cavities created were approximately 30 cm high, 60 cm wide, and 40 cm deep. These dimensions are similar to those created by Becker (1981).

Blasted cavities were cleaned by hand, leaving some rock debris for nesting material. White latex house paint was applied using a plastic squeeze bottle to simulate natural raptor whitewash and to make the artificial site more attractive to falcons (Fig. 6). Cavity construction cost $65.00/site and required approximately 1 day of effort.

The handling and storage of the explosives required for this technique should be by experienced individuals who are familiar with appropriate federal, state, and local regulations. Special caution must be exercised when firing the shaped charges as they are encased in metal, and shrapnel-like pieces of casing are propelled at potentially lethal velocities over considerable distances. Under no circumstances should personnel be allowed to view the shaped charges as they are being fired.

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4-AMINOPYRIDINE HYDROCHLORIDE BAITS ON BAITING LANES PROTECT RIPENING CORN FROM BLACKBIRDS

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The loss of ripening corn to birds in the United States (U.S.) was estimated at 339,000 metric tons worth $34.8 million in 1981 (Besser and Brady 1982). This loss represents the largest loss to birds for any agricultural crop in the U.S. Approximately 39% (132,000 metric tons) of the loss is estimated to occur in fields that incur >189 kg/ha loss, considered by Besser and Brady (1982) to be the threshold of cost-effective control with a bird-frightening chemical such as 4-aminopyridine (4-AP). If a chemical could reduce blackbird losses in these high-damage fields so that a 2:1 benefit: cost ratio could be obtained, the chemical would have the potential to save U.S. corn growers about 66,000 metric tons of corn annually, worth $9.0 million at 1983 prices ($136/metric ton).

Avitrol® FC-Corn Chops-99, the federally registered 4-AP commercial product, has performed poorly in protecting ripening corn from bird damage in recent years (Woronecki et al. 1979, Somers et al. 1981, Conover 1984). A recent study (Cunningham 1983) reported that the probable cause of the poor performance was the unexpected rapid sublimation of 4-AP at the 21–35 C temperatures at which baits are usually stored and used in late summer in corn-growing states. This problem has been largely corrected with the addition of hydrochloric acid (HCl) to stabilize the 4-AP in baits. The reformulated 4-AP HCl baits should give results similar to the 85% reduction in damage to corn and the $9:$1 benefit: cost ratio obtained with 4-AP baits by De Grazio et al. (1972) in 1965 baiting trials in South Dakota, when baits were used within 3 days of their preparation.

Baiting lanes allow rapid treatment of cornfields with mechanical equipment at low cost. The value of baiting lanes in common sunflower (*Helianthus annuus*) fields to allow more ready access of applicators to bait fields and of birds to baits applied has been reported by Besser et al. (1984).

Fields of ripening corn are most susceptible to blackbird damage shortly after ears reach the milk stage. In a 2-year study in New York, Bridgeland (1979) found that 71% of all blackbird damage occurred in a 6-day period within 11 days after half the ears in a field had reached the milk stage. Hence, protection efforts are likely to be most profitable during that 6-day period.

This study determined the effectiveness of 4-AP HCl baits in protecting ripening field corn from blackbirds and the benefit: cost ratio of baiting during a vulnerable 6-day period.

METHODS

The study was conducted from 17 August to 2 September 1983 in 12 (6 pairs) experimental units in ripening cornfields at Sand Lake National Wildlife Refuge, Brown County, South Dakota. The study area included some of the same area used by De Grazio et al. (1972) in a study of 4-AP baits broadcast in cornfields in 1965. Experimental units ranged in size from 5.7 to 11.6 ha. Two pairs of experimental units consisted of individual fields separated by 100-m strips of small grain stubble. The other 4 pairs were obtained by splitting larger fields (11 to 21 ha); 2 of these were planted perpendicular to pairs of perennial blackbird flightlines emanating from marsh roosts. Baiting lanes were established at 55-row intervals in all experimental units on 12 July 1983 to facilitate bait application in August. One row of young corn plants in each of these lanes was destroyed by running over the plants with an all-terrain cycle (ATC) (Model 90, Honda Motor Co., Ltd., Tokyo, Japan).[1]

When blackbirds began damaging milk-stage corn in experimental units, sampling plots consisting of 1.8 m of a row were randomly established in each pair of units at a rate of 2 plots/0.8 ha of unit. Damage was assessed by the method of De Grazio et al. (1969). Damage was reassessed on each pair of units 3 days after the initial appraisal, and 1 unit/pair was randomly chosen for baiting. Baiting was accomplished by broadcasting 4.8% 4-AP HCl (3% 4-AP) chopped corn diluted with 99 parts untreated chopped corn at the rate of 0.9 kg/ha of unit over a 5.8-m swath centered on baiting lanes. Bait was broadcast from an electric seeder (Herd Co., Logansport, Indiana) mounted on an ATC. The amount of bait used and time spent baiting were recorded.

Baited and unbaited units were observed daily for 10-min time-rotated periods between sunrise and 1000 hours, and the peak numbers of blackbirds observed in the unit and adjacent (50 m) vegetation were recorded. Additionally, baited units were observed for a 1-hour period (from the time birds first entered the unit) the first day of baiting and as often as time permitted thereafter to determine the number of birds affected by the chemical, the speed of distress-display responses, and flock clearances in baited units.

If >1,000 blackbirds had been observed feeding in the unit the previous day, units were rebaited when 1.3 cm of rain fell. Portions of units were also rebaited when >90% (<1 particle/0.2m^2) of the bait was estimated missing by visual examination from any 100-m segment of the baiting lane. These segments were rebaited with half the initial rate (0.45 kg/ha of unit).

A search for dead birds on baiting lanes was made as time permitted. A final search of randomly chosen rows, totaling 5% of all rows in each baited unit, was made at the end of the test. All intact birds were necropsied for the presence of chopped corn bait particles in the gullet and gizzard.

Six days after baiting a unit, a third and final dam-

[1] Mention of commercial products does not imply government endorsement.

Table 1. Loss of corn to blackbirds in 6 pairs of 4-AP HCl baited and unbaited experimental units, Brown County, South Dakota, 17 August–2 September 1983.

Experimental unit	Size (ha)	Kg (±SE) Loss	
		Pre-treatment	Treatment
1U	5.7	520.7 (±243.8)	2,382.6 (±411.5)
1T	7.3	866.2 (±203.2)	175.3 (±63.5)
2U	5.9	226.1 (±45.7)	264.2 (±58.4)
2T	6.7	175.3 (±63.5)	68.6 (±30.5)
3U	11.6	1,018.5 (±223.5)	1,427.5 (±185.4)
3T	10.0	1,130.3 (±116.8)	119.4 (±30.5)
4U	4.9	22.9 (±20.3)	81.3 (±30.5)
4T	5.7	307.4 (±170.2)	114.3 (±66.0)
5U	6.0	124.5 (±61.0)	180.3 (±58.4)
5T	4.5	205.7 (±149.9)	45.7 (±22.9)
6U	7.3	157.5 (±96.5)	472.5 (±142.2)
6T	4.9	256.6 (±78.7)	109.2 (±58.4)
Total U	41.4	2,070.2	4,808.4
T	39.1	2,941.4	632.5
$\bar{x}$ U	6.9	345.0[a]	801.2
T	6.5	490.2[a]	105.4

[a] $P = 0.031$.

age assessment was made on both pairs of units and corn loss ascertained. The difference between expected and observed damage on baited units served as the measure of damage reduction (protection afforded) by baiting. Expected damage (T_2) on each baited unit (if no treatment had been made) was computed from the following equation:

$$T_1/U_1 \times U_2 = T_2$$

where

T_1 = kg loss on the baited unit, pre-treatment days 1–3
U_1 = kg loss on the unbaited unit, pre-treatment days 1–3
U_2 = kg loss on the unbaited unit, treatment days 1–6
T_2 = expected kg loss on the baited unit, treatment days 1–6.

Data obtained on observed and expected loss of corn to blackbirds on pairs of experimental units were analyzed by Wilcoxon (1945) signed rank tests for effects of baitings. Differences in the dollar value of observed and expected losses on baited units were divided by costs of baiting to derive a benefit : cost ratio.

RESULTS AND DISCUSSION

Efficacy

Unbaited units of test pairs lost 4,808 kg (124.0 kg/ha) of corn to blackbirds during the 6-day treatment periods, whereas baited units lost 633 kg (16.2 kg/ha) (Table 1). Baited units lost 86.8% less corn than unbaited units during the treatment period. However, losses to birds on pairs of experimental units during the 3-day pre-treatment periods varied from 1.1 to 13.4-fold, with pre-treatment losses being greater ($P = 0.03$) on treated units in 5 of 6 pairs (Table 1). Therefore, a comparison of observed losses on treated units during the baited period with expected losses gave a better indication of the protection afforded by the baiting. Comparison of expected vs. observed losses on baited units during the treatment period showed that losses were 92.0% ($P = 0.02$), less than expected during the baiting period (Table 2).

Table 2. Observed and expected loss of corn to blackbirds in 6 baited experimental units during a 6-day treatment period, Brown County, South Dakota.

Experimental unit	Kg loss		Percentage less damage then expected
	Observed	Expected[a]	
T1	175.3	3,962.6	95.6
T2	68.6	205.7	66.7
T3	119.4	1,585.0	92.5
T4	114.3	1,092.2	89.5
T5	45.7	297.2	84.6
T6	109.2	769.7	85.8
Totals	632.5	7,912.4	92.0
$\bar{x}$	105.4[b]	1,318.7[b]	

[a] Based on losses occurring on the unbaited units throughout the 9-day test and on the treated units during the 3-day pre-treatment period.
[b] $P = 0.016$.

Bird Observations

The peak number of blackbirds damaging test units ranged from 1,500 (Unit #5T) to 14,300 (Unit #3T) during the 9-day test period (Table 3); peak numbers on unbaited units ranged from 2,000 to 9,500, and from 1,500 to 14,300 on baited units. Peak numbers on baited units during the treatment period were always observed during the first 3 days and usually on the first morning following the initial baiting.

The peak populations observed during the

Table 3. Peak blackbird numbers observed in 6 pairs of experimental units in cornfields in Brown County, South Dakota, 17 August–2 September 1983.

Pair	Untreated		Treated			Ratio observed/ expected on the baited unit
	Pre-treatment	Treatment	Pre-treatment	Treatment	Expected[a]	
1	5,500	4,500	6,000	3,000	4,909	0.61
2	3,000	2,000	4,000	2,000	2,666	1.33
3	1,500	9,500	2,000	14,300	12,666	0.89
4	3,000	7,000	200	4,000	467	8.58
5	2,000	2,700	1,500	500	2,738	0.18
6	2,000	2,000	2,000	3,000	2,000	1.5
Totals	17,000	27,700	15,700	26,800	25,446	1.05

[a] Based on numbers seen on the untreated unit throughout the 9-day test and on the treated units during the 3-day pre-treatment period.

10-min daily observation periods were composed of 68.4% red-winged blackbirds (*Agelaius phoeniceus*), 30.8% yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), and 0.8% common grackles (*Quiscalus quiscula*) (Table 4). During about 28 hours of observing baited fields, a total of 27 affected blackbirds was recorded. Of the 23 affected blackbirds identified, 13 were red-winged blackbirds (9 males and 4 females) and 10 were yellow-headed blackbirds (5 of each sex). The species composition of affected birds was similar to that of birds observed in the units. Only 4 blackbirds (3 red-winged and 1 yellow-headed) were found dead on baiting lanes, and no dead birds were found in the final search of 5% of the rows in the field.

Hazards

Two house sparrows (*Passer domesticus*) were the only nonblackbirds seen affected or found dead. The low hazard of baits in cornfields conformed with our observations that few nontarget species were present in cornfields during the 20 August–2 September period. A few (<10 each) ring-necked pheasants (*Phasianus colchicus*), mourning doves (*Zenaida macroura*), brown thrashers (*Toxostoma rufum*), and song sparrows (*Melospiza melodia*) were the only other species observed in baited units.

Cost Effectiveness

The cost of bait ($277.04) and loss of corn yield from installing baiting lanes ($81.77) amounted to $358.81 ($8.20/ha) on the baited units and the benefits (corn saved) were calculated to be $988.79 ($22.49/ha) (Table 5). Therefore, the benefit : cost ratio was $2.76:$1 (exclusive of labor and equipment depreciation).

Baiting and rebaiting the units and installing baiting lanes required 4.67 hours. The net benefit of $629.98 ($14.47/ha) would have resulted in a payment to the grower of $139.40/hour for labor.

Bait-feeding insects were a major reason for not obtaining a higher benefit : cost ratio. In

Table 4. Species composition of the peak numbers of blackbirds observed on baited units of cornfields in Brown County, South Dakota, 20 August–2 September 1983.

Experimental unit	Peak no. by species observed			Totals
	Red-winged blackbirds	Yellow-headed blackbirds	Common grackles	
T1	720	2,250	30	3,000
T2	1,600	400	0	2,000
T3	10,700	3,550	50	14,300
T4	2,360	1,520	120	4,000
T5	100	380	20	500
T6	2,850	150	0	3,000
Totals	18,330	8,250	220	26,800
%	68.4	30.8	0.8	100.0

Table 5. Cost : benefits of baiting 6 experimental units in cornfields with 4-AP HCl for 6-day periods, Brown County, South Dakota, 20 August–2 September 1983.

Experimental unit	Costs			Benefits		Benefit : cost ratio	Labor	
	Bait[a]	Baiting lanes[b]	Totals	kg saved[c]	$ saved[d]		Hours	Earnings[e] per hour
T1	$ 82.80	$32.99	$115.79	3,787.3	$514.40	4.44	1.41	$282.70
T2	37.95	16.68	54.63	137.1	18.63	0.34	0.84	−42.86
T3	57.04	17.94	74.98	1,465.6	199.07	2.65	0.92	134.88
T4	40.25	5.16	45.41	977.9	132.83	2.93	0.61	143.31
T5	38.30	3.64	41.94	251.5	34.16	0.81	0.60	−12.97
T6	20.70	5.36	26.06	660.5	89.70	3.44	0.29	219.45
Totals	$277.04	$81.77	$358.81	7,279.9	$988.79	2.76	4.67	$134.90

[a] $2.54/kg (applicator price in <1,000 kg lot, delivered).
[b] Prorated by the percentage of total damage occurring on the untreated units during the treatment period. Yield loss calculated at (5,021.3 kg/ha—32.7% growth compensation) × 1.82% of each ha destroyed × $0.1358/kg for corn lost.
[c] Expected minus observed losses for the baited period.
[d] $0.1358/kg (price 15 Aug 1983, Chicago, Ill., market).
[e] Based on rates of 40 ha/hour for application of baits and 12 ha/hour for creating baiting lanes.

some units, insects, chiefly ground beetles (*Harpalus erraticus*) and black field crickets (*Gryllus assimilis*) removed nearly all baits during 2- to 3-day periods; and in 1 unit (#T1) bait applied at 1700 hours disappeared before 0700 hours the next morning. This unit had to be rebaited at dawn each day (6 baitings) whereas other units were rebaited 1–3 times mainly because of insects. One rain of 1.4 cm fell on 26 August, necessitating rebaiting 3 units. The other 13 rebaitings had to be made because of insects, in effect nearly doubling bait costs and halving benefit : cost ratios. An insecticidal pre-treatment may be needed in insect-infested fields, such as the cricket-infested fields reported by Woronecki et al. (1979) in Ohio.

MANAGEMENT IMPLICATIONS

Previous problems with the stability of 4-aminopyridine baits for protecting ripening cornfields from blackbirds have been overcome with the addition of hydrochloric acid. The effectiveness of present commercial baits containing this chemical frightening agent should be such that most serious losses caused by blackbirds in cornfields can be economically combatted. Restricting the use of 4-AP HCl to periods when cornfields are most vulnerable should maximize benefit : cost ratios. Establishment of baiting lanes in cornfields at planting time or shortly thereafter allows rapid treatment of fields with small seeders mounted on all-terrain vehicles at greatly reduced application costs, and should also allow adjacent rows to partially compensate for the yield loss of the missing row. A suitable insecticidal treatment to reduce losses of baits to insects may be needed in some fields having this irregularly occurring problem.

SUMMARY

4-Aminopyridine baits, stabilized with hydrochloric acid (4-AP HCl), were evaluated in ripening cornfields in South Dakota in August-September 1983. Baits treated with 4.8% 4-AP HCl (3.0% 4-AP) were broadcast at a rate of 0.9 kg/ha of unit in a 5.8-m swath from baiting lanes in 6 of 12 paired experimental units using a small electric seeder mounted on an all-terrain cycle. Baited units lost 633 kg (16.2 kg/ha) during the 6-day treatment periods, or 92% less than the loss of 7,912 kg (202.4 kg/ha) expected ($P = 0.02$).

Peak number of blackbirds damaging individual units ranged from 1,500 to 14,300 during the test period. The species composition of feeding flocks was estimated to be 68%

red-winged blackbirds, 31% yellow-headed blackbirds, and 1% common grackles. Only 31 blackbirds and 2 house sparrows were seen affected and found dead.

The benefits of baiting were calculated to be $2.76 for each $1 spent for bait and loss of corn yield in baiting lanes. Growers in this situation would have saved about $139 of corn for each hour spent baiting and creating lanes. Benefit : cost ratios would have been higher if insects had not destroyed much of the bait, necessitating daily rebaiting in some units.

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