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# Evaluation of eight repellents in deterring eastern cottontail herbivory in Connecticut

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***Abstract***: Herbivory by eastern cottontails (*Sylvilagus floridanus*) can be the source of significant agricultural, nursery, and managed landscape damage. Where cottontails cannot be managed by lethal means or where trap and release is infeasible, repellents may be a reasonable alternative. We tested 8 different repellent formulations (Bobbex Deer Repellent® Canadian formulation concentrate, Bobbex Deer Repellent® Canadian ready-to-use (RTU), Bobbex-R Animal Repellent® concentrate, Bonide Repels All® concentrate, Bonide Deer & Rabbit Repellent® concentrate, Liquid Fence® Deer & Rabbit Repellent concentrate, Plantskydd® soluble powder, and Rabbit Stopper® RTU) on Johnny jump-ups (*Viola tricolor*), lettuce (*Lactuca sativa*), and alfalfa (*Medicago sativa*). Three wild, eastern cottontails were trapped and translocated to a 107 $m^2$ enclosure, resulting in a relative density of 280 cottontails/ha. After 2 weeks exposure to cottontails, remaining plant material was removed, dried, and weighed. Difference between dried plant mass of treated and untreated vegetation was determined. Repellent effectiveness was defined as the sum of the product of caloric demand rank and rank of dry mass difference for each repellent. Physical exclusion performed the best, followed by Plantskydd, Bobbex-R, Bobbex Deer Repellent Canada RTU, Bobbex Deer Repellent Canada Concentrate, Bonide Repels All, Rabbit Stopper, Liquid Fence Deer & Rabbit Repellent, and then Bonide Deer & Rabbit Repellent. Our results show that repellent usage can be a practical solution for deterring rabbit herbivory.

***Key words***: damage, eastern cottontail, herbivory, human–wildlife conflicts, repellent, *Sylvilagus floridanus*

Eastern cottontails (*Sylvilagus floridanus*) were introduced into New England on a massive scale in the 1930s, and their increase in population caused a drastic decline in native New England cottontail (*Sylvilagus transitionalis*) abundance (Probert and Litvaitis 1996). In addition to outcompeting native rabbit species, burgeoning eastern cottontail populations can cause significant agricultural damage, not only in New England, but throughout the country. In Nebraska, rabbits and hares annually caused an estimated $780,000 ($2.2 million modern equivalent) to major field crops and destroyed nearly 500 acres of new forest plantations (Johnson and Timm 1987). Eastern cottontails significantly damaged trees planted for shelterbelts and windbreaks in Minnesota (Swihart and Yahner 1983). Eastern cottontails and black-tailed jackrabbits (*Lepus californicus*) consumed 10% of biomass in food plots intended for other game species in southern Texas (Donalty et al. 2003). Of concern for recreational gardeners and the commercial nursery industry is eastern cottontail herbivory damage to flower and vegetable crops during spring and summer. Throughout the fall and winter, herbivory preferences often transition to available woody plants and can be a nuisance or cause significant economic losses (Craven 1994).

A popular and effective control technique for preventing herbivory by eastern cottontails and other mammalian species is physical exclusion (Craven 1994). However, fencing can be unsightly, may violate local zoning ordinances in some communities, and can be prohibitively expensive over large areas (Williams et al. 2006). Other control techniques include removal by shooting or regulated hunting (Craven 1994). Lethal techniques utilizing firearms can be effective, but often, proximity to houses and roads can preclude their usage as a viable technique in suburban settings. Trapping eastern cottontails has been used successfully for decades to alleviate damage (Geis 1955, Bailey 1969, Chapman and Trethewey 1972, Craven 1994).

Repellents are a popular method for preventing mammalian herbivory to suburban gardens and landscape plantings (Conover

1984, 1987; Swihart and Conover 1990; Ward and Williams 2010) because they are perceived as humane, easy to apply, and effective. Repellents are available at many local feed and agricultural supply establishments and can be classified into 4 categories: fear, conditioned aversion, pain, and taste (Beauchamp 1997, Mason 1997, Wagner and Nolte 2001).

In a simplified food chain, plants are producers; herbivores, such as eastern cottontails, are the primary consumers of plant matter; and carnivores, such as coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), and bobcats (*Lynx rufus*) are secondary consumers. Predator urine or other repellents containing sulfurous compounds may cause cottontails to flee the area for fear of being ambushed (Williams et al. 2006). Putrid egg solids are a common ingredient in fear-based repellents with a sulfurous scent that mimics predator odors.

Conditioned aversion repellents cause some type of illness, such as gastrointestinal distress or nausea. Such repellents often contain ammonium soaps of fatty acids. Animals that consume plants treated with these repellents will eventually associate their distress with the consumption of the treated vegetation (Conover 1995). Because rabbits need time to associate discomfort with treated plants, a significant amount of damage can occur before they become conditioned.

Repellents with active ingredients, such as ammonia, capsaicin (the active ingredient in hot peppers), and naturally occurring extracts (e.g., peppermint) evoke pain when they come in contact with the eyes, gut, and mucous membranes of the mouth and nose (DeNicola et al. 2000). Animals learn to avoid vegetation treated with such products due to immediate discomfort after consumption or contact.

Taste-based repellents usually contain a bitter-tasting substance to make the treated vegetation unpalatable (DeNicola et al. 2000). Animals learn to avoid vegetation that has been treated with bitter-tasting substances. Many of the commercial repellents combine a taste-based formulation with the other 3 categories.

Efficacy of rabbit repellents has not been well-studied; only a few studies have compared 1 or 2 repellents (Boh et al. 1999, Mason et al. 1999, Bosland and Bosland 2001, Figueroa et al. 2008). Due to the dearth of information on the topic, we conducted a study comparing multiple formulations. Our objective was to test the effectiveness of 8 different rabbit repellent formulations using temporarily captive, wild-caught eastern cottontails.

## Materials and methods

### Rabbit enclosure

We constructed a rabbit enclosure at the Connecticut Agricultural Experiment Station's Lockwood Farm in Hamden, Connecticut. The pen measured 7.3 × 14.6 m (107 m$^2$) and was constructed of 3.0-m-long treated wooden fence posts spaced at 2.4 m intervals apart (Figure 1). We sank posts 60 cm into the ground, creating walls 2.4 m in height. Galvanized poultry fencing (Yard Guard Fence, Atlanta, Ga.) with 3.5-cm-tall hexagonal mesh openings also was buried 60 cm deep around the interior perimeter and 2.4 m galvanized, graduated (7.6 × 15.2 cm openings on the bottom to 15.2 × 15.2 cm at the top) fixed-knot fencing (Academy Fence Co., Orange, N. J.) was wrapped around the enclosure exterior. Galvanized poultry fencing was affixed to the interior of the graduated fixed-knot fence up to 3.0 m. Additionally, polypropylene fencing (Tenax C-flex, Tenax Corporation, Baltimore, Md.) with 4.5 cm square mesh was affixed to the outside of the graduated fixed-knot fence and over the top of the enclosure to prevent aerial and terrestrial predators. The entire enclosure was ringed with 1.0 m silt fencing at ground level to prevent terrestrial predators from seeing the rabbits, helping to keep them calm. RoundUp® (Monsanto Co., St. Louis, Mo.) was prepared according to label instructions and sprayed twice during the project within the enclosure on either end containing the raised beds for wild vegetation management (Figure 2).

We constructed an area for rabbit cover and nesting within the enclosure by piling cut logs and cut brush along with 2 sheets of plywood 1.2 × 2.4 m in an area roughly 5.0 × 5.0 m placed in the center portion of the enclosure. We installed 2 supplemental covered feeding stations on either side of the enclosure. Each feeding station consisted of 2, 2.7-kg aluminum feeders (Pet Agree, Deer Creek Business, Camden, Ind.) containing rabbit pellets (Agway Rabbit 18%, Agway Inc., Westfield, Massachusetts)

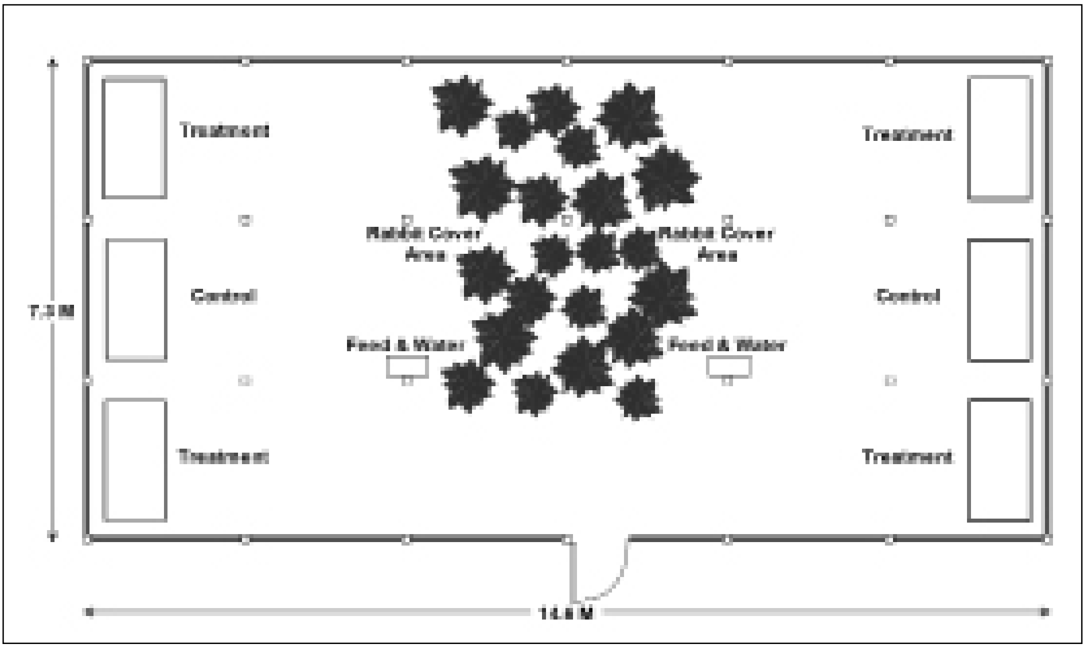


**Figure 1**. Eastern cottontail enclosure configuration.

and 2, 1.9-L ball-point tube cap water bottles (Lixit Corporation, Napa, Cal.). We provided supplemental water by leaving a garden hose to trickle into a galvanized metal tray in the tall brush near the rabbit cover area. Food was provided *ad libitum.*

## Rabbit capture

We trapped eastern cottontails on Lockwood Farm using Havahart® large, 1-door traps, Model #1079 (Woodstream Corp., Lititz, Pa.). In the evening, we set traps baited with cut McIntosh apples and checked them in the morning. Care was taken to identify eastern cottontails for inclusion in the study; any captured New England cottontails were released. Trapping and handling protocols followed guidelines of the American Society of Mammalogists for the use of wild animals in research (Sikes and Gannon 2011) and were approved both by the Wildlife Division of the Connecticut Department of Energy and Environmental Protection (#1213002) and the Connecticut Agricultural Experiment Station's Institutional Animal Care and Use Committee (P16-12). We captured 2 juvenile and 1 adult eastern cottontail and translocated them to the pen, resulting in a relative density of 280 cottontails/ha.

## Repellents and plant material

Twenty-eight flats were prepared for each trial. We inserted ITML® 1020 web trays into ITML 1020 traditional flats (Myers Industries Lawn & Garden Group, Middlefield, Oh.) before filling with ProMix BX® (Premier Tech Horticulture, Rivière-du-Loup, Québec, Canada). We moistened ProMix before filling, then evenly spread it into flats, smoothed it out, and evenly distributed a pre-measured amount of seed over the top and lightly watered them in. We left flats to germinate in a greenhouse. This method allowed for easy and complete removal of plant material at the end of the trials.

We constructed planting beds to hold the flats with treated plants during each trial; 7 beds, 0.91 m × 1.8 m were constructed of pressure treated lumber (Figure 2). We placed 3 planting beds at either end of the enclosure and one outside the enclosure ($n$ = 7). The planting bed outside the enclosure was surrounded by 1.2-m galvanized poultry fencing to act as a positive control. We used the center planting beds within either end of the enclosure for dedicated, untreated, negative control and to increase space between treatment beds to insure minimal neighboring repellency influence. At transplant time, we removed web trays containing soil and live plant material from flats and set them into composted leaf litter, 4 trays per raised bed.

**Figure 2**. Photograph taken at the conclusion of 1 of the lettuce trials. The center raised bed was an untreated control, while the other two were treated. Note silt fence, vegetation management within the enclosure, and web trays planted in the raised beds. Photographer is standing in the central vegetated rabbit cover area.

We selected plant material based upon findings from literature searches and informal interviews of nursery professionals; all material was known to be highly susceptible to rabbit damage. We chose *Viola tricolor* L. ("Helen Mount" Johnny Jump-Up), *Lactuca sativa* L. ("Allstar" Gourmet Lettuce Mix), and *Medicago sativa* L. ("Summer" Alfalfa) from Johnny's Select Seeds (Winslow, Me.). Most repellents we tested were not labeled for use on produce, except for Bonide Deer & Rabbit Repellent. Despite its being grown for human consumption, we chose *Lactuca sativa* because it was a plant reported to be highly susceptible to rabbit herbivory.

We conducted 6, 2-week repellent trials using 3 plant genera to test 2 sets of 4 ($n$ = 8) repellent formulations. Trial 1 compared the effectiveness of Bonide Repels All®, Bonide Deer & Rabbit Repellent® (Bonide Products Inc., Oriskany, New York), Liquid Fence® Deer & Rabbit Repellent (The Liquid Fence Co., Blakeslee, Pennsylvania) and Rabbit Stopper® (Messina Wildlife Management, Washington, New Jersey; hereafter, collectively referred to as Repellent Suite 1) on *Viola tricolor*. Trial 2 also used *Viola tricolor* and compared Bobbex-R Animal Repellent® from concentrate, Bobbex Deer Repellent® Canadian formulation from concentrate, Bobbex Deer Repellent® Canadian ready-to-use (RTU) formulation (Bobbex Inc., Monroe, Connecticut) and Plantskydd® soluable powder (Tree World Plant Care Products, St. Joseph, Missouri; hereafter, collectively referred to as Repellent Suite 2). We germinated 300 mg of *Viola tricolor* seed per flat on March 27, 2012, for use in Trial 1 and on April 2 for use in Trial 2. Flats were planted and treated on May 24 for Trial 1 and on June 8 for Trial 2; both ran 14 days.

Trial 3 utilized Repellent Suite 1, and Trial 5 tested Repellent Suite 2 on *Lactuca sativa*. We germinated 200 mg of *Lactuca sativa* seed per flat on June 4, 2012, for use in Trial 3, and on July 30 for use in Trial 5. Trial 3 began on June 25 and ran 14 days; Trial 5 began August 20 and ran 15 days. Initially, germination failure and subsequent planting timing resulted in 56 days elapsing between trials comparing repellents on *Lactuca sativa*.

Trial 4 utilized Repellent Suite 2, and Trial 6 tested Repellent Suite 1 on *Medicago sativa*. We germinated 250 mg of *Medicago sativa* seed per flat, on June 25, 2012, for use in Trial 4 and on August 6 for use in Trial 6. Trial 4 began on July 23, and Trial 6 began on September 5; both ran 14 days. Whitefly (*Aleyrodidae*) damage and eventual loss of 1 *Medicago sativa* planting in the greenhouse resulted in 44 days between trials. All *Medicago sativa* flats were treated with liquid Sevin® (GardenTech Inc., Palatine, Il.) in the greenhouse, thereafter, to prevent secondary failure.

## Repellent treatments

We mixed each repellent and applied treatments following label directions: Bobbex-R (1:8 dilution), Bobbex Deer Repellent Canadian formulation (1:5), Bonide Repels All (1:7), Bonide Deer & Rabbit Repellent (1:15), and Liquid Fence Deer & Rabbit Repellent (1:15). All were concentrated formulas and appropriately diluted with water into 1.4-L pressurized sprayers. Rabbit Stopper and Bobbex Deer Repellent Canadian formulation were both ready-to-use (RTU) and came in their own dedicated pressurized sprayers. Plantskydd was a soluble powder formulation that was rehydrated by mixing it into a watering can using a cordless drill fitted with a stirring device, as per label instructions, in 0.33 kg/3.8 L water. The mixture was then poured over the foliage.

**Table 1**. Analysis of variance tables using "Trial" as the nested categorical variable for the effects of rabbit repellents on all plant genera tested. Values used were the difference in dry mass (g) of treated vegetation remaining from untreated controls after 14 to 15 days.

| Source | df | Mean square | *F* ratio | *P* |
|---|---|---|---|---|
| Mass (all genera), $r^2 = 0.74$ | | | | |
| Trial | 5 | 2,878.2 | 27.1 | <0.001 |
| Repellent (Trial) | 24 | 572.2 | 5.4 | <0.001 |
| Error | 90 | 106.4 | | |
| *Medicago sativa*, $r^2 = 0.98$ | | | | |
| Trial | 1 | 883.6 | 292.1 | <0.001 |
| Repellent (Trial) | 8 | 586.4 | 193.8 | <0.001 |
| Error | 30 | 3.0 | | |
| *Viola tricolor*, $r^2 = 0.50$ | | | | |
| Trial | 1 | 5,349.2 | 17.4 | <0.001 |
| Repellent (Trial) | 8 | 491.0 | 1.6 | 0.1665 |
| Error | 30 | 306.8 | | |
| *Lactuca sativa*, $r^2 = 0.94$ | | | | |
| Trial | 1 | 59.4 | 6.4 | 0.0173 |
| Repellent (Trial) | 8 | 639.2 | 68.3 | <0.001 |
| Error | 30 | 9.4 | | |

At the time of treatment, the 3 plant genera were ready to be transplanted; *Viola tricolor* were flowering, *Lactuca sativa* were approximately 15 cm tall, and *Medicago sativa* approximately 25 cm tall. To avoid raised bed contamination, flats were removed from the greenhouse in the morning, randomly grouped in blocks of 4, randomly assigned a treatment, then treated with the designated repellent until all foliage was wet. Once the plants were dry, flats were transported to the enclosure 500 m away, and the 4 treated flats were set into randomly designated planting beds in either corner of the enclosure. We placed 4 untreated flats in each of the 2 control beds between treated beds at either end of the enclosure (Figure 1). Leaf compost medium was mounded around the flats. We watered flats from the base of plants, insuring that water did not immediately run over treated foliage. We hand-watered plants as necessary throughout the trials, but all were equally exposed to dew and precipitation.

At the end of the 2-week trials, flats with remaining plant material were removed from planting beds. Using scissors, we cut all living plant material from each treatment at soil level and placed it into individual paper bags. Bags with vegetation were initially air dried in a well-ventilated greenhouse for 1 week and then dried for 5 days in a forced-air oven at 70° C. We weighed each bag with and without plant material to the nearest 0.5 g to determine the dry mass of vegetation for each flat.

## Data analysis

We subtracted the dry mass values of flats from negative, untreated controls from the dry mass of adjacent treated vegetation flats for each end of the enclosure to calculate plant mass protected by each repellent formulation. This reduced the potential bias of rabbit preference for either side of the enclosure. Additionally, this standardization process allowed us to compare repellent effectiveness among the 3 different plant genera. We ran a 2-factor (trial and repellent) analysis of variance (ANOVA)

**Table 2**. Summed dry mass (g) difference from adjacent negative controls (DM Diff) for each repellent tested (and positive fenced controls) on *Viola tricolor* for Trials 1 and 2. Summed DM Diff values with the same letter (Significance) are not significantly different.

| *Viola tricolor* | DM Diff | Significance |
|---|---|---|
| Bobbex-R | 217.0 | a |
| Fenced Control 1 | 181.3 | ab |
| Bobbex Deer Repellent Canada RTU (ready-to use) | 171.5 | ab |
| Fenced Control 2 | 146.6 | ab |
| Plantskydd | 137.0 | ab |
| Bobbex Deer Repellent Canada Concentrate | 125.0 | ab |
| Bonide Repels All | 107.8 | ab |
| Liquid Fence Deer and Rabbit Repellent | 45.5 | b |
| Rabbit Stopper | 34.8 | b |
| Bonide Deer & Rabbit Repellent | 34.5 | b |

using trial as a categorical variable on adjusted dry mass values to determine if differences existed between repellent formulations for all plant genera combined and also within plant genera. We ran a 1-factor ANOVA (trial) on adjusted dry mass values and used Tukey's HSD test to determine differences in adjusted dry mass values among trials. Dry mass from each flat was a replicate, resulting in 4 replicates/repellent/trial ($n$ = 168 replicates; 4 flats each for 4 repellent treatments and 3 controls for 6 trials). We also used Tukey's HSD test to determine differences among repellent effectiveness within each plant genus.

## Overall repellent effectiveness

To determine an overall repellent effectiveness index, each replicate flat was ranked in ascending order by the cumulative daily caloric demand (RDCD; explanation below) for a given 2-week interval: replicate flats with the same cumulative daily caloric demand were assigned the same rank value. Replicate flats were then ranked in ascending order by the difference in dry mass from unfenced controls. The 2 assigned ranks were multiplied, and repellent effectiveness (RE) was determined by ranking the sum of the product for each repellent (RE = RDCD × RDM). Because there were 8 repellents tested in 2 different trials for each plant genera, there were 8 replicate flats for positive controls, whereas there were only four for each treatment. As a result, for the purpose of the effectiveness index, duplicate positive control values were averaged within each plant genera, resulting in 9 treatments of 4 replicate flats each.

# Results

There were significant differences in overall repellent performance and repellent performance among plant genera (Tables 1–3). Additionally, some repellents performed better than others on different plant genera. Repellent performance was significantly different when using trial as a categorical variable for both *Medicago sativa* and *Lactuca sativa* but not for *Viola tricolor* (Table 1).

Positive fenced controls outside the enclosure generally resulted in highest dry mass values of remaining vegetation. The exception was the *Viola tricolor* trials. Dry mass values were greater for Bobbex-R than both fenced positive controls and where Bobbex Deer Repellent Canadian RTU dry mass was greater than 1 of the fenced controls (Table 2). However, all 3 Bobbex products, Plantskydd, and Bonide Repels All were not significantly different from fenced positive controls in the *Viola tricolor* trial (Table 2).

Vegetation for fenced positive controls averaged 68% more dry mass at the end of the trails than vegetation from unfenced negative controls within the enclosure. For all trials combined, positive fenced controls had more remaining dry mass than other treatments and negative unfenced controls had the least remaining dry mass; no repellent performed poorer than no treatment or better than physical exclusion. Our rankings indicate that a fence was the best protection against rabbit herbivory, followed by Plantskydd, Bobbex-R, Bobbex Deer Repellent Canada RTU, Bobbex Deer Repellent Canada Concentrate, Bonide Repels All, Rabbit Stopper, Liquid Fence Deer & Rabbit Repellent, and then Bonide Deer & Rabbit Repellent. The effectiveness index for all repellents including costs can be found in Table 5.

**Table 3**. Summed dry mass (g) difference from adjacent negative controls (DM Diff) for each repellent tested (and positive fenced controls) on *Medicago sativa for* Trials 4 and 6. Summed DM Diff values with the same letter (Significance) are not significantly different. RTU = ready-to-use.

| *Medicago sativa* | DM Diff | Significance |
|---|---|---|
| Fenced Control 1 | 121.5 | a |
| Fenced Control 2 | 124.5 | a |
| Plantskydd | 91.5 | b |
| Bobbex Deer Repellent Canada RTU | 47.0 | c |
| Bobbex Deer Repellent Canada Concentrate | 31.5 | cd |
| Bobbex-R | 28.0 | d |
| Bonide Repels All | 3.0 | e |
| Rabbit Stopper | 3.0 | e |
| Liquid Fence Deer and Rabbit Repellent | 1.0 | e |
| Bonide Deer & Rabbit Repellent | 0.1 | e |

**Table 4**. Summed dry mass (g) difference from adjacent negative controls (DM Diff) for each repellent tested (and positive fenced controls) on Medicago sativa for Trials 4 and 6. Summed DM Diff values with the same letter (Significance) are not significantly different. RTU = ready-to-use.

| *Medicago sativa* | DM Diff | Significance |
|---|---|---|
| Fenced Control 1 | 121.5 | a |
| Fenced Control 2 | 124.5 | a |
| Plantskydd | 91.5 | b |
| Bobbex Deer Repellent Canada RTU | 47.0 | c |
| Bobbex Deer Repellent Canada Concentrate | 31.5 | cd |
| Bobbex-R | 28.0 | d |
| Bonide Repels All | 3.0 | e |
| Rabbit Stopper | 3.0 | e |
| Liquid Fence Deer and Rabbit Repellent | 1.0 | e |
| Bonide Deer & Rabbit Repellent | 0.1 | e |

## Discussion

We did not find a published report comparing the effectiveness of >2 rabbit repellent formulations. One report evaluated the effectiveness of capsaicinoids on lettuce to deter desert cottontail rabbits (*Sylvilagus audubonii*) and black-tailed jackrabbits (Bosland and Bosland 2001). Another evaluated the response of captive New Zealand, white lab rabbits (*Oryctolagus* spp.) to 2 protein hydrolysates (i.e., hrydrolyzed casein and gelatin; Figueroa et al. 2008). A third study evaluated a commercially available deer repellent on preventing rabbit herbivory (Mason et al. 1999). A fourth study investigated the effects of encapsulation of a single deer and rabbit repellent formulation (Boh et al. 1999). Our study was unique in that it examined multiple repellent formulations on several plant genera.

No repellent tested in this trial was 100% effective in deterring rabbit herbivory, physical exclusion is the only way to prevent all damage to plant material, but it can be costly and unsightly, and it requires periodic maintenance (Williams et al. 2006). Plantskydd, a blood-based product, performed the best of all tested products (Table 4). Dried blood meal has long been used to successfully deter rabbit

**Table 5**. Effectiveness index for all repellents tested for all plant genera. "Rank sum" is the sum of the product of the caloric demand rank and difference in dry mass of remaining treated vegetation less adjacent negative control rank. "Rank" is the repellent effectiveness based on the rank of "Rank sum." "Dilution" is the dilution rate for each repellent and $/L is the cost per diluted L of each product. Ready-to use costs are less the $15 for the pressurized tank sprayer included with the purchase for comparison.

| Treatment | Rank sum | Rank | Dilution | $/L |
|---|---|---|---|---|
| Fenced Control | 5728 | 1 | - | - |
| Plantskydd | 5342 | 2 | 1 kg/7.6–11.4 l | $5.26–$3.51 |
| Bobbex-R | 3872 | 3 | 1 : 8 | $1.78–$3.22 |
| Bobbex Deer Repellent Canada | 3409 | 4 | RTU | $3.00 |
| Bobbex Deer Repellent Canada | 3107 | 5 | 1 : 5 | $2.67–$4.83 |
| Bonide Repels All | 1402 | 6 | 1 : 7 | $2.38 |
| Rabbit Stopper | 1293 | 7 | RTU | $3.00 |
| Liquid Fence Deer & Rabbit Repellent | 1186 | 8 | 1 : 15 | $1.69–$2.13 |
| Bonide Deer & Rabbit Repellent | 680 | 9 | 1 : 15 | $1.25 |

herbivory (Craven 1994), but is typically used in a dry application. The 3 Bobbex products were the next best performing, with Bobbex-R second behind Plantskydd (Table 5). Bobbex-R is specifically formulated to deter rabbit herbivory, though the concentrated and RTU Bobbex Deer Repellent Canadian formulations performed quite well. Bonide Repels All and Rabbit Stopper were next, and both had a pleasant odor to the applicator, but did not perform very well. Liquid Fence Deer & Rabbit Repellent and Bonide Deer & Rabbit Repellent (1:15) may have been more effective had we used a less dilute solution than recommended.

Our original experimental design was to test the 2 different repellent suites on the same plant genus in successive 2-week intervals. However, this design was altered due to unforeseen insect damage and germination failure. As a result, Trial 5 testing Repellent Suite 2 on *Lactuca sativa* and Trial 6 testing Repellent Suite 1 on *Medicago sativa* occurred later into the growing season than had been planned. Treated vegetation in both trials received a greater amount of damage, likely due to decreasing mean daily temperatures and decreasing photoperiod that increased total caloric demand. Despite the fact that *ad libitum* rabbit pellets were available, captive eastern cottontails preferred to consume at least some treated vegetation. This is consistent with other reports that when alternate food sources area available, but are scarce or not especially palatable, animals will continue to feed on preferred vegetation, albeit treated (El Hani and Conover 1995, Mason 1998). However, our data standardization procedure allowed for objective comparisons of trials conducted throughout the growing season.

Additionally, it is possible that rabbits changed feeding preferences over this time interval and that housing rabbits together could have obscured variation in individual responses to repellents. We also realize that our conclusions are based on a small sample of eastern cottontails in southern New England and that there will likely be variation in repellent performance across their range. We would not expect the same results if a similar duplicate study were executed elsewhere in the Northeast or Mid-Atlantic regions. However, we feel that our results are credible, objective, and give consumers guidance on the performance of several commercially available repellents tested at an unnaturally high relative eastern cottontail density.

## Costs and nuances

While the effectiveness index reported differences among products in deterring rabbit herbivory, there are other nuances and costs associated with products. One kg of Plantskydd costs approximately $30 to $40 and contains enough material to make 7.6 to 11.4 L of diluted product to treat 400 to 600, 30.5-cm broadleaf plants. Plantskydd needed to be mixed thoroughly in a watering can or bucket using a stirring device. Once mixed, it looked like blood, and when poured on vegetation, adhered to and caused leaves to curl; cleanup required a lot of water to thoroughly rinse the watering can.

Bobbex Deer Repellent Canadian RTU formulation cost could not be determined because the product was an experimental formulation. The American equivalent cost $18/L and comes with its own reusable 1.4-L pressurized hand sprayer. Rabbit Stopper cost was similar. The costs of these 2 products as reported in Table 5 is less the cost of a pressurized hand sprayer that we had to purchase for application of the other 5 concentrated repellents. Bobbex had a slightly unpleasant odor, and Rabbit Stopper a pleasant odor for a short period of time after application. Because these products were RTU, there was no need for dilution. Clean-up required only rinsing out the tank sprayer with water. Homeowners could purchase ready-to-use products and after use, fill sprayers with diluted concentrated product of their choice.

Bobbex-R Animal Repellent from concentrate and the American equivalent of Bobbex Deer Repellent Canadian formulation from concentrate both cost between $16 to $29/L, depending on volume purchased. The products had an initial slightly unpleasant odor that dissipated once dry. Bonide Repels All from concentrate cost $19/L and Bonide Deer & Rabbit Repellent from concentrate $20/L. The products had a less offensive, almost pleasant initial odor compared to other repellents.

Liquid Fence Deer & Rabbit Repellent from concentrate cost between $27 to $34/L, depending on volume purchased and had an initial unpleasant odor. All concentrated products needed to be diluted, requiring a measuring cup and an application device.

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