Tools and Technology Article

Blackbird Repellency of Selected Registered Pesticides

SCOTT J. WERNER,[1] *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA*

JOHN L. CUMMINGS, *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA*

SHELAGH K. TUPPER, *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA*

DAVID A. GOLDADE, *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA*

DONN BEIGHLEY, *Southeast Missouri State University, 700 Douglas Street, Malden, MO 63863, USA*

ABSTRACT Bird depredation of agricultural crops is a worldwide problem. New strategies to include chemical repellents are needed to mitigate crop losses. We evaluated 3 preplant seed treatments (Apron XL® LS [Syngenta Crop Protection, Greensboro, NC], Dividend Extreme® [Syngenta], and Maxim® 4 FS [Syngenta]), one foliar insecticide (Karate® with Zeon Technology™ [Syngenta]), and one foliar fungicide (Tilt® [Syngenta]) as potential blackbird repellents in caged feeding trials and a field study. For all repellents tested, red-winged blackbirds (*Agelaius phoeniceus*) discriminated between untreated and treated rice during preference testing in captivity. We observed a positive concentration–response relationship among birds offered rice treated with 25%, 50%, 75%, 100%, or 200% of the manufacturer label for Dividend Extreme, Karate, and Tilt. Relative to pretreatment, blackbirds ate 32% and 69% less rice treated with 100% and 200% Tilt label rates, respectively, during the concentration–response test. Maximum repellency of Dividend Extreme and Karate was 55% at 200% of their label rates. We observed no repellency of a combination of Apron and Maxim at 25–200% label rates during the concentration–response test. We subsequently measured rice crop consumption and propiconazole (active ingredient, Tilt) residues among 10 plots (i.e., netted enclosures) populated with red-winged blackbirds within a maturing rice field. Average mass of rice harvested between treated (Tilt) and untreated subplots did not differ. We recovered an average of 12.3 μg/g propiconazole immediately following the first application and 20.2 μg/g propiconazole immediately following the second application of Tilt. We recovered <0.1 μg/g propiconazole on 15 August 2006, just before populating plots with blackbirds. Thus, the label application of Tilt fungicide did not reduce blackbird consumption within a maturing rice field, and residues of the active ingredient were insufficient for repellent efficacy. Additional studies are needed to determine whether higher concentrations of Tilt repel blackbirds under field conditions and to evaluate other potential repellents for protection of newly planted and ripening crops. (JOURNAL OF WILDLIFE MANAGEMENT 72(4):1007–1011; 2008)

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KEY WORDS *Agelaius phoeniceus*, Apron XL® LS, chemical repellent, Dividend Extreme®, foraging behavior, Karate® with Zeon Technology™, Maxim® 4 FS, red-winged blackbird, Tilt®, wildlife damage management.

Red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), and brown-headed cowbirds (*Molothrus ater*) cause extensive damage to newly planted and ripening rice in the mid-south of the United States (Cummings et al. 2002, 2005). Cummings et al. (2005) estimated that blackbirds caused approximately $13.4 million of damage to United States rice production in 2001. These losses have motivated development and use of various bird damage mitigation practices, including chemical repellents. Because development of chemical repellents is costly, there are few avian repellents currently registered by the United States Environmental Protection Agency for agricultural applications.

Bird Shield™ (active ingredient: methyl anthranilate; Bird Shield Repellent, Spokane, WA) is currently registered as an avian repellent; however, it was not effective for repelling blackbirds from ripening rice and sunflower fields (Werner et al. 2005). Anthraquinone effectively protects rice seed from blackbirds under captive and field conditions but is not registered as a blackbird repellent in the United States (Avery et al. 1997, Cummings et al. 2002). Caffeine may be an effective, economical, and environmentally safe chemical repellent for reducing bird damage to newly seeded rice (Avery et al. 2005, Werner et al. 2007). Additional registration criteria, however, must be satisfied to enable field applications of caffeine as an avian repellent. Thus, our purpose was to evaluate 5 currently registered pesticides as candidate blackbird repellents for agricultural producers.

We conducted caged feeding tests and one field study to evaluate 3 preplant seed treatments (Apron XL® LS [Syngenta Crop Protection, Greensboro, NC], Dividend Extreme® [Syngenta], and Maxim® 4 FS [Syngenta]), one foliar insecticide (Karate® with Zeon Technology™ [Syngenta]), and one foliar fungicide (Tilt® [Syngenta]) as avian repellents. Apron XL LS, Karate, Maxim 4 FS, and Tilt are currently registered for application on cereal grains, including rice. Dividend Extreme is labeled for barley, cotton, sweet corn, wheat, and triticale. Because Apron XL LS and Maxim 4 FS are commonly combined for field applications, we evaluated these pesticides in combination. Although Linz et al. (2006) observed 41% less consumption by red-winged blackbirds offered sunflower treated with the label rate of Warrior T® insecticide (11.4% λ-cyhalothrin [Syngenta]), we were interested in evaluating Karate with Zeon Technology, an encapsulated and currently registered product.

Most bird depredation of agricultural crops in the United States occurs in late winter and early spring just after crops

[1] *E-mail: Scott.J.Werner@aphis.usda.gov*

are planted, and again, during late summer and early fall just before harvest. Newly planted crops can be protected from insects, diseases, and weeds using pesticide seed treatments. Foliar pesticide applications are used to protect emergent seedlings and ripening crops before harvest. We applied pesticides to rice seeds to investigate repellent efficacy during our feeding tests in captivity. We used a foliar pesticide application to investigate blackbird repellency under field conditions.

STUDY AREA

We conducted preference and concentration–response tests at the United States Department of Agriculture, National Wildlife Research Center's (NWRC) outdoor animal research facility in Fort Collins, Colorado, USA. We maintained all blackbirds in 4.9 × 2.4 × 2.4-m cages (25–40 birds/cage) within an open-sided building for ≥2 weeks before testing. We provided free access to water, grit, and maintenance food (2 millet:1 milo:1 safflower:1 sunflower) to all birds during quarantine and holding. We conducted feeding tests within individual cages (0.9 × 1.8 × 0.9 m) in an open-sided building.

In June 2006, we initiated a field study at the Southeast Missouri State University Rice Research Farm (Malden, MO) to evaluate repellency of Tilt fungicide within a maturing rice field. We ensured that all study plots were drained, rolled, and leveled before the study. The NWRC Analytical Chemistry unit in Fort Collins, Colorado, performed propiconazole residue analyses associated with our field evaluation.

METHODS

Concentration–Response Testing

We conducted a concentration–response test for each candidate repellent to evaluate efficacy. Active ingredients of Apron XL LS are 32.3% (*R*)-[(2,6-dimethylphenyl)-methoxyacetylamino]–propionic acid methyl ester and 1.0% related compounds (label rate = 0.055 ml/kg). Active ingredients of Dividend Extreme are 7.73% difenoconazole (Chemical Abstracts Service [CAS] no. 119446-68-3; label rate = 1.8 ml/kg), 1.87% (*R*)-2-[(2,6-dimethylphenyl) methoxyacetylamino]–propionic acid methyl ester, and 0.06% related compounds. Active ingredients of Maxim 4 FS, Karate, and Tilt are 40.3% fludioxonil (CAS no. 131341-86-1; label rate = 0.103 ml/kg), 22.8% λ-cyhalothrin (CAS no. 91465-08-6; 187 ml/ha), and 41.8% propiconazole (CAS no. 60207-90-1; 730 ml/ha), respectively.

To conduct tests, we used a cannon net to capture 172 experimentally naïve red-winged blackbirds (ad M) in 2005–2006 near Fort Collins, Colorado, and transported them to NWRC. We used adult male blackbirds for all feeding tests because gender affects rice consumption among blackbirds (Avery et al. 2005). We randomly assigned 43 blackbirds to each of 4 tests (Apron–Maxim combined, Dividend Extreme, Karate, and Tilt). We transferred birds to individual cages following group quarantine and holding and offered them untreated seed rice (ad libitum) in one food bowl for 5 days of acclimation. We provided all birds water ad libitum throughout concentration–response testing (i.e., acclimation, pretreatment, test). We offered 30 g of untreated rice in one bowl to all birds during each day of the 4-day pretreatment. We collected uneaten rice (remaining in food bowls) and rice spillage (remaining in trays beneath each bowl) at 0800–0930 hours daily and determined their mass (±0.1 g). We accounted for changes in mass of rice independent of rice consumption (e.g., desiccation) by weighing rice offered within a vacant cage. We offered the maintenance diet (ad libitum) to all birds in one bowl for 3 days between pretreatment and test periods.

We ranked blackbirds based upon average pretreatment consumption and assigned them to 1 of 5 treatment groups ($n = 8$–9 birds/group) such that each group was similarly populated with birds that exhibited high–low daily consumption. We randomly assigned treatments among groups. We used treatment groups to evaluate repellency associated with 25%, 50%, 75%, 100%, and 200% of the label rate for each candidate repellent. We applied treatment solutions (60 ml/kg rice) to 5 kg of certified seed rice (Louisiana State University Rice Research Station, Crowley, LA) using a rotating mixer and household spray equipment. Because pesticide applications often include antitranspirants and stickers, we added 3 ml Transfilm® (PBI/Gordon, Kansas City, MO) to each formulation (per manufacturer label). We formulated insecticide and fungicide treatments based upon an industry-standard seeding rate of 145 kg/ha (i.e., ml/ha to ml/kg conversion). We measured consumption of treated rice offered in one bowl during each day of the 4-day test.

We hypothesized that repellency would be directly related to repellent concentration. We predicted that test consumption associated with efficacious treatments would be <25% (i.e., ≥75% repellency; Schneider 1982) of pretreatment consumption. The dependent measure for concentration–response testing was percentage of repellency (i.e., test day 1 relative to average pretreatment consumption) as a function of pesticide concentration. We used regression procedures (SAS Institute, Cary, NC) to analyze repellency exhibited during concentration–response testing. We used descriptive statistics ($\bar{x} \pm$ SE) to summarize test consumption of treated rice. The NWRC Institutional Animal Care and Use Committee approved the capture, care, and use of birds associated with our feeding tests (NWRC study protocol QA1219).

Preference Testing

We conducted a preference test for each candidate repellent to determine whether blackbirds could discriminate between untreated and repellent-treated rice. We captured 92 experimentally naïve red-winged blackbirds in 2005–2006 near Fort Collins, Colorado, and transported them to NWRC. We randomly assigned 23 blackbirds to each of 4 tests (Apron–Maxim combined, Dividend Extreme, Karate, and Tilt). We repeated all quarantine, holding, acclimation, and pretreatment procedures (using 2 food bowls) used during concentration–response testing. We measured pretreatment and test consumption independently for food bowls located on the north and south sides of each cage. We offered the maintenance diet (ad libitum) to all birds in 2 bowls for 3 days between pretreatment and test periods.

We offered one bowl of untreated rice and one bowl of rice treated with one of the candidate repellents (30 g each) to all birds during each day of the 4-day test. We formulated pesticide treatments based upon the label rate (i.e., 100%) for each candidate repellent. We repeated all concentration–response formulation procedures. We randomized the north–south positioning of treatments within individual cages on the first day and alternated positioning on subsequent days of the test to overcome side preferences independent of treatments.

The dependent measure for preference testing was average (daily) rice consumption during pretreatment and test periods. We used the general linear-model procedure (SAS Institute, Cary, NC) to conduct an analysis of variance (ANOVA) associated with preference testing for each candidate repellent. We used fixed-repellent treatments among bird subjects. The independent variables (and associated error terms) of these analyses were testing periods and the period–treatment interaction (subject–period–treatment), and the period–day interaction (residual error). We offered one bowl of untreated rice on each of the north and south sides of all cages throughout pretreatment. Thus, we regarded pretreatment consumption of "treated" rice as that which was offered on the north (days 1 and 3) and south side (days 2 and 4) for statistical analyses. We used Tukey's tests to separate means of ANOVA effects ($\alpha = 0.05$). We used descriptive statistics ($\bar{x} \pm$ SE) to summarize test consumption of treated and untreated rice.

Field Evaluation of Tilt Fungicide for Maturing Rice

Rice consumption test.—We measured consumption of maturing rice by blackbirds within 10 experimental enclosures or netted plots (each 9.1 m long, 3.7 m wide) to evaluate repellent efficacy of Tilt fungicide under field conditions. Each plot contained 4 subplots (each 4 m long, 1.3 m wide). We randomly assigned treatments (treated, untreated) among subplots such that each plot had 2 subplots that contained maturing rice treated with Tilt fungicide and 2 subplots that contained untreated rice.

We applied Tilt on all treated subplots on 30 June 2006 (at first internode elongation) and on 12 July 2006 (at swollen boot), per manufacturer label. We used a backpack sprayer to apply approximately 448 ml/ha of Tilt and 1% Transfilm during each of 2 applications. The NWRC Institutional Animal Care and Use Committee approved the capture, care, and use of birds associated with our field study (NWRC study protocol QA1379).

We conducted rice consumption testing during the period between the milk stage of rice development (i.e., phenology subsequent to spikelet formation) and rice harvest. We populated each of 10 plots with 10 experimentally naïve red-winged blackbirds (ad) on 15 August 2006, which was 30 days before planned harvest, when blackbird depredation of ripening rice is greatest. We provided all birds water ad libitum throughout the study. Blackbirds foraged freely within plots during the 28-day test. We measured ($\pm$0.1 kg) rice harvested from treated and untreated subplots at the conclusion of the test. We used descriptive statistics ($\bar{x} \pm$ SE) and a paired *t*-test to summarize harvest data among treated and untreated subplots. We corrected harvest data (i.e., standardized for 31.4 m^2) to account for differences in the area among subplots (range = 28.1–33.6 m^2).

Propiconazole residue analyses.—We collected rice panicles to determine propiconazole residues among treated subplots. We collected 10 rice panicles from random sampling sites within each treated subplot on 30 June 2006 (immediately subsequent to the first application of Tilt), 12 July 2006 (subsequent to second application), and 15 August 2006 (before populating plots with blackbirds).

We ground rice panicle samples in a liquid nitrogen homogenizer (SPEX freezer mill 6850, SPEX Certiprep, Metuchen, NJ). We placed subsamples of the resultant powder (0.95–1.05 g) in 50-mL glass, screw-cap test tubes. We extracted the homogenized samples 3 times using a solution of 75% methanol and 25% water. The extraction procedure consisted of vortex mixing, followed by mechanical shaking for 10 minutes. We centrifuged test tubes at approximately 2,500 revolutions/minute (945 $\times$ *g*) and poured the supernatant into a clean 50-mL test tube.

We placed the combined extracts in a 60° C water bath and directed a gentle stream of nitrogen over the samples until they reached a final volume of approximately 5 mL. We loaded the concentrated extracts onto a 500-mg graphitized nonporous carbon/ethylenediamine-*N*-propyl silane-bonded silica (ENVI-Carb/PSA) solid-phase extraction (SPE) cartridge. We washed off potential matrix interferences from the SPE column with 5 mL of 75% methanol and 25% water. Propiconazole was eluted from the SPE column into a clean 25-mL test tube with 20 mL of 1:1 toluene:acetonitrile. We again evaporated samples in a 60° C water bath under a gentle stream of nitrogen. We then dried samples and reconstituted them in 1.0 mL of 1:1 hexane:acetone for subsequent residue analyses.

We quantified propiconazole residues using gas chromatography with mass selective detection (GC-MSD). We injected 1 µL of each sample extract into an 580 Series II gas chromatograph (Agilent, Santa Clara, CA) equipped with a 5972 mass selective detector and a 7673 auto injector. We performed the GC-MSD injection in splitless mode at 260° C. We maintained a DB-5MS column (30 m, 0.25-mm inside diam, 0.25-µm film thickness) at 120° C for 1 minute following sample injection before heating to 220° C at 35° C/minute (2-min holding) increments. We then increased oven temperature to 240° C at 5° C/minute increments and held it there for 3 minutes before increasing to the final temperature of 280° C at 35° C/minute steps. We maintained the final temperature for 3 minutes. We then passed the sample into the GC-MSD (280° C transfer line temp) where we achieved quantitation by single ion monitoring detection of the 2 primary fragments of

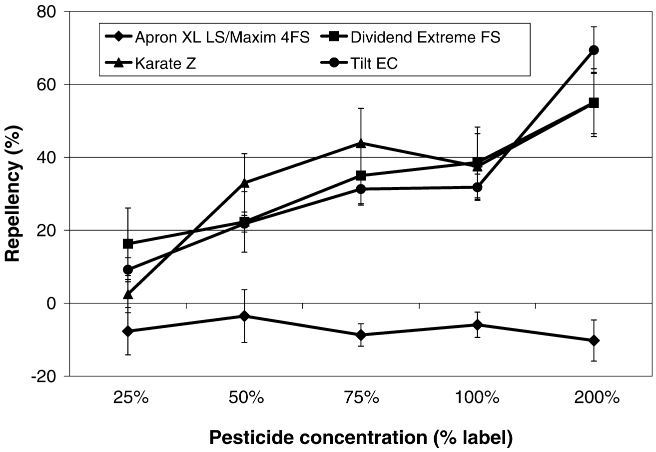

Figure 1. Avian repellency ($\bar{x}$ ± SE) associated with 5 concentrations of Apron XL® LS/Maxim® 4 FS seed treatments (Syngenta Crop Protection, Greensboro, NC), Dividend Extreme® seed treatment (Syngenta), Karate® with Zeon Technology™ insecticide (Syngenta), or Tilt® EC fungicide (Syngenta) at the National Wildlife Research Center in Fort Collins, Colorado, November 2005–November 2006. Repellency represents test (day 1) consumption relative to average pretreatment rice consumption (n = 7–9 red-winged blackbirds/group).

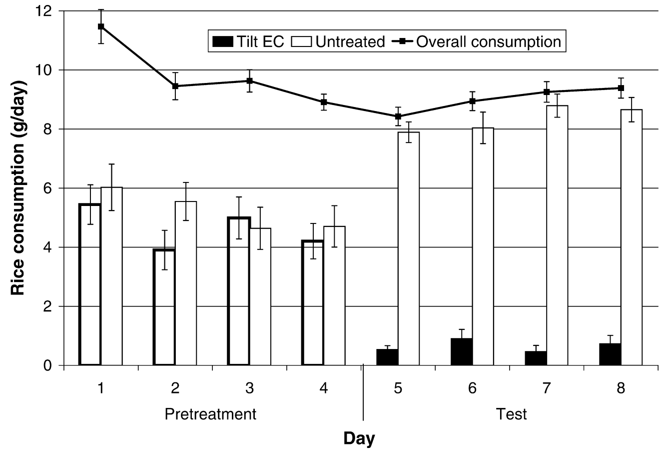

Figure 2. Rice consumption ($\bar{x}$ ± SE) among red-winged blackbirds offered untreated rice and rice treated with Tilt® EC fungicide (Syngenta Crop Protection, Greensboro, NC) at the National Wildlife Research Center in Fort Collins, Colorado, March–April 2006. Pretreatment (2 bowls untreated rice) and test data (1 bowl treated, 1 bowl untreated rice) reflect consumption among all birds (n = 23) from each of 2 bowls.

propiconazole (m/z = 173 and 259). We used descriptive statistics ($\bar{x}$ ± SE) to summarize propiconazole residues among treated subplots.

RESULTS

Concentration–Response Testing

We observed no concentration–response relationship for the combination of Apron XL LS and Maxim 4 FS seed treatments. Repellency (i.e., test relative to pretreatment consumption) of rice treated with Apron and Maxim was unrelated to tested concentrations ($r^2 = 0.007$, $P = 0.584$). Relative to pretreatment, we observed no decrease in rice consumption among blackbirds offered 25–200% of the manufacturer label for Apron and Maxim (Fig. 1).

Repellency was related to tested concentrations of Dividend Extreme ($r^2 = 0.227$, $P = 0.001$) and Karate insecticide ($r^2 = 0.247$, $P = 0.001$). Maximum repellency, however, was only 55% at 200% of the label rate for Dividend Extreme and Karate (Fig. 1). Repellency at 25–100% label rates for Dividend Extreme and Karate ranged from 16% to 39% and from 3% to 44%, respectively.

Relative to pretreatment, blackbirds consumed 32% and 69% less rice treated with 100% and 200% of the Tilt label, respectively (Fig. 1). We observed a direct concentration–response relationship among tested concentrations of Tilt ($r^2 = 0.741$, $P < 0.001$). Thus, rice consumption decreased with increasing concentrations of this registered fungicide, and we proceeded with an evaluation of Tilt as an avian repellent under field conditions.

Preference Testing

We observed less consumption of rice treated with Apron and Maxim than that of untreated rice during the pretreatment and test (i.e., period–treatment interaction; $F_{2,88} = 27.28$, $P < 0.001$). On average, blackbirds consumed 7.5 (±0.4) g per bird per day of untreated rice and 4.0 (±0.4) g per bird per day of rice treated with Apron and Maxim seed treatments ($P < 0.05$). We observed no difference in overall consumption during the pretreatment and test (i.e., period effect; $F_{1,88} = 3.52$, $P = 0.064$) or among days of these testing periods (period–day interaction; $F_{6,270} = 0.28$, $P = 0.944$).

Blackbirds ate less rice treated with Dividend Extreme than untreated rice during the pretreatment and test ($F_{2,88} = 26.31$, $P < 0.001$). Average consumption was 5.3 (±0.3) g per bird per day of untreated rice and 1.7 (±0.3) g per bird per day of treated rice ($P < 0.05$). We observed no period effect ($F_{1,88} = 0.26$, $P = 0.614$) or period–day interaction ($F_{6,270} = 0.45$, $P = 0.844$) during the Dividend Extreme preference test.

We observed less consumption of rice treated with Karate insecticide than that of untreated rice during the pretreatment and test ($F_{2,88} = 922.16$, $P < 0.001$). On average, blackbirds ate 10.3 (±0.2) g per bird per day of untreated rice and 0.4 (±0.1) g per bird per day of treated rice ($P < 0.05$). Overall consumption was greater during the test than pretreatment ($F_{1,88} = 9.85$, $P = 0.002$). We observed no period–day interaction ($F_{6,270} = 1.21$, $P = 0.303$) during the Karate preference test.

Blackbirds ate less rice treated with Tilt fungicide than untreated rice during the pretreatment and test ($F_{2,88} = 238.83$, $P < 0.001$; Fig. 2). Average consumption was 8.3 (±0.2) g per bird per day of untreated rice and 0.7 (±0.1) g per bird per day of treated rice ($P < 0.05$). We observed no period effect ($F_{1,88} = 2.99$, $P = 0.088$) or period–day interaction ($F_{6,270} = 1.14$, $P = 0.338$) during the Tilt preference test.

Field Evaluation of Tilt Fungicide for Maturing Rice

We observed no difference in average mass of rice harvested between treated (Tilt) and untreated subplots ($P = 0.929$). Average mass of rice harvested within treated and untreated subplots was 3.6 (±0.1) kg and 3.6 (±0.2) kg, respectively. Thus, the pesticide treatment did not reduce blackbird consumption of maturing rice under the field conditions of our test.

We recovered an average of 12.3 (±1.3) μg/g propiconazole immediately following the first application of Tilt on 30 June 2006. We observed 20.2 (±2.9) μg/g propiconazole among treated subplots immediately following the second application of Tilt on 12 July 2006. We recovered <0.1 μg/g propiconazole (GC-MSD method limit of detection) among treated subplots on 15 August 2006, just before populating plots with blackbirds. Thus, pesticide residues may have been insufficient to decrease blackbird consumption of rice treated with Tilt.

DISCUSSION

Blackbirds preferred untreated rice to rice treated with any of the candidate repellents throughout preference testing. We observed a positive concentration–response relationship among tested concentrations of Dividend Extreme seed treatment, Karate insecticide, and Tilt fungicide. Among tested compounds, Tilt fungicide was the most effective for reducing blackbird consumption of rice during the concentration–response test (i.e., 69% repellency at 200% of the Tilt label rate). Similarly, Linz et al. (2006) observed 81% repellency of the full-label rate of Lorsban-4E® insecticide (Dow AgroSciences, Indianapolis, IN) and Werner et al. (2007) observed >85% repellency of 2,500–20,000 ppm caffeine and sodium benzoate among red-winged blackbirds in captivity.

We also evaluated Tilt as a blackbird repellent under field conditions. We observed no difference in the mass of rice harvested from treated and untreated subplots during our field evaluation of Tilt. Thus, the label application of Tilt fungicide did not reduce blackbird consumption within a maturing rice field, and residues of the active ingredient were insufficient for repellent efficacy.

In the United States, blackbird repellents are most needed to protect agricultural crops 3–4 weeks after planting and 3–4 weeks before harvest. We evaluated repellent efficacy of Tilt fungicide applied to maturing rice (i.e., mid-season, foliar application). The manufacturer's label for Tilt prohibits its application within 35 days of crop harvest. Additional studies are needed to determine whether higher concentrations of Tilt repel blackbirds under field conditions and to further evaluate this and other potential repellents for protection of newly planted and ripening crops.

MANAGEMENT IMPLICATIONS

All pesticides that we evaluated are registered with the United States Environmental Protection Agency for agricultural applications. Thus, data required for registration of these products as preplant seed treatments, foliar insecticides, and fungicides already exist (e.g., product and residue chemistry, toxicity, nontarget plant protection, environmental fate, postapplication and applicator exposure). These data can be used to further develop these pesticides as avian repellents. An increased application rate of Tilt may be necessary to decrease blackbird damage within rice fields. Laboratory efficacy data must be reconciled with existing registration data to develop additional field efficacy studies of an increased application rate of Tilt for avian repellency.

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