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Goodhue and Baumgartner (1965) described the use of a chemical, 4-aminopyridine (4AP), that causes birds ingesting it to emit distress calls and exhibit erratic flight behavior that frighten other birds from the Immediate vicinity. Using 4AP baits in Brown County, South Dakota, in 1965, De Grazio, et al. (1972) reported a savings of $6,449 worth of field corn at a cost of $634 for treatment. Baiting field corn with 4AP also provided significant protection from blackbirds in a study in northern Ohio in 1969 (Stickley, et al., 1976). Efficacy data gathered in these and other studies provided a basis for federal registration of 4AP in April 1972 as Avitrol FC Corn Chops-99[1], a cracked corn bait treated with three percent 4AP and diluted 1:99 with untreated cracked corn (EPA Registration No. 11649-12).

From the results of these studies, we believed that 4AP might be similarly useful for protecting ripening sweet corn from damage by blackbirds. Canneries in Dodge County, Wisconsin, have reported that their contract growers have experienced heavy damage from blackbirds in over 400 ha of sweet corn in past years. Blackbird damage decreases not only the amount but the quality of corn for canning. This paper presents the results of a study conducted in Dodge County in August 1974 to determine the effectiveness and safety of Avitrol FC Corn Chops-99 for protecting ripening sweet corn from damage by blackbirds. It was conducted under an experimental permit (No. 11649-EXP-3G) granted by the Environmental Portection Agency on 27 June 1974.

We thank Richard Wetzel, Robert Personius, and Richard Schraufnagel for their assistance in this study, James Peterson for analyzing sweet corn samples for 4AP residues, and David Bowden and Charles Breidenstein for statistical consultation. Test fields were made available by the Joan of Arc Cannery, Mayville, Wisconsin, and their contract growers, whom we thank for their cooperation.

METHODS

The study was conducted in 28 sweet corn fields, ranging in size from 3.2 to 14.2 ha, located in a 351-km^2 (0.136 section) area east of Horicon National Wildlife Refuge and Sinissippi Lake. Four varieties of sweet corn were grown in the test fields: Target, with a maturation period of 80 days; Vanguard, 82 days; Pacer, 83 days; and Commander, 86 days. Fourteen of the 28 fields were randomly selected as eligible for treatment if bird pressure required it, and 14 served as untreated controls. All test fields were separated by at least 0.4 km to reduce the chance of the treatment protecting control fields.

For treatment, Avitrol FC Corn Chops-99 were aerially broadcast in late afternoon by fixed-wing aircraft at 1.12 kg/ha (1 lb/acre), the rate registered for use in field corn. Individual fields were first treated when a daily morning or evening bird count showed at least 100 birds present. Up to three additional treatments were then systematically applied at 3- or 4-day intervals. Fields were to be retreated if 1/2 inch or more rain fell within 24 hours, but since rains coincided with the regular treatment schedule, no extra treatments were required.

Indices of the number of blackbirds and other bird species visiting the 28 fields were obtained daily (until a field was harvested) from 10 to 30 August on two monitoring routes, each connecting 14 of the fields. Each field was observed for a 5-min period between a half-hour after sunrise and 1000 hours. Starting points on each route were alternated daily to minimize any time bias. Fields eligible for treatment, but not yet treated, were also briefly observed in the evening between 1 and 1.5 hours before sunset. Extended morning observations were made on two treated fields to determine flock response after baitings; field 4 was observed eight times and field 7 twice from about sunrise until birds left the fields (15-75 min).

Blackbirds using the study area roosted at both Horicon Marsh and Sinissippi Lake. Estimates of the blackbird populations occupying Horicon Marsh were made during 8-12, 18-20, and 25-28 August by observing flocks leaving or returning to the roost on distinct flightlines at dawn or dusk. The roost at Sinissippi Lake was not discovered until 15 August, and counts were made there during 18-20 and 25-28 August.

Bird damage in each field was assessed as closely as possible before scheduled harvest by examining 40 consecutive ears in each of 15 randomly selected plots (600 ears per field). On each plot, the number of bird-damaged ears, the greatest length of damage along a kernel row on each damaged ear and the plot length and row width were recorded. Since plot lengths varied, plot damage values were projected to per hectare losses per field. Plot values and projected values were analyzed by one-way analysis of variance with subsamples (Steel and Torrie 1960).

To determine treatment hazards, five percent of the rows in each baited field were randomly selected and searched for affected and dead birds during the damage surveys (the area searched totaled about 3 ha of the 59.3 ha baited). In addition, 42 unhusked ears were collected for residue analysis--three each from two randomly chosen damage survey plots in two control fields and in five treated fields that had been baited either three or four times. The sample ears were placed in plastic bags and frozen for later determination of 4AP residues by the method of Peterson (1975).

RESULTS AND DISCUSSION

Of the 14 fields eligible for treatment, four were not treated because of the lack of feeding bird pressure; three of the 14 control fields also showed this low level of bird pressure. The remaining 10 fields eligible for treatment were each baited one to four times between 13 and 30 August.

Damage Assessment

The results of damage surveys in the 28 fields are summarized in Table 1, The number of bird-damaged ears on survey plots averaged 5.7 times greater in the control fields than in the fields eligible for treatment (108 vs. 19), and the average length of damage to ears was 9.9 times greater in the control fields than in the treatment fields (697 cm vs. 70 cm). When plot values were projected to per-hectare losses, the control fields had an average of 7.6 times more damaged ears than the treatment fields (6,368 vs. 843) and 13.4 times more average length of damage (41,219 vs. 3,080 cm). For all four measurements, the difference between treatment and control fields was significant ($P < 0.02$). Data were also analyzed excluding treatment and control fields which did not meet the bird pressure treatment criterion. The results from these 21 fields were not appreciably different from those of the original analyses.

Of the four corn varieties grown in test fields, Target appeared to be damaged the most. Since Target fields had the earliest maturation time (80 days) and were the first to be harvested, they were probably vulnerable to birds before the other varieties matured. Cannery personnel reported that corn ears from the control fields required 10 times as much trimming to remove damaged areas as did ears from the treatment fields.

Blackbird Activity

Observations throughout the study period showed that Red-winged Blackbirds (*Agelaius phoeniceus*) caused most of the damage to sweet corn. Common Grackles (Q*uiscalus quiscula*), Yellow-headed Blackbirds (*xanthocephalus xanthocephalus*), Brewer's Blackbirds (*Euphagus cyanocephalus*) and Brown-headed Cowbirds (*Molothrus ater*) were of secondary importance.

Populations in the two roosts (Horicon Marsh and Sinissippi Lake) that contributed blackbirds to the study area were primarily Red-winged Blackbirds (80 percent) and Common Grackles (10 percent), with other blackbird species and Starlings (*sturnus vulgaris*) comprising the remaining 10 percent. Roosting populations at HoMcon Marsh increased from 50,200 during 8-12 August to 167,500 during 18-20 August and remained about the same (164,100) during 25-28 August. Populations at Sinissippi Lake increased from 40,000 during 18-20 August to 65,300 during 25-28 August. Birds from Horicon fanned out to the east over study fields on six flightlines; the two major ones, with a total of about 88,000 birds, passed over the central part of the study area. Birds from Sinissippi Lake took one flightline over the southern part of the study area.

Morning census routes produced a total of 434 5-min observations, 201 on control fields and 233 on fields eligible for treatment. During these observations, we counted an average of 3.4 times more birds per field in the 14 control fields than in the 14 treatment fields (2,988 vs. 878), and 3.9 times more birds per observation period in control fields than in treatment fields (208 vs. 53). Few birds were counted on the evening census routes, and these counts are not included in the above comparisons.

Patterns of bird activity and harvest schedules in the 21 fields (10 treated, 11 control) which met the bird pressure criterion for treatment showed the effects of the Avitrol baitings (Fig. 1). During the four counts before any fields were baited (10-13 August), the dally average number of birds per hectare was roughly the same in the treated and control fields, but the distribution changed markedly after the first five fields were baited on 13 and 17 August (Fig. 1A). Numbers of birds in the control fields increased greatly between 14 and 20 August, coinciding with the buildup in the roosting population at Horicon Marsh and Sinissippt Lake. Even in the face of this buildup, numbers of birds in the treated fields declined and remained below pretreatment numbers through 27 August. There was a sharp drop in numbers of birds in control fields during 21-24 August, which coincided with harvesting (Fig. 1B). Five control fields with heavy bird pressure (Nos. 15, 16, 17, 18, and 22) were harvested during this period; we suspect these fields were cut one or two days early because of the heavy damage they were taking from birds. Birds did not shift to treatment fields even though none had been harvested. During 25-27 August, as the roosting population continued to increase (to 229,400 birds) and more control fields were harvested, numbers in the remaining control fields again increased. There was no buildup in treatment fields until 28-30 August, when numbers returned to near pretreatment levels in the few remaining unharvested fields.

During extended morning observations in fields 4 and 7, the number of birds counted per minute of observation decreased abruptly within one to two days after baiting. The reduction in birds per minute one day after the first baiting in field 7 was 99.6 percent. In field 4, the reduction in numbers after the first baiting was 33.3 percent from day two to day four, 62.0 percent from day one to day three after the second baiting, and 80.0 percent from day one to day two after the third baiting. The overall average percentage reduction in birds per minute after three baitings in one field and one baiting in the second field was 68.7 percent. Only six affected blackbirds (one unknown species on 16 August, three Redwings and two Yellowheads on 22 August, all in field 4) were heard or seen during these observations.

In addition to the affected birds noted above, we saw four affected Grackles, two Redwings, and two Cowbirds while driving the census routes or while making cursory observations on other baited fields. This relatively small number of affected birds observed during the study was not surprising, considering the small average flock size in our baited fields and the small amount of time spent observing these fields. De Srazio, et al. (1972) reported that less than one percent of a flock visiting baited cornfields in South Dakota was affected by 4AP.

Dead bird searches, covering five percent of the area of baited fields, yielded a total of 10 blackbird carcasses (4 Redwings, 2 Yellowheads, 2 Grackles, and 2 Cowbirds); all contained corn bait particles in the gizzard.

Nontarget Birds

Approximately 300 individuals of 15 species of birds other than blackbirds were observed in study fields during censuses. The most abundant of these species included the House Sparrow (*passer aomesticus*), Robin (*rurdus migratorious*), and Indigo Bunting (*Passerina cyanea*). None of these nontarget birds was observed to be affected by 4AP. Aside from the 10 blackbird carcasses found, the searches for dead birds yielded feathers from a Mourning Dove and from an unidentified sparrow. We could not determine if these were casualties of the treatment. De Grazio, et al. (1972) also reported minimal hazards to nontarget species in cornfields baited with 4AP in South Dakota.

Residue Analysis

Residues of 4AP in corn ears were either not present or less than 0.01 ppm for all fields sampled, well within the 0.1 ppm tolerance limits set down in the experimental permit. The detection limits described for Peterson's (1975) method of determining 4AP residues are as low as 2-3 ppb

CONCLUSIONS

One to four aerial applications of Avitrol FC Corn Chops-99 were highly effective ($P < 0.02$) in reducing blackbird damage to sweet corn fields in Dodge County, Wisconsin. Initial baitings were applied only when 100 or more blackbirds were first seen in a field. Few target birds and no nontarget bird species were known to be affected by 4AP. Residues of 4AP in corn ears were negligible. On the basis of these data and those from similar studies conducted in the U.S. in 1974, Federal Registration 11649-12 for the use of Avitrol FC Corn Chops-99 in field corn was amended in August 1975 to include sweet corn "(except sweet corn in the northeast and southeast United States, including the states of New York, Pennsylvania, West Virginia, Kentucky, Tennessee, Arkansas, and Louisiana)." Adequate efficacy data were not available for these areas.

'Reference to trade names does not imply endorsement of commercial products by the U.S. Government.

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DISCUSSION

Smith: Has anybody checked with the users as to what kind of control they got?

Answer: Good question, Dick. I know for a fact that the Joan of Arc people in Wisconsin followed thru immediately in 1975 when it became available. And they were ecstatic. They really were appreciative of the compound being available, and they had tremendous results with protecting their crop. I have no idea what happened in Idaho.

Question: In New Jersey all the work that we have done with this material has shown no effective results with it. We have a feeling that the real function of the material is not as a repellent but as a poison. Would you comment on that?

Answer: First of all it's classified as a chemical frightening agent. I know for a fact it kills cowbirds; they do not display. We've run across the problem in sorghum. I think that the thing that you should look at is bird pressure. You need a considerable amount of bird pressure to get this thing to react. If we're only affecting 1% or lower of the flock, you've got to get more birds in there to get the kernel in.

Question: We have bird pressure.

Answer: Well then, I can't answer your question.

Dyer: This subject of bird pressure has come up several times. I need a lot of help in understanding what the reaction is between bird pressure, the reactivity, and the amount being eaten. I think there's a major resource dimension that's forgotten about which feeds back into the situation. I don't see any logical explanation yet why increased bird pressure should help give repellency when you can argue just as well the repellency will be threshold or the repellency will be obviated and you'll get more damage. We've seen lots of reports on this, so can you enlighten me on that at least?

Answer: Well from experience in this, Mel, and it's been somewhat limited, the more birds that are available to consume the treated particles, obviously the more you're going to have affected, stressing, displaying, and so forth. If you have large flocks of birds, you're probably going to get a quicker or larger flock response to treated or affected birds. And this would be my only answer to your question.

Dyer: I understand that and I've seen that, but when you have large numbers of birds, you also have more competition for that resource and you also have more competition for alternate resources. So the question must remain will the repellent cause the bird to starve to death in front of its food, and I know of no repellent that will do that yet except in John Roger's laboratory experiment using very noxious compounds. There's some circular reasoning involved here that will need to be straightened out.

Answer: Well, I'm not 100% sure I understand what you're getting at there, Mel, by starving to death there in front of his food source. I think in this particular case if Avitrol is working properly the critters will leave and go to an alternate food source. But that probably still doesn't answer your question.

Dyer: The point is that the missing dimension is the alternate food source. Where we see the relationship, I think, is between decreasing alternate food sources in combination with the amount of corn available; then we see different types of reactions with Avitrol. Responses to Avitrol, or any other repellent, according to John Roger's laboratory tests, then seem to break down.

Besser: Mel, you worked in South Dakota, and the food analyses in South Dakota indicated that actually during the corn damage season food consumption is no more than 30% of that corn; 44% of that was pigeon grass.

Question: You answered my question exactly the way I like to have the answers. As you pointed out in South Dakota there is a tremendous amount of alternate food supply, and Avitrol apparently worked; but it hasn't been demonstrated satisfactorily that it was needed in the first place. There's no doubt that corn damage was very low in South Dakota, but there's also no doubt that the alternate food supply was tremendous. That is not the case in the Midwest. I think that you have yet to explain in a scientific way that Avitrol is working in South Dakota to the same degree that it's working in the Midwest.

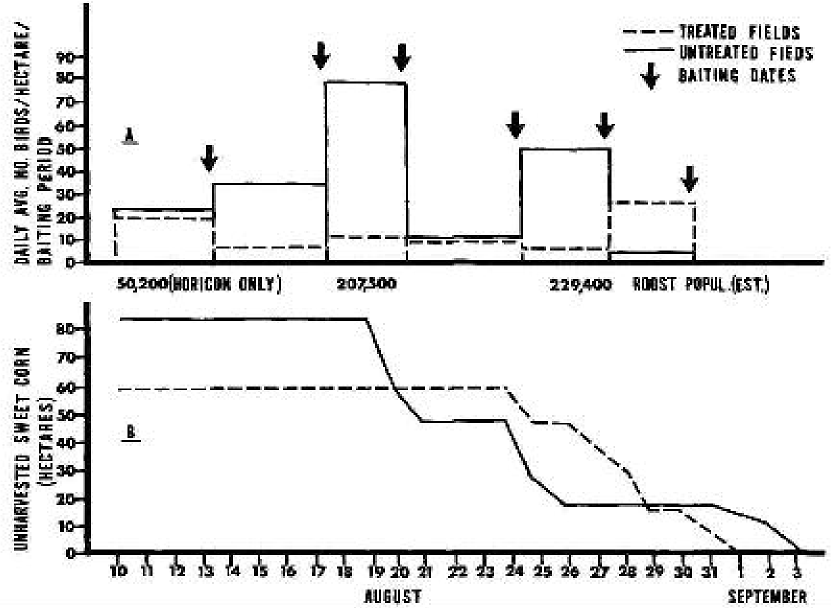

Figure 1 Relationships among blackbird activity patterns in the 10 baited and 11 control fields which met the bird pressure treatment criterion, estimated roosting populations in the area, and hectares of unharvested sweet corn available to blackbirds.

Table 1
Blackbird damage in 14 untreated and 14 treatment Wisconsin sweet corn fields

Field	Corn variety	Field size (ha)	No. of baitings	Damage in plots[a] Ears No.	Ears %	cm loss	Projected damage per hectare No. ears	cm loss
Treatment fields:								
1	Vanguard	8.1	4	47	7.8	185	2072	7573
2	Target	4.9	3	46	7.7	214	1601	7341
3[b]	Vanguard	12.1	0	38	6.3	96	1778	4411
4	Vanguard	4.5	4	36	6.0	151	1855	7061
5	Vanguard	6.1	4	35	5.8	119	1749	5814
6[b]	Commander	10.1	0	18	3.0	60	902	3055
7	Pacer	3.2	3	13	2.2	54	446	2040
8	Pacer	4.9	3	9	1.5	51	534	2453
9	Vanguard	7.3	1	9	1.5	26	464	1304
10	Vanguard	8.1	2	4	0.7	14	165	573
11	Target	7.3	1	3	0.6	11	141	619
12[b]	Target	8.9	0	2	0.3	6	91	272
13	Pacer	4.9	1	0	0	0	0	0
14[b]	Vanguard	8.1	0	0	0	0	0	0
	Means	7.0	1.8	19*	3.1*	70*	843*	3080*
Control fields:								
15	Target	6.3	0	419	69.8	3179	24574	181872
16	Target	6.5	0	280	46.7	1833	18266	116705
17	Target	11.3	0	228	38.0	1474	12950	86313
18	Target	6.9	0	176	29.3	1261	11636	83034
19[b]	Vanguard	4.0	0	167	27.3	946	9831	55498
20	Pacer	8.9	0	70	11.7	372	3260	16934
21	Vanguard	4.0	0	47	7.8	140	2181	6518
22	Target	8.5	0	42	7.0	276	2574	16863
23[b]	Vanguard	4.0	0	31	5.2	99	921	3102
24	Vanguard	4.0	0	29	4.8	106	1556	5800
25	Pacer	8.1	0	12	2.0	39	501	1620
26	Vanguard	12.1	0	9	1.5	20	526	1173
27	Vanguard	8.1	0	4	0.7	14	343	1200
28[b]	Target	14.2	0	0	0	0	0	0
	Means	7.6	0	108	18.1	697	6368	41219
Difference in means (control : treatment)				5.7x	5.8x	9.9x	7.6x	13.4x

[a]Total damage for 600 ears sampled per field (40 ears per plot).
[b]Fewer than 100 blackbirds seen at any one observation period.
*Significantly different from controls ($P \leq 0.02$).