February 1991

EVALUATION OF A NEW DEER REPELLENT ON JAPANESE YEWS AT SUBURBAN HOMESTEADS

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Abstract: Jersey,anexperimentaldeerrepellent,wasfieldtestedagainst2commercialrepellentsonJapaneseyews(Taxuscuspidata) near Ithaca, New York, during spring 1990. In Experiment 1, plots *(n = 24) of 4* individually-potted yews were established, with 2 yews at each plot randomly treated with Jersey and 2 left as controls. Plots *of 4 (1* x *4, n* =12) and 16 (4 x 4, n = 2) plants were used in Experiment 2, with individual plants being treated with Jersey, Hinder", or Big Game RepellentR (BGRR) or left as controls. Photographs with a grid matrix placed behind each h plant were taken from 2 m at the beginning *of* the experiment and after 10 weeks. These photographs were analyzed to produce a cover index *of* plant size. Plots were monitored weekly *to* record browsing. In Experiment 1 more control (46/48) than treated (7/48)plants were browsed ($P < 0.001$). Controls were browsed earlier (X =1.7 wk) than treated yews ($X = 4.4$ wk, $P < 0.01$). At the end of 10 weeks, control plants were reduced in size more than Jersey-treated plants ($P < 0.001$). In Experiment 2, browsing rates did not differ among treatments in the 1 x *4* plots or *4* x 4 plots. However, controls were browsed more frequently than treated at both plot types (10/12 at 1 x 4, and 6/8 at 4 x 4 plots) ($P < 0.05$). Browsing reduced control plants by 56.8% (*n* =10) in 1 x 4 plots and 47.2% (*n* = 6) in 4 x 4 plots. These results suggest that Jersey reduced deer damage to a shrub preferred by deer. Moreover, Jersey was as effective as BGRR and Hinder" at reducing browsing. Experiments may need to be conducted under more severe conditions and over a longer time-period to separate efficacy of the 3 repellents.

I'roc. East. **Wildl. Damage Control Conf. 5:38-43.1992.**

Browsing damage to ornamental trees and shrubs by whitetailed deer *(Odocoileus virginianus)* is common in many suburban areas of the eastern United States, and some homeowners report high economic losses (Decker and Gavin 1987, Connelly et a1.1987, Sayre and Decker 1990). Homeowners use various methods to prevent deer damage, including physical barriers such as fencing or tree wraps, commercial repellents, soaps, human hair or animal blood attached to plants, and scare devices (Decker and Gavin 1987, Connelly et al. 1987, Sayre and Decker 1990). Despite their popularity, most *of* these methods have limited long-term success in deterring deer (Harris et al. 1983, Matschke et a1.1984, Swihart and Conover 1990, Andelt et al. 1991). However, fencing and commercial repellents appear to be the most effective of these methods. Some people are reluctant *to* use fences or physical barriers because they can be expensive (Palmer et a1. 1985), and many consider them to be unsightly (Decker and Gavin 1987). Commercial repellents, although not a cure for deer damage problems, have successfully reduced browsing on shrubs and trees (Conover 1984, 1987; Swihart and Conover 1991). The primary limitations with commercial repellents are the expense and need for repeated applications. An effective and longlasting deer repellent is needed to reduce deer damage to ornamental plants.

Several studies *of* repellents have been conducted at commercial nurseries (Conover 1984, 1987; Swihart and Conover 1990), and with captive deer (Cambell and Bullard 1972, Palmer et al. 1983, Harris et a1.1983, Andelt et a1.1991), although to our knowledge, repellents have not been fieldtested at suburban settings. Foraging behavior *of* deer in a tree nursery may differ from foraging in a suburban landscape, where the plants are dispersed. Animal response to repellents also may differ between nurseries and homesites because *of* such differences in plant distribution. Controlled experiments with captive animals (e.g., Palmer et al. 1985, Andelt et al. 1991) provide valuable knowledge, but they have limitations because captive deer may behave differently from wild deer, which have alternative foods available. For example, Andelt et al. (1991) reported that hungry deer in captivity actually licked bars of soap suspended over apple twigs; this behavior would be unlikely in a wild setting.

We tested the effectiveness of an experimental deer repellent called "Jersey" (Patent No. 45,965,070) on Japanese yews (Taxes cuspidata), a shrub highly preferred by deer. The experiments were conducted in or near suburban homesites in central New York, and were designed to simulate conditions where plants might be expected to be more scattered than at a nursery or orchard. In Experiment 1, Jersey was tested against a control, and in Experiment 2, Jersey was compared to the commercial repellents BGRR and Hinders. These repellents were chosen because they are currently the most effective commercial repellents available (Conover 1984). We make no endorsement of these products. Three variables were tested to determine differences between treatments: (1) evidence of browsing; (2) elapsed time before browsing was first detected; and (3) reduction in plant size due to browsing.

We thank DeVisser's Nursery for donating the yews and are grateful to the homeowners who allowed us to conduct this

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Study on their property. We also thank T. Sayre for assistance n the field; K. Gerow and K. Newsome-Stuart for statistical advice and M. Fargione, N. Ingle, D. Jordan, and A.M. Wilkinson for comments and review of the manuscript. This project was funded by U. S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA/APHIS).

STUDY AREA

The study was conducted east and southeast of Cayuga lake near the city of Ithaca, Tompkins County, New York. experiment 1 was conducted in Lansing Village (LV), 2.5 km north of Ithaca, and Experiment 2 in LV, and in Ellis Hollow EH), 5 km east of Ithaca.

LV is a suburban community, with a mixture of residential and commercial developments, woodlots, abandoned fields, rid farmland still in production. Commercial and residential real constitute about one-half of the land area. Significant commercial developments include shopping malls, industrial search centers, and the Tompkins County Airport. EH is lore rural than LV, and consists of farmlands, woodlands, and single-unit houses along roads, which dissect the area at aproximately 1 km intervals.

These areas were located on the Allegheny Plateau, a region of large hills (elevation 450-610 m), dissected by narrow nines, and broad valleys with steep upper slopes. The soils ere formed from shale and sandstone glacial till (Neeley X65). The area is within the Hemlock-White Pine-Northern ardwoods region, and is dominated by sugar maple *(Acer Saccharum* and beech *(Fagus grandifolia)* and their associa (Braun 1950). Before settlement by Europeans, the area was densely forested, but it was logged andclearedforagriculture firing the 18th and 19th centuries. Much of the farmland has been abandoned since the late 1800s, and forests have regenered.

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The area has a continental and humid climate, with warm summers andcoldwinters. The averagemaximumtemperature is 21 C and the average minimum is -3 C. An average of 92.7 cm of precipitation falls annually, with relatively even distribution throughout the year (SE = 0.58 cm/month).

Actual population densities of deer in Tompkins County are not known. Hunting with firearms is prohibited in LV, but is allowed in EH. An average of 1.2 bucks/km2 were harvested from 1985-89 in the 140-km2 area immediately north of LV, and 1.2 bucks/kmz in the 250-kmz area surrounding EH. We conducted pellet transects in April 1990, which indicated 157.1 pellet groups/ha (± 62.0 SE, *n = 14* transacts) in LV, and 89.3 pellet groups/ha (± 22.3 SE, *n = 14* transacts) in EH. These indices indicate moderate-to-high use by deer in both areas.

METHODS

Individually-potted Japanese yews were placed in plots at sites in LV and EH, with each plant staked into the ground with a 30-cm nail to ensure the plants could not be moved easily.

Two photographs of each plant were taken from orthogonal directions using a 35 mm camera with a SO mm lens using color slide film (ASA 100 or ASA 200). A density board with a 5 x 5 cm grid matrix was placed 10 cm behind the plant for each photo. The camera was held at a height of 1 m, and a distance of 2 m from the plant. Plots were monitored weekly for 10 weeks to determine when browsing occurred. After 10 weeks, each plant was rephotographed from the original positions.

Experiment l.-Plots were established at 24 homesites in LV from 6 March through 2 April, and terminated from 15 May through 10 June 1990. All homesites contained ornamental trees and shrubs that had been browsed by deer during the months preceding the experiment. Most homesites were on medium-sized property lots (median = 0.71 ha; range = 0.2 to 9.2 ha).

One plot, each with 4 plants spaced 20 m apart, was established at each homesite. Two plants at each homesite were randomly selected and sprayed once with Jersey while the remaining 2 plants were left as untreated controls.

Experiment 2.-Two plot designs were used in Experiment 2, 1 x 4 plots (4 plants each) and 4 x 4 plots (16 plants each), with plants spaced 20 m apart in each plot. The 1 x 4 plots were established on 19 February in EH, and on 27 March in LV (n = 6 plots/study area). The 1 x 4 plots at EH were placed on properties ranging in size from 6 to 32 ha, while LV plots were placed on properties between 0.4 and 9.2 ha in size. Most plots were in fields, but there was 1 woodland plot selected in each study area. One plant in each plot was randomly selected for treatment with BGRR, Hinder', Jersey or designated a control. Repellents were applied once as in Experiment 1. Data collections were completed on 30 April in EH, and on 6 June in LV.

To determine long-term effects of the repellents, the 1 x 4 plots were left in the field 20 weeks beyond the designated 10weekstudy. The plantswererecheckedforevidenceofbrowsing on 1 October in EH, and 25 October in LV. Photographs of the plants were not analyzed because plant growth over the summer could confound measurements of browsed plants.

The 4 x 4 plots were established on 21 March and terminated on 30 May in EH, and from 28 March through 6 June in LV. Each plot was located on a 2 ha hay field, sided by woodlots. The plants were placed, 20 m apart, in 4 rows and columns, and treatment of the 3 repellents and control were assigned in a Latin square design.

Weather Data.-Weather data for the study period were obtained from the Meteorology Unit at Cornell University's Department of Soil, Crop and Atmospheric Sciences to document the effectiveness of the repellents through typical winter and spring conditions. The data were collected at a weather station, about half-way between LV and EH. We tabulated the data according to the date that each plot was established and terminated (Table 1).

Table 1. Mean temperature and precipitation data collected during Experiments 1 and 2 near study areas in Ithaca, New York, winter-spring 1990.

Weather Variable	Experiment 1' $\bar{X}$	Experiment 21' $\bar{X}$
Max. Temperature (C)	14.3	13.7
Min. Temperature (C)	3.5	2.8
Days Temperature < 0 C	21.8	20.8
Precip.(cm)	21.8	21.3
Days with Snow>_ 2.5 cm	7.0	8.9
Days with Precip. >_ 0.025 cm	33.7	32.8

' Experiment 1 conducted from 6 March through 10 June 1990. b Experiment 2 conducted from 19 February through 6 June 1990.

Photographic Analysis and Cover Class System.-The photographs were analyzed to measure change in plant size over the study period, using a cover class system based on the percentage occlusion by plant material over each S x 5-cm square of the grid matrix (Table 2). The total area occluded by the plant was calculated as the sum of each cover class multiplied by the assumed mid-point value (cm2) of that cover class (Table 2):

Area of plant = [nC, (M) + nC2 (M)... + nC., (M)),

where n number of grid squares observed of cover class, C,, C2,...C.,; and M is the midpoint area (cmz) of cover class C,...C,. The measurements of the north- and west-facing photographs were averaged to account for plant shape. The cover class data were coded and tabulated using a microcomputer and software from Lotus 1-2-3R (Lotus 1989). Percentage change in plant size was calculated by:

% change = 100 X [(area 10 wk/ area 0 wk) - 1].

Table 2. Quantification of cover classes used to measure deer consumption of Japanese yews' at study sites near Ithaca, New York, winter-spring 1990.

Cover class code	Range of cover class %	Class Midpointb %	$\bar{X}$ area of cover class° (cm2)
1	> 0 - 0.625	< 5	2.5
2	>_ 5 15.0 3.750	-	<25
3	>_25 37.5 9.375	-	<50
6	>95 - <100	97.5	24,375
	100	*100_0*	*25 V00*

' Individual cover class value consisted of the estimated percent occlusion by yews of 5"x5" cm grid matrix squares located 10cm the plant (modified from Daubenmire 1959

° Assumed'; percentage *of* grid square used *in* calculating total cover value for each cover class,

°$\bar{X}$ area of cover class = *class* midpoint *x* 25 cm *sa.*

This cover class system was modified from research methods to measure horizontal and vertical cover of vegetation (e.g., Daubenmire 1959, Thomson 1975). The cover (Table 2) was adapted from Daubenmire (1959). Bonham (1989) and Gysel and Lyon (1980) discuss the rise of photo and cover class systems to measure vegetation. Advantages o this method are that it provides a permanent record of plant size and a precise measure of degree of browsing on individual plants. However, 3 important assumptions must be made when using this technique: (1) the cover estimates are symmetrically dispersedaround the midpoint (Bonham 1989:127); (2) changes in plant size not due to browsing can be accounted for; and (3) the photographs are taken from the same position each time.

Analysis.-All statistical analyses were consistent with Steel and Tome (1980). In Experiment 1, differences in browsing rates after 10 weeks were compared using the Chisquare test of significance. The t-test was used to test for differences in elapsed time before browsing. Plant size changes were compared with 2-way ANOVA. In Experiment 2, differences in browsing were tested using Fischer's Exact Test, because the sample size was too small for the Chi-square technique. Differences in plant size among treatments were l tested using 2-way ANOVA and followed with orthogonal contrasts to examine whether control and treated plants differed in size, and whether plant sizes differed among treatment plants after 10 weeks. Analyses were conducted with either a hand calculator or MinitabR (Ryan et al. 1985).

RESULTS

The weather during the study period was wet and cool, typical of late winterand spring in central New York. Measurable precipitation L 0.025 cm) was recorded on nearly one-half of the days during the study period, and a trace of precipitation (< 0.025 cm) was recorded on an additional 14 days (Table 1). The mean temperature was 8.3 C, with the coldest temperature of -19 C recorded on 7 March, and the warmest of 32 C on 29 April. There were no differences in temperature orprecipitation between Experiment 1 and Experiment 2 (Table 1).

Experiment 1.-Jersey reduced the frequency, delayed the onset, and lessened the severity of browsing by deer on the yews. By the end of the 10-week study period, 46/48 of the control plants were browsed, compared to only 7/48 of the treated plants *(X2* = 64.7, df = 1, P < 0.001) (Table 3). Deer began feeding on the control plants earlier ($\bar{X}$ =1.7 weeks) than on the treated plants ($\bar{X}$ = 4.4 weeks) (t = -3.4, 6 df, P < 0.05) (Table 3). After 10 weeks, all control plants averaged a 57.3 % reduction in size, whereas treated plants were reduced, on average, by 5.2% (F = 585.1, 1,48 df, P < 0.001) (Table 3). *Furthermore, controls that were browsed* were reduced *XD 2* greater degree(59.4%) than the treated plants (11.'1 %) (F =104.4, 1 t51 df ι P <0 .001 Finally the unbrowsed plants, both treated

and control , tended to be slightly %MAX%, aCw' 10 weeks ~x *plant* 43%,SE=12,n =43).

Table 3. The number of Jersey-treated and untreated Japanese yews browsed by deer after 10 weeks, and the elapsed time before first browsing at homeowner plots in Lansing Village, New York, spring 1990.

Variable	Control	Jersey
Plants (n)	48	48
Browsed 10 wk *(n)*	46'	7
T wk before browsing (± SE)	2' (0)	4 (2)
X Plant size cm2 (± SE)		
0 wk	1527 (55)	1496 (65)
10 wk	652° (47)	1412 (60)
X Change (%) in plant size 10 wk (± SE)		
All	a	
Browsed only	-59' (2)	-11 (9)

' Control and Jersey different (P < 0.01).

Experiment 2.-In the 1 x 4 plots, most control plants (10/12) were browsed after 10 weeks, with an average of 2.6 weeks elapsing before browsing was observed (Table 4). Only 1 treated plant (Hinder') was browsed after 10 weeks, and it was first observed to be browsed after 2 weeks. Incidence of browsing after 10 weeks was greater for the controls than on treated plants *(n* browsed: Hinders = 1/12, BGRR = 0/12, and Jersey = 0/12; Fischer's ExactTest, P = 0.0003), but there were no differences among treatments. Moreover, controls were reduced more than the treated plants *(F*= 37.0,1,33 df, P < 0.01), although there was no difference between Jersey, BGRR, or HinderR *(F* = 0.22,1,33 df, P > 0.05) (Table 6). After 10 weeks the size of unbrowsed plants, regardless of treatment, remained essentially the same (X size change = + 0.05%, SE = 2.14, *n* = 37).

Five plants from the 1 x 4 plots were destroyed by mowers during the summer, and these data were eliminated from the sample. After 30 weeks, more controls (12/12) than treated plants *n* browsed: BGRR = 7/11, Hinder' = 6/10, and Jersey 3/10) were browsed (Fischer's Exact Test, P = 0.002). The number of plants browsed by deer did not differ between treatments (Fischer's ExactTest,P=0.081). However, occular estimates made in the field indicated that 4/7 yews treated with BGRR and 3/6 treated with Hinder" were severely browsed (> 50% of plant material removed); whereas, only 1/3 of the plants treated with Jersey had > 50% of plant material removed by deer.

Most control plants (6/8) in the 4 x 4 plots were browsed after 10 weeks (Table 5). An average of 2.0 weeks elapsed

Table 4. Browsing rates, X plant size, and percentage change in plant size of Japanese yews at 1 x 4 plots in Lansing Village and Ellis Hollow, New York, spring 1990.

Variable	Control	BGR	Hinder	Jersey
Plants *(n)*	12	12	12	12
Browsed 10 wk *(n)*	*10'*	*0*	*1*	*0*
X wk before browsing (± SE)	3 (0)	-	2 (NA)	-
X Plant size cmz (± SE)				
0 wk	617 (52)	605 (51)	627 (75)	643 (54)
10 wk	320 (62)	576 (45)	575 (64)	623 (40)
X Change (%)in plant size 10 wk (± SE)				

' Control and treated different (P < 0.001).

Table 5. The number of treated and untreated Japanese yews browsed by deer after 10 weeks, and the elapsed time before first browsing at 4 x 4 plots in Lansing Village and Ellis Hollow, New York, spring 1990.

Variable	Control	BGR	Hinder	Jersey
Plants *(n)*	8	8	8	8
Browsed 10 wk *(n)*	6`	0	1	0
7 wk before browsing (± SE)	2 (0)	-	1 (NA)	-
X Plant size cmz (± SE)				
0 wk	999 (42)	1048 (49)	1128 (50)	1011(58)
10 wk	663 (105)	1050 (49)	1086 (58)	1002 (64)
X Change (%) in plant size 10 wk (± SE)				
All plants	-34' (9)	+ 0 (1)	- 4 (2)	- 0 (1)
Browsed only	-47` (8)	-	- 23 (NA)	-

Control and treated different (P < 0.01).

before browsing was observed. After 10 weeks, browsing rates were less for treated plants than control plants (n = browsed: BGRR = 0/8, Hinder" -1/8, Jersey 0/8; Fischer's ExactTest, P = 0.0002) (Table 5). Moreover, control plants were reduced in size more than treated plants (F = 5.69,1,15 df, P < 0.05) (Table 8). Changes in plant size were not found among treatments (F = 0.0003, 1,15 df, P > 0.05). As in the lx 4 plots, unbrowsed plants in the 4 x 4 plots remained approximately the same size after 10 weeks (7 _ - 0.43%, SE = 0.97, *n = 25*).

DISCUSSION

Experiment 1 indicated that during late winter, Jersey reduced damage on Japanese yews, a preferred deer food. Although exert densities of deer were not known, browsing by deer wassevereinLV; a1124 homeowners hadplantsdamaged by deer during the weeks or months preceding the study. The fact that 70% of the control plants were browsed within the first week, and 95% were browsed after 10 weeks, also indicates relatively high deer pressure through most of the study.

Deer avoided most Jersey-treated yews in Experiment 1, even though the plants were subjected to a wide variety of weather conditions, including extended periods of rain, snow, and freezing temperatures. This implies that Jersey has good adhesive properties. However, in early April, several days of cool weather and snowfall preceded browsing on some Jersey treated yews *(n* = 5). Deer may have fed on these plants because they were food-stressed and looking for alternative forage. Deer are likely to search for new food sources during such late winter conditions (Brown and Doucet 1991). Furthermore, repellents may wash off during rain. Andelt et al. (1991) reported thatrepellent-treated apple twigs (Malus) sprayed with water were browsed more extensively than twigs that had not been sprayed with water. Although some browsing of treated plants occurred in Experiment 1, damage remained light throughout the study period.

In Experiment 2, Jersey repelled deer as effectively as BGRR and HinderR, two repellents with demonstrated effectiveness in field studies (Conover 1984, 1987; SwihaR and Conover 1990), and in experiments with captive animals (Palmer et al. 1985, Actdelt et al. 1991). Differences in browsing rates between Jersey, BGRR, and Hinder' plots were not found in the initial 10-week study, possibly because browsing races on all treated plants remained low. Jersey may repel deer longer than the other repellents during summer, although sample sizes were too small to determine statistical differences. A longer winter study may be needed to compare the efficacies of the repellents. The effectiveness of Jersey in our preliminary experiments indicates that this repellent warrants further study.

Unbrowsed plants were also reduced in size at the end of Experiment 1, but not Experiment 2. Most plants in Experiment 1 were rephotographed before 15 May, whereas most plants in Experiment 2 were rephotographed at a later date. Some new growth may have occurred on plants in the latter experiment to offset the loss of size attributed to desiccation and abscission.

Analysis of photographs with the cover class system p to be a useful method to quantify browsing levels on den foliated evergreens such as yews. Procedures were replicated, acquisition of necessary materials was simple, the technique was easily learned. Moreover, photographs be stored and reevaluated again at a later date. Howe additional experiments may be needed to determine the tionship between grid cover classes and plant biomass, and technique was time-consuming. Analysis of each photo took 5-10 min., and this method may not be practical with samples.

Deer apparently prefer Japanese yews as a winter for ag and use of this plant to evaluate repellents provides a string test. Any repellent that protects Japanese yews would expected to work even better on species that are less preferred by deer. However, there has been no research to substantial this expectation.

The efficacy of a particular repellent under condition where all or most of the people in an area are using repellents is not known. If little or no untreated forage were available, deer may either move from the area or continue feeding in s pi of the repellent. Starving deer will eat even treated plan (Andelt et al. 1991). Therefore, under extreme conditions o food shortage and or high deer density, the use of fencing physical barriers may offer the best protection alternative.

MANAGEMENT IMPLICATIONS

These experiments were conducted during late winter/ spring, when yews are susceptible to intense browsing in areas with moderate-high deer densities. The effectiveness of these repellents under severe conditions, when food supplies are extremely scarce, was not determined. Nevertheless, the protection afforded by both Jersey and BGRR, as opposed to doing nothing, suggests that repellents are a viable and less expensive option than fencing or other physical barriers under the conditions described here.

Although Jersey has shown promise as a deer repellent, it may not be available for public use for several years. More field tests are needed, and Jersey must be registered by the Environmental Protection Agency (EPA). Even though the ingredients in a repellent have been approved previously, the EPA requires that all new mixtures be tested as a pesticide before they are registered. This process, although necessary, is lengthy, complicated, and expensive (Matschke 1977, Jacobs 1989).

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