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Crop Protection 19 (2000) 225–230

Crop Protection

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Evaluation of overspraying as an alternative to seed treatment for application of Flight Control® bird repellent to newly planted rice

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Received 21 September 1999; received in revised form 20 December 1999; accepted 21 December 1999

Abstract

Anthraquinone is a promising candidate as a repellent to protect newly planted rice from blackbird depredation. Current technology for applying chemicals to rice seed prior to planting might be incompatible with the relatively large volume of bird repellent material needed on rice seeds. Therefore, an alternate method of application, overspraying the field after the seed is planted, could prove more efficient and practical. We examined this approach in pen and field trials. In group pen tests, red-winged blackbirds (Agelaius phoeniceus) consistently avoided Flight Control (50% anthraquinone) applications equivalent to 23.3 and 37.2 l/ha, but were not deterred by 9.3 l/ha. Several test birds vomited after they fed on treated seeds. In a 0.2 ha flight pen, blackbird flocks removed 58% of rice seed from untreated plots compared to 6% taken from plots sprayed with Flight Control at a rate of 18.6 l/ha. In southwestern Louisiana, plots of newly planted rice were sprayed with Flight Control at either 9.3 or 18.6 l/ha. We did not observe blackbird repellency at any of the treated sites. Anthraquinone residues on rice from the test plots indicated that there was insufficient repellent on the seeds in the fields to deter depredating blackbirds. For overspraying to be practical and effective, methods must be devised to deliver the chemical more efficiently to the planted seeds. Published by Elsevier Science Ltd.

Keywords: Agelaius phoeniceus; Anthraquinone; Bird repellent; Blackbird; Crop damage; Rice; Seed treatment

1. Introduction

Bird damage to newly planted rice is a serious problem for many growers in southwestern Louisiana (Wilson et al., 1989) and eastern Texas (Decker et al., 1990). Blackbird population reduction using toxic brown rice bait is one approach to controlling damage (Glahn and Wilson, 1992), but nontoxic, bird-deterrent seed treatments offer potential alternatives to lethal control. Cage tests and aviary trials have identified several candidate repellent rice seed treatments (Daneke and Decker, 1988; Avery and Decker, 1991; Avery et al., 1995), yet none is currently registered with the US Environmental Protection Agency (Mason and Clark, 1992).

One promising candidate for rice seed treatment use is 9,10-anthraquinone, a compound that has a long history as an effective feeding deterrent. Anthraquinone was patented as a bird repellent in the 1940s and was evaluated as a possible blackbird feeding deterrent on rice seed in the 1950s (Neff and Meanley, 1957). Recent investigation confirmed the potential utility of anthraquinone (Avery et al., 1997, 1998), and field trials with Flight Control® (Environmental Biocontrol International, Wilmington, DE), a formulated commercial product, produced consistent and satisfactory results as a seed treatment (J.L. Cummings, 1998, unpublished data).

There is, nevertheless, some concern for the compatibility of Flight Control with machines currently used to apply chemicals to rice seed. This treatment system, developed by Rhône-Poulenc (Research Triangle Park, NC), is designed to apply relatively small amounts of insecticide to pre-sprouted rice seed (Klittich et al., 1999). In contrast, to be effective, Flight Control must be applied at much greater rates which requires inconvenient modifications to the seed treatment system. It is therefore of interest to determine whether Flight Control can be effective as a blackbird deterrent without having to treat

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0261-2194/00/$ - see front matter. Published by Elsevier Science Ltd.
PII: S0261-2194(00)00012-0

seeds before planting. Such an approach would eliminate dependency upon availability and capacity of seed treatment machinery and would focus repellent applications specifically on areas receiving bird damage. Therefore, in this study we evaluated the overspray method, first with captive birds in a series of pen tests, and then in a field trial.

2. Methods

2.1. Group test pens

At the Florida Field Station of the USDA's National Wildlife Research Center, we removed red-winged blackbirds from their communal holding cages and placed them in groups of three in outdoor test pens ($9.3 \times 3.1 \times 1.6$ m). Each pen had several shaded perches, a waterer, and a bowl for maintenance food (rice plus commercial quail starter). In the center of each pen, we placed two stainless-steel trays ($60 \times 75 \times 3$ cm) 25 cm apart, and filled them to a depth of 2 cm with soil. We designated at random one tray in each pen for treatment. The birds were allowed to acclimate for 3 d.

On each test day, we removed maintenance food from each pen 30 min prior to the trial and thoroughly wetted the dirt in each tray. We scattered 100 rice seeds over the surface of each tray. On test day 1, both trays were untreated. On days 2–4, using compressed air, we sprayed 10 ml of Flight Control mixture on the tray assigned for treatment. We sprayed the untreated tray with 10 ml of plain water. Three hours later, we recorded the uneaten seeds remaining in each tray. Also, on days 2–4, we observed feeding behavior of one set of birds for 2 h from an adjacent blind and recorded time spent feeding in each tray. After each daily trial, birds again received maintenance food and we replaced the upper 0.5 cm of dirt in the treated tray with fresh soil. We banded and released all birds after the study.

We tested three levels of Flight Control equivalent to field application rates of 9.3, 23.3, and 37.2 l/ha. We achieved these rates by preparing 10 ml aqueous mixtures containing 0.5, 1.25 and 2.0 ml of Flight Control, respectively. Flight Control contains 50% (by mass) 9,10-anthraquinone as the active ingredient. We tested each level with four groups of birds.

2.2. Flight pen

Within a 0.2 ha outdoor flight pen, we tilled and smoothed two test plots (15 m $\times$ 20 m) and randomly assigned one for treatment. We removed 10 male red-winged blackbirds from their communal holding cages and placed them in a group pen (9.3 m $\times$ 3.1 m $\times$ 1.6 m) within the flight pen to acclimate for 24 h.

At the start of each trial, we randomly located 20 sampling quadrats (0.19 m2) in each plot. We then scattered by hand 1.5 kg of rice seed (presoaked in water for 24 h) over each plot. We revisited each sampling site and set the initial count within each quadrat to 48 seeds. We then sprayed the designated treated plot with 3 l of an aqueous mixture containing 600 ml Flight Control. This was equivalent to a field application rate of 18.6 l/ha. We applied the mixture using a 30 psi CO_2-powered sprayer through an aluminum spray wand containing 4 TeeJet SS 8002 nozzles. Immediately after spraying, we released birds into the flight pen.

We conducted three replications, each of which lasted 10 d. Each day, we recorded the number of uneaten seeds on each of the sampling quadrats in each plot. We also recorded daily precipitation. During the third replication, we collected seed samples from the treated plot 1, 3, 7, and 9 d after application. Anthraquinone residues were determined using high performance liquid chromatography by Environmental Biocontrol International (Wilmington, DE). After test day 10, we banded and released all birds.

2.3. Field trial

In southwestern Louisiana, we selected 6 study sites each of which consisted of 2 test plots (2–5 ha) separated by a 5–10 m buffer zone. Plots were prepared and flooded by the cooperators, and rice was aerially seeded. The seed remained underwater up to 4 d until sufficiently germinated, and then the water was drained. One day later, the Flight Control was aerially applied to the germinated seed. We applied Flight Control at either 9.3 or 18.6 l/ha by mixing the appropriate volume of Flight Control with sufficient water to produce a total application volume of 93 l/ha. In addition, we added 350–470 ml of a commercial sticker to increase adherence of the repellent to the seeds. The spray aircraft were configured with 58 CP nozzles set to an orifice size of D-12 and using $12\frac{1}{2}°$ deflectors to reduce droplet size.

Prior to application of the repellent, we placed four pans, each with 20–30 g of rice, in a central location in each treated plot to receive unobstructed exposure to the repellent application. Seed from the pans was collected 1 h, and 1, 3 and 7 d after repellent application. We also placed samples of seed on screens situated within shallow muddy water in five of the study sites to assess the amount of repellent that reached seed planted into the flooded fields. These samples were collected 1 h to 3 d after spray application. Each sample was bagged, labeled and frozen until shipped to Environmental Biocontrol International for residue analysis.

After the study plots were drained, we documented bird activity until we counted sprouted rice 7 d later. We observed birds from a vehicle positioned to provide complete coverage of the plots yet not affect the activity of the birds. We recorded the initial number of birds in the field and then recorded continuously the number of birds entering and leaving each plot for 1 h in the morning. From these data, we calculated a running total for each observation period that enabled us to estimate bird pressure and facilitated comparisons among days.

One week after water was drained from the plot, we assessed sprout density by counting the number of rice sprouts in sampling quadrats (0.09 m^2) at 150 points throughout each plot. Sample points were distributed by randomly selecting 6 transects across each of five equal-sized strata within each study plot. We then randomly assigned five sampling locations to each transect (Otis et al., 1983). In addition, at 10 random locations per plot, sprouts were counted in sampling quadrats protected from bird damage by wire exclosures. Counts from the exclosures served as a check to account for factors other than bird damage that might affect sprout density. At each study site, we compared mean sprout counts from transects in the treated plot with those in the untreated plot by applying one-way ANOVA (Steel and Torrie, 1980).

At one of the six study sites, the pilot inadvertently applied Flight Control to both study plots. As a result, there was no untreated plot and we had no means to determine the effectiveness of the treatment at that location. At a second site, there was virtually no birds throughout the study, so no behavioral response could be determined. We excluded these sites from bird activity and sprout count analyses. However, we retained the residue information.

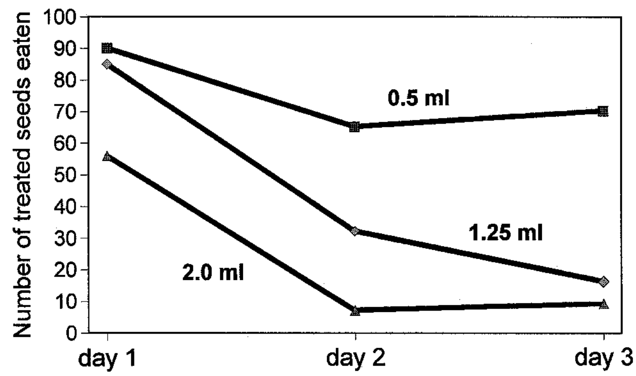

Fig. 1. Rice seeds eaten from trays sprayed with different levels of Flight Control® bird repellent. Each tray held 100 seeds initially. There were three red-winged blackbirds per group, and four groups per level.

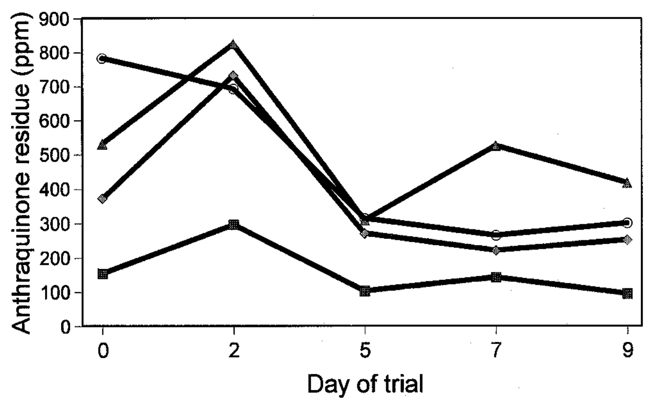

Fig. 2. Anthraquinone residues from rice seed collected at four locations within a 20 × 25 m test plot. The plot was sprayed with Flight Control® bird repellent at a rate equivalent to 18.6 l/ha. There was 70 mm of rain between days 2 and 5.

3. Results

3.1. Group test pens

3.1.1. Seed consumption

All untreated seed was eaten each day, so analyses were performed on treated seed consumption only. The amount of treated seed eaten varied ($F_{2,9} = 5.94$, $P = 0.023$) among treatment levels. Seed loss was greatest (75%) at the 0.5 ml level and least (24%) at the 2 ml level. Across all treatments, seed loss varied by day ($F_{2,18} = 39.61$, $P < 0.001$). On day 1, 77% of the seed was taken, whereas only 35% and 32% was lost on days 2 and 3, respectively. The interaction between day and treatment level ($F_{4,18} = 3.32$, $P = 0.033$) reflected sharp reductions in consumption after day 1 at the 1.25 and 2 ml levels compared to relatively constant seed removal at the 0.5 ml level (Fig. 1).

3.1.2. Feeding activity

Observations of feeding activity revealed that birds spent more time ($F_{2,9} = 8.60$, $P = 0.008$) at trays with untreated seed (17.1 min/period, SE = 2.6) than at trays treated with 1.25 ml (5.0 min/period, SE = 3.6) or 2 ml (2.2 min/period, SE = 1.7). Two of the three groups observed received the 2 ml Flight Control treatment. Two birds in one group and all three in the other group vomited on day 1 after feeding on treated seed. The third group observed received 1.25 ml Flight Control. On day 1, these birds fed on treated seed, appeared lethargic, but none vomited.

3.2. Flight pen

3.2.1. Anthraquinone residues

Seed samples from four points within the treated plot revealed that one sampling location had consistently lower residues than the others (Fig. 2). All sampling points showed a marked decline in anthraquinone residue from day 2 to 5. We recorded 70 mm of rain on day 3.

3.2.2. Seed consumption

Overall, mean daily seed consumption from untreated plots ($\bar{x} = 56.1$, SE = 5.4) greatly exceeded ($F1,4 = 366.00$, $P < 0.001$) that from treated plots ($\bar{x} = 5.7$,

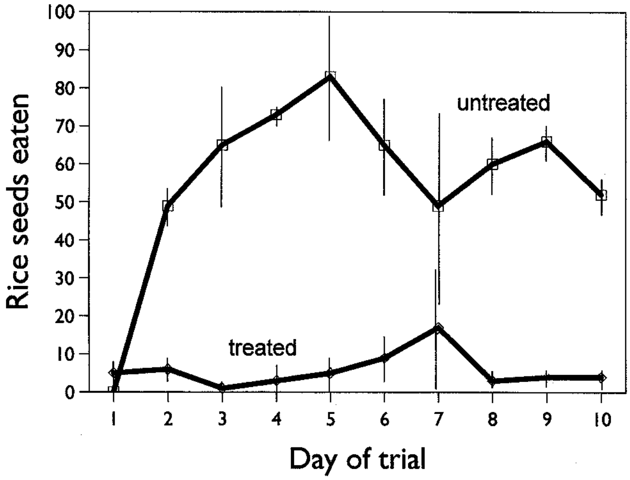

Fig. 3. Mean number of rice seeds removed from sampling quadrats in treated and untreated plots by three groups of 10 male red-winged blackbirds within a 0.2 ha flight pen. The treated plot was oversprayed with Flight Control® bird repellent at a rate equivalent to 18.6 l/ha.

SE = 1.8). Total consumption of rice seed was consistently low on day 1 ($F_{9,36} = 1.93$, $P = 0.078$) but increased steadily through day 5, after which it declined through the end of the 10 day trial (Fig. 3).

3.3. Field trial

3.3.1. Blackbird activity

Blackbird numbers were similar among sites prior to repellent application, but varied considerably thereafter (Fig. 4). On the day of treatment, total blackbird numbers (treated plot plus untreated plot) at 3 sites that received the 18.6 l/ha treatment averaged 112 birds/min (SE = 15), compared to 105 birds/min at the site that received 9.3 l/ha. Three days posttreatment, the mean number of blackbirds recorded at the 3 high-rate sites decreased to 40 birds/min (SE = 4) whereas numbers at the 9.3 l/ha site rose to 214 birds/min.

In the treated plots only, bird numbers relative to pretreatment levels declined through day 3 at 2 sites, but then increased (Fig. 4). At a third site, blackbird numbers in the treated plot remained low through day 6 before increasing markedly on day 7. In contrast, at the 9.3 l/ha site, numbers of blackbirds in the treated plot steadily increased throughout the study period (Fig. 4). We did not observe any adverse reaction by individual birds feeding on rice in treated plots.

3.3.2. Rice sprout density

At three of four study sites, counts of sprouted rice seed were extremely low (Table 1). Only one site produced sprout counts that would result in an acceptable stand of rice. At this site, however, the treated plot did not differ from the untreated plot ($F_{1,58} = 0.13$, $P = 0.718$).

3.3.3. Anthraquinone residues

One hour after spraying, anthraquinone residue on test seed in pans from 18.6 l/ha plots ranged from 274 to 467 ppm. Residues from seed in pans at 9.3 l/ha sites varied from 72 to 131 ppm. Although there was considerable variability among sites, the temporal pattern of decline in anthraquinone residues was similar between treatment rates (Fig. 5). With one exception, residues from seed on screens was substantially less than that obtained from corresponding seed samples in pans (Table 2). Rice seed in contact with mud and water in test fields received considerably less anthraquinone coverage

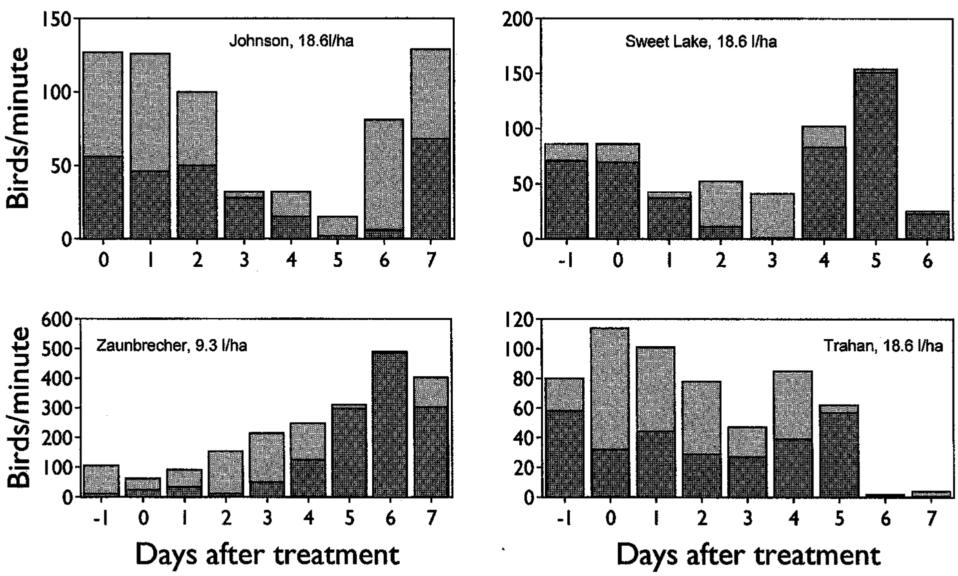

Fig. 4. Mean numbers of blackbirds recorded in treated (dark) and untreated (light) rice seed test plots in southwestern Louisiana, March 1999. Treated plots received an overspray of Flight Control® bird repellent at the rate indicated.

Table 1
Sprouted rice seeds counted in 150 sampling quadrats (0.09 m^2) throughout blackbird repellent test plots and under bird-proof exclosures ($n = 20$/plot) within the test plots at four locations in southwestern Louisiana, March–April 1999. Treated plots received an overspray of Flight Control bird repellent at the indicated rate when the plots were drained

		Sprout density (plants/quadrat)							
		Test plots				Exclosures			
Study site	Treatment rate (l/ha)	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Zaunbrecher	9.3	0.2	0.1	3.4	0.5	23.7	1.7	26.7	2.3
Trahan	18.6	14.3	0.8	13.9	0.8	15.7	1.9	15.8	2.0
Sweet Lake	18.6	0.7	0.1	1.1	0.2	12.3	1.5	9.4	1.5
Johnson	18.6	3.4	0.4	0.6	0.1	21.6	3.1	14.6	2.2

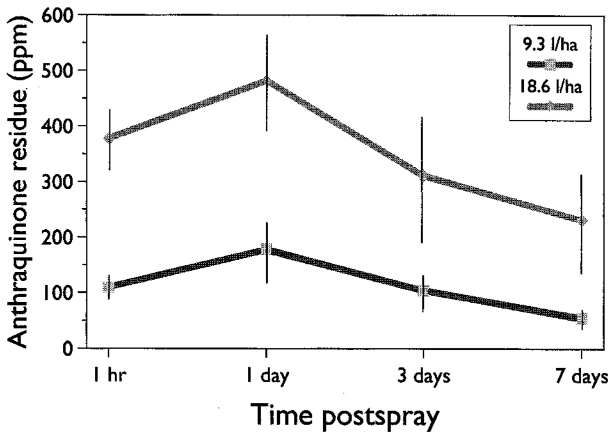

Fig. 5. Anthraquinone residues from rice seed in test plots in southwestern Louisiana treated with an overspray of Flight Control® bird repellent.

Table 2
Anthraquinone residues from rice seed samples placed in pans exposed to repellent application and from screens placed in the same fields but partially obscured by mud and water

	Residue (ppm)		
Site and sample time	Screen	Pan	Screen/pan
Trahan, 1 h	218	186	1.17
Zaunbrecher, 1 h	131	188	0.70
Hardee, 1 h	97	221	0.44
Sweet Lake, 1 day	253	462	0.55
Sweet Lake, 3 day	132	481	0.27
Johnson, 3 day	204	221	0.59

than did seed with unobstructed exposure to the spray application.

4. Discussion

In pen trials, our findings support the idea that overspraying newly planted rice with Flight Control bird repellent can reduce losses to blackbirds. However, field use of this technique was not successful. One possibility for the apparent ineffectiveness of the field treatment is that the depredating flocks of blackbirds were not constant from day to day. Anthraquinone, the active ingredient in Flight Control, operates via food aversion learning which means that birds must eat treated food, experience the post-ingestional effects, and thereby learn to avoid the treated food items (Avery et al., 1997). If composition of the depredating flock varied daily, then new birds were being exposed to the treatment each day and thus consumption of the treated rice would not be reduced by the repellent.

As an alternative explanation, we hypothesize that there was insufficient anthraquinone on sprouted seed to produce a conditioned avoidance response. Support for this interpretation comes from anthraquinone residues on seeds in 9.3 l/ha plots (Fig. 5). Residues on test seeds from 18.6 l/ha sites were considerably greater, however, and were similar to those on rice seeds that did produce repellency in flight pen trials (Fig. 2). The sample rice seeds in our field test plots likely received maximum exposure to the repellent because they were on screens at ground level. In contrast, much of the rice seed eaten by blackbirds in test plots was partially submerged or obscured by mud and received a lighter repellent dose than did fully exposed test seeds (Table 2).

Birds need to ingest a sufficient quantity of anthraquinone on their food before they experience post-ingestional distress and learn to reject that food (Avery et al., 1997). We observed no obviously ill birds in the field, but some birds could have become sick without exhibiting overt symptoms. Or they could have left the site before manifesting the symptoms. Regardless, not enough birds were affected to curtail depredations.

Whereas we obtained adequate levels of anthraquinone on rice seed in captive bird trials and on rice seed exposed at ground level in the field, we did not achieve sufficient coverage on seeds actually within field test plots. Even though we observed a gradual decline in bird use of the treated plot at two sites, this response was insufficient to protect the crop. For overspraying to be an effective, practical technique, means must be devised to obtain adequate coverage of repellent on rice seeds in drained, muddy fields.

Acknowledgements

Support for the study was provided by the Louisiana State University Rice Research Station and the National Wildlife Research Center. The cooperation of rice growers Vincent Berken, Dwight Hardee, Paul Johnson, Joel Trahan, John Zaunbrecher, Mark Zaunbrecher, and the Sweet Lake Land and Oil Company made the study possible. Ken Ballinger, Environmental Biocontrol International, donated the test chemical and provided analytical chemistry services. Russ Mason reviewed the manuscript.

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