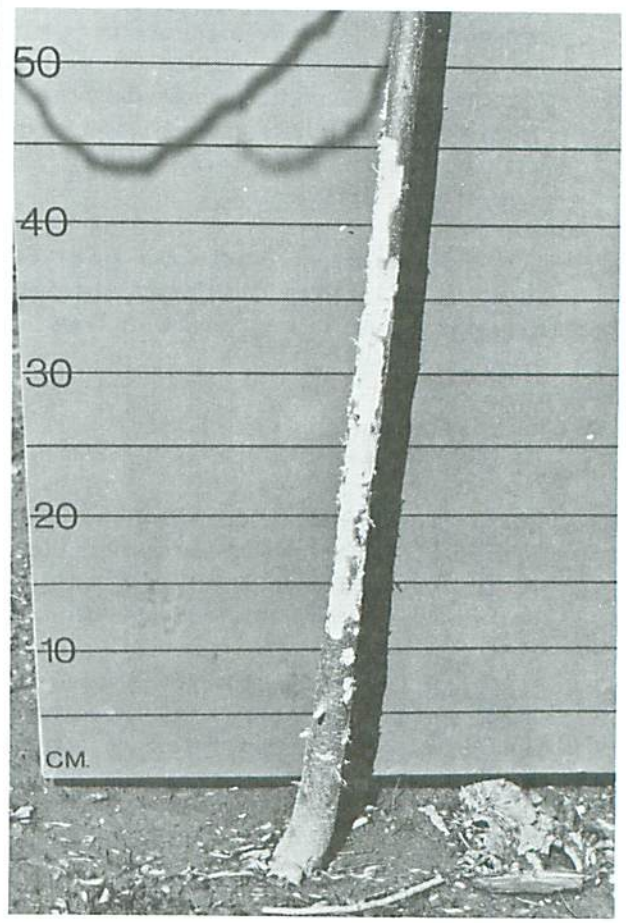

Figure 14. Stem of thornless locust gnawed by cottontail rabbits.

Fencing the total regeneration area is very effective in preventing browsing damage but the high cost makes this method economically unattractive (Pepper 1976). Individual high-value trees, growing near the periphery of a plantation or scattered throughout a plantation or woodlot, may be protected from browsing if the whole tree is enclosed in a sleeve of wire or plastic netting, or if a sleeve is placed over the leader. In a sugar maple plantation located adjacent to a white pine (**Pinus strobus** L.) plantation, sleeves of hardware cloth, 60 cm high and 30 cm in diameter, provided 100% protection against bark gnawing by rabbits (Fig. 15) while 85% of the unprotected trees were so severely damaged that they are not expected to produce stems of acceptable size and form. The sleeves were slipped over the newly planted seedlings and were held in place by two wire pins. Tree growth has not been adversely affected by the sleeves because their 30 cm diameter was sufficiently large to allow crown development during the first two years after planting when the crowns were contained within the sleeves. Despite snow accumulations of up to 30 cm no stems have been gnawed and no leaders browsed above the sleeves.

Stroempl (1980) investigated the effects of plastic netting (trade name "Vexar") on red oak growth and its efficacy in preventing gnawing or browsing damage. Sleeves with diameters of 7.5 and 15 cm were tested in lengths of 90, 120 and 150 cm. All sleeves with a diameter of 7.5 cm restricted shoot development because the leaves were bunched tightly within the sleeves. No serious restrictions were observed in sleeves 15 cm in diameter. Sleeves 90 cm long were supported by wire rods interwoven through the netting while sleeves 120 and 150 cm long required wooden stakes for support. The netting at all lengths provided 100% protection against rabbit damage while all unprotected seedlings were severely damaged.

While Stroempl (1980) used tubular netting, Du Pont now produces flat sheet netting with the code number E-1107. This netting is black (for long life), 57 cm wide and is sold in rolls 30.5 m long. The mesh opening is 12 mm. To produce sleeves 57 cm high and 20 cm in diameter the netting is cut every 63 cm, rolled into a cylinder and either stapled together with hog rings or stapled to a wood stake.

Plastic tree guards in lengths of 60 to 120 cm have been commercially available for many years for the prevention of gnawing damage. These guards consist of a strip of spirally wrapped, rather firm plastic, which is wrapped around the stem and stays in place without additional support. The guard is ideal for protecting trees with clear stems of 60 cm or more. For shorter trees the guards must be cut because their diameter of approximately 5 cm retards shoot growth when the tree crown is contained within the sleeve. Cutting the guards poses no problem, but as the tree grows, the short guard protects only the lower part of the stem (Fig. 16). This necessitates the replacement of the original, short guard with a longer guard. Since the guards are durable they may be reused, but replacement requires planning and labor.

An alternative to mechanical protectors is the spraying or brushing of repellents on tree trunks and branches. Repellents cost less than mechanical barriers, and are usually easier to apply (Anon. 1960). However, they are also less reliable in providing protection since the trees must be re-treated with repellents each year, and the total cost of protection may therefore be more than the original cost of mechanical protectors.

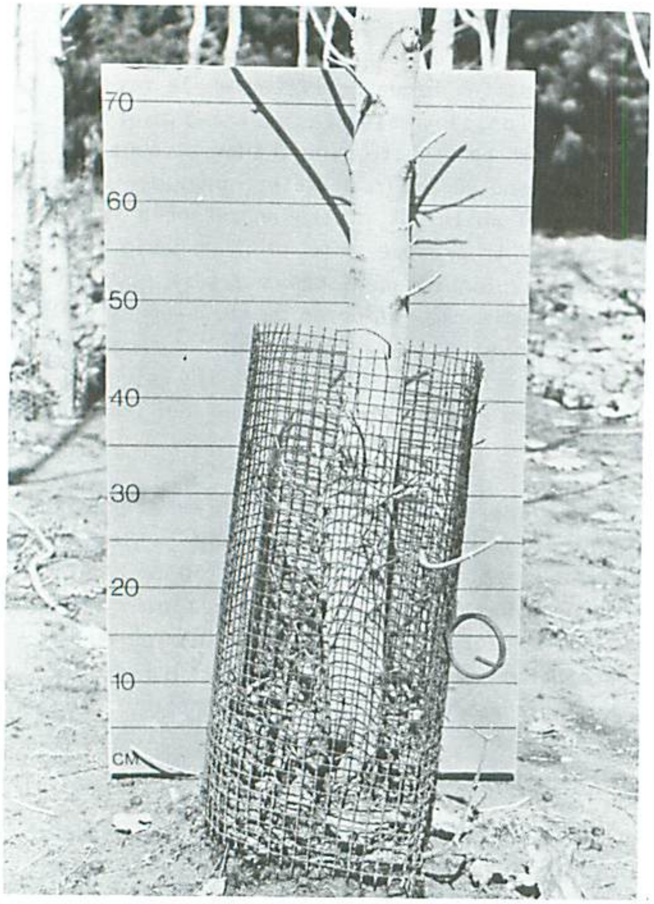

Figure 15. Sleeve of hardware cloth held in place by two wire pins has protected this eight-year-old sugar maple seedling from gnawing by rabbits or girdling by mice.

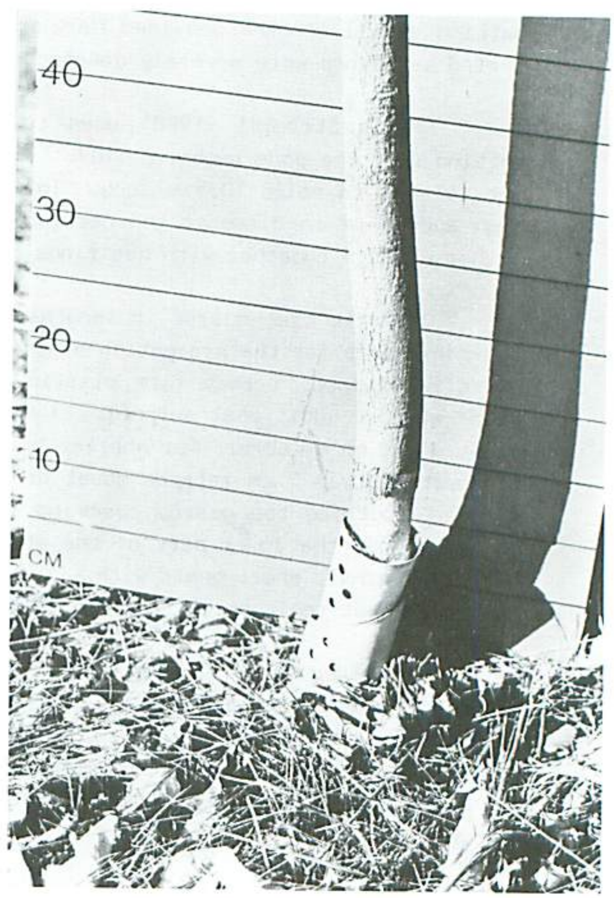

Figure 16. Short plastic tree guard was useful when tree was planted but has failed to protect larger tree.

Area or odor repellents, such as mothballs, creosote oil, bone tar oil, blood, tobacco dust, etc., have generally been ineffective in preventing gnawing or browsing damage (Anon. 1981a). More promising results have been obtained with a mixture of rosin and ethyl alcohol (Kelly 1957). However, the mixture should be applied only to dry surfaces at temperatures above freezing. Trees treated with rosin-alcohol repellent always turn white in the next snow or rain. This, however, does not alter the effectiveness of the repellent and may even be useful for showing if any trees have been missed.

A repellent-screening program by the Denver and Patuxent Wildlife Research Centres, in which approximately 8,000 chemicals were tested, resulted in the development of formulations marketed under different trade names by a number of companies. The three active ingredients in these products are trinitrobenzene-aniline (TNB-A), tetramethyl thiuram disulfide (TMTD), and zinc dimethyldithiocarbamate cyclohexylamine complex (ZAC) (Tigner and Besser 1962). The TNB-A is formulated in an organic solvent and can be applied in freezing temperatures, but it is toxic to conifers and growing hardwoods. The TMTD and ZAC products are water-dispersible concentrates that are diluted before use. Both TMTD and ZAC must be applied when temperatures are above freezing.

Bailey and McNally (1982) compared the effectiveness of different types of rodent repellents in the prevention of rabbit browsing of newly planted 3 + 0 red pine seedlings in Nova Scotia. Aaprotect (active ingredient Ziram) gave the best browsing protection. Skoot (active ingredient TMTD) and Arasan (active ingredient TMTD) with latex sticker added also gave significant protection. An Arasan application without the sticker gave no appreciable protection. This was believed to be due to the short retention period of the product without the sticker. In a test of different repellents by the British Forestry Commission, Aaprotect, applied in November, proved to be the most effective repellent (Pepper 1976).

STEM GNAWING BY GROUNDHOGS

The Problem

Groundhogs seldom cause extensive damage but their habit of gnawing or biting off the stems of trees growing near their burrows can be highly annoying to a plantation owner. Similarly annoying is the destruction of planted trees in woodlot openings or under a shelterwood canopy. For reasons unknown, groundhogs prefer to gnaw the bark of the introduced species while ignoring all natural regeneration except that growing in the immediate vicinity of their burrows.

Possible Solutions

Introduced or high-value trees may be protected from gnawing by plastic tree guards wrapped around the stems or by chemical repellents painted on the bark. Where damage is extensive the only sure method of protection is the elimination of the groundhogs by hunting or poisoning. The Ontario Ministry of the Environment recommends the use of aluminum phosphide with the trade name Phostoxin (Anon. 1977). To kill the groundhog throw a tablet well into the burrow, using a piece of poly-tubing wide and

Table 3. Estimated cost of different methods of protecting hardwood seedlings from stem gnawing and browsing by rabbits and hares.

Treatment	Material ($)	Labor $6.00/hr ($)	Total cost ($)	Remarks
1. Enclosure of total tree in a sleeve of chicken wire 60 cm high, 20 cm in diameter, held in place by two wire pins	1.30/tree	0.30/tree	1.60/tree	Trees 60 cm and taller may be subject to browsing damage.
2. Enclosure of total tree in a sleeve of "Vexar" plastic netting 57 cm high and 20 cm in diameter held in place by two wire pins	1.10/tree	0.30/tree	1.40/tree	durability up to 10 years depending on color Trees 57 cm and taller may be subject to browsing damage.
3. Enclosure of total tree in sleeve of "Vexar" plastic netting 120 cm high and 20 cm in diameter held in place by a wooden stake 5 x 5 x 122 cm	1.90/tree	0.30/tree	2.20/tree	durability up to 10 years depending on color: will protect leaders from browsing
4. Wrapping plastic tree guards 61 cm long around stems	0.70/tree	0.06/tree	0.76/tree	protection against stem gnawing only For trees with clear stems of less than 60 cm the guards must be cut.
5. Brushing or spraying chemical repellents on stems and leaders	0.07/tree	0.06/tree	0.13/tree	must be repeated annually

long enough to pass the tablet through to the bottom of the burrow. Fill in the hole with soil and tramp down firmly.

BROWSING BY DEER

The Problem

The deer population of southern Ontario is, at present, relatively small. However, local concentrations of deer can cause severe damage to hardwood regeneration by browsing terminal and lateral shoots and polishing or rubbing antlers on young trees (Schafer 1965). Enclosure studies by Jordan (1967), Richards and Farnsworth (1971), and Marquis (1974) showed that deer can reduce the height and density and change the species composition of seedlings and sprouts and can also cause complete regeneration failure. Marquis (1981) found that 62% of the clearcuts he examined in the Allegheny National Forest were unsatisfactorily stocked with preferred species. At least 87% of the unsatisfactorily stocked clearcuts had failed to regenerate because of deer browsing, because regeneration was satisfactory inside the fences in those areas (Marquis and Brenneman 1981).

Possible Solutions

Intensive hunting can be effective in keeping the deer population at an acceptable level. However, hunting may not be permitted, feasible or sufficiently successful to reduce the population adequately and prevent serious damage.

In Europe and the northeastern United States where deer populations are much higher than in Ontario, enclosures have proven very successful in preventing browsing damage (Jordan 1967, Richards and Farnsworth 1971, Marquis 1974, Bentz 1977, Pepper and Tee 1977, Berlit 1980, Harrison 1980, Sill 1980, Marquis 1981, Marquis and Brenneman 1981). Because fencing is a prerequisite of successful regeneration of some tree species, special, easy-to-erect, reusable wildlife fences have been developed in Europe. Nevertheless, the prevention of browsing damage by enclosure is very expensive. Harrison (1980) stated that by 1979 well over 8000 km of deer fencing existed in Scotland. Of this about two-thirds is on Forestry Commission land, where the annual cost of erection and maintenance is reckoned at some £500,000 ($900,000).

In the Pacific Northwest, nylon fishnet with 15 cm mesh and 2.44 m depth has been used successfully to protect regeneration from browsing by black-tailed deer **(Odocoileus hemionus columbianus)** and Roosevelt elk **(Cervus canadensis roosevelti)** (Mealey 1968). The average construction costs per linear metre in 1968 were estimated to be $0.32 with an additional average maintenance cost of $0.51 per linear metre for three years.

The United States Fish and Wildlife Service (Anon. 1981b) recommends the use of 2.50 m woven-wire fence for deer enclosures. Most woven-wire fencing is available in 1.25 m widths which may be used to construct a 2.50 m fence. Stay wires should not have more than a 15 cm spacing, and top and bottom wires should be at least nine-gauge, with a mesh of 11-gauge wire. Barbed wire may be strung above the woven wire if more height is desired.

An electric fence is a workable alternative to the very expensive woven-wire fence. Comparing the effectiveness of a five-strand vertical fence 147 cm high with a "figure four" three-strand fence 110 cm high, Brenneman (1982) found that both fences reduced browsing damage but that the five-strand fence provided the best protection. The fences were charged with a battery-powered energizer having a maximum output of 5,800 volts. Average time between battery charges was about six weeks. The material costs for the electic fence were $0.46 to $0.59 per linear metre in comparison with $1.48 for the conventional 2.50-m-high woven wire fence.

Another method of preventing browsing damage by mechanical barrier is the protection of individual, whole trees or terminal shoots with wire or plastic netting (Borrecco 1976). Campbell and Evans (1975) successfully protected newly planted Douglas fir (**Pseudotsuga menziesii** [Mirb.] Franco) seedlings from browsing by black-tailed deer and elk by enclosing the seedlings in rigid tubing "Vexar", a polypropylene plastic mesh. Wire pins, staples, or wooden lath were used to anchor and support the tubes. Older seedlings were protected by pressing the tube down over the leader where it is held in place by lateral branches protruding through the netting.

Trees may also be protected from browsing by the application of repellents. There are two general categories: odor and taste repellents. The most common odor repellent is tankage, a byproduct of animal packing plants. Though not highly recommended, tankage has proven effective in some cases as an all-season odor repellent. For best results place 10 to 150 g of tankage in 8 cm by 12 cm cloth bags (Anon. 1981b). Hang bags loosely on the tree requiring protection. Small trees require only one tankage bag, while larger trees may require up to four bags. Other odor repellents which have been applied with varying success are bone tar oil, moth balls and rosin.

Taste repellents are generally more effective in preventing browsing damage than are odor repellents. The most common taste repellents, which are marketed under several trade names (Skoot, Arasan and Improven Z.I.P.), are available in most garden centres. Their active ingredients are zinc dimethyldithiocarbamate cyclohexylamine complex (ZAC), and tetramethyl thiuram disulfide (TMTD) (Williston 1974). Driscoll (1963) reported that deer browsing of ponderosa pine (**Pinus ponderosa** Laws.) seedlings was reduced by spraying with 10% solutions of either ZAC or TMTD, each mixed with 10% Rhoplex AC-33, 0.2% Methocel (a thickening agent), and 0.6% Hexadecanol-ethanol (a defoaming agent). ZAC provided the best year-round protection but the treatment had to be reapplied annually.

Another approach to preventing browsing damage is the use of attractants to lure deer away from valuable trees (Dasmann et al. 1967). This includes spraying molasses, other sweeteners, minerals or trace elements on plants to increase palatability to deer; using supplements such as hay and pellets, or felling trees to provide browse. Although some experiments have shown that deer were attracted to the sprayed vegetation, more research is needed to ascertain the value of these treatments in preventing browsing damage.

Table 4. Estimated cost of different methods of protecting hardwood seedlings from browsing by deer.

Treatment	Material ($)	Labor $6.00/hr ($)	Total cost ($)	Remarks
1. Fencing the total area with a 2.4-m-high woven wire fence	1.48/linear metre	0.30/linear metre	1.78/linear metre	Cost will vary widely depending on size and shape of area to be fenced, accessibility, etc.
2. Fencing the total area with a five-strand, 1.47-cm-high electric wire fence	0.53/linear metre	0.30/linear metre	0.83/linear metre	same as above
3. Enclosing the total tree in a sleeve of "Vexar" plastic netting 120 cm high and 20 cm in diameter held in place by a wooden stake	1.70/tree	0.50/tree	2.20/tree	durability up to 10 years depending on color of "Vexar" and treatment of wooden stakes
4. Enclosing the terminal shoot in a sleeve of "Vexar" plastic netting 57 cm long and 5 cm in diameter	0.04/tree	0.03/tree	0.07/tree	best suited to trees 0.5 - 1 m in height with well developed leaders
5. Brushing or spraying chemical repellents on leaders	0.03/tree	0.04/tree	0.07/tree	must be repeated annually

DAMAGE CAUSED BY CATTLE

The Problem

Some landowners allow cattle to graze in hardwood woodlots because they wish to utilize the ground vegetation for feed and the mature trees for shelter and shade. These landowners are generally unaware of the serious damage to the productive capacity of the woodlot caused by prolonged cattle grazing. Cattle destroy the regeneration by browsing, breaking and trampling (Fig. 17). They also browse and break the branches of larger trees. Serious damage is also caused by soil compaction and injury to the feeder roots growing near the soil surface. These roots are responsible for nutrient uptake, and injury will invariably result in growth reductions and general deterioration of the health of the trees.

Figure 17. Pastured woodlot on the right. On the left, natural regeneration in woodlot protected from cattle browsing.

Possible Solutions

The only solution is the exclusion of cattle from the woodlots. If shelter and shade are essential for the wellbeing of the cattle and cannot be provided otherwise, only a small part of the woodlot should be made accessible to the cattle and a sturdy fence should be erected to keep the cattle out of the remainder of the woodlot.

SUMMARY

Mice, squirrels, rabbits, hares, groundhogs, deer and cattle can cause serious damage to natural and artificial hardwood regeneration. Sound silvicultural practices such as effective weed control during the first few years after planting and the exclusion of cattle from woodlots can prevent unnecessary damage. However, damage resulting from large increases in rodent populations caused by favorable climatic conditions or damage caused by deer following the elimination of the hunting season are beyond the control of the landowner or forester and can be prevented only by the application of special control methods.

The most common control methods are discussed in this report and cost estimates are provided. All control methods add to the cost of stand establishment and management, but without damage control, the regeneration may fail and the money and labor expended to date may be lost. It is therefore of the utmost importance to the landowner and forester to be able to evaluate the possible success of all available control methods. The method selected must ensure damage reduction to an acceptable level at the lowest possible cost. However, under no circumstances should the survival or growth of natural or artificial regeneration be jeopardized by the selection of an inferior control method because of cost considerations.

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