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Evaluation of foliar sprays to reduce crop damage by Canada geese

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Abstract: South Dakota Department of Game, Fish and Parks annually spends >$500,000 managing crop damage caused by grazing Canada geese (*Branta canadensis*). Foliar applications of a chemical feeding deterrent could provide an effective alternative to the methods currently being used to reduce damage. In 2011 and 2012, we evaluated Rejex-It Migrate Turfguard®, Bird Shield®, Avian Control®, and Avipel® as grazing deterrents. We used a ground sprayer to apply the treatments every 7 days to plots in soybean fields in Day County, South Dakota. We monitored activity in the plots using time-lapse photography. We began treating the plots after geese had begun using them (late June through mid-July). Damage was estimated after geese had abandoned the plots (August). The methyl anthranilate products (Rejex-It, Bird Shield, and Avian Control) were ineffective at reducing crop damage. Damage was 100% on all plots treated with these products. Use of plots significantly increased ($P < 0.02$) between the pretreatment and postreatment periods for Rejex-It (180 minutes/day and 313 minutes/day) and Bird Shield (200 minutes/day and 299 minutes/day); whereas, use was similar ($P = 0.99$) between plots treated with Avian Control (111 minutes/day) and reference plots (104 minutes/day). Less time was spent on plots treated with the anthraquinone-based product, Avipel (44 minutes/day) than on reference plots (132 minutes/day; $P < 0.01$). Additionally, soybean damage was less on Avipel-treated plots than on reference plots ($P < 0.01$). We recommend more research on Avipel to assess rates and timing of application to make this product efficacious and economical in the field.

Key words: anthraquinone, Canada geese, crop damage, human–wildlife conflicts, methyl anthranilate, soybeans

Canada geese (*Branta canadensis*) historically nested throughout the Great Plains. Canada geese (henceforth, geese) were nearly extirpated in South Dakota because of overhunting and egg collecting in the Twentieth Century (Vaa et al. 2010). The South Dakota goose population began to rebound in the late 1980s with the help of reintroduction efforts. In the last several years, the population has expanded rapidly, exceeding management objectives of the South Dakota Department of Game, Fish, and Parks (SDGFP). The spring population estimate in 2012 was 270,000 birds (U.S. Fish and Wildlife Service 2013) compared to the management objective of 80,000 to 90,000 birds (Vaa et al. 2010). South Dakota Department of Game, Fish, and Parks has been trying to reduce the goose population with special hunting seasons (Dieter et al. 2010).

Requests to SDGFP for assistance to alleviate crop damage have increased as the goose population has risen (Dieter and Anderson 2009). Damage has been reported for corn, wheat, oats, and alfalfa (Schaible et al. 2005, Gigliotti 2007); however, soybeans are damaged the most (Radtke and Dieter 2010). Both the relatively short height and palatability of soybeans makes this crop an excellent food source for geese, but it is most vulnerable to damage during early stages of development (Cleary and Reynolds 1984). Early damage to soybeans can affect yield (Reed et al. 1977). Crop damage by geese is greatest during the brood-rearing and molting periods (Dieter and Anderson 2009). Not only are the goslings rapidly growing, the adults must replenish their lost reserves and meet the increased energetic requirements of molt (Raveling 1979, Alisauskas and Ankney 1992). Adult and juvenile geese are flightless during these times, and they walk from wetland areas to nearby agricultural fields (Hanson 1965). Adult geese

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often move their broods to areas where soybean fields are easily accessible, because soybeans might be preferred over other foods (Flann 1999, Schaible et al. 2005).

To assist farmers, SDGFP developed an operational management program funded by a $5 surcharge on most hunting licenses (Vaa et al. 2010). From 2000 to 2010, SDGFP spent >$500,000 annually on Canada goose damage activities in 22 counties in South Dakota (Vaa et al. 2010). An integrated approach that utilizes hazing with tools such as propane cannons, pyrotechnics, use of electric fences, buffer crops, and feeding stations have successfully reduced crop damage by 90% in 2006 and 80% in 2007 (Radtke and Dieter 2011). Additionally, Radtke and Dieter (2010) documented that the farthest Canada geese will travel inland to feed on soybeans was 36 m. However, with current high commodity prices, farmers are planting closer to water bodies, thus, increasing the opportunity for geese to feed on crops.

Chemical deterrents have the potential to be less labor intensive and perhaps more effective and economical than methods currently used by SDGFP to reduce goose damage. Past research indicates that topical chemical applications may have strong deterring effects, have multiple modes of deterrence, and may be long lasting (Dolbeer et al. 1998, Ballinger et al. 1999, Werner et al. 2009). A chemical that proves successful at reducing crop damage by flightless geese would be important to both SDGFP and agricultural producers.

Chemical deterrents are categorized as either primary or secondary (Avery 2003). Primary deterrents are painful or irritating upon contact and usually affect the nasal, ocular, or oral regions. Ingestion does not need to occur for primary deterrents to be successful, and, generally, there is little or no phytotoxic damage to crops. Individuals affected by primary chemical deterrents quickly sense the chemical, and they seek other food sources. Secondary deterrents need to be ingested for them to be effective. Symptoms are usually gastrointestinal (e.g., vomiting). The avoidance behavior is developed when the afflicted bird associates the negative, post-ingestional consequences with the color and taste of the recently utilized food (Avery 2003). Secondary deterrents can create stronger and longer-lasting avoidance behavior than primary deterrents.

Examples of primary deterrents are Bird Shield® (Bird Shield Repellent Corporation, Pullman, Wash.), Rejex-It® (Natural Forces LLC, Davidson, N.C.), and Avian Control® (Avian Enterprises Inc., Sylvan Lake, Mich.), which use methyl anthranilate (methyl 2-aminobenzoate, $C_8H_9NO_2$) as the active ingredient. Methyl anthranilate (MA) is a naturally occurring compound that is used in the food industry to impart grape or fruity flavor to candy, gum, soft drinks, and other consumable goods and is listed as generally regarded as safe by the U.S. Food and Drug Administration (FDA; Avery 2003).

An example of a secondary deterrent is Avipel® (Arkion Life Sciences LLC, New Castle, Del.) that uses anthraquinone as the active ingredient. Anthraquinone is chemically produced by oxidation processes and is mixed with water prior to being applied to such surfaces as turf, ornamental bushes, nonfood plants, buildings, and hedges (Ballinger et al. 1999). Fine crystals of the compound remain bound to the surface after the water carrier has evaporated. The long persistence (half-life of 28 days) with eventual degradation allows the treatment to stay viable without being permanant. Anthraquinone is stable in sunlight and there is no appreciable loss to evaporation (Ballinger et al. 1999).

Our goal was to determine if there was a commercially available chemical that could be applied to reduce soybean damage by geese in the conditions present in eastern South Dakota. Our objectives were to evaluate selected primary and secondary chemical deterrents to assess their effectiveness and provide preliminary management recommendations on the feasibility of applying chemical deterrents.

Study area

All study sites were located <25 km from Webster, South Dakota, in Day County (2,826 km^2). Day County (GPS N45 22.21 W97 36.23) is in eastern South Dakota, lying within the Prairie Pothole Region, a productive wetland-dominated region renowned for its waterfowl (Smith et al. 1964). The landscape was flat to gently rolling, which is characteristic

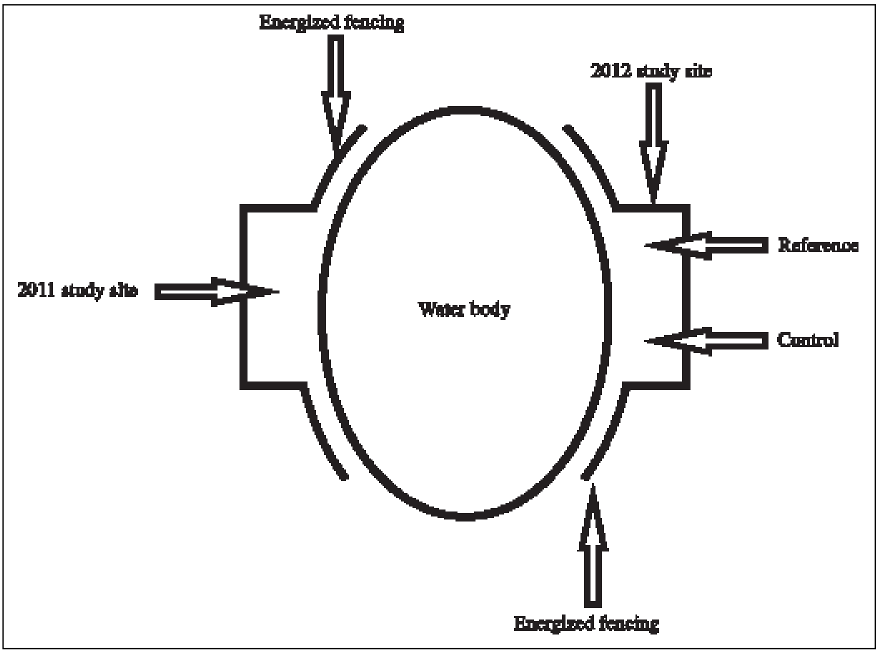

Figure 1. Study site diagram for Canada goose study in Day County, South Dakota, during 2011 and 2012. In 2011, the entire study site was treated, while in 2012, the study site was enlarged and contained a treatment and reference.

of the glacial origins of the Prairie Coteau physiographic region (the glaciated region of northeast South Dakota; Hogan 1991). The vegetation type was mixed-grass prairie. Land use was dominated by agriculture, with soybeans, corn, and wheat as the primary crops. The climate of Day County is classified as humid continental with mean maximum and minimum temperatures of 12.1° C and -0.06° C, respectively. During summer, maximum and minimum average temperatures are 25.5° C and 12.3° C. Annual precipitation is 58.1 cm, and during summer, precipitation averages 8.18 cm (Hogan and Fouberg 1998). Day County has had the highest number of requests for damage assistance in South Dakota (Vaa et al. 2010). The SDGFP has spent about $180,000 per year on goose damage in Day County since 2000 (R. Murano, SDGFP, personal communication).

Methods

Study site selection and preparation

We selected study sites on private lands with soybean fields close to small, landlocked waterbodies (<75 ha) having multiple family groups of geese. Each study site had 30 to 100 flightless geese. We contracted the landowners, paying each $540 for a 0.4-ha plot of soybeans. We selected study sites with little visual obstruction between the field and the adjacent water body, as these areas often are used by geese to forage (Radtke and Dieter 2010).

We used electric fencing to establish a foraging boundary around each study plot. The fences consisted of single, polystrand wire connected to a solar-powered 6-volt, 7-ampere hour battery (Gallagher Animal Management Systems®, North Kansas, Mo.). Electrical resistance was 209 ohms/km. The system was grounded using a 1-m-long metal post. The wire was clipped to 1.2-m fence posts approximately 0.5 m above the ground (Dare Products® Inc., Battle Creek, Mich.).

We created a 3-sided rectangle parallel and open to the water body using the boundary fencing (Figure 1). We fenced only the soybean field, so that geese were free to move to other areas around the wetland to feed. We used Plotwatcher® cameras (Day 6 Outdoors, LLC Columbus, Ga.) to monitor activity on the plots. At the end of each rectangular plot, we mounted a camera on a small fence post viewing down the middle of the plot. We programmed the cameras to photograph the plots at 10-second intervals during daytime. Pictures were stored on 8-gigabyte USB drives. Exclosures (4.88 m^2) were created by wrapping plastic poultry wire around 4 metal stakes. The wire was 1.22-m-high and prevented geese from damaging soybeans inside the structure. These structures were placed 9 m from the shoreline and 30 m from the sides of each study site.

We used different study designs between years. In 2011, we selected 16 study sites. We tested 2 MA products, Rejex-It and Bird Shield. Five study sites were allocated to each treatment, and there were 6 reference sites. The assignment of treatments was randomly selected for the first site and alternated between products thereafter. Size of the test plots was approximately 18.2 m × 91.4 m, with the long side running parallel to the shoreline (Figure 1).

In 2012, we selected 12 study sites, eight of which were allocated for treatment with Avipel, and 4 sites were allocated for treatment with Avian Control. In 2012, the open-sided, rectangular plot was 24.5 m × 111 m. We divided the rectangle in half and randomly assigned a reference and treated plot (Figure 1). A fence post placed near the water's edge was used to mark the separation between the treated and reference plots. We placed 1 4.9-m^2 exclosure on each plot and installed 2 Plotwatcher cameras on each site. The cameras were placed in the middle of the rectangle, each facing along the long segment of the rectangle on their assigned treatment halves. We observed the study sites daily without disturbing the geese. We checked the cameras at night and downloaded images onto a laptop computer. Camera batteries were changed every 4 days.

Site spraying (2011)

Bird Shield and Rejex-It were applied according to label directions and rates recommended by the distributors. Both products are registered by the U.S. Environmental Protection Agency (EPA) for agricultural use as foliar sprays (Rejex-It: Reg. No. 58035-9; Bird Shield: Reg. No. 66550-1). We applied the products using a 56.8-l Fimco® tank sprayer with a 3.66-m boom and 7 nozzles (Fimco Industries, Dakota Dunes, S. D.) on a 2010 Honda Rancher® all-terrain vehicle (ATV). At the start of the field season, we moved the boom to its lowest possible setting (approximately 0.3 m above the soybeans) and continued to move it upward as soybeans grew. We calibrated the nozzles to spray 26.5 L per 0.2 ha, with the ATV traveling at 6.4 km/hour.

Before treating a plot, we mixed the appropriate amounts of product and water. The products were characterized by a gray to blue aqueous slurry with a pH of 5.3 to 5.9. A recirculating pump in the tank kept the mixture under constant agitation. During spraying, the boom was monitored to assure that leaves of all plants within each plot were covered. The tank and boom sprayer were triple rinsed between applications to reduce contamination. We sprayed every 7 days throughout July and August or until the soybeans had been completely consumed by geese. We sprayed during optimal conditions (light winds <15 km/hour) with low possibility of rain and geese not actively feeding.

Each product had a different MA chemical concentration (Rejex-It, 14.5% active ingredient; Bird Shield, 26.4% active ingredient) and different label instructions for mixing. Rejex-It was mixed with 1 part chemical to 10 parts water, and Bird Shield was mixed with 1 part chemical to 99 parts water. When using Rejex-It, we added 0.12 L of surfactant (Miller Chemical Company Hartford, Conn.) and 0.07 L of Invisidye® (Natural Forces LLC, Davidson, N.C.). Invisidye is an ultraviolet (UV) agent that may enhance the efficacy of Rejex-It. The UV agent was added because waterfowl can see in the UV spectrum, and it has been hypothesized that UV may enhance a chemicals deterrent's effectiveness (Avery 2003). Bird Shield was applied at a lower rate because of its greater percentage of active ingredient. A UV agent and surfactant were present in Bird Shield, and no additives were used.

Site spraying (2012)

Based on equivocal results from 2011, we evaluated 2 other commercially available chemical deterrents, Avian Control and Avipel. Avian Control is an MA product that was reformulated by the manufacturer with an additional chemical intended to enhance effectiveness. Avian Control is approved for use as foliar spray on food crops (EPA Reg. No. 33162-1).

The active ingredient of Avipel (50%) is anthraquinone. Avipel effectively reduces depredation of planted seed (e.g., rice and corn) by multiple species of birds. Avipel is regulated under the Federal Insecticide, Fungicide, and Rodenticide Act, specifically as a seed treatment under Sections 18 and 24. Currently, Avipel can be applied experimentally only on soybean crops as a foliar treatment because no Section 18 or Section 24 has been granted for topical application on soybeans in South Dakota. However, the EPA allows researchers to apply unregistered chemicals on ≤4.1 ha.

We used similar spraying equipment and methods as in 2011. Immediately after a site was developed, we applied the treatments and began monitoring goose activity. Sites were sprayed every 7 days to ensure chemical coverage. For Avian Control, based upon manufacturer's recommendations, a 6:1 ratio of water to product concentration was used. Volume recommendations for Avipel as a foliar application have yet to be established. We decided to apply a 6:1 ratio of water to liquid Avipel to treatment plots. With no previous knowledge of appropriate application rates, we believed that this concentration would test the effectiveness of the chemical on geese.

Site closures

We monitored study sites until the birds had moved to other areas or had begun to fledge (August 1), at which point, we removed all project equipment and conducted yield evaluations and damage surveys. In 2011, all treatment and reference plots were destroyed by geese, and only exclosures could be evaluated for soybean yield. We used a yield estimation guide provided by Monsanto Co. (St. Louis, Mo.; Lee and Herbeck 2005). We gathered all the plants from the exclosures and allowed them to dry. To estimate yield, we documented pods per plant, seeds per pod, and seed weight. In 2012, the Avian Control plots were completely destroyed by geese. Yield estimates were, thus, done only for the exclosures using the Monsanto method.

On the Avipel treatment plots, we developed a method to visually estimate and compare damage between treated and reference plots. We established 4 transects running the length of the plots. The first transect was closest to the water, about 1 m from the edge of the field. The last transect was 1 m inside the outer boundary of the plot. The other 2 transects were evenly spaced between the outer transects. We walked the transects and placed a 1 × 1 m wooden quadrat every 9.14 m. We evaluated the amount of damage present inside the quadrat and gave a ranking of 0 to 3. A ranking of 0 indicated 100% damage, 1 was 50 to 99% damage, 2 was 1 to 49% damage, and 3 was 0% damage. To avoid sampling bias, only 1 person was appointed to estimate damage.

Data analysis

Data from camera observations and transects were analyzed using SAS® (SAS Institute Inc., Cary, N.C.). We described goose use as any time there were ≥1 geese present on the plot. Data were normally distributed (z = 0.67), and we used a student's *t*-test to compare goose use (minutes/day) of plots during pretreatment and post-treatment periods (2011) and between reference and treated plots (2012). In 2012, a Chi-square test was used to analyze categorical differences in damage between references and treatments on Avipel plots. All activities were approved by the South Dakota State Institutional Animal Care and Use Committee (Study No. 10-081A).

Results

2011

The median dates for site construction and application were July 1 and July 12, respectively. Bird use on each plot was monitored and recorded 2 days prior to the initial treatment and 6 days after each treatment. At all of the study sites, we completed only 1 or 2 applications because geese had completely destroyed the soybeans, and there was no foliage left. On plots treated with Bird Shield, geese spent an average of 200 minutes/day before treatment and 299 minutes/day after treatment. On plots treated with Rejex-It, pretreatment use was 180 minutes/day and posttreatment use was 313 minutes/day. Goose use increased after each initial application (Figures 2 and 3) and was significant for both Bird Shield (t_1 = 3.30, P < 0.01) and Rejex-It (t_1 = 5.22, P < 0.01). The average soybean yield in exclosures in both treated and reference plots was 60 bushels/ha, which was similar to the average for Day County. Yield outside of exclosures on all plots was zero bushels/ha.

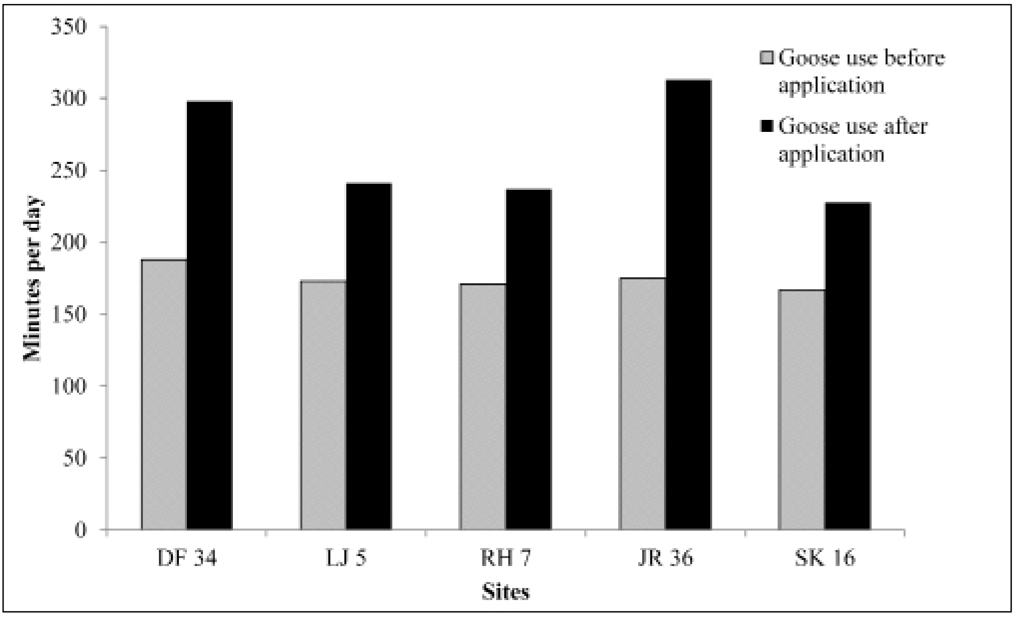

Figure 2. Daily Canada goose activity based on photographs taken with a Plotwatcher® camera at Bird Shield® plots before and after treatment was applied in 2011.

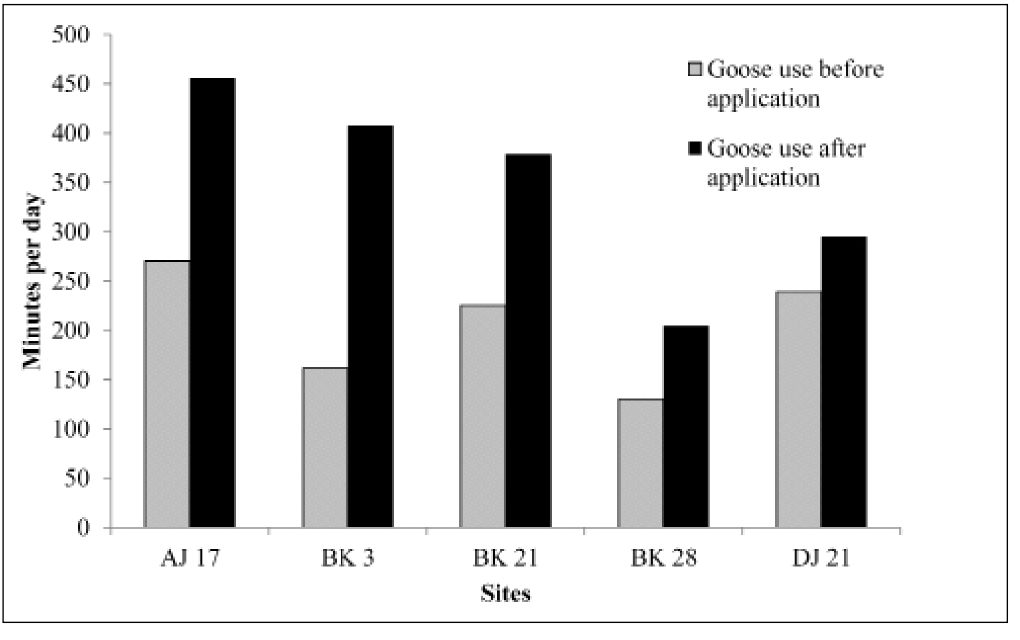

Figure 3. Daily Canada goose activity based on photographs taken with a Plotwatcher® camera on Rejex-It® plots before and after treatment was applied in 2011.

2012

The median date for site construction and treatment was June 23. Avian Control did not deter grazing by geese, and yield on the treated plots was zero. At all sites, we completed only 1 or 2 applications, because all the soybeans had been consumed by geese. In the exclosures, yield averaged 60 bushels/ha. Camera observations revealed that geese at the avian control plots sites spent an average of 104 minutes/day on reference plots and 111 minutes/day on treated

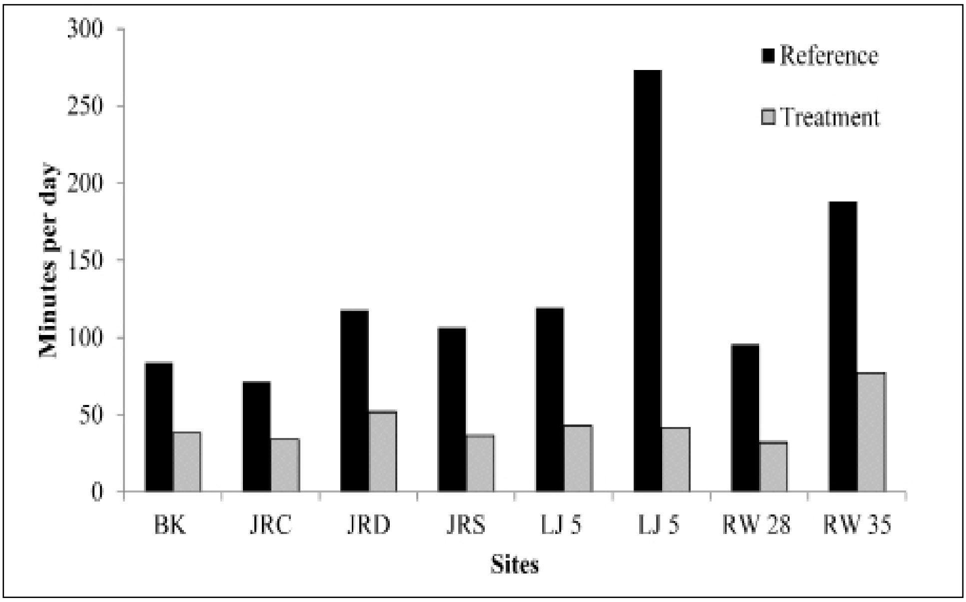

Figure 4. Daily Canada goose activity on treated and untreated plots based on photographs taken with a Plotwatcher® camera on Avian Control® plots in 2012.

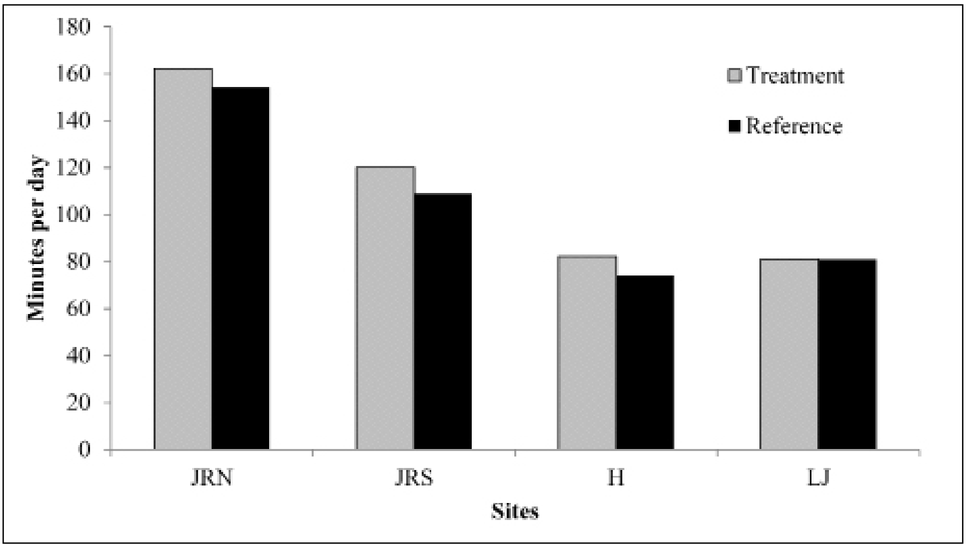

Figure 5. Daily Canada goose activity based on photographs taken with a Plotwatcher® camera on Avipel® plots in 2012.

plots (Figure 4). Use by geese was not different between plots among sites ($t_1 = 0.02$, $P = 0.99$).

On Avipel sites, goose-use differed between the reference and treated plots ($t_1 = 7.99$, $P < 0.01$). Geese spent an average of 132 minutes/day on reference plots and 44 minutes/day on treated plots (Figure 5). Frequencies of damage categories showed that damage was less on treated plots than on reference plots at all Avipel treated sites ($\chi^2_3 = 199.6$, $P < 0.01$; Figure 6).

Discussion

Methyl anthranilate products

Methyl anthranilate is a primary repellent that, theoretically, is reflexively avoided by birds because it irritates the trigeminal nerve. Thus, minimal feeding occurs before

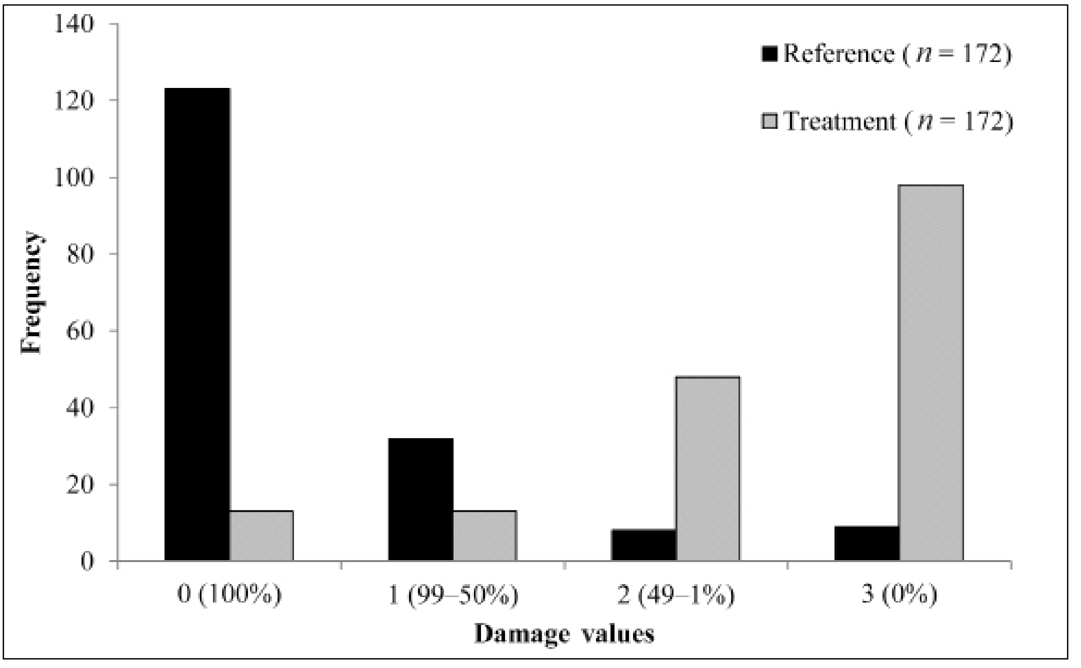

Figure 6. Estimated soybean yield on transects on Avipel® treatment plots in 2012. A score of 0-3 was given based on the level of damage (0 = 100% damage; 1 = 50 to 99% damage; 2 = 1 to 49% damage; 3 = 0% damage). When all sites were combined, the difference in soybean yield between treatment and reference plots was significant (χ^2_3 = 199.6, P < 0.01).

avoidance is learned (Cummings et al. 1995). Some research has found that MA applied at concentrations from 1 to 2% effectively repels waterfowl (Cummings et al. 1992). However, in experiments involving Canada geese, MA has had mixed results in deterring feeding behavior (Cummings et al. 1991, 1992, 1995; Belant et al. 1996). Grazing by geese is sometimes reduced on turf and grasses that have received recent MA treatments; however, some level of feeding still occurs even after treatment. Grazing typically will increase over time as MA chemically breaks down and and habituation behavior begins to take effect (Cummings et al. 1991, 1995; Belant et al. 1996).

The avoidance of MA in some previous studies may have been because the birds in the study were able to fly, and they could easily move to alternate feeding sites. In our study, all geese were flightless, and all 3 MA products were completely ineffective at deterring crop damage. In many cases, geese fed on freshly treated (<2 hours) soybeans and showed no negative responses, such as head shaking or drinking copious amounts of water. The cameras showed how quickly soybeans sprayed with MA were destroyed by geese. In light of the evidence, we do not recommend using any MA products to deter crop damage by Canada geese in eastern South Dakota.

Anthraquinone-based products

Anthraquinone is a secondary repellent that causes post-ingestional distress in birds (Avery 2003), but is nontoxic (Dolbeer et al. 1998). Behavior studies have shown that Canada geese that sample the compound shake their heads and attempt to wash it off (Ballinger et al. 1999). Aversion to the compound occurs after ingestion and absorption into the large intestine (Werner et. al. 2009). Studies have shown that anthraquinone can be seen in the ultraviolet range by Canada geese (Dolbeer et. al. 1998). This ultraviolet spectrum is also where the visual sensitivity in many bird species is maximal (Bennett and Cuthill 1994). It is believed that the combination of a strong secondary irritant along with visual cues is responsible for the rapidly learned response in Canada geese (Ballinger at. al. 1999).

Werner et al. (2009) found that anthraquinone effectively produced a conditioned avoidance response by Canada geese following initial exposure to treated corn seed. The authors

Figure 7. Aerial photo showing where geese ate untreated beans (light area), passing over beans treated with anthraquinone (dark areas).

found that a threshold concentration of 1,450 ppm anthraquione was necessary to achieve 80% repellency. A study performed at the Portland [Oregon] International Airport reported a dramatic decrease in goose observations after application of anthraquinone (Gordon and Lymann 2000). Before applications, geese were observed in treated plots 65% of the time. After application, observations gradually increased from 0% to <36% over a 6-week period. Devers et al. (1998) reported a 95% reduction in goose activity on treated plots after application of anthraquinone in Fort Collins, Colorado. The activity on the adjacent control plots increased dramatically (312%), indicating that the birds could sense the compound and avoided it rather than leave the area.

In our study, anthraquinone showed a high level of deterrence (Figure 7). Both camera and transect data show that geese selected untreated soybeans. In many cases, adult geese approached treated soybeans and cautiously examined the plants. After a visual inspection, it appeared that they led the juveniles in search of untreated soybeans. It is possible that these adult geese had tasted anthraquinone-treated soybeans and responded negatively due to the characteristic UV reflectance. As a secondary repellent, geese ate some amounts of treated soybeans during the study, as indicated by damage measurements. However, previous work has shown that a substantial amount of damage can occur before the plant is destroyed (Radtke 2008). On all study sites, it was evident that geese quickly learned to avoid the treated soybeans. We believe anthraquinone holds the most promise for reducing goose damage to crops in eastern South Dakota.

Management implications

The damage management program administered by SDGFP has been most effective when using electric fences to deter crop damage by Canada geese. However, in many cases, landowners are not aware of damage, and a large amount of damage may occur prior to having the electric fences erected. A treatment, such as a chemical spray, could be applied to all fields next to wetlands to prevent damage before it occurs. We believe that anthraquinone-based products hold the most promise as a chemical deterrent to crop damage by Canada geese in the field conditions present in South Dakota. However, there are some problems to overcome to get anthraquinone available for use as a foliar spray. Anthraquinone has to be certified for use by the EPA and U.S. Food and Drug Administration prior to widespread use. In addition, research is needed to determine the best application rate, application schedule, size of area to be treated, and related financial costs. There is likely no need to spray the entire field, as flightless geese do not venture far from the safety of water (Radtke 2008). Based on the history of crop damage by geese, there will likely be damage to crops in the future. Higher commodity and input prices and lower levels of landowner tolerance will also influence the development of a chemical deterrent that could serve as a valuable tool for managers to employ.

Acknowledgments

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Literature cited

Alisauskas, R. T., and C. D. Ankney. 1992. The cost of egg laying and its relationship to nutrient reserves in waterfowl. Pages 30–61 *in* B. D. J. Bart, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, Minnesota, USA.

Avery, M. L. 2003. Avian repellents. Encyclopedia of agrochemicals. Wiley, New York, New York, USA.

Ballinger, K. E., M. K. Gilmore, and R. W. Price. 1999. Recent developments in the use of Flight Control to repel birds from airports. Proceedings of the Bird Strike Committee, USA-Canada 1:1–8.

Belant, J. L., T. W. Seamans, L. A. Tyson, and S. K. Ickes. 1996. Repellency of methyl anthranilate to pre-exposed and naïve Canada geese. Journal of Wildlife Management 60:923–928.

Bennett, A. T. D., and I .C. Cuthill. 1994. Ultraviolet vision in birds; what is its function? Vision Research 34:1471–1478.

Cleary, E., and K. Reynolds. 1984. Canada goose numbers and goose damage in northeastern Indiana. Proceedings of the Eastern Wildlife Damage Control Conference 1:237–238.

Cummings, J. L., J. R. Mason, D. L. Otis, and J. F. Heisterberg. 1991. Evaluation of dimethyl and methyl anthranilate as a Canada goose repellent on grass. Wildlife Society Bulletin 19:184–190.

Cummings, J. L., D. L. Otis, and J. E. Davis Jr. 1992. Dimethyl and methyl anthranilate and methiocarb deter feeding in captive Canada geese and mallards. Journal of Wildlife Management 52:349–355.

Cummings, J. L., P. A. Pochop, J. E. Davis Jr., and H. W. Krupa. 1995. Evaluation of ReJeX-it AG-36 as a Canada goose grazing repellent. Journal of Wildlife Management 59:47–50.

Devers, P., P. Reichert, and R. Poche. 1998. Field trial using Flight Control as a repellent for Canada goose (*Branta canadensis*) control in Fort Collins, CO. Proceedings of the Vertebrate Pest Conference 18:345–349.

Dieter, C. D., and B. J. Anderson. 2009. Reproductive success and brood movements of giant Canada geese in eastern South Dakota. American Midland Naturalist 162:373–381.

Dieter, C. D., B. J. Anderson, J. S. Gleason, P. W. Mammenga, and S. Vaa. 2010. Late summer movements by giant Canada geese in relation to a September hunting season. Human–Wildlife Interactions 4:232–246.

Dolbeer, R. A., Seamans, T. W., Blackwell, B. F., Belant, J. L. 1998. Anthraquinone formulation (Flight Control™) shows promise as avian feeding repellent. Journal of Wildlife Management 62:1558–1564.

Flann, C. J. 1999. Flightless giant Canada goose depredation abatement and digestibility of selected crops in South Dakota. Thesis, South Dakota State University, Brookings, South Dakota, USA.

Gigliotti, L. M. 2007. Wildlife damage management program: 2006 landowner survey/evaluation report. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Gordon, S. E., and N. Lyman. 2000. Flight Control as a grazing repellent for Canada geese at Portland International Airport. Proceedings of the International Bird Strike Committee 25:265–281.

Hanson, H. C. 1965. The giant Canada goose. Southern Illinois University Press, Carbondale, Illinois, USA.

Hogan, E. P. 1991. The geography of South Dakota. Center for Western Studies, Sioux Falls, South Dakota, USA.

Hogan, E. P., and E. H. Fouberg. 1998. The geography of South Dakota. Pine Hill Press, Freeman, South Dakota, USA.

Lee, C., and J. Herbeck. 2005. Estimating soybean yield. University of Kentucky College of Agriculture, Lexington, Kentucky, USA

Radtke, T. M. 2008. Crop damage by resident Canada geese in eastern South Dakota. Thesis, South Dakota State University, Brookings, South Dakota, USA.

Radtke, T. M., and C. D. Dieter. 2010. Selection of pathways to foraging sites in crop fields by flightless Canada geese. Human–Wildlife Interactions 4:202–206.

Radtke, T. M., and C. D. Dieter. 2011. Canada goose crop damage abatement in South Dakota. Human–Wildlife Interactions 5:315–320.

Raveling, D. G. 1979. The annual cycle of body composition of Canada geese with special reference to control of reproduction. Auk 96:737–745.

Reed, A., G. Chapdelaine, and P. Dupuis. 1977. Use of farmland in spring by migrating Canada geese in the St. Lawrence Valley, Quebec. Journal of Applied Ecology 14:667–680.

Schaible, D., C. D. Dieter, R. Losco, and P. Mammenga. 2005. Quantifying crop damage by giant Canada geese in Day County, South Dakota, 2003. Proceedings of the South Dakota Academy of Science 84:259–264.

Smith, A. G., J. H. Stoudt, and J. B. Gollop. 1964. Prairie potholes and marshes. Pages 39–50 *in* J. P. Linduska, editor. Waterfowl tomorrow. U.S. Government Printing Office, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2013. Waterfowl population status, 2013. Division of Migratory Bird Management, Report 80, <https://migbirdapps.fws.gov/>. Accessed March 24, 2014.

Vaa, S., P. Mammenga, M. Grovijahn, J. Kanta, A. Lindbloom, R. Schauer, S. Lindgren, K. Fisk, T. Kirschenmann, C. Switzer, and C. Huxoll. 2010. South Dakota resident Canada goose management plan. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Werner, S. J., J. C. Carlson, S. K. Tupper, M. M. Santer, and G. M. Linz. 2009. Threshold concentrations of an anthraquinone-based repellent for Canada geese, red-winged blackbirds, and ring-necked pheasants. Applied Animal Behaviour Science 121:190–196.

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Curiong Ren (photo unavailable) was a statistician and an assitant professor in the Department of Plant Science at South Dakota State Univeristy.