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Comparison of active ingredients and delivery systems in deer repellents

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Abstract In some situations chemical repellents are a socially appealing nonlethal alternative to reduce deer (*Odocoileus* spp.) damage to plants. New products are continually becoming available, but their ability to repel deer is very variable. We tested 20 repellents representing 4 modes of action (fear, pain, taste, and aversive conditioning) and 2 delivery systems (topical applications and area repellents [scent packets]) to evaluate current products and identify trends that could be used to predict efficacy of future products. During fall 1998, we placed treated western red cedar (*Thuja plicata*) seedlings in pastures with black-tailed deer (*Odocoileus hemionus*) and recorded number of bites taken from each seedling at weekly intervals for 18 weeks. Four of the 5 most effective repellents used fear as a mode of action. We tested the 5 most effective repellents again in spring 1999 when trees were growing actively and were more palatable to deer. Only Plantskydd™ and Deer Away Big Game Repellent® powder reduced damage. However, unlike the winter study, the Deerbuster's™ and Bye Deer® sachets were hung on stakes at half the height of the seedlings instead of near the terminal buds. When an additional study was conducted with the sachets mounted near the terminal buds so that repellent could drip from bags onto the plants as in the winter study, Deerbuster's sachets and Bye Deer sachets reduced deer foraging. In general, products using fear as a mode of action were more effective than products using other modes of action and topical repellents were more effective than area repellents.

Key words animal damage, black-tailed deer, *Odocoileus hemionus*, repellents, Washington

Deer (*Odocoileus* spp.) foraging can be detrimental to reforestation efforts in the United States (Black et al. 1979, Borrecco and Black 1990, Conover et al. 1995). Deer browsing also can result in significant economic damage to nurseries, ornamental plants, and field crops (Campbell 1987; Austin and Urness 1987,1989; Conover and Decker 1991). Chemical repellents are a nonlethal alternative to reduce damage in some situations, especially in cases where plants are vulnerable to damage for a limited portion of the year.

A wide variety of repellents are available, but not all products are effective (Nolte et al. 1994*a*, Beauchamp 1997, Nolte 1998). Although many of these products have been tested in prior studies, most studies only test 1 or a few repellents (e.g., Harris et al. 1983, Palmer et al. 1983, DeYoe and Schaap 1987, Andelt et al. 1994, Mason 1997). Variations in experimental design, environmental conditions, test foods, season, and condition of the test subjects make it difficult to make direct comparisons among products. Additionally, new products are continually becoming available.

Despite the variety of products available, the active ingredients in these products can be categorized into 1 of 4 modes of action (fear, conditioned aversion, pain, and taste; Beauchamp 1997; Mason 1997). Fear-inducing repellents contain some compound which emits sulfurous odors (e.g., predator urine, meat proteins, garlic). Herbivores may

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perceive these odors as indicators of predator activity and avoid treated items (Epple et al. 1993, 1995; Nolte et al. 1994*b*). Products that use conditioned aversion cause animals to form an association between the treated item and illness and subsequently avoid eating the target item (Garcia 1989). Pain-inducing repellents contain ingredients like capsaicin, allyl isothiocyanate, or ammonia, which cause pain or irritation on contact with trigeminal receptors located in the mucus membranes of the eyes, mouth, nose, and gut (Mason 1997). When used in sufficient concentration, trigeminal irritants can reduce foraging (Andelt et al. 1994), but the concentration response thresholds are unknown for most species and active ingredients. Deer repellents that use taste as a mode of action generally contain bittering agents like denatonium benzoate (Bitrex). However, herbivores generally do not avoid bitter compounds and deer repellents containing these compounds have had little success (Andelt et al.1992, 1994; Nolte et al. 1994*c*; Nolte 1998).

We evaluated the efficacy of 20 products in reducing black-tailed deer (*Odocoileus hemionus*) foraging on Western red cedar (*Thuja plicata*) and tested for trends in efficacy among the different modes of action and delivery systems currently in use. Repellent efficacy is always relative and may vary depending on numerous factors, including seasonal changes in plant palatability. Therefore, we tested the most effective products from the first (winter) study again in spring and summer when seedlings were growing actively and were more palatable to deer.

Methods

Study area

We used the captive herd of black-tailed deer (hereafter, deer) at the National Wildlife Research Center, Olympia, Washington, field station for all tests. The deer were born on the station and were tolerant of humans but not tame. To minimize handling stress, we opportunistically divided the deer into 5 enclosures with 5–6 deer/ enclosure. Each enclosure contained both sexes and all age classes. Deer enclosures varied in size from 0.75 to 2 ha with natural habitat consisting of Douglas-fir (*Pseudotsuga menziesii*), alder (*Alnus rubra*), and associated understory vegetation. Some natural forage was available and all animals had free access to pelleted food and water.

Winter test of all repellents

After reviewing current literature, catalogs, and the Internet, we identified 32 products advertised as deer repellents. From this list, we selected 20 products representing the widest possible range of active ingredients, including combinations of ingredients (Table 1). We included all 4 modes of action (fear, conditioned aversion, taste, and trigeminal irritants) and the 2 most common delivery systems (topical applications and area repellents). Topical applications were applied directly to plant surfaces. Area repellents generally consisted of a scent dispenser (sachet, capsule, sponge, etc.) which was mounted on or near the plants to be protected. These dispensers emit scents which may prevent deer from approaching treated areas and plants.

We established 21 experimental plots in each of the 5 enclosures. Each plot consisted of 3 rows of 3 western red cedar trees spaced 1 m apart. In a study evaluating repellent efficacy on 3 tree species—Western red cedar, Douglas-fir, and Ponderosa pine (*Pinus ponderosa*)—used commonly in commercial reforestation in the Pacific Northwest, red cedar seedlings were damaged more frequently than either of the 2 other species (Nolte 1998). Seedlings were an average of 52.2 cm tall (SD=9.1) with numerous lateral branches. Because of the natural vegetation in the pens, we were unable to evenly space all plots within a pen. However, all plots were $\geq$10 m apart, a distance greater than the <one m average effective distance of area repellents that we observed in other tests with similar products (Nolte and Wagner, unpublished data). We planted seedlings in test plots immediately prior to treatment. We randomly assigned treatments, a control (untreated) and the 20 selected products, among the plots within an enclosure.

Fifteen products were topical applications that we applied directly on plant surfaces. We followed manufacturer application recommendations for all products. All but 3 of the 15 products were either premixed solutions or concentrates mixed with water and were applied following label directions. Of the remaining 3 topical repellents, 1, Deer Away Big Game Repellent® powder (BGRP), was dusted on plants after we misted the seedlings with water. We obtained special directions from the manufacturers for use with Hot Sauce® and Orange TKO®. We mixed Hot Sauce, Vapor Gard®, and water to form a solution that contained 6.2% Hot Sauce and 2.0% Vapor Gard. The Hot Sauce concentration was one recommended by the product label, but the

Table 1. Product names, sources, active ingredients, and modes of action for repellents evaluated to reduce black-tailed deer damage to Western red cedar seedlings in an outdoor pen study conducted from October 1998 to March 1999 in Olympia, Washington, USA.

Mode	Product	Active Ingredient
CA[a]	Detour™, Sudbury Consumer Products Co., Phoenix, Ariz.	7% thiram
Fear	Deerbuster's™ Coyote Urine Sachet, Trident Enterprises, Frederic Md.	50% coyote urine
Fear	Wolfin, Pro Cell Bioteknik, Hornefors, Sweden	Di (N-alkyl) sulfides
Fear	Deerbuster's™ - Deer and Insect Repellent, Trident Enterprises, Frederic, Md.	99.3% garlic juice
Fear	Deer Away® Big Game Repellent, powder, IntAgra, Inc. Minneapolis, Minn.	36% putrescent whole egg solids
Fear	Deer Away® Big Game Repellent, spray, IntAgra, Inc. Minneapolis, Minn.	4.93% putrescent whole egg solids
Fear	Bye Deer®, Security Products, Co., Phoenix, Ariz.	85% sodium salts of mixed fatty acids
Fear	Hinder®, Pace International LP, Kirkland, Wash.	0.66% ammonium soaps of higher fatty acids
Fear	Plantskydd™, Tree World®, Lackawanna, N.Y.	87% edible animal protein (in concentrate)
Pain	Hot Sauce®, Miller Chemical and Fertilizer Corp., Hanover, Pa.	0.53% capsaicin and related compounds
Pain	Deer Away® Deer and Rabbit Repellent (DRR), IntAgra, Inc., Minneapolis, Minn.	0.625 capsaicin and related compounds, 0.21% allyl isothiocyanate
Taste	Ropel®, Burlington Scientific Corp., Farmington, N.Y.	0.065% denatonium benzoate, 0.35% thymol
Taste	Tree Guard®, Nortech Forest Technologies, Inc., ST. Paul, Minn.	0.2% denatonium benzoate
Taste	Orange TKO, TKO Industries, Calgary, Alberta, Canada	d-limonene
Multiple	Deer Stopper™, Landscape Plus, Chester, N.J.	3.8% thiram, 0.05% capsaicin, 1.17% egg solids
Multiple	Not Tonight Deer™, Not Tonight Deer, Mendocino, Calif	88% dehydrated whole egg solids, 12% Montok pepper (in concentrate)
Multiple	Plant Pro-Tec®, Plant Pro-tec, LLC, Palo Cedro, Calif	10% oil of garlic, 3% capsaicin and related compounds.
Multiple	Dr. T's Deer Blocker, Dr. T's Nature Products, Inc. Pelham, Ga.	3.12% putrescent whole eggs, 0.0006% capsaicin, 0.0006% garlic
Multiple	Deerbuster's™ Deer Repellent Sachets, Trident Enterprises, Frederic Md.	99% meat meal,1% red pepper
Multiple	N.I.M.B.Y.®, DMX Industries, St. Louis, Mo.	0.027% Capsaicin and capsaicinoid product, 4.3% castor oil

[a] Conditioned aversion.

Vapor Gard concentration was 4 times the labeled concentration. The new concentration of Vapor Gard was recommended by the manufacturer in response to data from Wagner and Nolte (2000) that indicated there may be problems with Hot Sauce durability under field conditions. The label for Orange TKO stated that it could be used as a deer repellent, but did not specify the formulation. We used the manufacturer recommended concentration of 3.1% Orange TKO.

The 5 remaining products were area repellents. Four products—Plant Pro-Tec®, Bye Deer®, Deerbuster's™ sachets, and Wolfin—were in prepackaged units. We attached 1 Plant Pro-Tec capsule near the terminal bud of each seedling in a plot. We used 2 Wolfin capsules/plot with each capsule attached to a metal stake at 1.2 m above the ground. We centered stakes within diagonally opposite quarters of the plot. We tied Deerbuster's and Bye Deer sachets to wooden stakes and placed the stakes as close to each seedling as possible. Sachets were at a height equal to or just above the terminal bud of the seedlings. Deerbuster's urine sachets did not come in a prepackaged unit. We soaked sachets containing an absorptive gel in a 1:1 coyote (*Canis latrans*) urine:water solution for 24 hours before application. We placed 4 urine sachets on stakes at the perimeter of each plot, 0.30 m diagonally from each corner seedling. Like Bye Deer and Deerbuster's sachets, we set urine sachets at a height equal to or just above the terminal bud of the seedlings.

We examined seedlings for browse damage at 24 hours, 48 hours, and 1 week post planting, and then at 1-week intervals thereafter for 18 weeks. We recorded number of bites taken from each seedling (damage score), but limited bite counts to a maximum of 25, because after 25 bites the seedlings were generally defoliated. We regarded seedlings that were pulled out of the ground as completely defoliated and thereafter recorded as having >25 bites. The mean damage score for the 9 seedlings/treatment/pen was used in the data analysis. We used a general linear model analysis (SAS® Version 6.12, SAS Institute Inc, Cary, N.C.) to test for treatment effects within each data-collection interval. When treatment effects were observed for a data interval, we used pairwise comparisons to test the hypothesis that there was no difference in damage between untreated seedlings and seedlings with any other treatment. We also tested the hypothesis that there was no difference between damage to seedlings treated with BGRP and seedlings with any of the other treatments. Big Game Repellent powder is used commonly by the timber industry and served as a standard for comparison of repellent efficacy in our test.

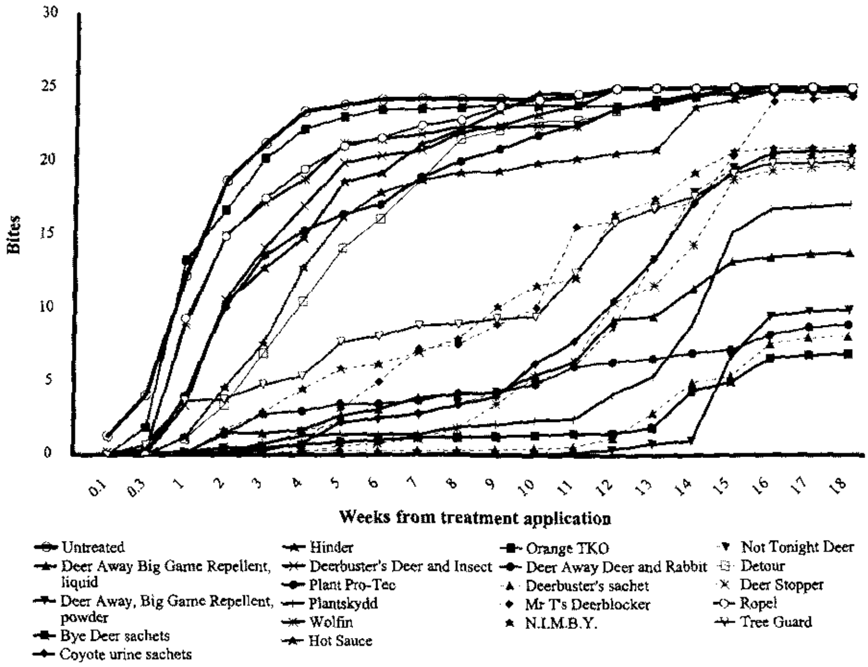

Figure 1. Average number of bites (maximum = 25) taken from repellent-treated Western red cedar seedlings by black-tailed deer in an outdoor pen study conducted from October 1998 to March 1999 in Olympia, Washington, USA.

All animal care and use for this study was approved by National Wildlife Research Center's Institutional Animal Care and Use Committee, protocol numbers 595 and 706.

Spring test of the 5 most effective products

We repeated the study from May to July 1999 using a control (untreated) and 5 products that reduced damage for the longest period of time in the winter test (Plantskydd™, Deerbuster's sachets, Bye Deer sachets, BGRP, and Deerbuster's Deer and Rabbit Repellent® [DRR]). We applied Plantskydd, BGRP, and DRR in the same manner as the winter study. Although Plantskydd and Deer Away Big Game Repellent liquid (BGRL) had similar results in the winter test, we selected Plantskydd because it did not drop to moderately effective until later in the study and because it provided the opportunity to test a different active ingredient. Due to a communication error, Deerbuster's sachets and Bye Deer sachets were mounted at half the height of the seedling or lower instead of being mounted at the same height as the terminal bud as in the winter test. We collected and analyzed data in the same manner as the winter study.

Summer test of area repellents

The difference in application method for the Deerbuster's and Bye Deer sachets between the winter and spring tests may have influenced product efficacy. Therefore, we repeated the study again from June to July 1999 using control (untreated), Bye Deer, and Deerbuster's sachets as treatments. We applied sachets in the same manner as in the winter study. Data collection and analysis were identical to the winter study.

Results

Winter test of all repellents

Foraging pressure on the seedlings was relatively low and there were no treatment effects ($F_{20,80} \leq 0.90$, $P \geq 0.49$) during the first 48 hours (Figure 1, Table 2). Damage to seedlings treated with Orange TKO, Wolfin capsules, and Ropel did not differ from damage to untreated seedlings at any point in the test ($F_{1,80} \leq 2.60$, $P \geq 0.11$). Average number of bites taken from seedlings was the least for seedlings

Table 2. Time (weeks) in each damage class for repellents evaluated to reduce black-tailed deer damage to Western red cedar seedlings in an outdoor pen study conducted from October 1998 to March 1999 in Olympia, Washington, USA.Treatments did not differ until week 1.

Product	Mode of action	Delivery system	Damage < Untreated[a]	Damage > BGRP[a]
Wolfin	Fear	Area	0	1–18
Ropel	Taste	Topical	0	1–18
Orange TKO	Taste	Topical	0	1–18
Hinder	Fear	Topical	1–4	2–18
Deerbuster's Deer and Insect Repellent	Fear	Topical	1–4	2–18
Plant Pro-Tec	Pain	Area	1–6	2–18
Detour	CA[b]	Topical	1–6	3–18
Hot Sauce	Pain	Topical	1–6	3–18
N.I.M.B.Y	Pain	Topical	1–11	5–18
Tree Guard	Taste	Topical	1–12	5–18
Dr. T's Deerblocker	Fear, Pain	Topical	1–12	7–18
Deerbuster's Coyote Urine	Fear	Area	1–13	12–18
Not Tonight Deer	Fear, pain	Topical	1–13	13–18
Deer stopper	CA[b], fear, pain	Topical	1–14	12–18
Deer Away Big Game Repellent, liquid	Fear	Topical	1–18	12–14
Plantskydd	Fear	Topical	1–18	0
Deer Away Big Game Repellent, powder	Fear	Topical	1–18	0
Deer Away Deer and Rabbit Repellent	Pain	Topical	1–18	0
Deerbuster's Deer Repellent sachet	Fear, Pain	Area[c]	1–18	0
Bye Deer sachet	Fear, Pain	Area[c]	1–18	0

[a] $P > 0.05$

[b] Conditioned aversion.

[c] Repellent dripped from sachets onto plant surfaces. Product may have been working as an area and a topical repellent.

treated with BGRP until week 15, when seedlings treated with Bye Deer had the least average number of bites. Deer Away Big Game Repellent powder, BGRL, DRR, Plantskydd, Bye Deer, and Deerbuster's sachets had less damage than controls from week 1 to the end of the study ($F_{1,80} \geq 3.76$, $P \leq 0.05$). Except for BGRL, damage to seedlings with these products did not differ from damage to BGRP seedlings ($F_{1,80} \leq 3.04$, $P \geq 0.08$). BGRL seedlings had more damage than BGRP seedlings from week 12 through week 14 ($F_{1,80} \geq 4.04$, $P \leq 0.04$). Deer Stopper™, coyote urine sachets, and Not Tonight Deer™ seedlings had less damage than controls for 13-14 weeks ($F_{1,80} \geq 5.93$, $P \leq 0.02$) and did not differ from BGRP ($F_{1,80} \leq 3.59$, $P \geq 0.06$) until weeks 12-13. Tree Guard, N.I.M.B.Y., and Dr. T's Deerblocker seedlings had less damage than controls for 11-12 weeks ($F_{1,80} \geq 3.67$, $P \leq 0.05$) but more damage than BGRP after weeks 4-6 ($F_{1,80} \geq 8.53$, $P < 0.01$). Hot Sauce, Deerbuster's Deer and Insect Repellent, Plant Pro-tec, Hinder, and Detour™ had less damage than controls for 4-6 weeks ($F_{1,80} \geq 4.82$, $P < 0.03$) and had more damage than BGRP seedlings after 2-3 weeks.

The compound in the coyote urine sachets that absorbed the urine also absorbed rainwater. The clear gelatin-like substance in the bags overflowed the bags and was found in clumps at the base of the stakes for the first 10 weeks of the study. None of the repellent fell on the seedlings. Some of the product in the Deerbuster's sachets and the Bye Deer sachets dissolved in rain and left a residue on plant parts below the sachets.

Spring test of the 5 most effective products

There was no difference among treatments until week 3 ($F_{5,20} \leq 2.49$, $P \geq 0.07$, Figure 2). The only difference in damage among untreated, DRR, Bye Deer sachet, and Deerbuster's sachet seedlings was during week 5 when seedlings with Deerbuster's sachets had less damage than untreated seedlings ($F_{1,20} = 4.24$, $P = 0.05$). BGRP and Plantskydd ($F_{1,20} \leq 1.30$, $P \geq 0.27$) had less damage than untreated seedlings for weeks 3-11 ($F_{1,20} \leq 5.33$, $P \geq 0.03$). For weeks 3 and 4, BGRP seedlings also had less damage than seedlings with DRR, Deerbuster's sachets, or Bye Deer sachets ($F_{1,20} \geq 4.44$, $P \leq 0.05$). For weeks 5 and 6, BGRP seedlings had less damage

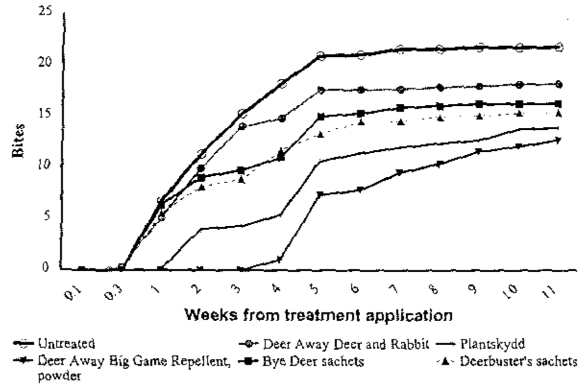

Figure 2. *Average number of bites (maximum = 25) taken from* repellent-treated Western red cedar seedlings by black-tailed deer in an outdoor pen study conducted from May to July 1999 in Olympia, Washington, USA. Sachets were placed on stakes beside seedlings at approximately one-half the height of the seedling.

than control, DRR, and Bye Deer seedlings ($F_{1,20} \geq 4.10$, $P \leq 0.05$). During weeks 7 and 8, BGRP seedlings still had less damage than control and DRR seedlings ($F_{1,20} \geq 4.20$, $P \leq 0.05$). From week 9 to 11, only untreated seedlings had more damage than BGRP seedlings ($F_{1,20} \geq 7.19$, $P \leq 0.01$).

Summer test of area repellents

We did not observe a treatment effect until week 1 ($F_{2,8} \leq 4.16$, $P \geq 0.06$, Figure 3). Deerbuster's and Bye Deer sachets had less damage than control seedlings ($F_{1,8} \leq 3.09$, $P \geq 0.12$) for the duration of the test.

Discussion

Plantskydd, BGRP, BGRL, DRR, Bye Deer, and Deerbuster's sachets reduced damage for all 18 weeks of the winter study. BGRP and BGRL have reduced deer foraging in several earlier studies (BGRL, Harris et al. 1983, Conover 1984, Andelt et al. 1994; BGRP, Milunas et al. 1994, Nolte et al. 1995, Nolte 1998). In our study, BGRP appeared to be more effective than BGRL. Whether this difference was attributable to differences in concentration of active ingredient, delivery system, or differences in product formulation (sticker used to adhere product to plant surfaces) is unclear. Plantskydd also reduced deer foraging on tree seedlings in 2 prior studies (Bergquist and Örlander 1996, Nolte 1998).

Of the 5 products tested in spring and summer, all but DRR reduced damage in at least 1 test. However, Deerbuster's and Bye Deer sachets were effective only when the sachets were placed so that any product dissolving in rainwater could drip onto plant surfaces. Reasons for the diminished deer response to DRR in spring study were unclear. It is possible that the concentration of trigeminal irritants in DRR was insufficient to deter foraging when plant palatability was great.

Wolfin, Ropel®, and Orange TKO did not reduce damage during the winter test. Ropel has failed to reduce damage in several prior studies (Swihart and Conover 1990, Andelt et al. 1992, Witmer et al. 1997). Although data are not available on Orange TKO, like Ropel, its active ingredient is a bittering agent. As mentioned above, herbivores generally do not avoid bitter compounds, and other deer repellents containing these compounds have had little success (Andelt et al. 1992, 1994; Nolte et al. 1994*c*; Nolte 1998).

In general, topical repellents performed better than area repellents. Two of the 5 area repellents, Wolfin and Plant Pro-Tec capsules, either failed to reduce damage or reduced damage for ≤6 weeks. Only 1 area repellent, coyote urine sachets, was among the longest lasting repellents without some question as to its mode of action. Bye Deer and Deerbuster's sachets reduced damage throughout the winter test, but data from the spring and summer tests indicated that efficacy of these products may be attributable to their functioning as topical repellents and not as an area repellent. These products were effective only when sachets were placed near the terminal bud so that repellent could drip onto the seedlings. In winter and summer tests, product residue from the sachets could be seen accumulating on plant surfaces. Therefore, the sachets may serve as a continual delivery system for

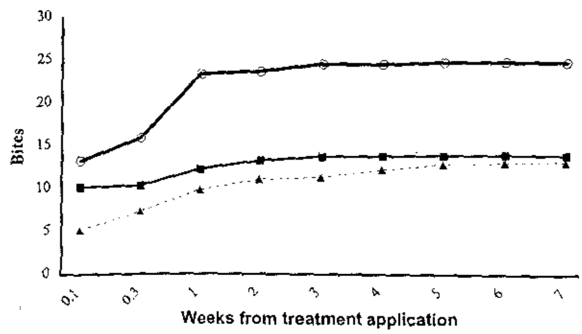

Figure 3. Comparison of the average number of bites (maximum = 25) taken by black-tailed deer from Western red cedar seedlings treated with area repellents in an outdoor pen study conducted from June to July 1999 in Olympia, Washington, USA. Sachets were placed on stakes beside seedlings at a height at or near the terminal bud.

A sample of the many deer repellents currently available.

a topical repellent. Alternatively, the size of the area that could be protected by the sachets may be extremely limited. With the sachets on higher stakes and close to the terminal bud, deer may encounter the odor early in their investigation of the seedlings and the sachets may have deterred further pursuit of the seedlings as food.

None of the modes of action were successful uniformly, but products emitting sulfurous odors generally had the greatest potential. Eight of the 9 products that remained in the class of repellents with the least damage for ≥11 weeks emitted sulfurous odors. Products containing decaying animal proteins did especially well. All products containing egg or other animal proteins had less damage than untreated seedlings for ≥12 weeks. In contrast, of the 8 products that did not use fear as a mode of action, 2 products never reduced damage, 4 products reduced damage for ≤6 weeks, and 2 reduced damage for 11-12 weeks.

Not all products emitting sulfurous odors reduced damage. Wolfin (Di [N-alkyl] sulfides) never reduced damage and Deerbuster's Deer and Insect repellent (garlic), Hinder® (ammonium soaps of higher fatty acids), and Plant Pro-Tec capsules (garlic) had less damage than untreated seedlings for ≤6 weeks. For Wolfin and Plant Pro-tec capsules, some of the problem may have been attributable to the delivery system (area repellent). For the products that did reduce damage for a brief period, it is possible that the limited efficacy was related to problems with repellent dilution or decomposition under field conditions. Additionally, all sulfurous odors are not equally effective in reducing damage and it is possible that the relatively low success of some of these products is related to the specific chemical compounds in the repellents. Epple et al. (1995) found that only some of the sulfur compounds extracted from predator urines and anal gland secretions were effective in reducing foraging by mountain beaver (*Aplodontia rufa*).

Performance of products containing trigeminal irritants may be attributable to the amount of active ingredient required to induce a response in the target species. In studies by Andelt et al. (1994) comparing impact of 0.06%, 0.62%, and 6.2% Hot Sauce solutions on mule deer foraging (*Odocoileus hemionus*), repellent efficacy increased as concentration of capsaicin increased. Of the topical repellents we tested, only DRR (0.625% capsaicin and related compounds) had a concentration of capsaicin or related compounds similar to the 6.2% Hot Sauce solution (0.53 % capsaicin and related compounds) which reduced deer foraging in other studies (Andelt 1994,Wagner and Nolte 2000). Dr. T's Deerblocker, N.I.M.B.Y.®, and Not Tonight Deer had concentrations of capsaicin and related compounds which were less than that of Hot Sauce formulations that provided moderate (0.62% Hot Sauce) or no (0.06% Hot Sauce) protection from deer foraging (Andelt et al.1994).

Repellents were applied to western red cedar seedlings planted in deer pens at the National Wildlife Research Center, Olympia Field Station.

As with some products emitting sulfurous odors, the limited period of efficacy for some products containing trigeminal irritants and aversive agents also may have been related to product formulation. Hot Sauce, Detour, and Deer Stopper all reduced damage for at least some part of the study. Hot Sauce also reduced damage for a brief period in a prior study (Wagner and Nolte 2000). Product durability under field conditions may be especially important for products that do not have an associated odor cue, because animals will continue to sample treated areas and may be quick to notice a reduction in repellent concentration.

This study provides some guidelines for product efficacy, but extensive work still needs to be done before the full potential of chemical repellents can be realized. Wide variations in product formulation and lack of information available on the compounds covered under the blanket label of "inert ingredients" will continue to make it difficult to make predictions about product efficacy. The greatest benefit may be achieved by identifying the concentration of active ingredient required to induce the desired response. Research efforts can then focus on products containing adequate amounts of these compounds. This information, combined with data from residue analysis of product exposed to set environmental conditions, also could be used to help predict product durability under field conditions.

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