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# Application strategies for an anthraquinone-based repellent to protect oilseed sunflower crops from pest blackbirds

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ABSTRACT

Non-lethal alternatives are needed to manage the damage caused by wild birds to oilseed sunflower crops (*Helianthus annuus* Linnaeus). We evaluated field residues and experimental applications of an anthraquinone-based repellent (active ingredient 50% 9,10-anthraquinone) to minimize red-winged blackbird (*Agelaius phoeniceus* Linnaeus) depredation of oilseed sunflower. Chemical residues from experimental applications of the anthraquinone-based repellent (4.7 l/ha and 9.4 l/ha; low, high) in a ripening oilseed sunflower field were 481 ppm and 978 ppm anthraquinone at the beginning of blackbird damage, and 385 ppm and 952 ppm anthraquinone at the end of blackbird damage, respectively. Prior to harvest, we observed 402 ppm and 462 ppm anthraquinone in the oil, and 27 ppm and 165 ppm anthraquinone in the pomace from crushed sunflower achenes previously sprayed with the low and high applications, respectively. For the purpose of developing application strategies useful for avian repellents, we subsequently investigated blackbird feeding response to oilseed sunflower treated with the anthraquinone-based repellent and either a registered insecticide or a registered fungicide popularly used for ripening sunflower. We observed a positive concentration–response relationship among blackbirds exposed to anthraquinone and the insecticide (a.i. 8.4% esfenvalerate), or anthraquinone and the fungicide (a.i. 23.6% pyraclostrobin). Blackbirds reliably discriminated between untreated sunflower and that treated with 1810 ppm anthraquinone and 0.1% of the insecticide or 1700 ppm anthraquinone and 0.14% of the fungicide during our preference experiments. Given that ripening achenes are inverted from conventional pesticide applications throughout much of the period associated with blackbird depredation, we also evaluated blackbird repellency of the anthraquinone-based repellent applied to involucral bracts (i.e., the back of sunflower heads) of oilseed sunflower. Blackbirds did not discriminate between untreated involucral bracts and those treated with foliar applications comparable to 4.7 l/ha or 9.4 l/ha; blackbirds consumed more achenes from untreated sunflower heads than from those treated with 18.7 l/ha of the anthraquinone-based repellent. Supplemental repellent efficacy studies should investigate blackbird response to anthraquinone-based repellents (e.g., ≥4.7 l/ha) within 10–100 ha sunflower fields and include independent field replicates with predicted bird damage, repellent application strategies developed for protection of ripening crops, pre- and at-harvest repellent residues, and bird damage and crop yield measurements.



## 1. Introduction

The feeding behavior of red-winged blackbirds (*Agelaius phoeniceus* Linnaeus), common grackles (*Quiscalus quiscula* Linnaeus) and yellow-headed blackbirds (*Xanthocephalus xanthocephalus* Bonaparte) negatively impacts production of confectionery and oilseed sunflower (*Helianthus annuus* Linnaeus) each year in the

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United States of America (Linz and Hanzel, 1997; Linz et al., 2011; Werner et al., 2005, 2009, 2011). Blackbird damage to sunflower was estimated to be $5.4 million annually in the prime sunflower growing area of North America (Peer et al., 2003). The effectiveness of lethal damage management is typically associated with localized populations closed to immigration; thus, non-lethal alternatives are needed to manage damage caused by non-localized, or mobile blackbirds to sunflower crops (Linz et al., 2011).

Chemical repellents provide a non-lethal alternative to managing wildlife damages to agricultural production, including blackbird depredation of sunflower crops (recently reviewed by Linz et al., 2011). Anthraquinone was identified as a promising avian repellent in the early 1940's (Heckmanns and Meisenheimer, 1944). Anthraquinone-based repellents have been used to effectively protect rice seed from blackbirds under captive and field conditions (Avery et al., 1997, 1998; Cummings et al., 2002a, 2002b; Neff and Meanley, 1957), turf from Canada goose grazing in captivity (Blackwell et al., 1999; Dolbeer et al., 1998), and whole-kernel corn and ripening corn from captive sandhill cranes and blackbirds, respectively (Blackwell et al., 2001; Carlson et al., 2013). Anthraquinone is a naturally-occurring, cathartic purgative; its action is principally on the large intestine, and it is not effective if transit through the small intestine is delayed (Fraser and Bergeron, 1991). No anthraquinone-based repellents are registered currently for agricultural applications in the United States of America.

We previously conducted laboratory efficacy experiments to estimate the threshold concentration of an anthraquinone-based repellent (active ingredient 50% 9,10-anthraquinone; Arkion Life Sciences, New Castle, DE, USA) for red-winged blackbirds (1475 ppm anthraquinone; Werner et al., 2009) and common grackles (9200 ppm anthraquinone; Werner et al., 2011). We conducted laboratory residue testing with confectionery sunflower heads treated with applications of the anthraquinone-based repellent comparable to 9.4 l/ha, 18.7 l/ha and 37.4 l/ha; we observed 3489 ppm, 6001 ppm and 16,638 ppm anthraquinone among sunflower seeds (i.e., achenes) sampled from these treated sunflower heads, respectively (Werner et al., 2011). Based upon these laboratory results, we predicted that our $CO_2$ backpack application of 18.7 l/ha to all sunflower heads in treated enclosures (i.e., experimental application strategy with expected maximized residues) would effectively repel common grackles within a confectionery sunflower field (Werner et al., 2011). We observed 18% sunflower damage among anthraquinone-treated enclosures and 64% damage among untreated enclosures populated with common grackles (Werner et al., 2011).

Although laboratory and field efficacy studies have been conducted for several chemical repellents on rice and confectionery sunflower (Avery et al., 2005; Cummings et al., 2002a, 2002b, 2011; Linz et al., 2006; Werner et al., 2007, 2008a, 2008b, 2010), additional research was needed to (1) evaluate field residues of blackbird repellents on oilseed sunflower and (2) develop repellent application strategies for protection of ripening agricultural crops (e.g., ground-based or aerial applications useful for field applications avian repellents). Although field studies of experimental pesticides are limited to <4.05 ha by the United States Environmental Protection Agency, these field residue and laboratory efficacy data are necessary for the commercial development and registration of agricultural pesticides in the United States of America. Thus, our purpose was to investigate experimental applications of an anthraquinone-based repellent for non-lethal protection of oilseed sunflower crops. Cost-effective field applications of agricultural pesticides often include a single application of combined chemicals (e.g., insecticides, fungicides, avian repellents). Thus, our objectives were to evaluate (1) the chemical residues from field applications of the anthraquinone-based repellent on ripening oilseed sunflower, and blackbird feeding responses to the anthraquinone-based repellent when (2) combined with either a registered insecticide or a registered fungicide and (3) applied to the back of sunflower heads (i.e., surface available for foliar repellent applications on ripening crops). The capture, care and use of all birds associated with our studies were approved by the Animal Care and Use Committee of the United States Department of Agriculture's (USDA) National Wildlife Research Center (NWRC Study Protocols QA-1739, QA-1793; S.J. Werner- Study Director).

## 2. Methods

Field residue studies and laboratory efficacy experiments are necessary for the development, registration, and commercialization of experimental pesticides in the United States of America, including blackbird repellents for sunflower crop protection (Werner et al., 2009, 2011). We conducted a field residue study to evaluate an anthraquinone-based repellent (Arkion Life Sciences) as a red-winged blackbird repellent within a ripening oilseed sunflower field. We conducted five subsequent laboratory efficacy experiments to evaluate blackbird feeding responses to experimental applications of the anthraquinone-based repellent on oilseed sunflower.

### 2.1. Field residue study in ripening oilseed sunflower

We established 24 enclosures, or netted plots (each 3.7 m long × 4.0 m wide × 1.8–3.1 m tall; 1.5-cm mesh, polypropylene netting) within the maturing oilseed sunflower field on near Steele, North Dakota on July 20–21, 2010. All nets were suspended with plots constructed of 5-cm diameter, galvanized poles. The bottom of all nets was secured within the field using 45-cm rebar stakes driven vertically through 3.7-m wooden boards (extended horizontally to complete enclosures). A zipper was installed in one end of each enclosure to enable daily care of test subjects throughout the field residue study.

For ripening sunflower, >75% of annual blackbird damage occurs within the first 18 days after anthesis (i.e., flowering period; Cummings et al., 1989). The end of anthesis for sunflower is marked by the emergence of the last anther, which coincides with the beginning of yellow ray flower drop (Siddiqui, 1975). We planned our field residue study with red-winged blackbirds based upon our previous laboratory and field efficacy results (Werner et al., 2009, 2011). Thus, a backpack $CO_2$ sprayer was used to apply 0 l/ha, 4.7 l/ha, or 9.4 l/ha of the anthraquinone-based repellent to the achenes on all sunflower heads within treated field enclosures ($n$ = eight enclosures per treatment, including untreated control) on August 24, when >50% of sunflower within our enclosures was at the R-6 growth stage (i.e., anthesis complete, ray flowers wilting or falling, heads drooping toward ground). A 100 ml sample of each repellent tank formulation was collected and all liquid samples were frozen in a labeled amber jar for anthraquinone residue analyses. Ultraviolet/visible (UV/VIS) spectrophotometry was used to analyze anthraquinone concentrations (±1 ppm anthraquinone) among tank mixtures associated with our field residue study.

On the day subsequent to the repellent application (August 25), we populated each of the 24 enclosures with ten experimentally-naïve red-winged blackbirds. Ten blackbirds per enclosure were maintained throughout the 14-day study. Maturing sunflower between enclosures (1.5–2 m tall) provided visual isolation among enclosures throughout the study. Blackbirds fed freely within field enclosures throughout the study. We offered 300 g of a maintenance diet (milo) in all treated and untreated enclosures, daily throughout the field study (Werner et al., 2011). Consumption of the