WITMER, G. W., R. D. SAYLER, and M. J. PIPAS. 1997. Repellent trials to reduce reforestation damage by pocket gophers, deer, and elk. Pages 321-332 *in* Mason, J. R., editor. Repellents in Wildlife Management (August 8-10, 1995, Denver, CO). USDA, National Wildlife Research Center, Fort Collins, CO.

27
Repellent Trials to Reduce Reforestation Damage by Pocket Gophers, Deer, and Elk

Gary W. Witmer, USDA/APHIS—Denver Wildlife Research Center, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164-6410

Rodney D. Sayler, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164-6410

Michael J. Pipas, USDA/APHIS—Denver Wildlife Research Center, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164-6410

ABSTRACT

We tested selected, potential repellents in pen and field trials to determine their ability to reduce consumption of palatable foods by pocket gophers *(Thomomys talpoides)*, deer *(Odocoileus* spp.), and elk *(Cervus elaphus)*. Only sulfur-based compounds (predator urines and Deer Away®) deterred feeding by captive gophers. Chemically hot, bitter, and noxious compounds and plants did not deter gopher feeding. Rapid reinvasion of available habitat by pocket gophers in a field trial occurred despite the presence of encapsulated, sulfur-based semiochemicals of stoat *(Mustela erminea)* on trial plots. Coyote urine and Deer Away deterred browsing by captive deer for the 3-day period of pen trials. A bitter compound, garlic oil, and encapsulated, sulfur-based semiochemicals of stoat did not deter feeding by captive deer. In a winter field trial with these test materials and Deer Away, hungry deer and elk were deterred only by Deer Away. We recommend further trials with encapsulated volatile compounds of predator urines.

KEY WORDS

Cervus elaphus, deer, elk, pocket gopher, repellents, semiochemicals, Odocoileus spp., Thomomys talpoides, wildlife damage

INTRODUCTION

Reforestation success in the Pacific Northwest is often hindered by feeding activities of pocket gophers, deer, and elk (Borrecco and Black 1990). Damage by gophers begins after spring tree planting, but can be acute during winter when forage is scarce. Trees can be damaged up to about 6 years in age. Deer and elk damage occurs during winter and spring and continues until lower branches grow above browsing height (about 1.5 m). Traditional damage control methods include the use of toxic baits or kill traps for gophers (Case and Jasch 1994) and the use of tubes around seedlings for deer and elk (Campbell 1987, Craven and Hygnstrom 1994, deCalesta and Witmer 1994). These methods are becoming less favorable due to various factors, including cost, social acceptance, or perceived environmental hazards.

Repellents offer a potential alternative to reduce reforestation damage with fewer constraints than traditional damage control methods (Nolte et al. 1994*a*). Although there has been some research on the effects of various potential repellents on pocket gophers, results have not been particularly promising and little work has been published (Case and Jasch 1994, Marsh and Steele 1992). However, Sullivan et al. (1988, 1990) noted that predator odors may be effective repellents for pocket gophers. It is reasonable that pocket gophers would be sensitive to predator odors above ground because they do substantial foraging above ground and juveniles often disperse above ground; both activities expose them to predators and predation rates can be substantial (Marsh and Steele 1992). No repellents are registered in the United States specifically for the reduction of pocket gopher damage (Jacobs 1994), although a few repellents registered for multiple mammalian species claim effectiveness against gophers. Thus there is a clear need to develop and register an effective gopher repellent.

Considerably more effort has been directed toward testing repellents against deer and elk feeding, and a number of products are registered in the United States (Craven and Hygnstrom 1994, deCalesta and Witmer 1994, Jacobs 1994). There is considerable debate over the effectiveness of these products, which seems to vary from one situation to another. Cost, the need for repeated treatments, and limitations on use are additional major obstacles to the extensive use of repellents (Craven and Hygnstrom 1994, Rochelle 1992). Hence, there is a need for further trials with these products, and trials with new, untested or little-tested materials.

Our objective was to test a variety of commercially available repellents, unregistered compounds, and unpalatable plants in pen and field trials for their ability to reduce feeding activities by gophers, deer, and elk. The materials contained bitter, hot, sulfurous, potentially toxic, or otherwise noxious substances. Reference to trade names or companies does not imply U.S. Government endorsement of commercial products or exclusion of a similar product with equal or better effectiveness. Feeding on treated foods was compared with untreated palatable foods in pen trials. Captive deer and pocket gophers maintained at Washington State University (WSU), Pullman, WA, were used for pen trials. Field trials were conducted on reforestation units of the Clearwater National Forest, ID.

STUDY AREAS AND METHODS

Pen Trials

Fourteen pocket gophers of both sexes were maintained indoors in individual metal tanks. Each tank was filled with soil about 0.3 m deep in which the resident gopher maintained a closed burrow system. The gophers received about 10 g of pelleted rabbit chow, a small piece of carrot and apple, and ad libitum water each day. Straw was provided on the surface for nesting material along with a small piece of willow (*Salix* sp.) branch for chewing material. All animals were maintained according to approved protocols. Facilities were inspected several times a year by veterinarians of USDA/APHIS or WSU. On trial days, pellets and water were provided as usual, but not carrot or apple pieces. The two-choice trials were structured as follows: wooden sticks, each with five skewered apple chunks (about 1-cm^3 each) were randomly placed (front or back) in the tank. One apple stick was treated with a test compound; the other was an untreated control. Gophers had to bite into apple chunks to remove them from the sticks. Appl sticks were checked 24 hr later and the number of remaining apple chunks recorded. The materials tested and percentage active ingredient were: coyote urine (diluted 1:2, urine:tapwater); bobcat urine (diluted 1:2, urine:tapwater); 4-cm tubes of encapsulated predator odor (EPO) of stoat, (10 mg mixture of 2 semiochemicals 3-propyl-1,2-dithiolane and 2-propylthietane encapsulated in an inert polymeric matrix); red pepper (dry, crushed); garlic powder (dry, ground); Ani-Pel® (dry, crushed tablets containing 14% denatonium benzoate); Ropel® (liquid, 0.065% denatonium saccharide); Tree Guard® (liquid, 0.2% denatonium benzoate); Sudbury Chaperone® (liquid, 7% thiuram); Chacon Liquid Animal Repellent® (liquid, 21% thiuram); Repel® (powder, 20% paradichlorobenzene); Deer Away® (36% putrid egg solids). Apple chunks to be treated were placed on sticks and dipped in liquid materials; powdered materials were sprinkled on apple chunks after the sticks and apple had been wet by dipping in a saturated, aqueous solution of the test material. Each animal received each treatment twice, but the same compound was never tested in consecutive trials. All statistics were calculated using JMP® statistical software (SAS Institute, Inc. 1995). A one-way ANOVA test was used to compare the consumption of treated apples. If overall means were significantly different, Dunnett's method was used to compare each treatment mean with the control mean.

Six to ten deer, maintained in a 1.0-ha fenced pasture at WSU for a variety of research and educational purposes, were fed a daily ration of nutritionally supplemented, pelleted deer food; and water was provided ad libitum. We presented the deer with pairs of potted seedlings (three seedlings per pot) that were untreated (controls) or treated with various test materials. Only one test material was used per pot, and pairs of pots were placed at least 3 m away from a pair of pots receiving another treatment to avoid confounding odor effects. Douglas-fir *(Pseudotsuga menziesii)* and western redcedar *(Thuja plicata)*, both palatable to deer and elk and important commercial tree species, were used in the trials. Pots were left in the deer pen for 3 days and then checked for browsing damage. These were multiple-choice trials with at least six pots and three compounds tested in each trial. The materials tested and percentage active ingredients were: coyote urine (diluted 1:2, urine:water); 4-cm tubes of EPO of stoat, (10 mg mixture of two semiochemicals, 3-propyl-1,2-dithiolane and 2-propylthietane encapsulated in an inert polymeric matrix); Tree Guard (liquid, 0.2% denatonium benzoate); Deer Away (36% putrid egg solids); garlic capsules (each containing 10% oil of garlic); plastic mesh tubes completely enclosing the seedling; and untreated (control) seedlings. Statistical analyses were not performed on these limited pen trials that were conducted as pretrials to a field trial. Additionally, the response in every case was all or none: either all seedlings of a given treatment were severely browsed or none were browsed.

Field Trials

A pocket gopher repellent field trial was conducted on a reforestation unit (T41N, R1W, Section 2) of the Clearwater National Forest, Latah County, near Bovill, ID. The unit was located in the ponderosa pine *(Pinus ponderosa)* forest zone at an elevation of approximately 1,000 m. The 17-ha unit had a northeast aspect and an average slope of 7%. The site was harvested and burned in the fall of 1991. Ponderosa pine seedlings were planted in May 1992, but pocket gophers removed most of those seedlings within 2 years of planting.

The entire unit was cleared of pocket gophers during the summer of 1994 by a U.S. Forest Service-directed contract baiting operation. Six 0.4-ha test plots were established. Additionally, kill-trapping was conducted the week before treatment application to remove any remaining resident gophers. The six plots received one of two treatments, randomly assigned: (1) application of 4-cm tubes of EPO of stoat, containing the two semiochemicals 3-propyl-1,2-dithiolane and 2-propylthietane in an inert polymeric matrix, both above and below ground, or (2) no treatment (control). EPO treatment involved the placement of a grid of capsules with a spacing of about 10 m over the entire 0.4-ha surface of each treated plot. Additionally, one or two EPO's were placed inside each burrow system that could be located (about 40 systems per ha) by probing on the EPO-treatment plots. After placement of the EPO in the burrow, the burrow was recovered with soil. Treatments were applied on 3 November 1994.

On 11 July 1995, the six 0.4-ha plots were surveyed for gopher surface activity (mounds and feeding plugs). Six transects (70 $\times$ 2 m) were established in each plot and the gopher activity enumerated in those transects. A cluster of surface activity was assumed to be from one active gopher burrow system. The number of active systems in treated and control plots was compared using a t-test.

A deer/elk repellent field trial was conducted on a reforestation unit (T41N, R6E, Section 27) of the Clearwater National Forest, Clearwater County, north of Orofino, ID. The unit is within the western redcedar/queen cup beadlily *(Clintonia uniflora)* habitat type at an elevation of approximately 800 m. The 8.4-ha unit has a west aspect and an average slope of 30%. The site was harvested and burned in the fall of 1993. Douglas-fir and white pine *(Pinus monticola)* seedlings were planted in May 1994. The area is important elk winter range, but also supports resident deer and elk.

There were 18 test plots on the unit. Each plot contained 5 rows of 5 seedlings each for a total of 25 seedlings, spaced at about 2- $\times$ 2-m intervals. The plots were distributed about the unit with at least 10-m spacing between plots. The six treatments were: (1) foliar application of Deer Away powder (36% putrid egg solids), (2) foliar application of Deer Away liquid (4.5% putrid egg solids when diluted as per label directions), (3) a clip-on garlic capsule, containing 10% garlic oil, (4) 4-cm tubes of EPO of stoat (containing 10 g of two semiochemicals 3-propyl-1,2-dithiolane and 2-propylthietane in an inert polymeric matrix), (5) foliar application of Tree Guard, containing 0.2% denatonium benzoate, and (6) foliar application of water only (control). Seedlings were sprayed with water before being completely sprinkled with Deer Away powder. Deer Away liquid and Tree Guard contain a latex formulation and were sprayed on seedlings until they were completely covered. One garlic capsule was clipped on the main stem of each seedling in that treatment group. One capsule of encapsulated predator odor was placed on the ground at the base of each seedling in that treatment group; it was assumed that the volatile predator odor would permeate the immediate area of the small (15–20 cm) seedlings. Treatments were randomly assigned to plots and replicated three times. Seedlings of previously planted conifer species (Douglas-fir and white pine) were used. Each seedling was uniquely identified with a wooden stake listing its plot number and a number from 1 to 25. All treatments were applied on the same day, 25 October 1994. Height and browsing damage by deer and elk were recorded for the seedlings initially (on treatment day) and on 16 May 1995. No attempt was made to differentiate between deer and elk damage. A one-way ANOVA test was used to compare the percentage of seedlings browsed between treatments. If overall means were significantly different, Dunnett's method was used to compare each treatment mean with the control mean (SAS Institute, Inc. 1995).

RESULTS AND DISCUSSION

Pocket Gophers

Fourteen materials were tested as potential gopher repellents in pen trials (Figure 1). Only predator urines and Deer Away significantly reduced food intake by gophers ($P < 0.001$). These compounds were all tested as contact (i.e., topically applied) repellents, but in two previous field trials with a potential systemic (i.e., a compound taken up by the root system and distributed throughout the plant) repellent, the bitter compound denatonium benzoate, we found no repellency of gophers to treated seedlings (G. Witmer, unpubl. data). Nolte et al. (1994*b*) also found predator urines to have repellency against several rodent species and speculated that the high sulfur content of urine of meat-eaters might be responsible. However, Swihart et al. (1991) isolated dichloromethane from bobcat urine and found that this compound was an effective herbivore repellent.

We did not detect repellency by wild ginger *(Asarum caudatum*; Figure 1), although other researchers have suggested that it possesses repellent characteristics (D. Campbell, pers. comm.). Most gophers took gopher purge plant *(Euphorbia lathyrus)* parts underground or into nest boxes, but appeared to do little feeding on them. The plant is toxic, but it is possible that a nontoxic extract could be isolated for use as a repellent. Similar work is being pursued with the toxic plant foxglove *(Digitalis purpurea*; D. Nolte, pers. comm.). It should be noted, however, that Von Carlowitz and Wolf (1991) did not demonstrate repellency from livestock and wild ungulate browsing using a latex extract of the toxic plant *Euphorbia tirucalli*.

The field trial with EPO and pocket gopher reinvasion was begun before the pen trials with potential gopher repellents were completed. The number of active gopher burrow systems on the EPO-treated plots ($\bar{x}$ = 24.7, SD = 6.7, n = 3) did not differ significantly (P = 0.374) from the number on the control (untreated) plots ($\bar{x}$ = 19.0, SD = 7.2, n = 3). Therefore, EPO application did not slow gopher reinvasion of vacant habitat. This result is consistent with the results of the pen trials (Figure 1); EPO's did not prevent many gophers from taking apple chunks. In pen trials, gophers occasionally took the EPO's down into their burrow systems. This result is contradictory to those reported by Sullivan et al. (1988, 1990). It is possible that by placing more

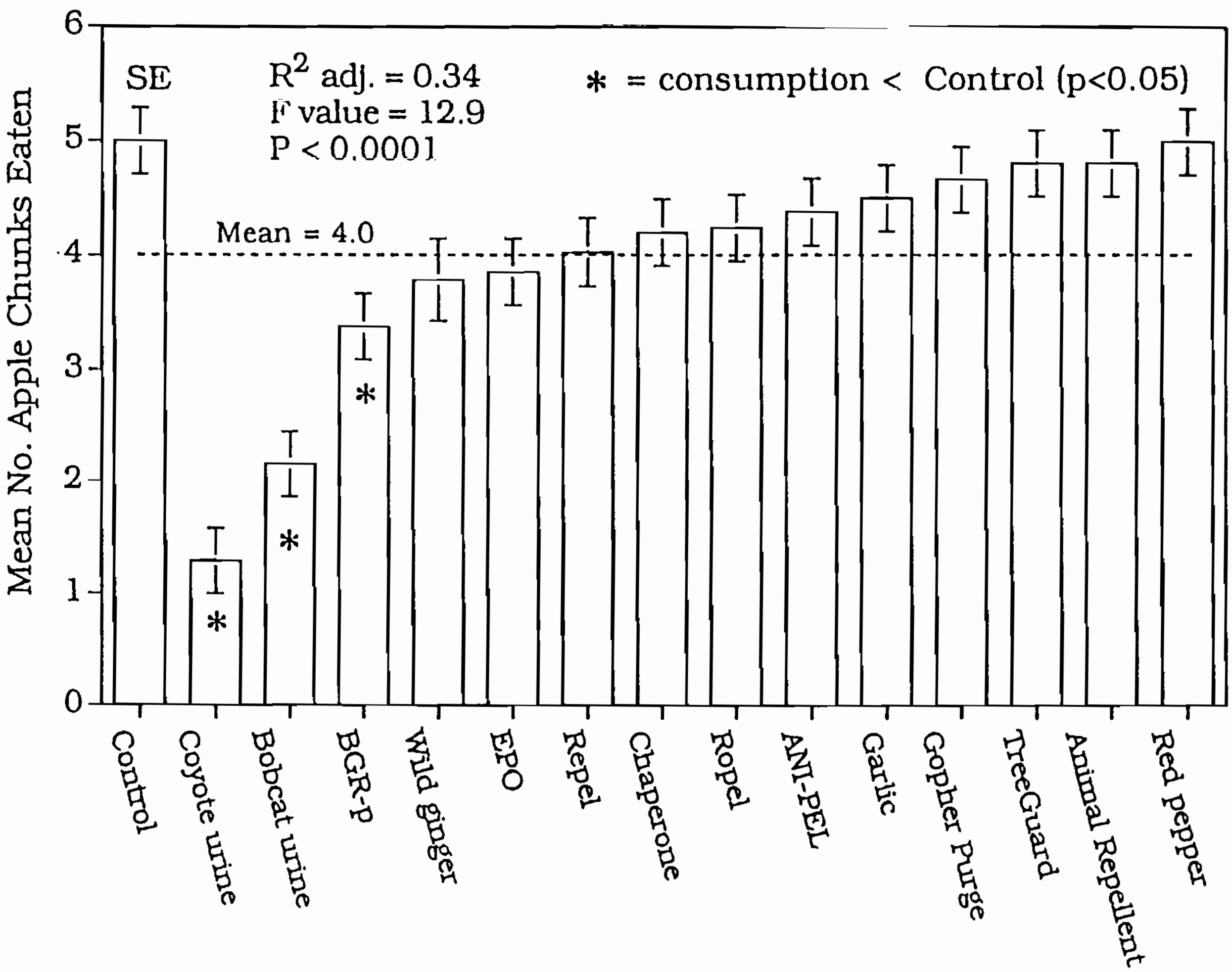

FIGURE 1. The average number (SE) of treated apple chunks eaten by pocket gophers in pen trials at Washington State University, Pullman, 1994–95.

EPO's into more burrow systems, we might have slowed gopher reinvasion to a greater extent. We do not believe that this would have occurred, however, because of the pen trial results and the fact that gophers can rapidly seal off portions of their burrow systems in response to noxious odors (Chase et al. 1982). It is possible that an encapsulated volatile compound from predator urine would be more effective as an EPO (Swihart et al. 1991).

Deer/Elk

Only coyote urine and Deer Away of the five repellents used in the deer pen trials repelled deer completely with none of the six seedlings treated with each repellent damaged. All six control seedlings and all seedlings (six each) treated with denatonium benzoate (Tree Guard), garlic capsules, and EPO's were heavily browsed. The 6 seedlings protected with plastic mesh tubes, a traditional method of protection against deer and elk, were also undamaged, although the tops of several tubes were chewed. USDA Forest Service personnel have noted damage to tubes by ungulates and livestock and subsequent high maintenance costs (G. Witmer, unpubl. observ.). It should be noted, however, that the deer in our pen trials received a normal food ration and hence were not considered food deprived. Hungry animals have been demonstrated to be less sensitive to repellents (Andelt et al. 1991, 1992).

Most repellents tried in the deer/elk field trial did not deter browsing, resulting in levels of damage very similar to that of the unprotected (control) seedlings (Figure 2). Only liquid and powder formulations of Deer Away (putrid egg solids) were effective as a repellent ($P<0.001$). Some researchers have found Deer Away to be an effective repellent (DeYoe and Schaap 1987, Palmer et al. 1983, Swihart and Conover 1990), while others have reported only moderate effectiveness (Conover 1984, Conover and Kania 1987). The effectiveness of Deer Away can decline over time, and effectiveness is related to how hungry the animals are (Andelt et al. 1991, 1992). Among reforestation specialists, there is disagreement as to whether Deer Away liquid or Deer Away powder is more effective as a deer/elk repellent. Our trials suggest that Deer Away powder is more effective, although it and Deer Away liquid both provided a substantial level of overwinter protection against deer/elk browsing.

Sulfurous garlic capsules, EPO, and a bitter compound (denatonium benzoate) did not deter deer/elk browsing (Figure 2). Sulfur-based compounds, common in most, if not all, predator anal gland, fecal, and urinary excretions, are presumably responsible for their repellency effect on herbivores (Nolte et al. 1994*b*). It is possible that deer/elk are exposed to enough predator odors that they are not adversely affected without reinforcement stimuli or that the EPO active ingredients (two semiochemicals from a small predator, the stoat) does not have a negative influence on them. Although some herbivores are repelled by some animal-generated (i.e., predator) odors that are sulfur-based (Nolte et al. 1994*b*), it appears that plant-generated sulfur odor materials (such as garlic) are not effective. Although we used stoat semiochemicals as the EPO in our field trial, coyote urine was effective in preventing deer browsing in our pen trials (as was Deer Away; both with sulfur-based compounds). We did not have an encapsulated predator urine available at the time of our field trials and did not include it as a test material. Other researchers have reported that predator urines and feces are effective repellents against deer or elk browsing (Melchiors and Leslie 1985, Müller-Schwarze 1972, Sullivan et al. 1985, Swihart et al. 1991). Nolte et al. (1994*a,b*) noted that the predator odors need to be from meat-eating predators, which increases sulfur compounds in the urine. The compounds evoking repellency are volatile and require encapsulation to extend the period of repellency (Sullivan et al. 1985, Swihart et al. 1991). Many (>25) volatile compounds have been isolated from bobcat urine, and further pen and field trials will be required to identify the most effective compound(s) (Mattina et al. 1991, Swihart et al. 1991).

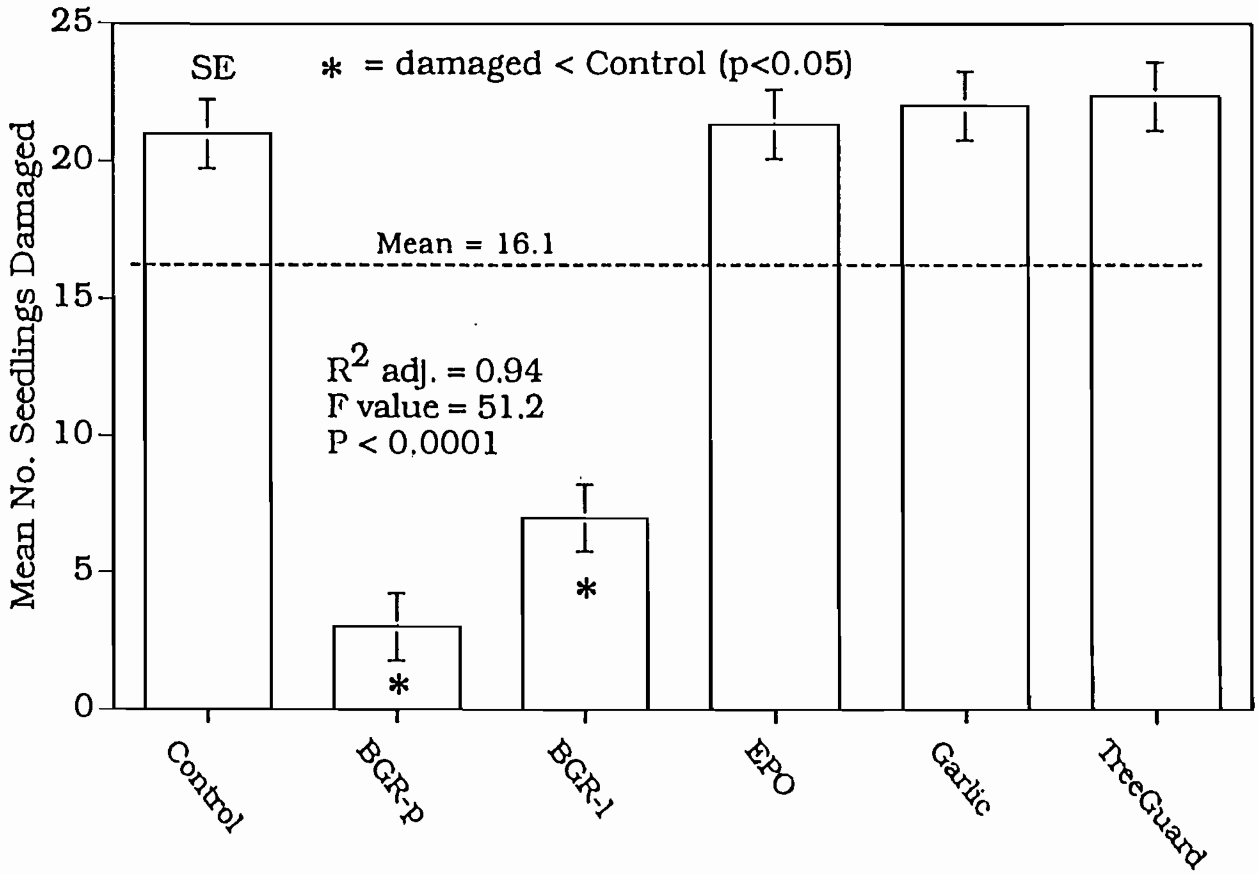

FIGURE 2. The average number (SE) of treated conifer seedlings damaged by deer and elk, Clearwater National Forest, ID, 1995.

There has been considerable effort put into developing bitter compounds (e.g., denatonium benzoate and saccharide) as animal repellents. Our trials and those of other researchers (Nolte et al. 1994*a*) have shown these to be rather ineffective, especially against herbivores. It could be that strict herbivores are adapted to eating bitter plant foods as part of their diet. It does appear, however, that omnivores (such as humans and bears that eat both plant and animal foods) are much more sensitive to bitter compounds. We are planning field trials to test the ability of bitter compounds to deter black bear *(Ursus americanus)* damage to trees.

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Based on our trials and those reported by others, we are not optimistic that an effective repellent for pocket gophers can be developed. However, predator urines do restrict feeding choices by pocket gophers in comparison to the other materials that we tested in short-term trials. Therefore, additional research should be directed towards volatile compounds of predator urines as these show the most promise of the various compounds tested. Meanwhile, traditional methods of gopher population reduction will be relied upon to reduce gopher damage. Other approaches, such as habitat modification by sheep grazing, may help reduce gopher populations and damage, but are not without some adverse environmental effects (Witmer and Campbell 1994). Physical barriers (such as plastic tubes) may provide some protection to seedlings (Engeman et al. 1995). Research on alternative gopher toxicants that are more target specific, have less secondary hazards, and degrade more quickly in the environment should continue (e. g., Clark 1994, Witmer et al. 1995).

There is reason for continued optimism about developing effective repellents to reduce damage by deer and elk. Several commercially available compounds are effective under some conditions, but for relatively short periods of time. Research to improve these compounds (reduce cost, extend length and effectiveness of repellency) should be conducted. Additionally, new repellents, especially those based on predator urine extracts, should be developed and made available, although problems of cost and duration of protection (because of volatility) will need to be addressed.

ACKNOWLEDGMENTS

We acknowledge the cooperation and support of the Clearwater National Forest, ID, and in particular, Bill Wolfe, Terri Ott, and Lonnie Waye.

LITERATURE CITED

Andelt, W. F., K. P. Burnham, and J. A. Manning. 1991. Relative effectiveness of repellents for reducing mule deer damage. J. Wildl. Manage. 55:341-347.

———, D. L. Baker, and K. P. Burnham. 1992. Relative preference of captive cow elk repellent-treated diets. J. Wildl. Manage. 56:164-173.

Borrecco, J. E., and H. C. Black. 1990. Animal damage problems and control activities on national forest system lands. Proc. Vertebr. Pest Conf. 14:192–198.

Campbell, D. L. 1987. Big game browse problems and control in the Pacific Northwest. Pages 109–110 *in* D. Baumgartner, ed. Animal damage management in Pacific Northwest forests. Washington State Univ. Press, Pullman.

Case, R. M., and B. A. Jasch. 1994. Pocket gophers. Pages B–17 - B–29 *in* S. Hygnstrom, R. Timm, and G. Larsen, eds. Prevention and control of wildlife damage. Univ. Nebraska Press, Lincoln.

Chase, J. D., W. E. Howard, and J. T. Roseberry. 1982. Pocket gophers. Pages 239-255 *in* J. Chapman and G. Feldhamer, eds. Wild mammals of North America. The John Hopkins Univ. Press, Baltimore.

Clark, J. P. 1994. Acrolein as a ground squirrel burrow fumigant. Proc. Vertebr. Pest Conf. 16:78–79.

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

———, and G. S. Kania. 1987. Effectiveness of human hair, BGR, and a mixture of blood meal and peppercorns in reducing deer damage to young apple trees. Proc. East. Wildl. Damage Control Conf. 3:97–101.

Craven, S. R., and S. E. Hygnstrom. 1994. Deer. Pages D–25 - D–40 *in* S. Hygnstrom, R. Timm, and G. Larsen, eds. Prevention and control of wildlife damage. Univ. Nebraska Press, Lincoln.

deCalesta, D. S., and G. W. Witmer. 1994. Elk. Pages D–41 - D–50 *in* S. Hygnstrom, R. Timm, and G. Larsen, eds. Prevention and control of wildlife damage. Univ. Nebraska Press, Lincoln.

DeYoe, D., and W. Schaap. 1987. Effectiveness of new formulations of deer repellents tested in Douglas-fir plantations in the Pacific Northwest. Tree Planter Notes 38(3):22–25.

Engeman, R. M., D. L. Campbell, D. Nolte, and G. W. Witmer. 1995. Some recent research results on non-lethal means of reducing animal damage to reforestation projects in the western United States. Aust. Vertebr. Pest Control Conf. 10:150–154.

Jacobs, W. W. 1994. Pesticides federally registered for control of terrestrial vertebrate pests. Pages G–1 - G–24 *in* S. Hygnstrom, R. Timm, and G. Larsen, eds. Prevention and control of wildlife damage. Univ. Nebraska Press, Lincoln.

Marsh, R. E., and R. W. Steele. 1992. Pocket Gophers. Pages 205-230 *in* H. C. Black, ed. Silvicultural approaches to animal damage management in Pacific Northwest forests. Gen. Tech. Rep. PNW-GTR-287. Portland, OR: U.S. Dep. Agric. For. Serv., Pacific Northwest Research Station. 422 pp.

Mattina, M. J. I., J. J. Pignatello, and R. K. Swihart. 1991. Identification of the volatile components of bobcat *(Lynx rufus)* urine. J. Chem. Ecol. 17:451-462.

Melchiors, M. A., and C. A. Leslie. 1985. Effectiveness of predator fecal odors as black-tailed deer repellents. J. Wildl. Manage. 49:358-362.

Müller-Schwarze, D. 1972. Responses of young black-tailed deer to predator odors. J. Mammal. 53:393-394.

Nolte, D. L., D. L. Campbell, and J. R. Mason. 1994*a*. Potential repellents to reduce damage by herbivores. Proc. Vertebr. Pest Conf. 16:228-232.

———, J. R. Mason, G. Epple, E. Aronov, and D. L. Campbell. 1994*b*. Why are predator urines aversive to prey? J. Chem. Ecol. 20:1505-1515.

Palmer, W. L., R. G. Wingard, and J. L. George. 1983. Evaluation of white-tailed deer repellents. Wildl. Soc. Bull. 11:164-166.

Rochelle, J. A. 1992. Deer and elk. Pages 333-349 *in* H. C. Black, ed. Silvicultural approaches to animal damage management in Pacific Northwest forests. Gen. Tech. Rep. PNW-GTR-287. Portland, OR: U.S. Dep. Agric. For. Serv., Pacific Northwest Research Station. 422 pp.

SAS Institute, Inc. 1995. JMP statistics and graphics guide. Cary, NC. 593 pp.

Sullivan, T. P., D. R. Crump, and D. S. Sullivan. 1988. Use of predator odors as repellents to reduce feeding damage by herbivores: IV. Northern pocket gophers *(Thomomys talpoides)*. J. Chem. Ecol. 14:379-389.

———, ———, H. Wieser, and E. A. Dixon. 1990. Response of pocket gophers *(Thomomys talpoides)* to an operational application of synthetic semiochemicals of stoat *(Mustela erminea)*. J. Chem. Ecol. 16:941-949.

———, L. O. Nordstrom, and D. S. Sullivan. 1985. Use of predator odors as repellents to reduce feeding damage by herbivores: II. Black-tailed deer *(Odocoileus hemionus columbianus)*. J. Chem. Ecol. 11:921-935.

Swihart, R. K., and M. R. Conover. 1990. Reducing deer damage to yews and apple trees: testing Big Game Repellent®, RoPel®, and soap as repellents. Wildl. Soc. Bull. 18:156–162.

———, J. J. Pignatello, and M. J. I. Mattina. 1991. Aversive responses of white-tailed deer, *Odocoileus virginianus*, to predator urines. J. Chem. Ecol. 17:767–777.

Von Carlowitz, P. G., and G. V. Wolf. 1991. Potential and limitations of natural repellents against early destructive browsing by livestock and game. Agroforestry Syst. 16:33–40.

Witmer, G. W., and D. Campbell. 1994. Research on nonlethal methods of pocket gopher (*Thomomys* spp.) damage management. Northwest Sci. 68:158.

———, G. H. Matschke, and D. L. Campbell. 1995. Field trials of pocket gopher control with cholecalciferol. Crop Prot. 14:307–309.