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Efficacy of selected repellents to deter deer browsing on conifer seedlings

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Abstract

Foraging deer can negatively impact agricultural resources. Repellents offer a plausible approach to inhibit browsing. The efficacy of Big Game Repellent-Powder (BGR), Deer Stopper (DST), Plantskydd (PLA) and ECX95BY (ECX) to deter black-tailed deer (*Odocoileus hemionus columbianus*) browsing of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*) seedlings was assessed during the winter. Extent of damage was expressed as number of seedlings damaged, number of terminal buds damaged, number of lateral bites taken and the number of seedlings with severe damage. BGR, DST and PLA significantly reduced deer damage relative to controls for at least 14 weeks. After 1 week, damage to seedlings treated with ECX was similar to that inflicted on control seedlings. Aversive agents contained in BGR, DST and PLA probably produce sulfurous odors, while ECX contained denatonium benzoate, a bittering agent. Published by Elsevier Science Ltd.

1. Introduction

Deer (*Odocoileus* spp.) occur across the United States and provide many desirable recreational and aesthetic opportunities. Unfortunately, deer foraging, particularly where population densities are high, can negatively impact agricultural resources. Deer damage a variety of grain crops, forage crops, vegetables, fruit trees, nursery trees and ornamentals (Craven and Hygnstrom, 1994). Beyond the immediate browse damage there is often residual crop damage, such as future yield reductions or growth deformities. Expanding ungulate populations are also a widespread detriment to reforestation efforts in the Pacific Northwest (Rochelle, 1992). Ungulate browsing causes growth suppression and regeneration delays, as well as mortality among seedlings that are repeatedly browsed or pulled out of the ground (Crouch, 1976; Evans, 1987; Tilghman, 1989).

Repellents offer a plausible approach to inhibit browsing. Particularly in areas where the damage is inflicted over a specific and relatively short duration. For example, repellents may work well on a reforestation unit where damage occurs as deer migrate between winter and summer ranges. Repellents are also more likely to provide suitable protection when applied in areas with readily available alternate forage. Hungry animals are more difficult to deter than satiated animals (Andelt et al., 1992).

In this study, the efficacy of selected repellents to reduce black-tailed deer (*Odocoileus hemionus columbianus*) browsing of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*) seedlings was assessed during the winter. Big Game Repellent-Powder (BGR) was included for comparative purposes. The efficacy of BGR to repel ungulates has been previously demonstrated (Conover, 1987; Andelt et al., 1991, 1992; Nolte et al., 1995) and is a product generally known by timber producers. Deer Stopper (DST), Plantskydd™ (PLA) and ECX95BY (ECX) are new products or experimental materials intended as tools to enhance reforestation efforts. Compounds or mixtures within BGR, DST and PLA probably produce a sulfurous odor. ECX contained denatonium benzoate, a bittering agent. The use of trade names in this manuscript is for the purpose of identification and does not indicate endorsement of commercial products by the U.S. Department of Agriculture.

2. Materials and methods

2.1. Subjects

A resident contained herd of 15 adult black-tailed deer served as subjects. Subjects were penned in 5 groups with

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3 deer in each group. Enclosures varied in size from 0.75 to 2 ha with natural habitat consisting of Douglas-fir and alder (*Alnus rubra*) and associated under-story vegetation. Although natural forage was readily available, animals were also provided free access to deer pellets and water throughout the study.

2.2. Repellents

BGR was obtained from IntAgra (Minneapolis, MN), while DST (Messina; Long Valley, NJ), PLA (Tree World; Sechelt, BC) and ECX (Ecogen, Langhorne, PA) were donated by the respective producers. Repellents were prepared and applied according to the label or directions provided with each product. Seedlings were lightly misted with water before being dusted with BGR. PLA was first mixed thoroughly in 5 l of water and allowed to stand until the foam dissipated (20 min). The mixture was then poured through a filter to remove coagulants before it was sprayed on seedlings. DST was diluted with 3 parts water per 1 part DST. The product was thoroughly mixed prior to and post dilution to ensure even distribution of the active ingredient. No product preparation was necessary for ECX. Control (CON) seedlings were not treated. Repellents were applied to all parts of the seedlings, the liquid repellents to the point of runoff. Liquids were repeatedly mixed throughout the application process. No noticeable precipitation occurred for at least 24 hours post treatment.

2.3. Procedure

Seedlings were planted in test plots immediately prior to treatment (January 12, 1996). Test plots consisted of 8 rows of 3 seedlings. A Douglas-fir (DF: mean height of 66 cm), a ponderosa pine (PP: mean height of 31 cm) and a western red cedar (RC: mean height of 65 cm) were randomly assigned within each row. Rows and seedlings within a row were spaced at 1 m intervals. All plots were separated by at least 25 m. Treatments (ECX, DST, BGR, PLA, CON) were randomly assigned among each of the 5 plots established within each enclosure.

Seedlings were examined for browsing damage at 24 and 48 hours after treatment and then at 1 week intervals for 14 weeks. Browsing damage generally consisted of terminal damage along with a few bites from lateral foliage or complete defoliation. Damage to the terminal bud and the number of lateral bites was recorded for each seedling. Lateral bite counts were limited to a maximum of 25, because after 25 bites the seedings were virtually defoliated. Seedlings pulled out of the ground were regarded as completely defoliated and thereafter recorded as having terminal damage and greater than 25 bites. The evaluation criteria provided an accurate assessment of: 1) the number of damaged seedlings; 2) the number of seedlings with terminal damage; 3) the mean number of lateral bites taken; and 4) the number of completely defoliated seedlings (25 bites). Although these evaluation measures are inter-related we report all 4 criteria because they are indicative of different levels of damage intensity.

2.4. Data analysis

The data for each evaluation criterion were initially assessed in separate three factor repeated measures analysis of variance (ANOVA). In all cases, there was a significant interaction ($P < 0.0001$) among treatment, species and evaluation period. Intensity and onset of browsing varied among species, as well as treatment. Therefore, a two factor ANOVA was used to assess differences among treatments and species at 48 hours and 1, 7, and 14 weeks post application. Deer herds were nested within treatments and the 2 factors were repellents (5 levels) and tree species (3 levels). Tukey tests (Winer, 1967) were used to isolate significant differences among means subsequent to the omnibus procedures ($P < 0.05$).

3. Results

3.1. Damaged seedlings

There was an interaction among treatments and species at the 48 hour ($P = 0.0125$) and the 1 week ($P = 0.0001$) evaluations (Fig. 1). Overall, RC seedlings were more frequently damaged than were DF or PP seedlings. The number of CON seedlings damaged and number of ECX seedlings damaged was similar after 48 hours and again at 1 week post treatment. At 48 hours, however, there was no significant difference among any of the repellent treatments. While after 1 week, deer had browsed a greater number of ECX seedlings than they did BGR, DST or PLA seedlings. There was not an interaction between treatment and species at 7 weeks ($P > 0.550$) and 14 weeks ($P = 0.505$) post treatment. Similar numbers ($P = 0.083$) of RC, DF and PP seedlings were damaged at 7 weeks, while after 14 weeks deer had browsed a greater ($P = 0.0016$) number of RC seedlings than they did DF or PP seedlings. Efficacy of the repellents varied at the 7 week ($P = 0.0001$) and the 14 week ($P = 0.0001$) evaluations. At both intervals, a similar number of CON seedlings and seedlings treated with ECX had been browsed, while fewer seedlings treated with DST, BGR or PLA were browsed. The extent of damage among DST, BGR and PLA seedlings was similar.

3.2. Terminal damage

The interaction between treatment and species was significant at the 48 hour ($P = 0.0016$), the 1 week ($P = 0.0001$) and the 7 week ($P = 0.0062$) evaluations (Fig. 2). Generally, deer browsed more terminal buds of

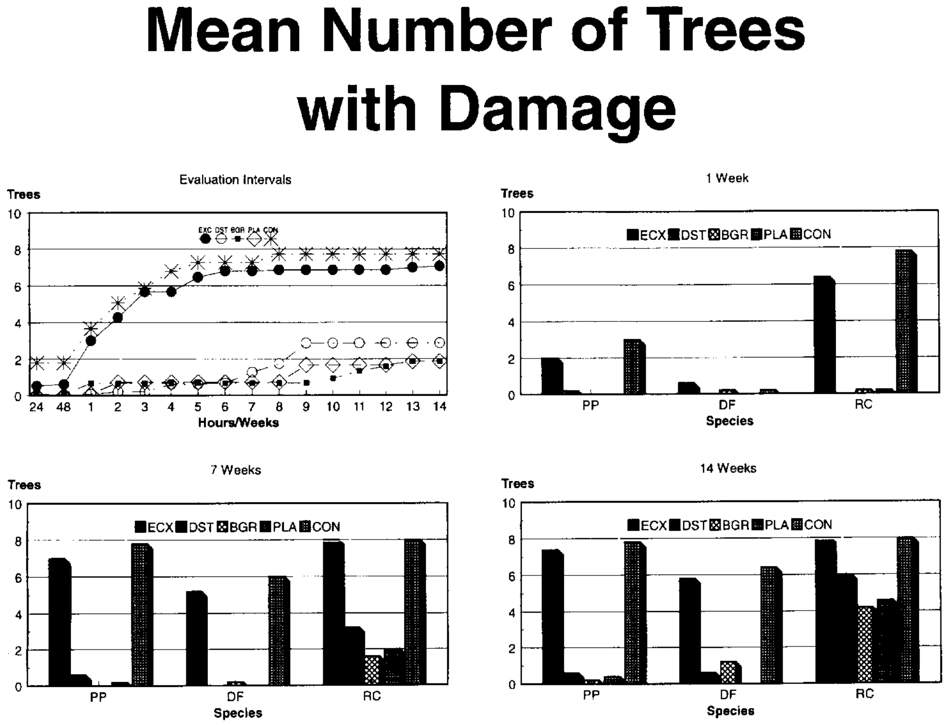

Fig. 1. Mean number of seedlings treated with ECX (ECX95BY), DST (Deer Stopper), BGR (Big Game Repellent-Powder), PLA (Plantskydd) or CON (untreated), with some form of damage at each of the evaluation intervals; and the number of damaged PP (ponderosa pine), DF (Douglas-fir) and RC (western red cedar) seedlings treated with the same repellents at the 1, 7 and 14 week intervals.

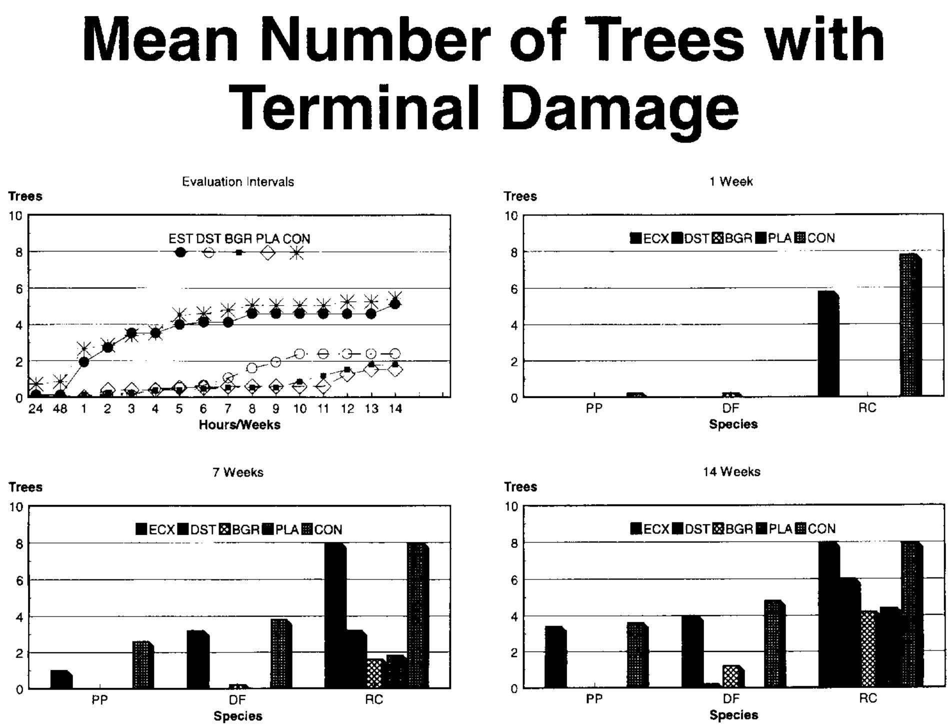

Fig. 2. Mean number of seedlings treated with ECX (ECX95BY), DST (Deer Stopper), BGR (Big Game Repellent-Powder), PLA (Plantskydd) or CON (untreated), with terminal damage at each of the evaluation intervals; and the number of PP (ponderosa pine), DF (Douglas-fir), and RC (western red cedar) seedlings treated with the same repellents with terminal damage at the 1, 7 and 14 week intervals.

RC seedlings than they did DF or PP seedlings. Few terminal buds were clipped after 48 hours. However, damage to CON, BGR, and ECX seedlings was similar and greater than that inflicted on DST and PLA seedlings. The number of seedlings with terminal damage was similar for CON and ECX at 1 week and 7 weeks post treatment. Terminal damage during these evaluations was similar among seedlings treated with DST, BGR or PLA, which was less than that inflicted on ECX or CON seedlings. An interaction did not occur at 14 weeks post treatment ($P > 0.5500$). Terminal damage varied among species ($P = 0.0011$) and among treatments ($P = 0.0004$). Deer clipped more RC terminal buds than they did DF or PP buds, which had similar numbers of buds clipped. Differences among treatments were the same as reported for 7 weeks post treatment.

3.3. Lateral bites

Again there was an interaction between treatment and species at the 48 hour ($P = 0.0028$), 1 week ($P < 0.0001$) and 7 week ($P = 0.0203$) evaluations (Fig. 3). Lateral bites taken from seedlings were similar across treatments at 48 hours post treatment. However, more bites were taken from RC seedlings than from DF or PP seedlings. Deer inflicted a similar number of bites on seedlings treated with ECX as they did CON seedlings at the 1 and 7 week evaluations. Though bite counts increased over time, regardless of treatment, there was no difference among BGR, DST, and PLA treatments and seedlings with these treatments consistently had fewer bites taken from them than did the ECX or CON seedlings. There was not an interaction at 14 weeks post treatment ($P = 0.2694$). Lateral bites varied among species ($P = 0.0037$) and treatment ($P < 0.0001$). As before, RC seedlings were more severely damaged than were either DF or PP seedlings. Protection provided by BGR, DST and PLA was similar and greater than protection provided by ECX which was similar to CON.

3.4. Defoliated seedlings

Few seedlings were defoliated after 48 hours (Fig. 4). Consequently there was no interaction ($P > 0.55$), nor were there significant differences among treatments ($P = 0.4374$) or among species ($P = 0.4116$). An interaction among treatments and species occurred at 1 week ($P < 0.0001$) and at 7 ($P = 0.0001$) weeks. RC seedlings were defoliated more rapidly than either DF or PP. ECX inhibited deer from defoliating seedlings for the first week better than CON but not as well as BGR, DST or PLA. At 7 weeks, however, a similar number of CON and ECX trees were defoliated and this was substantially more seedlings than those treated with BGR, DST or PLA. There was not an interaction between treatment and seedling species at the 14 week evaluation ($P > 0.5500$). Spec-

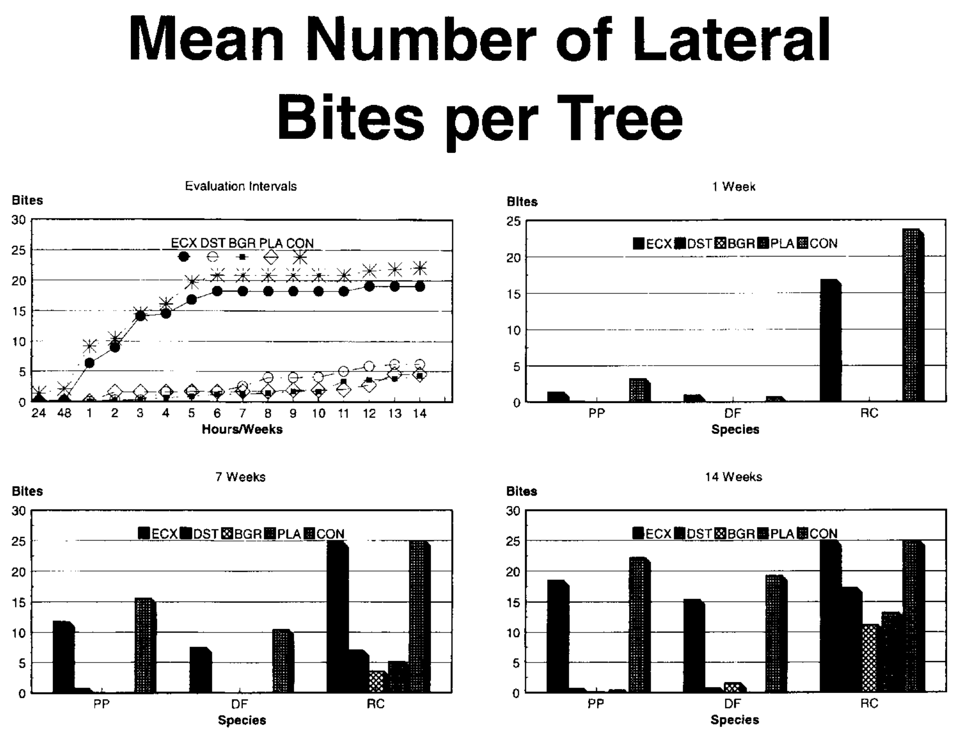

Fig. 3. Mean number of lateral bites inflicted on seedlings treated with ECX (ECX95BY), DST (Deer Stopper), BGR (Big Game Repellent-Powder), PLA (Plantskydd) or CON (untreated) at each of the evaluation intervals; and the number lateral bites taken from PP (ponderosa pine), DF (Douglas-fir) and RC (western red cedar) seedlings treated with the same repellents at the 1, 7 and 14 week intervals.

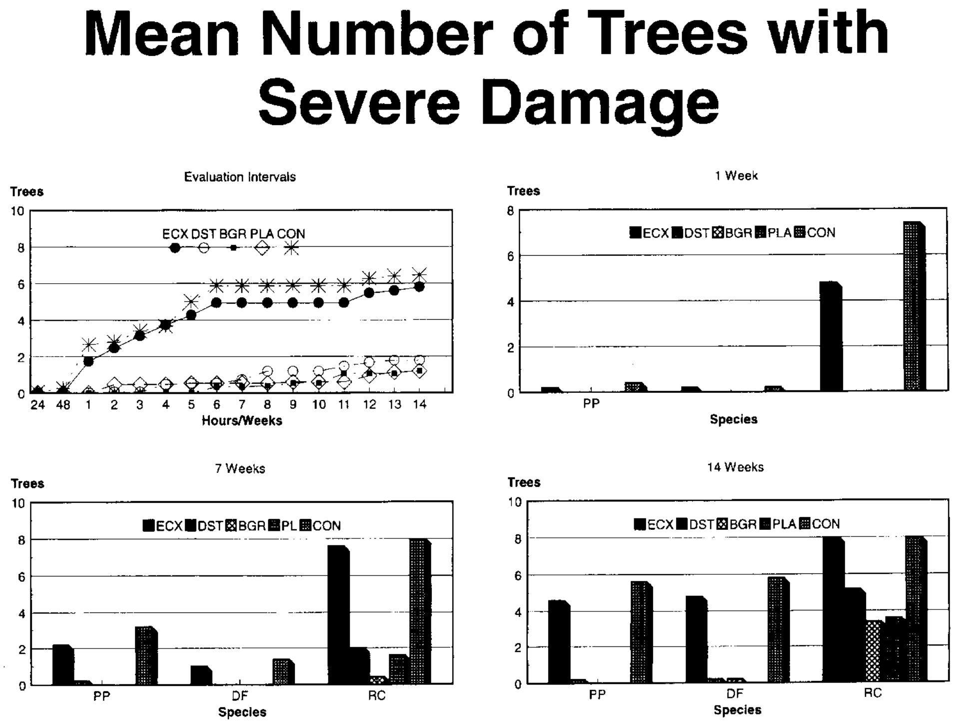

Fig. 4. Mean number of seedlings treated with ECX (ECX95BY), DST (Deer Stopper), BGR (Big Game Repellent-Powder), PLA (Plantskydd) or CON (untreated), with severe damage at each of the evaluation intervals; and the number of severely damaged PP (ponderosa pine), DF (Douglas-fir) and RC (western red cedar) seedlings treated with the same repellents at the 1, 7 and 14 week intervals.

ies susceptibility to damage varied ($P = 0.0075$) with RC being more severely browsed then either DF or PP. Efficacy to prevent damage also varied among treatments ($P = <0.0001$). A similar number of CON seedlings and seedlings treated with ECX were defoliated, while fewer seedlings treated with DST, BGR or PLA were defoliated.

4. Discussion

Damage inflicted by deer increased with time, regardless of the criteria used to assess browsing intensity. BGR, DST and PLA inhibited browsing relative to controls throughout the experiment. ECX initially provided some protection. However, within a week damage levels were similar to that incurred by CON seedlings. These results are consistent with other experiments that tested the efficacy of similar active ingredients to repel herbivores (Dietz and Tigner, 1968; Harris et al., 1983; Palmer et al., 1983; Melchoirs and Leslie, 1985; Conover 1994; Swihart and Conover, 1990; Andelt et al., 1991; Milunas et al., 1994; Nolte et al., 1995).

Several studies report BGR to inhibit foraging by black-tailed deer (Melchoirs and Leslie, 1985; Nolte et al., 1995), mule deer (*Odocoileus hemionus*; Andelt et al., 1991), white tailed deer (*Odocoileus virginianus*; Dietz and Tigner, 1968; Harris et al., 1983; Palmer et al., 1983; Conover, 1984; Swihart and Conover, 1990; Milunas et al., 1994) and elk (*Cervus elaphus*; Andelt et al., 1992). The efficacy of BGR appears to depend on the odor of volatile short-chain fatty acids and sulfur compounds (Bullard et al., 1978). Sulfurous odors produced by degradation or digestion of proteins may evoke a fear-response in prey species (Mason et al., 1994). PLA, a blood meal mixture, most likely also emits a sulfurous odor. DST contains thiram (tetramethylthiuram disulfide) which prior studies have indicated will reduce foraging by deer (Harris et al., 1983; Conover, 1984; Andelt et al., 1991). Avoidance of thiram, however, is generally regarded to be through taste rather than olfaction (Andelt et al., 1992).

Thiram may also induce conditioned food aversions (Campbell and Bullard, 1972). Conditioned food aversions occur when ingestion of novel foods is paired with nausea (Garcia, 1989). Avoidance of foods that cause conditioned aversions is expected to increase with exposure. Andelt et al. (1991) reported the efficacy of thiram to increase with progressive test days, while deer increased their intake of rations treated with other repellents. Similarly, elk intake of thiram treated foods decreased on each successive test day during an initial trial but this increased avoidance did not persist in a subsequent trial (Andelt et al., 1991).

ECX did not repel deer for a prolonged period. Deer readily browsed ECX treated seedlings after only 48 hours. Avoidance for the first 48 hours may have been more because the deer were unfamiliar with the taste rather than an actual aversion to denatonium benzoate. Animals commonly sample novel or unfamiliar foods cautiously (Rozin, 1976). Bittering agents in other studies have also failed to deter deer foraging over prolonged periods (Swihart and Conover, 1990; Andelt et al., 1991, 1992).

Herbivores commonly ingest natural 'bitter' compounds, and bitter substances that fail to induce gastrointestinal malaise are largely ineffective as repellents for herbivores (Nolte et al., 1994). However, herbivores can detect bitter flavors and reliably acquire avoidance responses when these flavors are paired with gastrointestinal distress (Jacobs and Labows, 1979). Red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) offered food adulterated with 1000 ppm denatonium benzoate in a single-choice test did not restrict their daily intake (Wright and Milne, 1996). These animals did differentiate between treated and untreated food, however, and when offered a choice they restricted their intake of treated relative to untreated food.

RC seedlings were more frequently and more severely browsed by deer than either DF or PP seedlings. Deer clipped nearly all the terminal buds and inflicted multiple lateral bites on virtually all of the untreated RC seedlings after only 1 week (Figs 2 and 3). After only 7 weeks all the untreated RC seedlings were either pulled from the ground or completely defoliated (Fig. 4). Comparatively, few untreated PP and no untreated DF lost terminal buds the first week and nearly half of these seedlings retained terminal buds to the end of the study. At subsequent evaluations, however, terminal damage tended to be more severe on DF than on PP. The difference in terminal damage may have been because of the growth form of the seedlings. The terminal bud of DF is at the pinnacle of the seedling, while the lateral needles of PP tend to enclose its terminal bud. The overall damage levels, however, suggest that deer preferred PP relative to DF. Lateral damage tended to be more severe and inflicted on more untreated PP seedlings than on untreated DF seedlings.

Repellents deter foraging animals by decreasing a plant's desirability. Thus, the efficacy of a repellent depends on the desirability of the protected plant as well as the availability and palatability of the surrounding forage. An animal may select one food over another because it is attracted to the first or because it is avoiding the alternative (Galef, 1985). The apparent high palatability of RC makes it a difficult plant to protect. Though experimental conditions allowed deer access to browse and pelleted feed, they still severely browsed RC seedlings, regardless of treatment. Repellents provided better protection for the less desirable DF and PP seedlings; few DF or PP seedlings treated with BGR, DST, or PLA were completely defoliated. The efficacy of test repellents was probably enhanced by the readily available alternative forage, since satiated animals are generally more easily deterred from food resources than are hungry animals (Andelt et al., 1992).

Trees are long-lived and browsing damage is difficult to prevent completely. No repellent is likely to provide total protection. Nevertheless, repellents can reduce damage during periods when trees are most vulnerable. BGR-P, Plantskydd and Deer Stopper may provide a feasible approach to protect seedlings when they are first outplanted, or during seasons when damage is most likely to occur, such as by migrating big game when the temporal span of damage is known and relatively short.

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