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Abstract: It was hypothesized white-tailed deer (*Odocoileus virginianus*) could be readily conditioned to 2 commonly used deterrents, Deer-Away® Big Game Repellent (BGR) and blood meal (BM). Plots were randomly assigned BGR, BM and control. Free-ranging deer were initially conditioned to forage for corn at each 49m² bare earth plots delivered at 0500 hr and 1600 hr by programmable sling-type feeders. Hoof prints were counted within a 3.7m² sample area of each plot to quantify activity. Following preconditioning, data were collected during 5, 5-day periods. Application of BGR and BM to their respective bare earth plots occurred during periods 2,4 and 5. Initial exposure decreased the number of hoof-prints for BGR ($P = 0.011$) and BM ($P = 0.033$) compared to the control. Subsequent exposure to BGR during periods 4 and 5 did not differ from the control ($P > 0.227$). Prints counted following exposure to BM were similar to the control in period 4 ($P = 0.267$), but lower ($P = 0.045$) in period 5. Within each treatment group, prints counted were lower during period 2 compared to periods 1, 3, 4 and 5 for both BGR ($P = 0.001$) and BM ($P = 0.018$). No differences ($P > 0.05$) were found among periods 1,3,4 and 5 within each treatment. Results support the hypothesis that white-tailed deer can readily be conditioned to these two commonly used deterrents.

Key words: conditioning, deterrents, Georgia, *Odocoileus virginianus*

Continued growth of the white-tailed deer population and human urbanization has greatly increased the magnitude of negative human-animal interaction. Documentation of damage to horticultural plants (Conover 1984, 1997), row crops (Conover 1994, Wywailowski 1994), young trees (Marquis 1981, Conover et al. 1995) and potential to alter ecological communities (Stromayer and Warren 1997) is extensive. Additional damage due to deer-vehicle collisions, (Conover et al. 1995, Romin and Bissonette 1996) and zoonotic concerns to humans (Gage et al. 1995,

Conover 1997) continues to increase.

Pressure to reduce damage by deer using non-lethal means has gained public (Liss 1997) and political (Waller and Alverson 1997) support. Although expertise in deer capture and relocating has advanced significantly, economic cost and potential mortality of deer is high (Schwartz et al. 1997, DeNicola and Swihart 1997, Kilpatrick et al. 1997).

Use of repellents to control wildlife

damage is highly accepted by the public (Liss 1997). Mason (1998), and El Hani and Conover (1997) present extensive reviews of repellents to control damage by ungulates. A number of repellents tested were composed of animal based materials that produce odors resulting from protein and volatile fatty acid degradation. Volatilization of sulfur resulting from this process may indicate presence of a predator (Nolte et al. 1994, Mason et al. 1997). Deer Away Big Game Repellent (37% putrescent whole egg solids) is among the most effective deer repellent (DeYoe and Schapp 1987, Conover 1987, Conover and Kania 1988). Conover and Kania (1988) also reported similar results using blood meal as a repellent. However, virtually all repellents provided approximately 50% or less reduction in browsing damage (El Hani and Conover 1997).

Effectiveness of repellents may decrease over time (Nolte et al. 1993, El Hani and Conover 1997). Availability of alternative forages (Conover 1987, Conover and Kania 1988) and loss of the applied deterrent by rainfall (Sullivan et al. 1985, Andelt et al. 1991) are among potential factors that influence degree of effectiveness of repellents. However, there has been little effort to evaluate if deer can be conditioned to repellents. Therefore, this experiment was designed to test the hypothesis that free-ranging deer exposed to Deer Away Big Game Repellent or blood meal could become conditioned to each compound.

Study area

This study was conducted on the Berry College campus in Northwest Georgia from 18 May to 5 July, 1999. Approximately 1620 ha of the 11,340 ha contiguous land area are

maintained as a wildlife refuge in cooperation with the Georgia Department of Natural Resources. Density of deer within the refuge is estimated to be 1 deer/4 ha (J. Beardon, Georgia Department of Natural Resources, personal communication). Deer have caused substantial damage to landscaping and horticultural gardens throughout the Berry College campus. Plant communities in the test plot locations of this study were perennial fescue pastures maintained for livestock, with intermittent areas composed of loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), red oak (*Quercus rubra*), southern red oak (*Q. falcata*), white oak (*Q. alba*), sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). Each of the test plots were >2.0 km apart, located <50 m from a paved road and within 500 m of an academic building on the Berry College campus. Soil types consist predominantly of Conasauga silt loam and Cunningham loam (Tate 1978). Typical precipitation in the area was >130cm/year.

Methods

Vegetation was removed from 3,7 x 7 m plots by herbicide and tilling. Each plot was enclosed with a 20 x 20 m 3-strand barbwire fence about 1.0 m in height to prevent intervention by grazing cattle. Each strand of barbwire was spaced about 29 cm apart to allow deer access to the plot. Programmable sling-type feed dispensers (Game Country®, Model DF-01B, Albany, GA) were suspended about 2 m above the ground by an aluminum tripod within the center of each 7 x 7 m tilled plot. Feeders were programmed to provide 1 kg of whole corn (Manna Pro®, #2 yellow dent), within the tilled area of each plot at 0500 hr and 1600 hr. A 25 L feed tub was placed immediately below the feeder. Four sets of central stakes were driven into the

ground 30.5 cm apart around the edge of the feed tub at 90° increments. A second corresponding pair of stakes were driven 3.0 m from each pair of central stakes creating a cross-type pattern centered below the feeder to the edge of the plot, forming transects. Area within the 4 transects (3.7 m²) was used to quantify deer activity by counting hoof prints. Deer began consuming corn within 48 hr of completion of each plot. A 14-day preconditioning period elapsed to ensure deer acclimatization to the plots and to standardize data collection procedures.

Each morning (0800 hr), throughout the preconditioning and subsequent periods, a string was placed around the perimeter of each set of central and corresponding stakes at the edge of each plot. Total number of hoof prints within the four transects (3.7 m²) was used to quantitate deer activity. Prints bisected by the string were included in the data. Two counts were recorded for each plot by one of two observers. Average of the two counts was used for statistical analysis. Each observer counted for 3 consecutive days. Deviation in hoof print counts between the two observers, determined during the preconditioning period, was < 3%.

Plots were randomly assigned as control; Big Game Repellent (BGR); (Deer Away® Big Game Repellent, IntAgra, Inc., Minneapolis, MN) or blood meal (BM); (Vigoro®, Pursell Industries, Inv. Sylacauga, AL). The control plot was counted first, followed by BM and BGR, respectively. To minimize cross-contamination, disposable polyurethane boots were utilized and discarded for each site during all time periods. Lawn rakes used to eliminate prints post-counting, were also maintained at each plot. A small garden tiller was used to break the top 5

cm of surface soil at each plot during non-treatment periods.

Following preconditioning, data were collected during 5, 5-day treatment periods. No repellents were applied during periods 1 and 3. BGR and BM were applied to their respective plots during treatment periods 2, 4 and 5. Duration of subsequent treatment periods was determined during treatment period 2. BGR and BM were determined to be ineffective and treatment period complete when prints observed reach 80% of the mean number of prints determined in period 1. This occurred day 5, post-treatment during period 2. The five-day treatment periods were used throughout the remainder of the study to facilitate statistical analysis.

During each treatment application period, 454 g of BGR was distributed by hand broadcasting within the designated 7 x 7 m plot. Based on BGR manufacturer recommended dose level for protection of conifer seedlings, and regional density planting rates for pine seedlings of 2964 trees/ha; dose levels used in this study to treat 49 m² should be sufficient to protect 500 trees on 1686 m². This treatment level was sufficient to clearly visualize the compound on the soil. The BM (250.4g) was applied at a rate sufficient to provide visual, uniform coverage of the respective 7 x 7 m plot. Sufficient rainfall to inhibit determining hoof prints occurred during day 4 of period 4. In order to maintain a balanced data set, prints observed day-5 and day-6 post-treatment were included in period 4. Rainfall also eliminated visual presence BGR and BM and potential effectiveness as deterrents. Therefore, treatment period 5 was added to provide an additional challenge to the conditioning hypothesis.

Univariate analysis of variance procedures of SPSS 9.0 (SPSS 1996) were used to determine differences in mean number of deer prints between each treatment and control periods, and within each treatment. Duncan's Multiple Range Test was used to evaluate differences ($P < 0.05$) in number of deer prints between periods, within each treatment.

Results

Initial treatment of repellents during period 2 decreased mean number of hoof prints for both the BGR ($P = 0.011$) and BM ($P = 0.033$) compared to the control (Table 1).

Subsequent applications of BGR in periods 4 and 5 did not alter number of hoof prints observed from the control ($P > 0.227$). Prints counted following exposure to BM were similar to the control in period 4 ($P = 0.267$), but lower ($P = 0.045$) in period 5. Hoof prints counted during period 2 were lower in BGR ($P = 0.001$) and BM ($P = 0.018$) plots than the other four periods within each treatment. No differences ($P > 0.05$) on hoof prints were observed between periods 1, 3, 4, and 5 within each treatment (Table 2).

Table 1. Mean number of white-tailed deer hoof prints (\pm SE) counted within the 3.7m² sample areas for each treatment plot.

Period	BGR ^a ($x \pm$ SE)				Control ($x \pm$ SE)	
	x	SE	x	SE	x	SE
1	294.9	6.9	276.6	4.6	286.2	23.5
2*	164.9	4.3 ^{cd}	178.5	23.5 ^{cg}	280.3	32.1
3	280.4	17.5	257.7	14.9	267.1	18.9
4*	300.1	42.9	294.7	39.2	249.6	23.7
5*	281.1	3.3	247.5	15.2 ^f	310.1	21.9

* Treatment application on day 1 of each 5 day period.

^a BGR = Deer Away® Big Game Repellent.

^b BM = Vigoro® Blood meal.

^c Difference between BGR period 2 and Control period 2 ($P = 0.011$)

^d Difference between BGR period 2 and BGR periods 1,3,4 and 5 ($P = 0.001$)

^e Difference between BM period 2 and Control period 2 ($P = 0.033$)

^f Difference between BM period 5 and Control period 5 ($P = 0.047$)

^g Difference between BM period 2 and BM periods 1,3,4 and 5 ($P = 0.018$)

Table 2. Average number of white-tailed hoof prints counted daily within the 3.7m² sample areas for each treatment plot.

Period	Day	BGR ^a	Bm ^b	Control
1	1	291.0	274.0	262.5
1	2	293.5	263.5	364.5
1	3	288.5	272.0	315.5
1	4	280.5	289.5	246.5
1	5	321.0	284.0	242.0
2*	6	159.5	130.5	193.0
2	7	148.5	165.0	230.5
2	8	121.0	134.0	303.0
2	9	197.0	212.5	379.0
2	10	194.0	250.5	296.0
3	11	271.5	244.5	213.0
3	12	272.0	270.5	296.5
3	13	348.5	310.0	258.0
3	14	249.0	237.0	247.0
3	15	261.0	226.5	321.0
4*	16	268.5	220.5	379.0
4	17	242.5	246.5	348.0
4	18	285.5	246.5	396.0
4	19	236.0	325.0	366.0
4	20	468.0	435.0	259.0
5*	21	284.0	298.0	398.0
5	22	278.5	238.0	257.0
5	23	292.5	255.0	288.5
5	24	274.0	242.5	301.0
5	25	276.5	204.0	315.0

"Treatment application of BGR and BM.

^aBGR = Deer Away® Big Game Repellent.

^bBM = Vigoro® Blood meal.

Discussion

A reduction of about 50% was observed in the number of deer prints within treatment plots following initial exposure to BGR and BM. While methodology used to determine efficacy of a repellent vary, these results concur with other field tests concerning initial repellent effects of BGR (Conover 1987, De Yoe and Schaap 1987, Conover and Kania 1988) and BM (Conover and Kania 1988). It has also been proposed that the signal quality of avoidance is likely to be short-lived (Nolte et al. 1993). Results of this study indicate subsequent reapplication of repellents (period 4 and 5) had (period 4 and 5) had no effect in reducing the presence of deer within the BGR plot compared to the control. It is important to acknowledge that number of prints counted within the BM plot was similar to the control during period 4 and lower in period 5. Reapplication of BM to moistened soil following rain that occurred during period 4 may have enhanced initial effects of BM relative to that plot in the fifth period.

Regardless, if the objective of a deterrent is to provide protection at a particular location, data pertaining to effects at each treatment site has greater biological importance and management implications. In this study hoof prints observed following initial application of each treatment were lower for BGR and BM than the other four periods. No differences in hoof prints observed during periods 1,3,4 or 5 were noted within each treatment site. Therefore, this experiment provides clear evidence of white-tailed deer ability to become conditioned to the deterrents tested.

Non-climatic factors that influence degree of protection afforded by repellents include: size of area to protect, density of animals, availability of alternative forage, dose level of repellent and palatability of the forage being treated (Mason 1998). In consideration of these factors, the Berry College campus and wildlife refuge provided an exceptional location for this type of field test. Size of area we attempted to protect was small, 49 m², with a relatively high estimated deer density (1 deer / 4 ha). While no attempt was made to quantify other food sources, alternative forages of both natural and ornamental plants appeared readily available and utilized throughout the duration of this study. Corn was utilized throughout the study as the forage product to be protected by the repellents. It was considered important to minimize changes in palatability or nutritional value, and subsequent selective preferences of deer that may occur when using living plant material. The nutritional value of corn should be considered high and could result in a motivational factor likely contributed to the relatively short effective period of each repellent upon initial exposure to each treatment. As previously indicated, BGR was applied to bare ground and at a rate that far exceeds manufacturer recommended dose level for protection of conifer seedlings. No recommended levels of BM for repellent purposes were found. While repellents were not directly applied to the corn, deer would have direct olfactory and likely ingestion of repellents when consuming corn from the bare ground.

Degradation of proteins resulting in the release of sulfur has been proposed to be the primary mechanism of action for BGR, BM, predator urine and feces (Mason et al. 1997). Sulfur may provide an indication of the

presence of carnivores (Nolte et al. 1994). Numerous toxic plants also produce sulfur (Mason et al. 1997). Upon repeated exposure to such compounds and sufficient motivation to remain, food palatability or nutrition, habituation is likely to occur without additional stimulus such as visualizing a predator or other negative influence. It would also be likely using a different deterrent that functions on a similar basis, such as sulfur production, would be ineffective under similar conditions. Also, degree of initial exposure to a potential repellent may alter the effectiveness and duration of that repellent. Human hair was reported to be somewhat effective in field trials (Conover and Kania 1988) but not effective in captive deer (Harris et al. 1983). Habituation to humans of deer maintained in pens or other forms of captivity are likely to be a contributing factor to the varied response to human hair. In this study no effort was made to differentiate age or size of animal based on size of hoof print. However, the presence of prints from recently born offspring occurred from the end of period 3 to the termination of the study. It is possible that exposure to a particular deterrent at an early age could effectively eliminate response to that type of compound throughout the animals life. In domestic horses, experiences afforded the young animal, both positive and negative, have been shown to influence future behavior (Fiske and Potter 1979, Heird et al. 1986, McCall 1990).

Management Implications

Results of this study indicate that deer can be readily conditioned to a repellent when provided the opportunity in a consistent manner. Miller (1997) presented a review of the importance of considering social behavior in the management of overabundant deer

populations. We concur that recognition of social behavior within a particular deer population is likely to influence effectiveness of management procedures. This study supports the concepts that integrated pest management (IPM) and other strategies of combining multiple forms of deterring stimulus including olfactory, visual, auditory, and systemic are likely to be more effective than a single repellent (Avery 1997, Beauchamp 1997, Mason 1998).

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