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ABSTRACT: In August 1995 the development of a new bird repellent, Flight Control containing anthraquinone, was initiated. A series of laboratory formulation testing, cage and pen studies were conducted. The anthraquinone discrimination threshold (concentration at which birds could detect the test material) for starlings (*Sturnus vulgaris*) was 151 ppm in treated feeds. The model revealed that to achieve 90% repellencey with Flight Control, the treated material should receive 1,131 ppm of anthraquinone. Bird feed containing pesticide granules treated with 1% anthraquinone and control feed in a lab choice study, resulted in zero mortality in quail chicks (*Colinus virginianus*). Pen studies with American robins (*Turdus migratorius*) demonstrated Flight Control repelled the species when holly berries were treated with 500 ppm anthraquinone. Pen studies in Louisiana using Flight Control-treated rice seeds generated efficacy in excess of 90% to cowbirds (*Molothrus ater*) and red-winged blackbirds (*Agelaius phaeniceus*).

KEY WORDS: Flight Control, anthraquinone, starling, red-winged blackbird, robin, choice test, repellency, discrimination threshold

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INTRODUCTION

Genesis Laboratories, Inc. was contracted by Environmental Biocontrol International (EBI) of Wilmington, Delaware, in August 1995 to assist in the development of a new bird repellent—Flight Control, containing anthraquinone. As a result, a research and development plan was drafted to complete various laboratory, pen, and field studies to identify the optimum formulation of Flight Control to achieve maximum efficacy.

The objective of this project was to examine for efficacy of Flight Control when used to repel key target bird species. The potential primary hazard reduction of granular pesticides treated with Flight Control was investigated using young and adult birds.

MATERIALS AND METHODS

Flight Control

The Flight Control test material was a liquid formulation containing 50% anthraquinone (CAS No. 84-65-1; SHA 122701; EINECS 201-549-0). The repellent was a tan-colored liquid packaged in plastic bottles by EBI. This study was initiated on August 28, 1995 and research is continuing to date.

Test Birds

Scientific collecting permits were obtained for the various species used in this study from the U.S. Fish & Wildlife Service and the Louisiana Department of Wildlife & Fisheries, Environmental Branch. Birds were collected using mist nets and modified Australian crow traps. The species utilized included the European starling (*Sturnus vulgaris*), American robin (*Turdus migratorius*), cowbird (*Molothrus ater*), red-winged blackbird (*Agelaius phaeniceus*), and Northern bobwhite quail (*Colinus virginianus*). Starlings were collected from Larimer and Weld counties, Colorado. Birds were captured near cattle or sheep feedlots, in sugarcane fields, along tree lines, and in rice fields. All birds used in the testing, with the exception of bobwhite quail, were obtained from wild populations. Bobwhite were obtained from Barrett's Quail Farm, Houston, Texas. Quail chicks were hatched from captive bobwhite utilizing incubators at Genesis Laboratories.

Housing and Maintenance of the Test Birds

Cage studies were conducted at the Genesis facility near Wellington, Colorado. Racks on rollers contained nine individual cages (63 x 63 x 45 cm), with stainless steel dividers separating birds. Only one bird per cage was used during the research in order to obtain information on individual variation in food consumption. Test rooms were equipped with automatic timers to maintain light at 12 hours light/dark. A central heating system maintained test rooms between 20-22°C and the relative humidity between 35-55%. Test rooms were isolated and only one species per room was allowed. Noise was kept to a minimum as not to disturb the captive birds.

Captive birds were fed a maintenance ration consisting of 75% Ranchway Feed Game Bird Grower, 20% whole grain millet or wheat, and 5% oyster shell grit. If birds tested in choice studies were to use millet as a carrier, millet was included in the maintenance ration.

Laboratory Choice Tests

Starlings were used as the main laboratory test birds since the species is ubiquitous, a common problem to farming operations, and very abundant in the U.S. (approximately 600 million in the continental mainland). Wild birds were allowed to condition to the test facility and conditions for approximately one week or more before assigned to a study. Birds were presented treated grain and control (untreated grain) in separately marked cups in choice tests. The position of the cups was reversed daily. In most studies, the exposure period normally lasted four days. Consumption was recorded daily (nearest 0.1 g).

Test groups per dose level consisted of 9 to 10 starlings. All birds were adults or sub-adults (young of the year which were adult sizes but have not fully come into adult plumage). Similar studies were repeated on red-winged blackbirds and robins in Louisiana.

A study was conducted to determine the discrimination threshold, or the concentration at which Flight Control might have repellency action. Methods described by Bennet (1989) and Bennet and Schafer (1989) were followed.

Laboratory choice tests using 10-day-old bobwhite quail chicks were conducted to determine at what dietary level repellency induced by Flight Control might be achieved to reduce bird consumption of products in the field, such as granular herbicides or insecticides. Birds were housed in brooders, where the temperature was maintained at approximately 38°C. Tests were from 3 to 5 days exposure with food trays reversed daily. In some of the studies, it was possible to calculate the discrimination threshold.

A laboratory study was completed to assess whether or not the repellency action of Flight Control was related to taste or odor. A feeding container was devised using a modified base for a standard 0.5 L bird waterer. The metal water receptacle contained a center portion that screwed onto water jars. The outer portion of the lid, contained the area where water is available to birds. Flight Control treated millet (1,000 ppm) was placed in the outer portion of the lid and covered with wire mesh. Untreated millet was provided in the center of the lid and served as the basal diet for the individually housed birds. Feed consumption was recorded after two consecutive days, with the position of the cups reversed each day. The hypothesis tested was thus: if odor is the major role involved in repellency, then feed consumption in the feed trays with treated Flight Control would be significantly less than the cup with the untreated seed.

Studies were conducted to determine if granular pesticides treated with Flight Control were avoided by 10 to 15 day old bobwhite quail chicks. Birds were offered treated trays with insecticides and control food trays. Mortality was recorded over 5-day exposure and 3-day observation periods.

Pen Studies

Repellency studies on granular products were conducted at the Genesis facility in Colorado, utilizing Northern bobwhite quail adults (groups of 5 to 10) housed in 5 x 10 m outdoor pens. In all pens studies conducted, water and maintenance feed were provided *ad lib.* when birds were not on tests. During studies sufficient food and water were made available to avoid undue stress to birds. Pesticide granules were treated with various concentrations of test material and presented in choice test along with control feeds. Designs included direct treatment of granules and combined feed and granular mixtures treated with the test material. Consumption was recorded daily and mortality monitored.

Pen studies were also conducted in Louisiana using red-winged blackbirds, cowbirds, and American robins to determine the potential repellency on rice, millet, and berries. Six 10 x 3.5 x 3 m and one 10 x 3.5 m pen were constructed in a secluded area amongst sugarcane fields. Food and water were provided *ad lib.* Choice tests were employed in both individually caged birds and pens. Oil field pipe and plastic netting were used to enclose the pens. An opaque cloth was placed over the top one-third of pens to protect birds from unnecessary stress induced by sunlight and rain. Perches were installed at each end of the pens to provide roosting sites and protection against bad weather.

Methods similar to those developed by Avery (1989), Avery and Decker (1991), Avery et al. (1993) and Holler et al. (1982) were used. Within pens, 1 x 1 m raised plots 5 cm above ground level were constructed with wood and filled with dirt. These were positioned equidistant from the perimeters of the pen and a minimum of 1 m apart. The number of plots varied from 4 to 10 depending on the number of birds (2 to 20) placed into the pens (red-winged blackbirds or cowbirds). From 200 to 1,000 rice seeds were placed onto the plot after appropriate preparation. Control plots received soaked rice with no Flight Control. After a 1 to 3 day exposure period, the number of remaining seeds was counted. Birds were conditioned to the pens for a minimum of three days before test material was applied.

In southern Louisiana, rice farmers generally soak rice seed in water and air dry before planting. This is to help the seeds germinate before planting, in hopes that the young plants will become established sooner and bird damage might be less. For studies with sprouting rice, rice was soaked for 24 hours and allowed to air dry before usage. Two types of treatment were used: pre-soak, where the rice was treated with the Flight Control, soaked in water for 24 hours, air dried for 24 hours, then applied to plots. Post-soak treatment involved: soak the rice for 24 hours, air dry for 24 hours, treat with the appropriate amount of Flight Control, air dry for one hour, then applying to the test plots (see Holler et al. 1982).

For studies with grains and berries, the appropriate amount of Flight Control was weighed out and mixed with the carrier in plastic bags for five minutes. The formulated product was then allowed to air dry for about 30 minutes before use. Methods developed by Tobin and DeHaven (1983) were used in establishing these choice tests between treated and control berries or grains.

RESULTS AND DISCUSSION

The initial studies revealed that starlings were able to detect Flight Control at 151 ppm, however, the compound did not have a sufficient repellency effect until a higher dose was used. The discrimination test results are presented in Table 1. To attain 90% repellency using Flight Control against starlings, the treatment concentration would require 1,131 ppm of anthraquinone.

Experiments were conducted with various carriers. Table 2 presents the results of Flight Control in m-pyrol formulation. The results for a 500 ppm treatment during this stage of early product development showed little effects on repelling birds. Other formulations tested using different solvents at 100 ppm showed no significant effects on repellency at lower concentrations of Flight Control (Table 3).

Results of the odor test are presented in Table 4. There was no difference in seed consumption between the treated and control containers. Odor does not play a role in the repellency of Flight Control. Observations from

Table 1. Values for determining the discrimination threshold for Flight Control in starlings.

Group	Nominal Concentration ppm	Log Concentration (X)	Log (Unit/Treatment) (Y)
T-1	0	0.0	0.00
T-2	100	2.0	0.07
T-3	250	2.4	0.22
T-4	500	2.7	0.38
T-5	1000	3.0	0.73

X^{DT} = 2.178
Slope of regression line above X^{DT} = 0.85
Discrimination threshold (antilog X^{DT}) = 151 PPM
95% Confidence limits ($F_{1,3}$ = 10.13):

Table 2. Four-day choice test and a new carrier using adult starling, with nine birds per group. Flight Control-treated millet was compared to untreated millet. Results are in grams.

Groups	Average Untreated	Average Treated	Total Consumption	Percent Untreated	Percent Treated
Control	17.01	19.38	36.39	46.7	53.3
M-pyrol Blank	14.96	9.16	24.12	62.0	38.0
100 ppm	9.58	10.18	19.76	48.5	51.5
300 ppm	12.48	14.01	26.49	47.1	52.9
500 ppm	14.28	11.53	25.81	55.3	44.7

Table 3. Average daily feed consumption of starlings during a three-day discrimination test (choice) with three Flight Control formulations.

Groups	Nominal Concentration (ppm)	Feed Consumption (grams/bird/day)				
		Treated	%	Untreated	%	Total
Control	0	8.3	61	5.2	39	13.5
PCC-942	100	0.6	3	15.7	97	16.3
PCC-943	100	5.7	27	15.2	73	20.9
PCC-944	100	12.1	55	9.8	45	21.9

PCC-942: 1% w/w napthalene. PCC-943: 1% w/w; corn oil. PCC-943: 1% w/w in tap water.

Table 4. Four-day choice test to determine if odor is repellent mode of action for Flight Control using ten (10) adult starlings. Consumption is given in grams.

Day	Average Untreated	Average Treated	Total Consumption	Percent Untreated	Percent Treated
1	7.73	6.54	14.27	54.2	45.8
2	7.20	7.39	14.59	49.3	50.7
3	6.38	8.13	14.51	44.0	56.0
4	11.07	4.57	15.64	70.8	29.2
Total	31.44	25.89	57.33	54.8	45.2

Initial feed amount for all feed pans was 30 grams. Millet was used as the carrier. 2000 ppm anthraquinone formulation was used.

both the laboratory and pen studies revealed that there were no adverse effects on the behavior and health of birds used in Flight Control research.

Table 5 presents the results of a choice test with bobwhite quail chicks presented Flight Control treated and untreated trays of insecticide granules. This study was a choice test to determine the discrimination threshold (DT): the dietary concentration at which northern bobwhite chicks begin to consume a greater proportion of untreated feed than treated feed.

Table 5. Laboratory choice test using bobwhite quail chicks (12 days old) in which Flight Control treated insecticide-treated granules or untreated granules and quail feed were provided over a five-day exposure period.

Treatment Groups	% Mortality
Control (0 ppm)	6/20 = 30
Vehicle Control (4.0 mL solvent)	2/20 = 10
T1 (2,000 ppm)	2/20 = 10
T2 (5,000 ppm)	3/20 = 15
T3 (10,000 ppm)	0/20 = 0

Control = insecticide-treated granules in one tray and quail feed in another; VC = insecticide-treated granules with 1% carrier; Replications I and II were added together for a total of 20 birds in each treatment group.

Cumulative mortality data is presented in Table 6. Deaths during the no choice test occurred on the first day in both treatment groups as a result of the birds consuming lethal quantities of the treated feed. To determine the mortality, two diets were used: 8,000 ppm treated insecticide granules mixed with feed and insecticide granules and feed mix. Two groups of 10 were used for each treatment group, as well as two groups of 10 for the control group. Group T1, insecticide treated, had 16 deaths by the end of the five-day test period and group T2, insecticide-treated, had 14 deaths. Mortality was 80% and 70%, respectively. The toxicity of the granule afforded little time for a learned behavior response, thus inducing high mortality.

The results of the 5-day discrimination threshold test conducted with Flight Control in northern bobwhite chicks showed the discrimination threshold to be 1,180 ppm (Table 7). To determine the discrimination threshold, certain criteria must be met; the vehicle control group must have, basically the same X and Y values and the treatment groups' X and Y values should increase proportionately. The vehicle control group ate considerably more of the raw feed treated with corn oil as opposed to raw feed only (Table 8). The Y values, LOG (untreated/treated), did not increase as the X values, LOG concentration, increased.

To determine the discrimination threshold, eight treatment levels were used; 10 ppm, 25 ppm, 50 ppm, 100 ppm, 200 ppm, 400 ppm, 800 ppm, and 1,600 ppm. At the 800 ppm level, there was a marked change in the feeding habits of the chicks, implying that at this level the Flight Control did repel the birds.

Pen and cage studies conducted in Louisiana during January 1996 revealed the potential for Flight Control for use as a repellent against American Robins and red-winged blackbirds (Table 9). Although the highest concentration tested was only 1,000 ppm, the repellency was 60%, indicating the potential for more effective damage reduction at higher levels.

Subsequent studies during the summer and fall of 1996 demonstrated the efficacy of Flight Control in sprouting rice to repel red-winged blackbirds and brown headed cowbirds. Table 10 presents the data for treatments at different periods, presoak and post-soak treatments. In both cases, Flight Control has shown to be potentially effective in pen situations.

Pen and field observations of bird behavior were made throughout the studies. In no situation were adverse effects or discomfort induced by Flight Control to the birds observed. In feeding on rice seeds, the birds squeezed the grain from the hull then ejected the hull from the mouth and ate only the inner grain. During this feeding activity, which maximized contact with Flight Control, the treated seeds did not affect the bird's behavior or induce pain. Consumption of Flight Control did not affect feeding behavior, in terms of grams of feed per day.

Upon completion of all studies, birds were released near the original point of capture. No test birds died due to exposure to Flight Control. In a separate study, it was found the LD_{50} in northern bobwhite quail to be in excess of 2,000 mg/kg body weight. This was the standard limit test conducted for the U.S. Environmental Protection Agency.

In the laboratory studies involving quail chicks, mortality was induced by other pesticide granules, and not the test substance in question. Results of this research indicate the possibility of using Flight Control as a bird repellent when formulated with toxic granular pesticides.

Table 6. Mortality of northern bobwhite quail chicks during a study using Flight Control corn oil formulation to treat insecticide-treated granules.

Group	Nominal Flight Control (ppm)	Mortality Group Size
VC-R1	0	1/10
VC-R2	0	0/10
Total		1/20
T1-R1	8,000	7/10
T1-R2	8,000	9/10
Total		16/20
T2-R1	8,000	6/10
T2-R2	8,000	8/10
Total		14/20

VC = Raw feed + corn oil
T1 = insecticide-treated granules + 1,000 ppm Flight Control and raw feed + corn oil
T2 = insecticide-treated granules + raw feed + corn oil
R1 and R 2 = replicates

Table 7. Values for determining the discrimination threshold of Flight Control with corn oil carrier in a choice test using northern bobwhite quail chicks.

Group	Nominal Concentration Flight Control (ppm)	Log Concentration (X)	Log (Unt/Trt) (Y)
VC	0	0.000	-0.504
T-1	10	1.000	-0.260
T-2	25	1.398	-0.346
T-3	50	1.699	-0.604
T-4	100	2.000	-0.521
T-5	200	2.301	-0.184
T-6	400	2.602	-0.382
T-7	800	2.903	0.449
T-8	1600	3.204	0.125

X^{DT} = 3.072
Slope of regression line line above X^{DT} = 0.211
Discrimination Threshold (antilog X^{DT}) = 1180 PPM
95% Confidence Limits ($F_{1,7}$ = 5.59)

Table 8. Mortality in one month old northern bobwhite chicks exposed to insecticide granules treated with various concentrations of Flight Control over a five-day test period.

Treatment Group	Total Mortality	Percent Mortality
Control	0/13	0.0
0 ppm	2/26	7.7
2,000 ppm	14/24	58.3
5,000 ppm	17/25	68.0
10,000 ppm	0/26	0.0

All treatment groups received Flight Control + insecticide-treated granules. Control was raw feed.

Table 9. Results of cage and pen studies conducted on birds in Louisiana during January 1996. The carrier (fruit or grain) was treated with Flight Control. Untreated carrier was provided as control food in the choice studies. Birds were caged individually, when more than one was placed into pens.

Flight Control (ppm)	Target Species	Treated	% Repellency
Cage Studies			
50	American Robin	holly berries	53.0
250	American Robin	holly berries	52.4
400	American Robin	holly berries	33.5
500	American Robin	holly berries	51.3
1,000	American Robin	holly berries	60.0
50	red-winged	rice	60.5
500	red-winged	millet	68.9
1,000	red-winged	millet	66.4
Pen Studies			
500	American Robin	holly berries	68.9
1,000	American Robin	holly berries	69.7

Table 10. Results of pen studies conducted in Louisiana using 5,000 ppm Flight Control treated rice when presented to red-winged blackbirds and cowbirds.

Species	Exposure Period	No. Birds	Treatment Type	Seeds Per Pen	Consumption Control	Consumption Treatment	Repellency (Percent)
red-winged	2 days	3	Pre	2,400	753	198	79.2
red-winged	2 days	3	Post	2,400	1,200	701	63.1
red-winged	2 days	3	Pre	2,400	2,160	240	90.0
red-winged	2 days	3	Post	2,400	2,129	271	88.7
cowbirds	2 days	20	Post	10,000	4,892	2,105	69.9
cowbirds	2 days	20	Post	10,000	2,661	1,164	80.0
cowbirds	1 day	10	Pre	10,000	2,459	864	74.0
cowbirds	1 day	10	Pre	10,000	4,590	459	90.1

[1]Treatment type: pre-soaked rice (Flight Control treatment before rice was soaked in water for 24 hours; post-soaked rice (Flight Control treatment after rice soaked for 24 hours and air dried for 24 hours).

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