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Foraging behavior of red-winged blackbirds (*Agelaius phoeniceus*) on sunflower (*Helianthus annuus*) with varying coverage of anthraquinone-based repellent

Brandon K. Kaiser
North Dakota State University--Fargo

Mike Ostlie
North Dakota State University, mike.ostlie@ndsu.edu

Page E. Klug
USDA APHIS Wildlife Services, pklug@usgs.gov

Foraging behavior of red-winged blackbirds (*Agelaius phoeniceus*) on sunflower (*Helianthus annuus*) with varying coverage of anthraquinone-based repellent

BRANDON A. KAISER
North Dakota State University, Environmental and Conservation Sciences, Biological Sciences Department, Fargo, ND

MIKE OSTLIE
North Dakota State University, Carrington Research Extension Center, Carrington, ND

PAGE E. KLUG
USDA-APHIS Wildlife Services, National Wildlife Research Center, North Dakota Field Station, Fargo, ND

ABSTRACT: Animals attempt to maximize foraging efforts by making strategic foraging decisions. Foraging efforts can be influenced by chemically defended food. Food resources that are chemically defended force foragers to balance the nutritional gain with the toxic costs of foraging on a defended food resource. Chemical defense, in this case sunflower treated with chemical repellent, may be capable of deterring birds from foraging on treated crops. Blackbirds (*Icteridae*) cause significant damage to sunflower (*Helianthus annuus*) with damage estimates of $3.5 million annually in the Prairie Pothole Region of North Dakota, the largest sunflower producing state. Chemical repellents may be a cost-effective method for reducing bird damage if application strategies can be optimized for sunflowers. Anthraquinone-based repellents have been shown to reduce feeding on sunflower achenes by more than 80% in lab studies, but results in the field are inconclusive due to application issues where floral components of sunflower result in low repellent contact with achenes. Ground rigs equipped with drop-nozzles have shown promise in depositing repellent directly on the sunflower face but coverage is variable. We propose to evaluate the feeding behavior of red-winged blackbirds (*Agelaius phoeniceus*) and the efficacy of an anthraquinone-based avian repellent when applied directly to the sunflower face in a lab-based experiment. Our main objectives are to 1) evaluate the coverage needed on the face of the sunflower to establish repellency, 2) evaluate achene removal rates over time to understand time to aversion at varying repellent coverages, and 3) evaluate the feeding behavior and activity budgets of red-winged blackbirds on treated and untreated sunflower. The results of this study will inform repellent coverage needed at the scale of the sunflower plant to deter feeding or alter time budgets of foraging red-winged blackbirds to ultimately reduce sunflower damage.

Key Words foraging, *Agelaius phoeniceus*, repellent, sunflower, blackbird

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Foraging theory predicts that animals maximize foraging efforts and these efforts can be influenced by a chemically defended food resource where foragers must balance the nutritional gain with the toxic costs (Emlen 1966; MacArthur & Pianka 1966; Skelhorn & Rowe 2007). Chemical defense, in this case sunflower treated with chemical repellent, may be capable of deterring birds from foraging treated crops. Blackbirds (*Icteridae*) cause significant damage to sunflower (*Helianthus annuus*) in the Prairie Pothole Region of North Dakota with damage estimates of over $3.5 million annually (Peer et al. 2003; Klosterman et al. 2013; Hulke & Kleingartner 2014). Various management strategies have been considered to reduce blackbird damage to crops although current strategies suffer from a combination of limited extent of effectiveness in space and time, cost-benefit ratios, or the habituation of birds toward the tool (Gilsdorf et al. 2002; Linz et al. 2011; Klug 2017). Chemical repellents may be a cost-effective method for reducing bird damage if application strategies can be optimized for sunflowers. Anthraquinone-based repellents have been shown to reduce feeding on sunflower achenes by more than 80% in lab studies, but results in the field are inconclusive due to application issues where floral components of sunflower result in low repellent contact with achenes. In semi-natural field tests, blackbird consumption was successfully reduced when the repellent was applied directly to the sunflower face using a CO_2 backpack sprayer (Werner et al. 2011; 2014). Repellent application using ground rigs equipped with drop-nozzles have shown promise in depositing repellent directly on the sunflower face, but Klug (2017) found coverage to be variable (range 0-71%). Complete coverage of each sunflower head in a field is improbable, but partial coverage may be sufficient to reduce bird damage by altering foraging behavior. The purpose of our study is to assess the efficacy of an AQ-based repellent to reduce blackbird damage when applied to the face of ripening sunflower and evaluate how partial coverage of an avian repellent affects blackbird foraging behavior at the scale of a single sunflower head. We will test the chemical repellent applied to sunflower heads in a lab setting to determine 1) the repellent coverage on a sunflower face that results in > 80% repellency; 2) the amount of seeds consumed and time to aversion for each treatment by evaluating seed removal rates; and 3) changes in foraging behavior and time budgets between untreated sunflower heads and sunflower heads treated with different repellent coverage.

METHODS

Repellent Efficacy

We will test birds naïve to AQ in individual cages to evaluate repellency at repellent coverages ranging from 25%-100%. We will test 48 male red-winged blackbirds using no-choice tests to evaluate repellency for each treatment without alternative food. We will test 48 additional male red-winged blackbirds using two-choice tests to evaluate repellency for each treatment with alternative food available (untreated sunflower head). Tests include 1 day of acclimation, 2 days of pretest, and 1 day of treatment (2 days of treatment for two-choice tests). We will record both daily damage and consumption by weighing sunflowers before and after each day. Birds will be ranked according to pretest daily consumption and assigned to treatments such that each treatment group is similarly populated with birds exhibiting high to low daily consumption. Residue analyses will be conducted on both achenes and disk flowers to assess repellent concentrations for each treatment.

Foraging Behavior

We will evaluate foraging behavior on treated sunflower heads by video recording the aforementioned no-choice and two-choice tests. We will record bird activity for 8 hours between 08:00 and 16:00 as this is when red-winged blackbirds are most active (Hintz & Dyer 1970). We will measure achene and disk flower removal by using a 5-cm^2 template grid to measure removal at set intervals (every 5 minutes for the first hour, every hour for the remaining 7 hours). Treated and untreated removal rates will be compared and used to estimate how long it takes an individual bird to consume the necessary amount of repellent to reach aversion for each treatment. Additionally, we will record foraging activities while birds are exposed to untreated (control) and treated sunflowers to evaluate changes in foraging activity budgets. Activities will be will be recorded during the first 60 minutes and the last 15 minutes of each subsequent 7 hours of feeding. Intervals will include time not on the sunflower as well as time of specific behaviors when on treated or untreated sunflowers (Table 1). We will record pecking events during sampling intervals and compare pecking frequencies when birds are exposed to untreated and treated sunflowers as pecking rates are an accepted index for feeding rates (Smith 1977). For each activity, we will record position on the sunflower using a 360^{o} protractor transparency to identify the part of the sunflower heavily used by blackbirds. We will construct frequency distributions and compare between treated and untreated sunflowers.

SUMMARY

The results of this project will be informative for both foraging theory and sunflower damage management. Foraging theory enables the prediction of how animals forage. This study will further our understanding of foraging decisions at the scale of a single sunflower head and how the

Table 1. Foraging behaviors to be used in evaluating time budgets during feeding trials of red-winged blackbirds (*Agelaius phoeniceus*) on unadulterated sunflower (*Helianthus annuus*) and sunflower treated with various coverages of anthraquinone-based avian repellent. Previous studies recognize that granivorous birds, such as red-winged blackbirds, are capable of compatible food handling, where food can be processed while scanning their surroundings. Therefore, we will record the behavior as scanning in the absence of an achene being processed and as seed handling with the presence of achene processing. We will record birds as 'NOSF' if not on the sunflower in the 'no-choice' test and not on either sunflower in the two-choice test. During the two-choice test the sunflower treatment will be identified with the prefix 'T' for treated and 'N' for not treated to identify where the behavior is taking place.

Code	State (duration)	Description
ALBE	Alert Behavior	Sudden increased scanning, crouching, neck extension, or feather compression
BRTE	Bract Tearing	Pecking, tearing, or manipulating bracts; bird not focused on seeds
HAND	Handling	Processing seed; includes seed entering beak until hull ejected or seed processing complete
PREE	Preening	Cleaning feathers, stretching legs or wings, wiping beak, or head shaking
SRCH	Searching	Selecting seed, from the time a bird begins looking at seeds until a seed is obtained or search ended
SCAN	Scanning	Scanning surroundings without seed in beak
NOSF	Not on Sunflower	Bird is off the sunflower and/or not within camera view

presence of a toxin, in this case an added repellent, can influence those decisions. Additionally, this study will evaluate how toxin presence affects foraging decisions both with and without an alternative food resource. Furthermore, foraging behavior studies also neglect to relate changes in GUD to displayed behaviors of foragers. Our study will quantify foraging behavior changes before and after the presence of a repellent in a captive setting to evaluate key behavior changes that influence GUD in the presence of varying toxin densities. In terms of avian damage to sunflowers, chemical repellents can be a cost-effective management tool provided application difficulties can be overcome and alternative food is available for foraging birds (Klug 2017). Results from this study would inform the potential efficacy of an AQ-based repellent for use on foliar sunflower as well as inform repellent application strategy needed to maintain repellency considering the growth form and protective disk flowers of sunflower. Our study will also inform repellent effectiveness both with and without an alternative food source. Additionally, understanding how a repellent changes the time budget of individuals can be useful in implementing more effective integrated pest management strategies (e.g., decoy crops and physical hazing) that exploit these time budget changes. Future studies should investigate repellent coverage at the scale of an entire field, focusing on the required percentage of treated sunflower heads within a field to influence birds to abandon foraging at a field. Eventually, research should evaluate how the distribution of repellent coverage over the landscape influences repellency of each field.

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