250 man-hours of labor at $3.00 per hour	$ 750
5 pounds of 4-aminopyridine at $60.00 per pound	300
Methocel and acetone for 16 gallons of spray	15
Sprayer parts plus one-fourth the cost of sprayer	35
	$1,100

Although spraying 4-aminopyridine on partially husked ears of standing corn appears to be an effective and economical method of control, highly restrictive precautions must be taken to ensure that all treated plots are adequately marked and that all treated ears are retrieved as soon as they become unpalatable to blackbirds.

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CHEMICALS AS BIRD REPELLENTS: TWO PROMISING AGENTS

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Abstract: Of 724 chemicals screened as repellents for red-winged blackbirds (*Agelaius phoeniceus*), only 6 satisfied criteria for high repellency and low toxicity. Of these, 4–methylthio–3,5–xylyl *N*–methylcarbamate (methiocarb) and 2–methyl–α,α–diphenyl–1–pyrrolidinebutyramide (DRC 3324) were consistently effective against house sparrows (*Passer domesticus*), grackles (*Quiscalus quiscula*), pheasants (*Phasianus colchicus*), tricolored blackbirds (*Agelaius tricolor*), brown-headed cowbirds (*Molothrus ater*), and California quail (*Lophortyx californicus*).

Throughout recorded history, man and birds have been in conflict over the consumption of grains, fruits, and vegetables. Man has created many bird problems through drastic changes in cultural practices, and he now needs a safe and effective method to control bird damage to agricultural crops. Through the years, many novel devices have been used to frighten birds from crops, but, in time, the birds usually learn to ignore them. The most productive area of research for alleviating bird damage in the past decade has been the development of chemical

agents to kill, immobilize, stupefy, and repel destructive species. Since all birds have beneficial qualities, and most are protected by law, the most potentially useful compounds are nontoxic repellents.

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METHODS

Since 1961, personnel of the Denver Wildlife Research Center have screened 724 compounds in a search for safe and effective avian repellents. These have included commercial and experimental pesticides and commercially available organic, inorganic, and organometallic compounds. Screening tests were conducted with the red-winged blackbird because it is one of the primary species involved in agricultural damage in the United States, it is available throughout much of the year, it adapts reasonably well to aviary conditions, and it is one of the more sensitive avian species to toxicants and repellents (E. W. Schafer and D. J. Cunningham, unpublished data). Although the procedures for testing repellents developed by this Center have been described in detail by Starr et al. (1964), a number of modifications have been made to allow for more rapid and effective appraisals of potential avian repellents. As modified, the test procedures consist of four essential phases.

1. Preconditioning—wild-trapped birds are acclimatized to captive conditions for 4–6 weeks, in groups of 50–100, in indoor cages ($7 \times 7 \times 7$ feet).

2. Conditioning—holding groups of 7–10 preconditioned birds for 3 days in cages $2 \times 2 \times 2$ feet.

3. Pretesting—determining individual bird performance under desired test conditions. Each conditioned bird is held in a cage $6 \times 9 \times 6$ inches and offered 25 untreated, hulled white rice seeds for 18 hours. Only birds that eat all seeds are retained for testing.

4. Testing—groups of five individually caged, pretested birds are offered 25 rice seeds, treated with a given concentration of a candidate chemical, for 18 hours. Birds that eat 12 or fewer seeds are considered repelled. The initial concentration of chemical offered is 1.0 percent (w/w), and if repellency is indicated (three or more birds repelled), another test is conducted on additional pretested birds, with the concentration reduced either by ¼ or ½ a logarithmic step. This procedure is followed until no repellency is noted at a given level, and the resulting data are analyzed by the method of Thompson (1947), Thompson and Weil (1952), and Weil (1952) for an R_{50} (R = repellent) value and 95 percent confidence limits.

Although the test procedures are similar for all species, minor variations may occur, such as size of cage or the kind of seed treated. Acute oral toxicity was determined by treating test birds with propylene glycol solutions of the compound using a stomach tube as described by DeCino et al. (1966) and Schafer et al. (1967).

Compounds were rejected if they did not meet the following criteria: (a) R_{50} for redwings had to be less than 0.1 percent concentration, (b) LD_{50} for redwings had to be greater than 3.2 mg/kg, (c) LD_{50} for laboratory rats had to be greater than 32 mg/kg, and (d) germination of corn seeds (*Zea mays*) could not be prevented by concentrations of less than 0.5 percent.

RESULTS AND DISCUSSION

Of the 724 compounds tested, all but 45 were rejected because of insufficient repellency (> 0.1 percent) to redwings. Of the remaining compounds, 24 were too toxic

Table 1. Repellency and toxicity data for six chemicals as bird repellents.

SPECIES		DRC 2823[a]	DURSBAN[b]	METHIOCARB[c]	DRC 3324[d]	DRC 3321[e]	NICOTINE SO_4[f]
Red-winged blackbird	R_{50}[g]	0.075 (0.047–0.124)	0.081 (0.051–0.129)	0.089 (0.051–0.156)	0.091 (0.061–0.134)	0.091 (0.043–0.195)	0.095 (0.042–0.216)
	LD_{50}[h]	10 (5.6–18)	13 (NC)	4.7 (2.4–8.5)	75 (NC)	13 (NC)	75 (NC)
House sparrow	R_{50}	0.487 (0.340–0.706)	0.056 (0.032–0.100)	0.042 (0.011–0.159)	0.237 (0.071–0.626)	0.650 (0.453–0.930)	0.562 (0.077–4.12)
	LD_{50}	—	10 (NC)	18 (10–32)	>100 (NC)	—	100 (56–178)
Grackle	R_{50}	—	≈1.00[i] (NC)	0.056 (0.018–0.178)	0.056 (0.002–1.443)	—	0.178 (0.047–0.671)
	LD_{50}	—	13 (NC)	10 (5.6–18)	>100 (NC)	—	>32 (NC)
Pheasant	R_{50}	—	>1.00[i] (NC)	0.421 (0.316–0.562)	0.178 (0.100–0.316)	—	0.421 (0.178–1.000)
	LD_{50}	—	8.4 (2.8–25)	56–1000 (NC)	>100 (NC)	—	>100 (NC)
Tricolored blackbird	R_{50}	—	—	0.022 (0.014–0.035)	0.032 (0.015–0.067)	—	—
	LD_{50}	—	—	5.6 (4.0–7.8)	>100 (NC)	—	—
Brown-headed cowbird	R_{50}	—	—	0.318 (0.153–0.660)	0.352 (0.201–0.631)	—	—
	LD_{50}	—	—	7.5 (4.2–13.3)	>100 (NC)	—	—
California quail	R_{50}	—	—	0.562 (0.252–1.26)	0.178 (0.060–0.525)	—	—
	LD_{50}	—	—	24 (NC)	>100 (NC)	—	—
Laboratory rat	LD_{50}	562	135–163	130–135	365	>220	50–60

[a] 3,5-diisopropylphenyl *N*-methylcarbamate. Chemical and rat LD_{50} supplied by Hooker Chemical Company, Niagara Falls, New York. Reference to trade names does not imply endorsement of commercial products by the U. S. government.
[b] *O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate. Chemical and rat LD_{50} supplied by Dow Chemical Company, Midland, Michigan.
[c] Chemical and rat LD_{50} supplied by Chemagro Corp., Kansas City, Missouri.
[d] Chemical and rat LD_{50} supplied by Upjohn Company, Kalamazoo, Michigan.
[e] *m*-Cresol-2,4-dichloro-5-ethyl *N*-methylcarbamate. Chemical supplied by Upjohn Company, Kalamazoo, Michigan.
[f] Rat toxicity from Frear (1965:223).
[g] In percent. Parentheses indicate confidence limits at $P = 0.05$. NC = Not calculable.
[h] In mg/kg. Parentheses indicate confidence limits at $P = 0.05$. NC = Not calculable.
[i] Toxicity obscured repellency.

to redwings, 9 were too toxic to rats, and 6 were too toxic to corn seeds. The remaining 6 compounds were subjected to screening tests with one or more of the following species: house sparrow, common grackle, ring-necked pheasant, tricolored blackbird, brown-headed cowbird, and California quail.

Two compounds, methiocarb and DRC 3324 maintained acceptable R_{50}'s and LD_{50}'s for the majority of species tested (Table 1), and they were chosen for preliminary field testing. DRC 2823, DRC 3321, and Nicotine SO_4 were not tested further after displaying poor repellency to house sparrows. Dursban was eliminated from further testing because of a lack of repellent activity, for pheasants and grackles, which resulted in a high mortality of birds offered seeds treated at a 1.0 percent concentration.

West (1968), West and Dunks (1969), and West et al. (1969) proved that methiocarb was effective for preventing damage to sprouting corn caused by ring-necked pheasants and boat-tailed grackles (*Cassidix mexicanus*). Other investigators (Guarino and Forbes 1970, A. R. Stickley and J. L. Guarino, unpublished data) showed similar results on common grackles, redwings, and crows (*Corvus* sp.). Results of tests conducted by Frank et al. (1970), in cooperation with personnel of this laboratory, showed that DRC 3324 was similarly effective against common grackles. Both compounds should be tested further because they appear to be promising as repellents for several species of birds that cause damage.

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