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Effectiveness of Foliar Applications of 9,10-Anthraquinone for Reducing Blackbird Damage to Sunflower

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ABSTRACT: Anthraquinone is an effective chemical seed repellent that protects newly planted crops from depredation by granivorous birds. We are experimenting with foliar applications of 9,10-anthraquinone (AQ) to reduce blackbird (Icteridae) damage to ripening sunflower. Sunflower heads generally turn downward as the achenes mature. With the methods currently available for spraying crops, application of AQ directly onto sunflower achenes is nearly impossible. Blackbirds sometimes remove sunflower bracts prior to eating achenes. Thus, getting AQ droplets directly on the achenes may not be necessary, and spraying the heads should expose blackbirds to AQ as they remove bracts. Studies using caged red-winged blackbirds showed that AQ sprayed onto the backs of sunflower heads reduced damage. However, field trials using fixed-wing aerial sprayers and ground sprayers produced inconclusive results. We are currently experimenting with methods to increase spray coverage of AQ while simultaneously attempting to reduce AQ contamination of achenes, thus reducing the likelihood of having to establish food tolerance limits for this comparatively long-lived compound. In this paper, we summarize results from several AQ studies and speculate on when a repellent might be available for sunflower producers.

KEY WORDS: 9,10-anthraquinone, bird damage management, blackbirds, crop damage, North Dakota, repellents, sunflower

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INTRODUCTION

Blackbird (Icteridae) damage is the most common reason that sunflower producers in North Dakota stop planting sunflower (Hulke and Kleingartner 2014). Blackbirds form large flocks in late summer that feed on ripening crops, including sunflower, corn, and small grains. In the Prairie Pothole Region of North Dakota, Klosterman et al. (2013) estimated annual blackbird damage was US $3.5 million for sunflower and $1.3 million for corn. Across the continental U.S., average costs of sunflower damage by blackbirds are about $10 million annually. These are direct costs of damage and do not include costs of damage management.

To manage blackbird damage, sunflower producers can use several techniques, singly and in combination (Linz et al. 2011, Linz and Hanzel 2015). Options range from using firearms, propane cannons, and pyrotechnics, to thinning dense stands of cattails (*Typha* spp.) with herbicide (Linz and Homan 2011). Most methods are time consuming, costly, produce inconsistent results, and generally ineffective when used to defend large fields. An effective chemical repellent would be very useful for protecting large fields of sunflower, which in North Dakota typically average ≥65 ha. Currently, 4 bird repellents are registered for use on ripening sunflower: Bird Shield® (Bird Shield Repellent Corp., Pullman, WA), Flock Buster® (Skeet-R-Gone, Inc., West Fargo, ND), Avex® (Corvus Repellent Inc., Greeley, CO), and Avian Control™ (Avian Enterprises, LLC, Jupiter, FL).

Bird Shield®, Avex®, and Avian Control™ contain methyl anthranilate (MA) as their active ingredient. The U.S. Food and Drug Administration (FDA) has designated this compound as 'generally recognized as safe' (GRAS), and MA is exempted from FDA food tolerance requirements. Several formulations are available, with MA concentrations ranging from 20% to 50%. In birds, MA acts as a chemosensory repellent that causes irritation to pain receptors associated with taste and smell. Methyl anthranilate usually requires repeated applications, and high concentrations are often needed to repel birds (Werner et al. 2005). Flock Buster® is a mixture of ingredients featuring various plant oils (e.g., clove, garlic, lemon) and proprietary plant extracts. Growers and field researchers have reported inconsistent results with these repellents (Werner et al. 2010, Linz and Homan 2013).

9,10-ANTHRAQUINONE (AQ)

Among numerous pesticides that have been tested for avian repellency, AQ is one of the most promising (Avery and Cummings 2003). Since the 1940s, AQ has been a known avian repellent (Avery 2002). Anthraquinone is a widely occurring phenolic compound found in bacteria, plants, and animals. Commercially available formulations are chemically synthesized. Upon ingestion, AQ causes gastrointestinal discomfort and nausea in animals. Organisms probably use AQ as a natural defense to predation and herbivory. Anthraquinone must be eaten and symptoms felt before avoidance behavior is developed.

Anthraquinone is an effective seed treatment used for reducing seed predation by granivorous birds. Numerous states have issued Section 24c (Special Local Needs) and Section 18s (Emergency Exemption) registrations for protecting newly planted crops, including canola, rice, corn, and sunflower (Avery and Cummings 2003, Werner et al. 2011). Arkion® Life Sciences (New Castle, DE) is the U.S. patent holder for commercially available AQ formulations such as Avipel® and Flight Control®. The company has recently applied for a full national registration under Section 3 of the Environmental Protection Agency's Federal Insecticide Fungicide, and Rodenticide Act (EPA FIFRA) to use AQ repellent on corn seeds.

CAGE TESTS AND ENCLOSURE TESTS WITH SUNFLOWER

Cage tests have demonstrated that blackbirds reduced their feeding rates by ≥80% after treatment with AQ (Avipel®; a.i., 50%). In cage tests, positive concentration-response relationships existed for red-winged blackbirds (*Agelaius phoeniceus*) and common grackles (*Quiscalus quiscula*), with threshold AQ repellencies (i.e., 80% repellency) at 1,475 and 9,200 ppm (Werner et al. 2009, Werner et al. 2011). Common grackles (COGR) first discriminated between AQ-treated and untreated achenes at 1,300 ppm (Werner et al. 2011). In enclosure tests done in standing fields of ripening confectionery sunflower, COGR damaged standing sunflower in untreated enclosures (64%) more than treated enclosures (18%) (Werner et al. 2011). Achenes harvested from heads averaged 2.54 kg and 1.24 kg (dry weight) in treated and untreated enclosures, respectively. An enclosure study was also done using RWBL in fields of ripening oilseed sunflower in North Dakota (Werner et al. 2014). Damage was significantly less in AQ-treated enclosures (34%) than the untreated enclosures (44%). Harvested achene mass was significantly higher (2.6 kg) in the treated enclosures than untreated enclosures (2.1 kg).

Werner et al. (2014) also conducted preference tests to evaluate repellency of AQ applied to involucral bracts of sunflower. The backs of sunflower heads were treated with application rates comparable to 4.7, 9.4, and 18.7 liters Avipel®/ha. Only the 18.7 l/ha concentration showed a significant treatment effect; red-winged blackbirds ate from 0 g to 4.9 g from treated heads, whereas from 7.4 g to11.4 g were eaten from untreated heads. The 4.7 , 9.4 , and 18.7 l/ha treatments yielded 45 ppm, 141 ppm, and 320 ppm anthraquinone on achenes, respectively. Carlson et al. (2013) followed this study with preference tests on Avipel-treated husks of ripening sweet corn. Red-winged blackbirds were 40% more likely to damage untreated sweet corn than treated sweet corn; average kernel damage to untreated and treated ears was 8.6% and 5.3%, respectively. These results suggest potential efficacy in treating sunflower bracts and corn husks with AQ. Research should be conducted to evaluate anthraquinone-based repellents under true field conditions with free-ranging birds. Research is also needed on AQ residue levels for setting chemical tolerance limits for food and feed use, with goal of keeping residue levels below minimum levels of detection.

In September 2013, Niner et al. (2013) tested an application of an AQ chemical formulation (AV2022, a.i. 25% AQ, Arkion Life Sciences) at the early-flowering stage of sunflower (i.e., pre-achene set). The study's objective was to test the concept of spraying AQ on the heads (particularly bracts), while avoiding the achenes, which were underneath a layer of anthers. A 'high boy'-style ground sprayer was used to treat 0.40 ha with 15.1 l AQ mixed with 56.8 l water. The spraying was done when 50% of the sunflowers had reached the R5.1-R5.3 stage (early flowering). Enclosures were then placed and populated with 3 to 4 RWBL. Significantly more damage occurred in enclosures in the AQ-treated plot (35%) than enclosures in untreated plots (25%). We do not have an explanation for the results, as a multitude of studies have shown AQ to be highly repellent to birds. Residue analyses showed very low levels of AQ on the achenes at harvest, ranging from 4 to 7 ppm. The residues on the bracts immediately after application ranged from 159 to 290 ppm. Based on results of previous concentration-response studies, the AQ concentrations were still too low to repel RWBL.

ANTHRAQUINONE FIELD TESTS

In 2008, plots of experimental sunflower at North Dakota State University were treated with AQ during 1of 3 growth stages: R-5.1, R-5.5, or R-5.9 (Kandel et al. 2009). Applications were made by mobile ground sprayers. Avipel® was applied at 9.3 l/ha. Residues on achenes averaged 16 ppm at R-5.1, 7 ppm at R-5.5, and 1 ppm at R-5.9. The decline in AQ concentration at later growth stages was probably from changes in head position as the sunflowers matured. In 2011, a fixed-wing aircraft was used to apply AQ to 3 oilseed sunflower fields in central North Dakota (Linz and Homan 2012). The applications were done in 0.4-ha strips during mid-September using 9.4 l Avipel®/ha and 46.7 l/ha water. Blackbird damage in the untreated and treated strips did not differ, averaging 8.8% and 9.1%, respectively. We speculate that the AQ concentration was insufficient and did not deter birds from pulling bracts and other vegetative structures from the back of the heads. Low levels of AQ residues were found on the achenes, the highest concentration being 4 ppm. Aerial application of Avipel® at 9.4 l/ha is unlikely to provide adequate coverage of ripening sunflower.

In 2012, we used a high boy ground sprayer to apply Avipel® to 3 fields of sunflower (Niner et al. 2013). In each field, a 61 × 274-m plot was divided into treated and untreated sections with a buffer area between sections. Two sprays were applied. The first spray was done in mid-August using 4.7 l/ha. The second spray was applied in late August at an application rate of 14.0 l/ha. The number of blackbirds using the plots was counted daily and sunflower damage was measured weekly. Of the 3 fields, only 1 had blackbirds actively feeding in the plots. Their numbers were nearly equal between AQ treated and untreated plots, averaging 5,672 blackbirds/plot. Overall bird damage in this field was not statistically different between treated and untreated plots. Despite initial differences in damages between the untreated and treated plots, by the end of the study, damage rates were not significantly different.

2014 PROPOSED RESEARCH

In 2014, we plan to use field tests to assess residues of a new AQ formulation, AV-4044, which contains a proprietary ingredient. Strips of sunflower will be sprayed with a high boy ground sprayer at the following ripening stages: 1) R5.1 to 5.5 (flowering 50% complete), and 2) R5.6 to R6.0 (ray flowers wilting). Plant samples (achenes and bracts) will be collected within 1 day of the spray application and at harvest to assess AQ residue levels. Bird damage will also be assessed at harvest and compared between treatments.

MANAGEMENT IMPLICATIONS

Our goal is to expand the use of 9,10-Anthraquinone bird repellent to include application to ripening sunflower under Section 24c of EPA's FIFRA. We caution that birds need to learn that AQ causes gastric distress so some damage can be expected in treated fields. This product represents a potential major advance in blackbird damage management if repellency can be maintained at field application rates. The caveat is that residue levels at harvest meet the yet to be proposed food tolerance guidelines. Without an established food tolerance, residue levels on the achenes must be below detectable levels. Finally, an effective repellent, in combination with perennial sunflower planted in Wildlife Conservation Sunflower Plots, should help sunflower producers reduce their losses from blackbird damage (Avery 2002, Hagy et al. 2008, Kantar et al. 2014, Linz et al. 2014).

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