PLANT GROWTH REGULATOR (STRONGHOLD®) ENHANCES REPELLENCY OF ANTHRAQUINONE FORMULATION (FLIGHT CONTROL®) TO CANADA GEESE

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Abstract: There is a need for nonlethal methods of reducing conflicts between burgeoning populations of resident giant Canada geese (*Branta canadensis*) and humans at airports and other settings. An anthraquinone-based formulation (Flight Control® [FC]; 50% anthraquinone [AQ], active ingredient) has shown promise in deterring grazing by Canada geese. We hypothesized that the addition of a plant growth regulator (Stronghold® [SH]) might enhance the effectiveness of FC by minimizing the exposure of new, untreated grass. To isolate the effects of grass height, plant growth regulator, and the combination of a repellent with a plant growth regulator on grazing by geese, we conducted 3 experiments, each using 24 geese in 6 18.3- × 30.5-m pens in northern Ohio during 1998. We evaluated the response of geese to short (4–11 cm) and tall grass (16–21 cm) in a 9-day test (15–23 Jul). Next, SH (applied at 1.2 L/ha) was evaluated as a grazing repellent in a 14-day test (30 Jul–12 Aug). Finally, we evaluated the effectiveness of FC (2.3 L/ha) combined with SH (0.9 L/ha SH) as a grazing repellent in a 22-day test (11 Sep–2 Oct). We found no difference (P = 0.529) in the number of geese per observation in tall- (1.7 ± 1.5; $\bar{x}$ ± SE) versus short-grass plots (2.3 ± 1.5), nor in bill contacts per minute (P = 0.777) in tall- (12.6 ± 9.3) versus short-grass plots (11.1 ± 7.9). In the SH test, 14 days postapplication, mean grass height was 12.9 cm in untreated plots and 7.2 cm in treated plots. However, the number of geese per observation on untreated (1.8 ± 1.3) and treated plots (2.2 ± 1.3) did not differ (P = 0.567). Also, there was no difference (P = 0.706) in the number of bill contacts per minute in untreated (15.3 ± 9.9) versus treated plots (18.1 ± 14.2). In contrast, over a 22-day FC/SH test, the mean number of geese per observation was 2.6 times greater (P < 0.001) on untreated (2.9 ± 0.5) versus treated plots (1.1 ± 0.5). Further, the mean number of bill contacts per minute was 8.2 times greater (P < 0.001) on untreated (54.4 ± 11.2) than treated plots (6.6 ± 2.3). We observed no abatement in repellency 22 days posttreatment. Thus, we conclude that SH greatly enhanced the repellency of FC to grazing Canada geese, and we contend that the use of a plant growth regulator with FC will prove effective in reducing goose foraging at airports and other sites.

JOURNAL OF WILDLIFE MANAGEMENT 63(4):1336–1343

Key words: airport, anthraquinone, *Branta canadensis*, Canada goose, grazing, plant growth regulator, repellent, tall grass management.

In North America, land-use changes over the past 3 decades in combination with climatic factors and changes in cultural practices have caused marked population increases in wildlife species such as white-tailed deer (*Odocoileus virginianus*), double-crested cormorants (*Phalacrocorax auritus*), gulls (*Larus* spp.), and Canada geese (*Branta canadensis*; Dolbeer 1998). The giant Canada goose population in Ontario, for example, increased from <10,000 individu-

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als in 1967 to approximately 200,000 birds by 1994 (Ankney 1996). From 1988 to 1997, the giant Canada goose population in the Mississippi Flyway increased 6%/year to over 1 million birds (Caithamer and Dubovsky 1997).

Expanding Canada goose populations (including, but not limited to giants) have contributed to numerous conflicts with people in agricultural, recreational (e.g., parks, golf courses), and airport settings (Hunt 1984, Kahl and Samson 1984, Conover and Chasko 1985, Cleary et al. 1998, Smith et al. 1999). From 1991 to 1997, 495 collisions between geese and civil aircraft were reported in the United States (Cleary et al. 1998). Such collisions are costly: 24 people were killed and $190 million in damages incurred when an AWACS aircraft crashed on take off at Elmendorf Air Force Base, Alaska, in September 1995, after striking Canada geese (Wright 1997).

As noted by Ankney (1996), it is impossible to accurately predict natural limits to further growth in giant Canada goose populations. However, lethal management of nuisance wildlife is often inconsistent with prevailing social ethics or is impractical (Dolbeer 1986, 1998; Smith et al. 1999). Nonlethal techniques designed to reduce bird–human conflicts, such as such as frightening and exclusion devices, generally have limited effectiveness and may be cost-prohibitive (Dolbeer et al. 1995). Further, as noted by Dolbeer et al. (1998), chemical repellents used against geese, such as methiocarb (Conover 1985, 1989; Cummings et al. 1992), are considered too toxic or have exhibited only short-term (≤4 days) and questionable effectiveness (e.g., methyl anthranilate, [Cummings et al. 1991, 1995; Belant et al. 1996] and dolomitic lime [Belant et al. 1997]).

However, a new AQ-based formulation, FC, has shown promise as a safe alternative turf treatment to repel Canada geese from grazing, as well as a seed treatment against brown-headed cowbirds (*Molothrus ater*; Dolbeer et al. 1998). Avian species consuming AQ for the first time typically exhibit no immediate aversion but are subsequently repelled (Avery et al. 1997, Dolbeer et al. 1998) due to a suspected post-ingestional response (see review by Avery et al. 1997). Still, a problem in the use of a repellent such as FC is that the active ingredient, AQ, adheres to grass but is not incorporated systemically. Thus, grass growth occurring after application remains untreated. For example, Dolbeer et al. (1998) showed that FC repellency to geese on grass treated during summer was minimal after 7 days, likely because geese foraged successfully on new growth below the treatment zone.

We hypothesized that the treatment of grass with a mixture of FC and a plant growth regulator might maximize the period of repellency. Plant growth regulators are currently used at airports and other sites to slow the growth of grass, thereby minimizing mowing costs. Our objective was to quantify the effectiveness of FC, applied in combination with a plant growth regulator, SH, as a grazing repellent for captive giant Canada geese in a 2-choice pen experiment.

METHODS

Important to our evaluation of the effectiveness of FC when combined with SH was the isolation of potential confounding effects of contrasting grass heights due to SH application, and the possibility that SH alone may elicit avoidance by geese. We thus evaluated the response of captive Canada geese first to short and tall grass, then to SH alone, and finally to FC applied in combination with SH.

Giant Canada geese of undetermined sex were captured during molt in northern Ohio on 29 June 1998 and transported to a 2-ha fenced pond in Erie County, Ohio. Grass and shade were available along the perimeter of the pond. The geese had primary feathers from 1 wing cut before being released into the pond. Whole-kernel corn and poultry pellets were provided as food supplements. A 0.4-ha fenced holding area adjacent to the pond was used to separate experimental from nonexperimental geese. This holding area contained grass, shade, and included about 20 m^2 of the pond. Geese in the holding area were also provided corn and poultry pellets.

A fenced chute connected the holding area to the test site, which consisted of 6 18.3- × 30.5-m pens (used in each of the 3 tests) constructed of 1.5-m-high fencing. The test area was fertilized 4 weeks before testing. Pens were spaced 5–12 m apart, and a 1.5-m-high heavy plastic fence was placed between adjacent pens to serve as a visual barrier. Each pen comprised 2 15.2- × 18.3-m plots (treated, untreated) delineated by a spray-painted line on the grass. A 0.5-m-diameter pan of water was positioned in the center of each plot. A rain gauge was placed at the test site to monitor precipitation.

Prior to each experiment, 24 randomly selected geese were herded from the pond to the holding area and each was assigned randomly to 1 of 6 pens (i.e., 4 geese/pen). Pen-specific color-coded neck bands were placed on geese to ensure the same individuals were placed in the same pen on each day. Over a 5-day acclimation period, the geese were herded from the pond to the pens at 0830 and allowed to graze until 1200, at which time they were herded back to the holding pen. Procedures involving the geese were approved by the National Wildlife Research Center Animal Care and Use Committee.

Grass Height

Grass in all pens was mowed to 5-cm height on 7 July. After conditioning 24 geese to the pens from 8 to 13 July, we randomly selected 1 side of each pen as tall grass, and on 14 July mowed the grass in the other side to a 5-cm height; all grass clippings were removed. The grass was not cut again until the experiment ended on 23 July.

We measured grass height within each plot by using 2 1-m rules positioned vertically and 1.5 m apart horizontally. The rules were connected by an adjustable string in which the length was leveled with the top of the majority of grass between the rules. A mean grass height for a location was calculated from the 2 measures of grass height on each rule. Four locations within each plot were randomly selected for grass height measurement; mean grass height for the plot was calculated from the 4 location means. One short-grass plot was measured on 15 July, and then each short-grass plot was measured on 17 and 23 July; all tall-grass plots were measured on each of the 3 days.

We began monitoring goose activity on 15 July (day 1) with 3 observers stationed on 4.9-m towers 15–30 m from the pens. Observations began 0.5 hr after geese were released into the pens. Each observer watched 2 pens, alternating observations between pens every 60 sec for 1 hr (resulting in 0.5 hr of observation/pen). During each 60-sec interval, observers recorded the number of geese initially observed in each plot (geese/observation) and the total number of bill contacts (for the 4 geese) with grass in each plot (bill contacts/min). Goose activity was recorded on each of the plots over 6 days through 23 July (day 9).

Plant Growth Regulator

Stronghold® plant growth regulator (PBI/Gordon, Kansas City, Missouri, USA) is registered by the U.S. Environmental Protection Agency (EPA; Registration No. 2217-802) as a general-use plant growth regulator for turf, contains 21.45% diethanolamine salt of mefluidide (N-[2,4-dimethyl-5 [[[(trifluoromethyl) sulfonyl]amino] phenyl] acetamide), 4.09% ammonium salt of imazethapyr [(±)-2-[4, 5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1-H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid], 0.15% ammonium salt of imazapyr [2-[4, 5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1-H-imidazol-2-yl]-3-pyridinecarboxylic acid]], and 74.31% inert ingredients. As recommended by the manufacturer, we used a low-foaming, nonionic spreader, Activator 90® (Loveland Industries, Greeley, Colorado, USA) containing 90% alkyl polyoxyethylene ether and free fatty acids and 10% inert ingredients, with SH at 0.25% vol/vol of the final mixture.

In the test of SH, we used the same geese as in the grass height test. Plots in each pen were mowed to 5 cm height on 29 July. We mixed SH with water and, using a boom sprayer at 27.6 Newtons/cm^2, evenly applied it at 1.2 L/ha on the 6 randomly selected plots; the remaining untreated plots served as controls. Observations of geese began on 30 July (day 1) and were made twice daily, beginning 0.5 and 2.5 hr after geese were released into the pens. Again, 3 observers watched 2 pens each, alternating observations between pens every 60 sec for 1 hr. A daily mean was calculated from 2 values (i.e., from the 2 observation periods) each for geese per observation and bill contacts per minute. Goose activity was recorded on each plot for 11 days through 12 August (day 14). The grass height in each plot was measured again on day 14.

At the end of the experiment, collars were removed from the geese, the previously cut primaries were pulled, and the birds released. On 31 August, we pulled the previously cut primary feathers from all remaining experimentally naïve geese.

Flight Control

Flight Control® (Environmental Biocontrol International [EBI], Wilmington, Delaware, USA), registered by the EPA (Registration No. 69969-1) as a general use turf treatment against geese, contains AQ (50%, active ingredient), surfactants (2%), and a latex-based filler (48%). The chemical is a light-tan liquid, miscible in water, and has a pH of 7.5–8.5. The oral LD_{50} for rats is >10,000 mg/kg, and the dermal LD_{50} is 1,000 mg/kg (FC Material Safety Data Sheet, EBI). As in Dolbeer et al. (1998), no adjuvant was used with FC.

For this experiment, 24 experimentally naïve geese were randomly selected for observation. All pens were cut to 5 cm on 8 September, and grass height was measured again on 28 September (day 18). Before the application of FC and SH, we placed 20 glass slides (2.5 × 7.6 cm) in a 0.5- × 2-m area in 1 treatment plot to determine the amount of AQ present over time. On 10 September, we mixed FC and SH with water and, using a boom sprayer at 27.6 Newtons/cm^2, evenly applied the mixture on the 6 randomly selected plots at 3.2 L/ha (i.e., 2.3 L/ha FC, 0.9 L/ha SH); the remaining untreated plots served as controls. We randomly selected 5 slides at 2 hr after application and on days 2, 5, and 7 for residue analysis (μg of AQ/slide). Residue analysis was performed by EBI personnel and converted to kilograms per hectare based on the surface area of the slides. The adjuvant, Activator 90™, was not used in this experiment. Further, as per preexperiment discussions with representatives from EBI (K. Ballinger) and PBI/Gordon (E. Tracy), we expected no chemical reaction between FC and SH that would enhance or inhibit the properties of either product.

We began monitoring goose activity on 11 September (day 1). Observations of geese were conducted as in the SH experiment. Goose activity was recorded on each plot for 18 days through 2 October (day 22). We note, however, that on day 18, 1 goose from the pen 5 group was eliminated from the experiment due to predation in the holding area. Daily totals for goose presence data in each plot within pen 5 were subsequently adjusted by a factor of 1.33. Because all 4 geese in a pen did not consistently forage at the same time, values for bill contacts per minute in pen 5 were not adjusted.

After the experiment, collars were removed from the geese, and the birds were returned to the fenced pond. The birds were able to fly from the area within 1 week.

For each experiment, we evaluated the mean number of geese initially observed within each plot and the mean number of bill contacts per minute via a 1-way repeated-measures analysis of variance (ANOVA; SAS 1988). The Tukey's HSD test (SAS 1988; Milliken and Johnson 1992) was used to isolate differences among means. All means are presented as ± standard error. Further, all statistical comparisons were made at $\alpha = 0.05$.

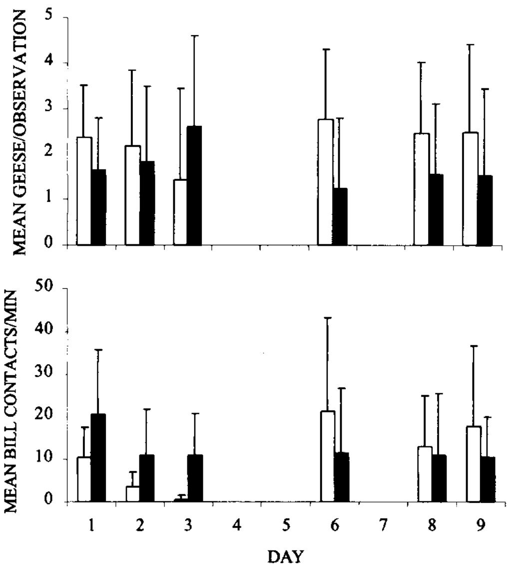

Fig. 1. Mean numbers and foraging rates of giant Canada geese on short- (white) and tall-grass (black) plots within 6 pens, each containing 4 geese, during a 9-day (15–23 Jul 1998) test in Erie County, Ohio. Capped vertical lines represent 1 standard error. No observations were made on days 4, 5, and 7.

RESULTS

Grass Height

Tall-grass plots had a mean grass height of 17.4 ± 3.3 cm on 15 July (day 1), which increased to 20.9 ± 4.0 cm on 23 July (day 9). Mean grass height in short-grass plots ranged from 4.2 ± 0.7 cm on day 1 to 11.0 ± 3.2 cm on day 9. Rainfall measured 81 mm from 15 to 23 July.

There was no difference ($F_{1,10} = 0.43$, $P = 0.529$) in number of geese per observation between tall- (1.7 ± 1.5) and short-grass plots (2.3 ± 1.5; Fig. 1). Also, there was no difference ($F_{1,10} = 0.08$, $P = 0.777$) in bill contacts per minute between tall- (12.6 ± 9.3) and short-grass plots (11.1 ± 7.9; Fig. 1).

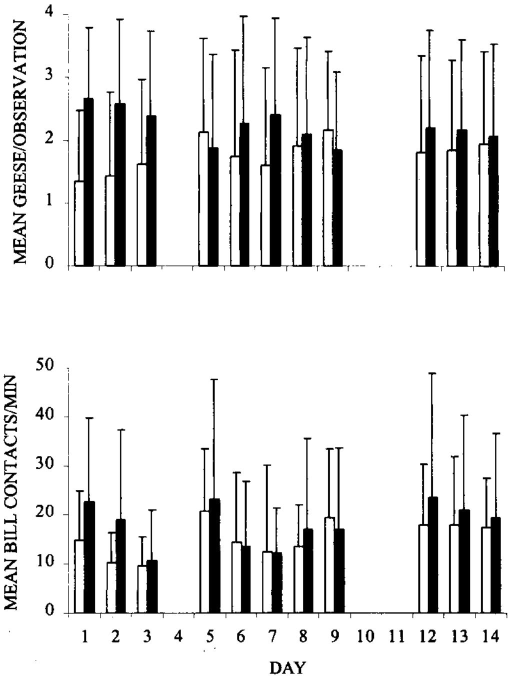

Fig. 2. Mean numbers and foraging rates of giant Canada geese on untreated (white) and treated (black) plots within 6 pens, each containing 4 geese, during a 14-day (30 Jul–12 Aug 1998) test of Stronghold® plant growth regulator (applied at 1.2 L/ha) in Erie County, Ohio. Capped vertical lines represent 1 standard error. No observations were made on days 4, 10, and 11.

Plant Growth Regulator

Grass discoloration (yellowing) in SH-treated plots was noticeable by day 2, evenly distributed, and increased and contrasted markedly with untreated plots by day 14. Also by day 14, mean grass height in the treated plots was 7.2 ± 0.5 cm compared to 12.9 ± 1.3 cm in the untreated plots. The plots received 43 mm of rain between days 7 and 12.

During the 14-day experiment, the mean number of geese per observation on untreated (1.8 ± 1.3) and treated plots (2.2 ± 1.3) was similar ($F_{1,10} = 0.35$, $P = 0.567$). Also, there was no difference ($F_{1,10} = 0.15$, $P = 0.706$) in the number of bill contacts per minute between untreated (15.3 ± 9.9) and treated plots (18.1 ± 14.2). There were no differences between untreated and treated plots on any particular day for goose presence or foraging (Fig. 2).

Flight Control

During the 22 days of observation, the mean number of geese per observation was 2.6 times greater ($F_{1,10} = 46.24$, $P < 0.001$) on untreated (2.9 ± 0.5) than treated plots (1.1 ± 0.5). Specifically, geese exhibited a preference ($P < 0.05$) for untreated plots on days 5–22 (15 Sep–2 Oct; Fig. 3).

Further, the mean number of bill contacts per minute was 8.2 times greater ($F_{1,10} = 105.45$, $P < 0.001$) on untreated (54.4 ± 11.2) than treated plots (6.6 ± 2.3) over the 22 days. Foraging rates of geese on untreated plots were greater ($P < 0.05$) than on treated plots for days 2 (12 Sep) and 5–22 (15 Sep–2 Oct; Fig. 3).

We recorded 2.00 mm of rain on day 6, 0.25 mm on day 11, and 1.50 mm on day 12. Residue analysis of slides taken from treated turf indicated AQ declined from a mean of 1.2 ± 0.22 kg/ha at application to 0.6 ± 0.4 kg/ha after 1 week. In addition, although there was no perceptible odor at the time of or after application, grass discoloration (i.e., yellowing) on treated plots was noticeable by day 2 and was evenly distributed. The contrast in coloration between untreated and treated plots became more distinctive over the 22-day period. Mean grass height on 28 September was 7.7 ± 0.8 cm in treated plots and 10.2 ± 1.2 cm in untreated plots.

DISCUSSION

In our evaluation of the combination of FC and SH as a grazing repellent for giant Canada geese, we first isolated the effects of grass height and then SH applied alone. Although use of tall grass to discourage geese is recommended (U.S. Department of Agriculture 1998), we found that geese exhibited no preference for short ($\bar{x}$ = 4.2–11.0 cm) compared to tall grass (17.4–20.9 cm) over a 9-day experiment. Finally, in the test of SH, although grass in treated plots turned a distinctly yellow color and grew at an average rate 0.3 times that of grass in untreated plots, there was no difference in goose presence and foraging rates between untreated and treated plots over the 14-day experiment. We conclude, therefore, that grass heights evaluated in these experiments (4–21 cm) did not influence geese. Furthermore, SH did not repel giant Canada geese from grazing over a 14-day experiment. Thus, the use of a plant growth regulator alone would likely do little to discourage geese from grazing at airports or other sites.

The question remained, however, as to whether SH might affect the repellent properties of FC. Dolbeer et al. (1998) noted that fur-

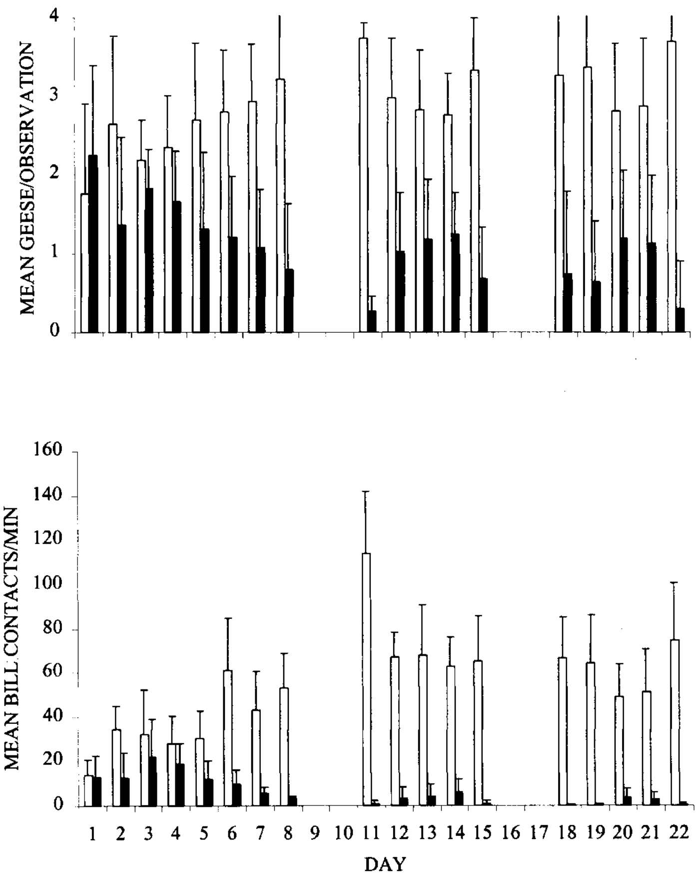

Fig. 3. Mean numbers and foraging rates of giant Canada geese on untreated (white) and treated (black) plots within 6 pens, each containing 4 geese, during a 22-day (11 Sep–2 Oct) test of Flight Control® and Stronghold® plant growth regulator applied in combination at 3.2 L/ha (i.e., 2.3 L/ha FC; 0.9 L/ha SH). Capped vertical lines represent 1 standard error. No observations were made on days 9, 10, 16, and 17.

ther lab and field studies were needed to refine minimum repellent levels of FC and to enhance retention on treated vegetation. In their 7-day experiment with captive Canada geese and FC applied at 4.5 L/ha, the greatest mean difference in goose presence and foraging rates between untreated and treated plots was on day 2, whereas plot use differed least on days 6 and 7. The increased use of treated plots corresponded with the rate of decline in AQ residue on glass slides taken from treated turf.

In this study, not only was giant Canada goose presence and foraging markedly greater on untreated plots over the 22-day experiment, but we noted an unexpected trend in decreased use (particularly in foraging) of treated versus untreated plots over time. This trend of decreased use of treated plots contrasted to that expected with the decline in AQ. For example, whereas the last sample of slides taken from treated turf for residue analysis indicated a nearly 2-fold decline in AQ concentration (kg/ha) over 7 days, geese foraged least on treated plots on days 11 and 22. In addition, although the AQ concentration after 1 week was nearly 3 times that reported by Dolbeer et al. (1998) for the same period (likely due to less rain), the lack of consistent increase in goose foraging on treated plots over 22 days contrasted markedly with observations reported by Dolbeer et al. (1998).

Further, in some instances we observed geese in treated plots make obvious efforts to forage at the base of the grass, while avoiding upper portions of the blades. Stronghold® likely caused new grass growth to be concentrated lower in the plant and within the root system (D. Austin, PBI/Gordon, personal communication). Thus, the shorter grass in treated plots may have made foraging on new growth beneath the FC layer difficult for geese, thereby increasing the probability of consuming any remaining chemical.

We recognize that a more powerful study would have involved concurrent tests of grass height, SH, FC, and the combination of FC and SH on grazing by geese. We suggest, however, that the time interval between the Dolbeer et al. (1998) test of FC and this study, as well as among the experiments conducted in this study, resulted in negligible confounding effects. As in the Dolbeer et al. (1998) study, FC exhibited an effective repellency without use of an adjuvant. In this study, however, the application rate was reduced by half that reported by Dolbeer et al. (1998), while the period and degree of repellency increased by a factor of about 3. Further, all experiments conducted in this study involved randomization of treatments, and no birds exhibited abnormal foraging, loafing, or group behavior.

MANAGEMENT IMPLICATIONS

In summary, we demonstrated a mean 88% reduction in foraging by giant Canada geese in grass plots treated with a combination of FC and SH, as compared to untreated plots. Remarkably, the reduction in foraging showed no sign of abating after 22 days. Because of the ineffectiveness of SH alone as a grazing repellent to geese and the short-term (≤7 days) effectiveness of FC alone as a grazing repellent (Dolbeer et al. 1998), we conclude that SH (by reducing the rate of new grass growth while likely concentrating new growth proximate to the zone treated with FC) acted synergistically to greatly enhance the repellency of FC to grazing Canada geese. Further, the discoloration of the grass in treated plots may have served as a visual cue, also enhancing the repellency of FC (see Dolbeer et al. 1992).

We note that grass discoloration associated with use of SH (likely as a result of the salts and acids in the active ingredients, and varying relative to the grass type, condition, and soil type [E. Tracy, PBI/Gordon, personal communication]) may limit practical application at sites such as golf courses. However, plant growth regulators that do not cause discoloration of grass are available. Also, the amount of FC and plant growth regulator necessary (for multiple applications) to produce and maintain repellency to geese will vary depending upon area, bird numbers, use of adjuvants, and weather. Flight Control® can be purchased for under $250/ha (K. Ballinger, EBI, personal communication), while SH is priced relative to mowing expenses (E. Tracy, PBI/Gordon, personal communication).

We believe, therefore, that the combination of a plant growth regulator with FC will serve as a safe and effective component of an integrated management strategy (see Smith et al. 1999) to reduce goose numbers at airports and other sites. Field experiments should be undertaken to further evaluate the repellency of FC with SH or other plant growth regulators.

ACKNOWLEDGMENTS

G. E. Bernhardt, D. A. Helon, N. Meade, L. A. Tyson, and S. W. Young assisted in data collection. We thank the Ohio Division of Wildlife for providing giant Canada geese for the experiments. Primary funding for this research was provided by EBI. Additional funding was provided by the Federal Aviation Administration (FAA), Office of Airport Safety and Standards, Washington, D.C.; and Airport Technology Branch, FAA Technical Center, Atlantic City International Airport, New Jersey.

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Received 27 January 1999.
Accepted 27 April 1999.
Associate Editor: Rattner.