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ABSTRACT

Eared doves (Zenaida auriculata) damage mature sunflowers in Uruguay. Although repellents might be useful as a control method, durability and expense have discouraged their use. In the present report, we describe laboratory, aviary, and field research designed to evaluate methiocarb and calcium carbonate as durable, economical repellents. Calcium carbonate ($CaC0_3$) was as effective as $CaCO_3$ /methiocarb in combination in deterring consumption of sunflowers. Moreover, treating field borders with $CaC0_3$ or the CaCQ /methiocarb combination was as effective as treating the entire field for at least 12 days. This period is sufficiently long to deter damage to sunflower during the critical period just before harvest. We conclude that CaCO3 can provide an economical tool to reduce bird damage to sunflower in Uruguay.

KEY WORDS

Eared dove, damage, repellents, sunflowers, Uruguay, Zenaida auriculata

INTRODUCTION

In Latin America, icterids, fringillids, psittids, columbids, and anatids cause agricultural damage in excess of US $6 million annually (De Grazio and Besser 1970). Lethal strategies have been used to reduce this damage; but these methods are expensive, frequently ineffective, and sometimes hazardous (Murton et al. 1974, Feare 1989). For these reasons, crop protection and not bird population reduction is now emphasized. Methods used include early harvest, synchronization of agricultural activities, use of resistant varieties, and chemical repellents.

Sunflower is the principal grain crop in Uruguay, and it is planted midspring (October) and midsummer (December). The latter planting is done at minimum cost, with minimal tillage and no fertilization. Yields are low but profitable, providing that bird damage can be economically controlled. The present experiment was designed to explore the use of methiocarb and a color cue ($CaCO_3$) as potential bird repellent for use on sunflower.

STUDY AREA

Laboratory studies were conducted at the facilities of the Plant Protection Division in Montevideo. Semi-field experiments were carried out near Colonia, 150 km northwest of Montevideo. Field experiments were conducted at Young, located 330 km northwest of Montevideo.

METHODS

Eared doves were trapped locally, and they were acclimatized and cage-tested in groups either in 1-m^3 cages (laboratory studies) or 9- x 4- x 4-m cages (aviary studies). Treated seeds or heads from an open-pollinated sunflower (Yatay) served as the test food.

Laboratory Experiments

In laboratory studies, both seeds and heads were paired with a less preferred food (barley seed or bird chow, respectively) and presented in two-choice preference tests. Methiocarb and calcium carbonate paint were applied to sunflowers singly and in combination. The paint was formulated by mixing it in a 1:4 ratio with water. The methiocarb was formulated according to the label instructions of the manufacturer, and concentrations were verified by high performance liquid chromatography (HPLC) analysis.

The two-choice preference test consisted of 7-day pretest, 7-day test, and 7-day posttest periods. No chemicals were used in the pretest and no methiocarb was used in posttest treatments. Repellency was measured as the percent of food consumed that was treated. The mean percent preference was calculated for each treatment. It was considered a repellency effect when a treatment reduced sunflower preference below 50% (Shumake et al. 1977). Data were transformed with the formula Y = ARCSIN SQRT Y, and a two-way analysis of variance (ANOVA) with repeated measures was conducted. The confidence limit was established at $P>0.05$. Newman-Keuls tests were used to isolate significant differences among means (Ott 1988).

Four laboratory experiments were conducted: (1) three methiocarb concentrations and paint were tested to determine dove preference for treated and untreated sunflowers versus laboratory chow; (2) the minimum concentration of methiocarb to decrease dove preference for sunflower versus barley seeds was determined; (3) the repellency of methiocarb, methiocarb-paint, and paint-only treatment were compared; and (4) the duration of repellency was determined.

Aviary Experiments

Aviary tests were similar to laboratory cage trials. Treated sunflower heads were presented in a two-choice test against bird chow. The treatments were 4.5 kg/ha methiocarbpaint, 4.5 kg/ha methiocarb-only, 20 kg/ha paint, and an untreated test food control. The data were evaluated in a randomized complete block ANOVA analysis with time as a blocking factor.

Field Experiments

Field studies were conducted in randomly selected 1.1 ha plots within large sunflower fields. Repellent effects (methiocarb versus paint) and application strategy (entire versus border) were compared during 21 days between the sunflower dough stage (90 days after complete anthesis) and harvest. Repellents were aerially applied. Paint was mixed 1:4 with water and applied at a rate of 80 L/ha of solution. Spray treatments were made in 18-m-wide bands along exterior rows of each plot. The six treatments of three replications were (1) entire plots treated with methiocarb-paint (MP), (2) entire plots treated with paintonly (P), (3) entire plots treated with methiocarb-only, (4) border application with methiocarb-paint (BMP), (5) border application with paint-only (BP), and (6) untreated (control).

A single versus multiple application strategy also was tested to determine whether one or multiple applications of paint would be needed to protect sunflowers. Three treatments of three replications each were tested: (1) paint applied once, (2) paint applied once and again after 14 days, and (3) a control plot without paint.

Five sunflower heads were collected from each plot immediately after application to determine methiocarb concentration. Samples were double-bagged, labeled, and frozen until analysis. Residues were quantified using an HPLC analytical method developed at the Plant Protection Services in Montevideo.

Sunflower damage was evaluated within each test plot once per week for 3 weeks. Seed loss/cm2 was quantified using the template method developed by Dolbeer (1975). Heads were selected for evaluation according to Rodriguez (1994). The first evaluation was conducted 14 days after anthesis (immediately before the treatment application); the second, 28 days after anthesis (a week after application); and the last evaluation, 35 days after anthesis (2 weeks following application).

Dove numbers were assessed before and during field tests. Counts were made every 7 days from a 3-m observation tower height mounted in the back of a truck. The number of doves entering a plot (D) was recorded during 5 min. of every hour between 0800 and 1800 hr for 5 min.

RESULTS

Laboratory Experiments

Methiocarb Threshold Concentration

There were significant differences among methiocarb concentrations, test days, and their interaction between these terms ($P<0.0001$; Table 1). Post hoc tests showed that there were no significant differences in preference between the pretest and posttest periods for sunflower treated with 2 kg/ha methiocarb-only concentration. However, food treated with 4.5 and 7 kg/ha was consumed significantly less during the treatment period during the pretest period. The 7 kg/ha concentration was significantly more repellent than the 4.5 kg/ha application.

Table 1. Laboratory Methiocarb Threshold Concentration Test. Numbers Represent Mean Percent Preference ± Standard Deviation for Sunflower Seeds Relative to Bird Chow during Pretest and Post-test Periods*

Methiocarb Treatment	**Pretest**	Post-test
7 kg/ha	75 ± 3.3*a*	11 ± 4.5*b*
4.5 kg/ha	77 ± 2.4*a*	17 ± 4.3*b*
2 kg/ha	74 ± 2.4*a*	71 ± 2.0*a*
Control	76 ± 4.0*a*	75 ± 1.9*a*

* Means in the same column followed by the same letter are not significantly different (Newman-Kauls test, $P < 0.05$).

Methiocarb and Paint Comparisons, and Repellent Duration Usinq Sunflower Seeds

There were statistically significant differences among treatments, experimental days, and an interaction between those terms ($P<0.0001$). Post hoc tests showed that all treatments differed from the control group (Table 2).

During the test-day phase of the experiment, there were no statistically significant differences among the noncontrol treatments. However, a repellency effect was obtained by applying methiocarb from 2 to 7 kg/ha together in combination with paint. During the 7-day posttest period, the preference for sunflower seeds over barley increased above the levels found during the test period (Table 2), but still was far below 50% for the methiocarb-paint treatments. No changes occurred for the control birds, accounting for the significant treatment-day interaction.

Table 2. Laboratory Evaluation of Methiocarb and Paint Treatments (Test Days) and the Duration of Repellent Effects (Post-test Days). Sunflower Seeds were Treated Either with Methiocarb and Paint (Test) or Paint Only (Post-test). Numbers Represent Mean Percent Preference ± Standard Deviation for Sunflower Seeds Relative to Barley during Pretest, Test, and Post-test Periods*

Methiocarb Treatment	Pretest	Test	Post-test
7 kg/ha	7.3 ± 5.2*ab*	6 ± 3.6*d*	16 ± 4.6*bcd*
4.5 kg/ha	65 ± 6.7*b*	13 ± 7.4*bc*	26 ± 5.8*b*
2 kg/ha	73 ± 5.4*ab*	11 ± 8.0*cd*	19 ± 8.5*bc*
Paint-only	72 ± 3.8a*b*	12 ± 5.7*cd*	24 ± 5.8*bc*
Control	73 ± 5.2*a*	77 ± 18.4*cd*	81 ± 5.8*bc*

*Means in the same column followed by the same letter are not significantly different (Newman-Keuls test, $P < 0.05$).

Methiocarb and Paint Comparisons and Repellent Duration Using Sunflower Heads

When the test food was sunflower heads instead of seeds, and chow was the alternate food instead of barley, the results were the same as in the previous experiment. There were significant differences among treatments, experimental days, and treatment-day interaction ($P < 0.0001$; Table 3).

Table 3. Laboratory Evaluation of Methiocarb and Paint Treatments (Test Days) and the Duration of Repellent Effects (Post-test Days). Sunflower Seeds were Treated Either with Methiocarb and Paint (Test) or Paint-Only (Post-test). Numbers Represent Mean Percent Preference ± Standard Deviation for Sunflower Seeds Relative to Bird Chow during Pretest, Test, and Post-test Periods*

Methiocarb Treatment	Pretest	Test	Post-test
7 kg/ha	72 ± 12.7*a*	16 ± 6.0*b*	14 ± 1.2*b*
4.5 kg/ha	77 ± 8.0*a*	18 ± 7.4*b*	13 ± 2.4*b*
2 kg/ha	66 ± 6.5*a*	12 ± 4.4*b*	14 ± 1.1*b*
Paint-only	72 ± 11.2a	13 ± 3.3*b*	14 ± 2.5*b*
Control	72 ± 8.3*a*	85 ± 6.6*a*	84 ± 10.2*a*

*Means in the same column followed by the same letter are not significantly different (Newman-Keuls test, $P < 0.05$).

Aviary Experiments

Methiocarb and Paint Comparisons, and Repellent Duration

There were significant differences among treatment levels during the pretest, test, and posttest periods, and an interaction between treatment levels and days ($P \sim 0.0001$). There were no statistically significant differences between blocks ($P > 0.23$). Post hoc tests showed that treatment groups ate significantly less than the control group. Methiocarb-only sunflower heads were avoided relative to untreated heads, but preference (58%) was not below the 50% repellency criterion (Table 4). The methiocarb-paint and paint-only treatments produced stronger effects (Table 4).

In the 7-day posttest experiment involving paint-only treatments to test for duration of repellency, dove preference for methiocarb-only treated seeds decreased to a repellency level similar to seeds which had received paint-only.

Table 4. Semi-field Evaluation of Methiocarb and Paint Treatments (Test Days) and the Duration of Repellent Effects (Post-test Days). Sunflower Seeds were Treated Either with Methiocarb and/or Paint (Test) or Paint-only (Post-test). Numbers Represent Mean Percent Preference ± Standard Deviation for Sunflower Heads Relative to Bird Chow during Pretest, Test, and Post-test Periods*

Treatment	Pretest	Test	Post-test
4.5 kg/ha Methiocarb	81 ± 7.9*a*	58 ± 3.7*b*	28 ± 4.9*a*
4.5 kg/ha Methiocarb/Paint	79 ± 9.8*a*	21 ± 4.2*a*	33 ± 6.4*a*
Paint-only	79 ± 6.6*a*	27 ± 4.0*a*	28 ± 9.0*a*
Control	78 ± 10.5*a*	74 ± 6.8*c*	85 ± 9.7*b*

*Means in the same column followed by the same letter are not significantly different (Newman-Keuls test, $P < 0.05$).

Field Experiments

Methiocarb and Paint Comparisons

There were significant differences among treatments, days, and an interaction between these terms ($P<0.0001$). Control plots received the most damaged (13%). The least damaged plots in the second and third evaluations were those treated with methiocarb-paint and paint-only.

Dove numbers are given in Figure 1. There were significant differences in dove numbers among treatments ($P<0.0001$) and days ($P\sim0.01$). Post hoc tests showed that few doves visited plots during the pretest period. After repellent applications, dove visitation rates increased in all plots. The fewest doves were seen visiting methiocarb-paint plots, an intermediate number visited those plots treated with only one of the repellents, and a larger number visited untreated plots. This suggests that the repellent-visual cue application is more effective than either repellent is separately.

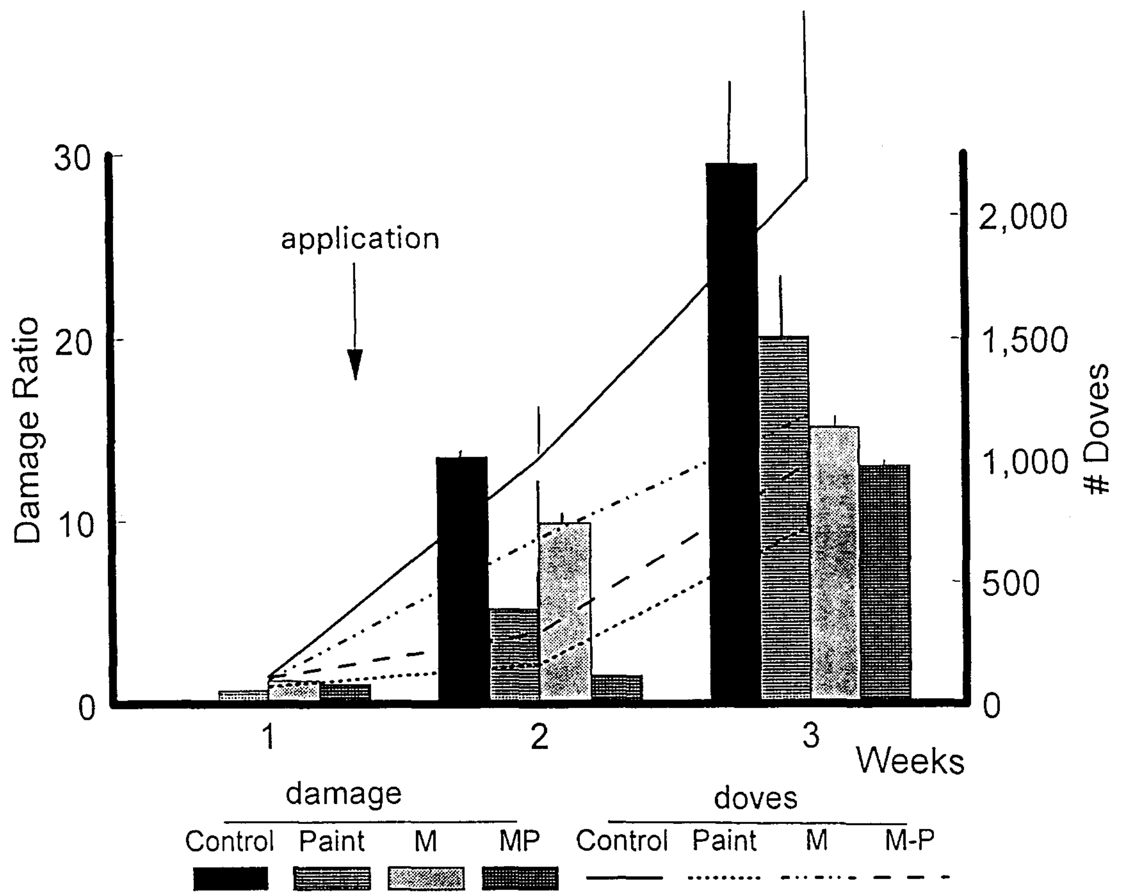

FIGURE 1. Field comparison between methiocarb and paint. Mean values for damage ratio and number of doves entering plots during pretest, test, and post-test periods. Test plots were treated with 4.5 kg/ha methiocarb (M), 4.5 kg/ha methiocarb and paint (MP) or paint-only (P).

Application Strategy: Entire Plot Versus Border Treatment Application

There were significant differences in damage among treatments and days, and an interaction between these terms ($P \sim 0.0001$; Figure 2). During the pretest period, there was little damage in any plot. During the treatment period, all treated plots received less damage than control plots.

The average number of doves entering plots treated entirely or only along the border also is shown in Figure 2. There were significant differences in dove numbers among treatments and days ($P \sim 0.0001$), and an interaction between these terms ($P \sim 0.0002$). Prior to treatment application, about the same number of doves entered the 15 plots. A week after the application, there were again no significant differences in the number of birds entering all plots, although a larger number visited the conkol plots. At 3 weeks, untreated plots were the most visited; the entirely methiocarb-treated plots, the second most visited; and bordertreated plots, the least visited. Dove visitation to the entire methiocarb-paint-treated plots was not statistically different from either entire paint-treated plots, or both border-treated plots.

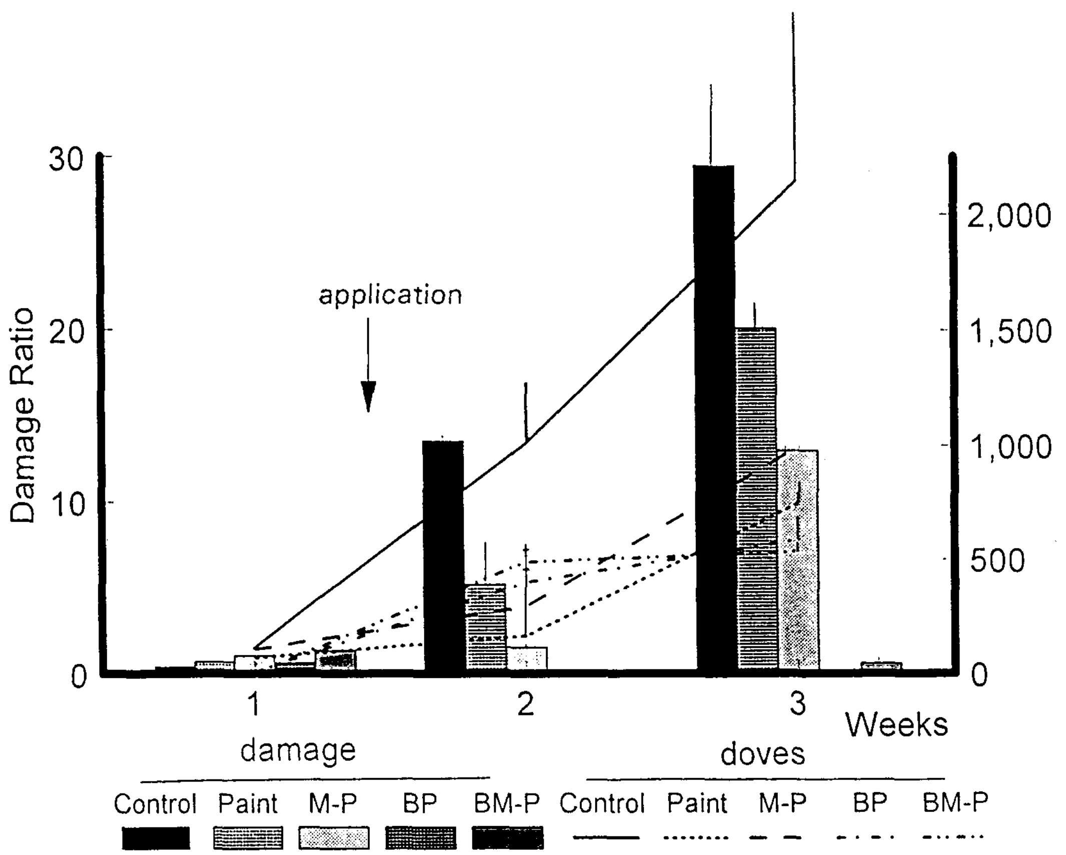

FIGURE 2. Field application strategy: Whole plot versus bord treatments. Mean values for damage ratio and number of doves observed during pretest, test, and post-test periods. Plots were treated entirely or in 18-m border applications with 4.5 kg/ha methiocarb and paint (MP or BMP) or with paint-only (P, or BP). Too little damage occurred in BMP and BP plots to appear in the figure.

Aviary and Field Methiocarb Residues Comparison

To develop the field application methodology, residues from field versus aviary applications were compared. Residues measured on sunflower heads treated aerially with 4.5 kg/ha methiocarb-only averaged 120 $\pm$ 23 ppm, while those on the sunflower heads used in semi-field experiments treated with the equivalent methiocarb concentration were 215 ppm $\pm$ 17ppm.

DISCUSSION

Calcium carbonate paint was the most repellent treatment to eared doves. This result was somewhat unexpected. According to previous studies with white $CaCO_3$ paints, paintalone as a repellent to granivorous birds was an unusual finding (Bullard et al. 1983, Elmahdi et al. 1985, Rodriguez 1988). However, other colors have been tested and found to be repellent to other species: blue to quelea and house sparrows (Bullard et al. 1983), and red to house finches (Avery 1984). For starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*), the effect of the color blue was so strong that some birds died rather than eat colored food (Greig-Smith and Rowney 1987). There appears to be considerable variation among bird species in their avoidance response to color.

This study indicated that paint was a better repellent than methiocarb. The low effectiveness of methiocarb-only treatments in aviary and field situations could be because the ppm chemical consumed by the eared dove was not enough to elicit a repellency effect. HPLC analyses indicated that the aerial application only deposited about 56% of the methiocarb measured on dipped heads from aviary studies.

Table 5 provides a cost comparison between methiocarb-paint and paint-only treatments. The average sunflower yield in Uruguay is 1,050 kg/ha, and the income per kg is US $0.18. Therefore, the cost of the methiocarb-paint application equals the income from 1,150 kg of sunflower, while the cost of the paint-only application equals the income from 147 kg of sunflower. Likewise, income from fields treated with methiocarb-paint does not cover the application cost, whereas only 14% of yield is needed to cover the paint application costs.

In addition to the economic benefits, the paint-only formulation is less toxic to animals than most chemical repellents and less likely to pollute the environment. The major ingredient in this paint formulation is calcium carbonate, which is a common chemical found throughout the environment and considered not to be harmful to plants or animals. Therefore, commercial paint also does not have to undergo the expensive process of pesticide registration required in most countries, including Uruguay, for many repellents.

With paint as the selected eared dove repellent, an application strategy was developed specifically for Uruguayan conditions. To prevent buildup of flocks, application should begin at the onset of physiological maturity when bird visitations are minimal. A second application will likely be needed if heavy rainfall occurs during the following 12 days when most dove damage occurs. This occurred during the experiment when 176 mm of rainfall fell (173 mm after the repellent application).

Table 5. Cost Comparison (U.S. $/ha) between a 4.5 kg/ha Methiocarb-Paint (6 kg/ha) and Paint-only Application, Young Uruguay

Treatment	Methiocarb-Paint	Paint-only
Methiocarb	180	
Paint	16	16
Airplane	9	9
Hand-labor	2	2
Total	207	27

Applications should be made to field borders where doves prefer to feed. To be economical, the savings from treating only part of the crop must exceed the value of the crop losses over the entire field. Our experimental design was one in which a third of the plot area was treated. With the cost values of damage being equivalent to 299 kg sunflower for entire field application and 49 kg for border application, the latter resulted in 210 kg more harvested sunflowers.

Border chemical applications have been used successfully in field experiments in Africa (Bruggers 1989), and semi-field experiments in the United States (Avery 1989). However, many questions remain since both the size and shape of fields can impact effectiveness. For example, an 18-m border for the entire field used in these studies would have been 16% of the area, whereas it was 30% for each of the l-ha test plots. The effectiveness of border applications might be related to the proportion of treated versus untreated crop. After initial exposure to the repellent, birds must encounter treated food often enough to reinforce their avoidance behavior (Avery 1985). A wider treated border may be necessary for large rectangular fields. In addition, a field pattern with a pronounced white border may produce an avoidance behavior to a flock of eared doves.

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