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Threshold concentrations of an anthraquinone-based repellent for Canada geese, red-winged blackbirds, and ring-necked pheasants

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ABSTRACT

Wildlife repellents provide a non-lethal alternative for managing the monetary impacts of agricultural depredation. For the purpose of developing of an effective avian repellent, we established repellency thresholds of an anthraquinone-based repellent for Canada geese (*Branta canadensis*), red-winged blackbirds (*Agelaius phoeniceus*), and ring-necked pheasants (*Phasianus colchicus*) in captivity. We conducted a concentration–response experiment with Canada geese offered corn seeds treated with six concentrations of Avipel® repellent (a.i. 50% 9,10-anthraquinone). Based upon our laboratory efficacy data, we used non-linear regression to predict a threshold concentration of 1450 ppm anthraquinone for geese offered treated corn seeds (i.e., 80% repellency; $r^2 = 0.85$, $P = 0.009$). We also observed a positive concentration–response relationship among red-winged blackbirds offered Avipel®-treated rice ($r^2 = 0.70$, $P = 0.039$) and sunflower seeds ($r^2 = 0.84$, $P = 0.010$). We predicted a threshold concentration of 1475 ppm anthraquinone for blackbirds offered treated sunflower seeds. Blackbirds also reliably discriminated between untreated food and rice treated with 2325 ppm anthraquinone ($F_{1,10} = 3414.05$, $P < 0.0001$) or sunflower treated with 1778 ppm anthraquinone ($F_{1,10} = 175.39$, $P < 0.0001$). We observed a positive concentration–response relationship among ring-necked pheasants offered corn ($r^2 = 0.95$, $P = 0.001$) and sunflower seeds ($r^2 = 0.99$, $P < 0.001$) treated with Avipel®. We predicted a threshold concentration of 10,450 ppm anthraquinone for pheasants offered treated corn seeds. Pheasants also reliably discriminated between untreated food and corn treated with 1900 ppm anthraquinone ($F_{1,10} = 919.86$, $P < 0.0001$) or hulled sunflower treated with 1140 ppm anthraquinone ($F_{1,10} = 177.35$, $P < 0.0001$). Avipel® seed treatments effectively conditioned avoidance of treated seeds among Canada geese, red-winged blackbirds, and ring-necked pheasants. Our laboratory efficacy data provide a reliable basis for planning future field applications of anthraquinone-based bird repellents for protection of agricultural crops, property, and related natural resources. Supplemental field efficacy studies are necessary for registration of anthraquinone-based repellents for managing agricultural depredation caused by wild birds.

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1. Introduction

Canada goose (*Branta canadensis*) populations in North America have increased dramatically during the past 40 years (Ankney, 1996; Sauer et al., 2008). Ankney

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(1996) suggested that waterfowl managers have successfully managed to prevent overharvest of geese for many years; now it is time for them to manage overpopulations of geese. Localized over-abundant Canada goose populations have increased the number of human–wildlife conflicts and magnified their intensity (Werner and Clark, 2006). From 1985 to 1998, geese were ranked as the second greatest hazard to Air Force aircraft in the United States of America (USA) (vultures were the greatest hazard; Zakrajsek and Bissonette, 2005). Among 6741 aircraft strikes reported from 1991 to 1998, the average cost per strike was greatest ($36,735 per strike) among those involving geese (Dolbeer et al., 2000). Grazing by Canada geese can negatively impact production of wheat (Flegler et al., 1987), rye (Conover, 1988), and grasses and legumes grown for seed. Canada goose conflicts in the eastern USA include intensive foraging and localized (aquatic and terrestrial) fecal contamination at recreational areas (Conover and Chasko, 1985). The close proximity of geese and humans also increases risk associated with pathogenic bacteria that are prevalent in Canada goose feces (Kullas et al., 2002; see Clark, 2003 for review).

Red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), brown-headed cowbirds (*Molothrus ater*), and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) negatively impact growth of newly planted rice in the mid-South of the USA (February–April; Werner et al., 2008a), and production of ripening rice and sunflower in August–October each year (Werner et al., 2005, 2008a,b). Cummings et al. (2005) estimated that blackbirds caused approximately $13.4 million of damage to USA rice production in 2001. Similarly, blackbird damage to sunflower was estimated to be $5.4 million annually (Peer et al., 2003), or approximately 2% of the total value of the annual sunflower crop in the USA (Kleingartner, 2003).

The South Dakota Department of Agriculture (Pierre, SD, USA) conducted a poll in February–March 2009 to determine the need for use of an avian repellent to protect newly planted sunflower seed from consumption by ring-necked pheasants (*Phasianus colchicus*). Approximately 14% (N = 67) of the estimated 478 South Dakota sunflower producers responded to the survey. Among the respondents, 98% reported sunflower seed or seedling losses from ring-necked pheasants. Forty-two percent of survey respondents reported <20 ha damaged by ring-necked pheasants. Sunflower damage attributable to ring-necked pheasants was reportedly 5–10% yield loss among 19% of survey respondents, and 11–20% and 21–50% yield loss for an additional 19% and 21% of respondents, respectively.

Several management alternatives have been used to reduce human–wildlife conflicts in the USA. These alternatives include aversive stimuli (Heinrich and Craven, 1990; Aguilera et al., 1991), non-lethal chemical repellents (Cummings et al., 1995; Dolbeer et al., 1998), trapping, physical exclusion, hunting, and reproductive inhibition (Converse and Kennelly, 1994) for Canada geese. Avian repellents are a socially acceptable, non-lethal approach to managing blackbird depredation of agricultural crops (Cummings et al., 2002a,b; Avery et al., 2005; Linz et al., 2006; Werner et al., 2007, 2008a,b) and goose–human conflicts (Werner and Clark, 2006).

Anthraquinone was identified as a promising avian repellent in the early 1940s (Heckmanns and Meisenheimer, 1944). Anthraquinone-based repellents have been used effectively protect rice seed from blackbirds under captive and field conditions (Neff and Meanley, 1957; Avery et al., 1997, 1998; Cummings et al., 2002a,b) and turf from Canada goose grazing in captivity (Dolbeer et al., 1998). Feeding reductions among Canada geese offered anthraquinone-treated corn seeds were 70.6%, 82.3%, and 96.9% at 0.05%, 0.5%, and 5% anthraquinone (wt/wt), respectively (Kreithen and Seamans, 1997, unpublished results). Anthraquinone is an emodin (i.e., phenolic) purgative; its action is principally on the large intestine, and it is not effective if transit through the small intestine is delayed (Merck, 1991). Although anthraquinone is a naturally occurring substance, no anthraquinone-based repellents are currently registered for agricultural applications in the USA.

Our purpose was to facilitate the development of an effective repellent for protection of newly planted and ripening crops from avian depredation. Our objective was to determine sufficient (i.e., threshold) concentrations of an anthraquinone-based repellent for wild birds associated with human–wildlife conflicts in the USA. We therefore conducted controlled feeding experiments to evaluate the repellency of varying concentrations of anthraquinone seed treatments with Canada geese, red-winged blackbirds, and ring-necked pheasants in captivity.

2. Materials and methods

2.1. Facilities, subjects and diets

We conducted feeding experiments in August 2008–March 2009 at the United States Department of Agriculture (USDA), National Wildlife Research Center's (NWRC) outdoor animal research facility in Fort Collins, Colorado (USA). We captured 24 Canada geese and 110 red-winged blackbirds, and purchased 55 captive-raised ring-necked pheasants for our concentration–response experiments. Additionally, we captured 22 red-winged blackbirds and purchased 11 captive-raised ring-necked pheasants for our preference experiments. We provided water *ad libitum* to all birds throughout our experiments. The capture, care, and use of all birds associated with our feeding experiments were approved by the NWRC Animal Care and Use Committee (NWRC Study Protocols QA-1574, QA-1590, QA-1635; S.J. Werner – Study Director).

Geese were maintained in individual cages (3 m × 3 m × 2.5 m) within wire mesh-sided buildings throughout the study (quarantine, holding, experiment). We maintained all blackbirds in 4.9 m × 2.4 m × 2.4 m cages (40–50 birds/cage) within a wire mesh-sided building for ≥2 weeks prior to our experiments (i.e., quarantine, holding). Blackbird experiments were conducted in individual cages (0.9 m × 1.8 m × 0.9 m) within a wire mesh-sided building. Pheasants were maintained in individual cages (0.9 m × 1.8 m × 0.9 m) within a wire

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