DIMETHYL AND METHYL ANTHRANILATE AND METHIOCARB DETER FEEDING IN CAPTIVE CANADA GEESE AND MALLARDS

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Abstract: We evaluated the repellency of dimethyl anthranilate (DMA) and methyl anthranilate (MA) in 1- and 2-choice feeding trials with and without methiocarb (MB) on captive Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*) because both species cause crop damage or nuisance problems. In 2-choice trials, concentrations of 1% (g/g) DMA and MA were avoided by both species. Concentrations of 2% DMA and MA, and an economically similar concentration of MB (0.1%), reduced ($P \leq 0.005$ and $P \leq 0.01$, respectively) consumption by geese and ducks in 1-choice tests. Of the 3 materials, MA and MB were the strongest feeding deterrents and warrant further testing in the field.

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North American Canada goose populations are increasing. For example, mid-December surveys of Canada geese in the Mississippi Flyway increased from 745,000 in 1980 to 1,850,000 in 1989 (Babcock et al. 1990). While these increasing populations signal a positive step in the conservation of waterfowl, Canada geese now are implicated frequently in habitat destruction, crop depredation, and nuisance problems (Laycock 1982, Conover and Chasko 1985, Mott and Timbrook 1988, Williams and Bishop 1990). Mallards, although decreasing continent-wide (U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 1989), also are implicated in local crop damage and nuisance complaints (Knittle and Porter 1988).

Management of damage caused by geese and mallards usually involves pyrotechnic and mechanical scare devices and traps (USDA 1986). However, use of these is often limited by cost, logistics, and/or effectiveness. These limitations have stimulated efforts toward the development of effective, economical, and environmentally safe chemical repellents to deter foraging. Two such repellents, dimethyl anthranilate (DMA, CAS-85-91-6) and methyl anthranilate (MA, CAS-134-20-3), even at low concentrations (<1.0%), are offensive to every species of bird tested to date (Mason et al. 1985, 1989; Kare and Mason 1986). Both chemicals are registered with the Food and Drug Administration (FDA) as flavor additives for human consumption.

We evaluated whether DMA and MA repel Canada geese and mallards, and we determined if economically comparable levels of methiocarb (Mesurol®), a registered chemical insecticide with known utility as a goose feeding deterrent (e.g., Conover 1985), and MA showed similar effectiveness.

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MATERIALS AND METHODS

We obtained DMA and MA entrapped in food grade starch from National Starch and Chemical Company (Bridgewater, N.J.). Technical grade methiocarb (MB, CAS No. 2032-65-7) was provided by Mobay Chemical Company (Kansas City, Mo.). All 3 chemicals were suspended in corn oil (1% g/g) and thoroughly mixed with shelled corn to produce DMA and MA concentrations of both 1.0% and 2.0% (g/g), and a methiocarb concentration of 0.1% (g/g). We used corn oil to assure that the repellents adhered to the corn particles.

Sixty adult geese of undetermined sex and 56 adult male mallards were cannon-netted (Dill and Thornsberry 1950) on the grounds of the

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Denver Federal Center, Denver, Colorado in February 1988, and were housed separately in 2 outdoor pens (8 × 4 × 2 m) with free access to shelled corn and water.

After 4 weeks in captivity, 12 geese and 12 mallards were assigned randomly to each of 3 experiments. Within experiments, pairs of geese and pairs of ducks were selected randomly and housed in 4- × 2.5- × 2-m test pens. We conducted each experiment between 0730 and 1630 hours for 4-day pre-conditioning and 4-day treatment periods, with the exception of experiment 3, which included a 2-day posttreatment period.

Experiment 1: 2-Choice Tests

On each of 4 pre-conditioning days, 6 pairs of geese and 6 pairs of ducks were presented with 2 plastic pans, each containing 250 g (geese) or 125 g (ducks) of untreated shelled corn. Even numbers of pairs of each species were assigned to 2 groups. During the 4 treatment days, 1 group received 1.0% DMA-treated shelled corn versus untreated shelled corn, while the other group received 1.0% MA-treated shelled corn versus untreated shelled corn. The positions of the treated and untreated feed were alternated daily. At the end of each day, consumption was recorded by weighing the remaining shelled corn.

Preference ratios were calculated separately for ducks and geese by dividing consumption of treated feed by total consumption. Preference ratios could vary from 1.0 (absolute DMA or MA preference) to 0.0 (absolute DMA or MA rejection). Ratios were evaluated in a 2-factor analysis of variance (ANOVA) with repeated measures over treatment days. Distributional and variance structure assumptions necessary for valid use of this analysis were examined using features of PROC GLM and PROC UNIVARIATE (SAS Inst. Inc. 1988). Shapiro-Wilk tests of standardized residuals from the ANOVA's revealed no ($P > 0.10$) departures from normality. F-tests for equality of the 2-treatment variances were not significant ($P > 0.05$) for either species, and sphericity tests for departure from required covariance matrix pattern also were not significant ($P > 0.10$). Tukey Honestly Significant Different (HSD) tests (Winer 1962: 198) were used to isolate differences ($P < 0.05$) among means.

Experiment 2: 1-Choice Tests

On each of 4 pre-conditioning days, 12 pairs of geese and 12 pairs of ducks were presented with a plastic pan containing 500 g (geese) or 250 g (ducks) of untreated shelled corn. For 4 treatment days, geese and ducks were assigned to 3 groups. One group (3 pairs each of geese and ducks) was given 1.0% DMA-treated shelled corn, 1 group (3 pairs each of geese and ducks) was given 1.0% MA-treated shelled corn, and 1 group (6 pairs each of geese and ducks) was given untreated corn, all on each of 4 treatment days. At the end of each day, consumption by each pair was recorded as in Experiment 1. A 2-factor ANOVA with repeated measures over days was used to assess whether consumption varied among groups. The PROFILE, REPEATED, and CONTRAST options of PROC GLM were used to test specific hypotheses concerning treatment differences and interactions over days. In this experiment and in Experiment 3, average consumption during the pre-conditioning period generally increased and reached a maximum on day 4. Therefore, the last pre-conditioning day and 4 treatment days were used in the analysis. Significance level was set at 0.05. We used Tukey HSD tests to isolate differences ($P < 0.05$) among means.

Experiment 3: 1-Choice Tests

On each of 4 pre-conditioning days, 6 pairs of geese and 6 pairs of ducks were presented with a plastic pan containing 500 g (geese) or 250 g (ducks) of untreated shelled corn. Even numbers of pairs of each species were assigned to 3 groups, each receiving 1 of the following treatments for the next 4 days: 2.0% DMA-treated shelled corn, 2.0% MA-treated shelled corn or 0.1% MB-treated shelled corn. Following treatment, pairs were presented with untreated shelled corn for 2 days. At the end of each daily test, consumption was recorded as in Experiment 1. Geese and ducks were evaluated separately using analyses similar to Experiment 2. The last pre-conditioning day, 4 treatment days, and 2 posttreatment days were included in the analysis.

RESULTS

Experiment 1: 2-Choice Tests

Preference ratios calculated on the basis of 2-choice tests were uniformly low for both species, indicting strong rejection of DMA- or MA-treated shelled corn (Table 1). For geese, there were no differences among treatments ($F = 0.09$; 1,4 df; $P = 0.77$) or days ($F = 1.06$; 3,12 df; $P = 0.40$), suggesting that DMA and MA were equally effective in suppressing consumption and that the degree of repellency remained constant over time (Table 1). For ducks, there was no difference ($F = 0.03$; 1,4 df; $P = 0.88$) among treatments, but there was a difference ($F = 11.16$; 3,12 df; $P = 0.0009$) among days. Small increases ($P < 0.05$) in preference ratios suggested a slight decrease in repellency over time (Table 1).

Experiment 2: 1-Choice Tests

For both geese and ducks, there were differences among treatments ($F = 8.93$; 2,9 df; $P = 0.007$; $F = 9.52$; 2,9 df; $P = 0.006$, respectively) and days ($F = 20.32$; 4,36 df; $P = 0.0001$; $F = 8.86$; 4,36 df; $P = 0.001$, respectively), and a significant interaction between these terms ($F = 8.66$; 8,36 df; $P = 0.0001$; $F = 9.24$; 8,36 df; $P = 0.0001$, respectively).

Overall consumption by geese decreased ($P = 0.001$) between the last pre-conditioning day and treatment day 1, and increased ($P = 0.0001$) between treatment days 1 and 2 (Fig. 1A). Individual comparisons between the last pre-conditioning day and treatment days 1, 2, 3, and 4 revealed differences ($P < 0.02$) among treatments because consumption of DMA- and MA-treated food decreased after treatment while consumption of control food increased.

Overall consumption by ducks also decreased ($P = 0.007$) between the last pre-conditioning day and treatment day 1, but increased ($P = 0.003$) between treatment days 3 and 4 (Fig. 1B). The difference between the last pre-conditioning day and treatment day 1 consumption and the last pre-conditioning day and treatment day 2 consumption was not the same for all treatments ($P = 0.0005$, $P = 0.005$, respectively). Both DMA and MA consumption sharply declined on these 2 days relative to the last pre-conditioning day levels, while control consumption increased. This trend was reversed ($P = 0.002$) between treatment days 2 and 3, i.e., consumption of DMA and MA increased and control consumption decreased.

Experiment 3: 1-Choice Tests

There were no differences (geese: $F = 0.06$; 2,3 df; $P = 0.94$; ducks: $F = 2.92$; 2,3 df; $P = 0.20$) among treatments. However, for geese and ducks, there were differences among days ($F = 48.90$; 6,18 df; $P = 0.0001$, and $F = 98.60$; 6,18 df; $P = 0.0001$, respectively). There was no significant interaction between treatments and days for geese ($F = 1.27$; 12,18 df; $P = 0.314$), but

Table 1. Mean preference ratios[a] and 95% confidence interval (CI) exhibited by captive Canada geese and mallards for dimethyl anthranilate (DMA)- or methyl anthranilate (MA)-treated shelled corn in a 2-choice test, Denver, Colorado, 1988.

Repellent	No. pairs	Treatment day[b] 1 $\bar{x}$	1 CI	2 $\bar{x}$	2 CI	3 $\bar{x}$	3 CI	4 $\bar{x}$	4 CI	Overall $\bar{x}$	Overall CI
Canada Geese											
DMA	3	0.028A	0.021	0.011A	0.025	0.029A	0.023	0.026B	0.015	0.024	0.018
MA	3	0.034A	0.021	0.023A	0.025	0.017A	0.023	0.025B	0.015	0.025	0.018
Mallards											
DMA	3	0.047AB	0.023	0.035A	0.022	0.095AB	0.058	0.094B	0.026	0.068	0.042
MA	3	0.058AB	0.023	0.041A	0.022	0.078AB	0.058	0.102B	0.026	0.070	0.042

[a] Calculated by dividing consumption of DMA- or MA-treated shelled corn by total treatment consumption (DMA or MA and untreated shelled corn consumption). A ratio of zero indicates complete rejection of DMA or MA; whereas ratios of 1.0 and 0.5 indicate complete preference or indifference, respectively.
[b] Means not sharing letters in the same row differ ($P < 0.05$); based on 2-factor ANOVA and Tukey HSD tests.

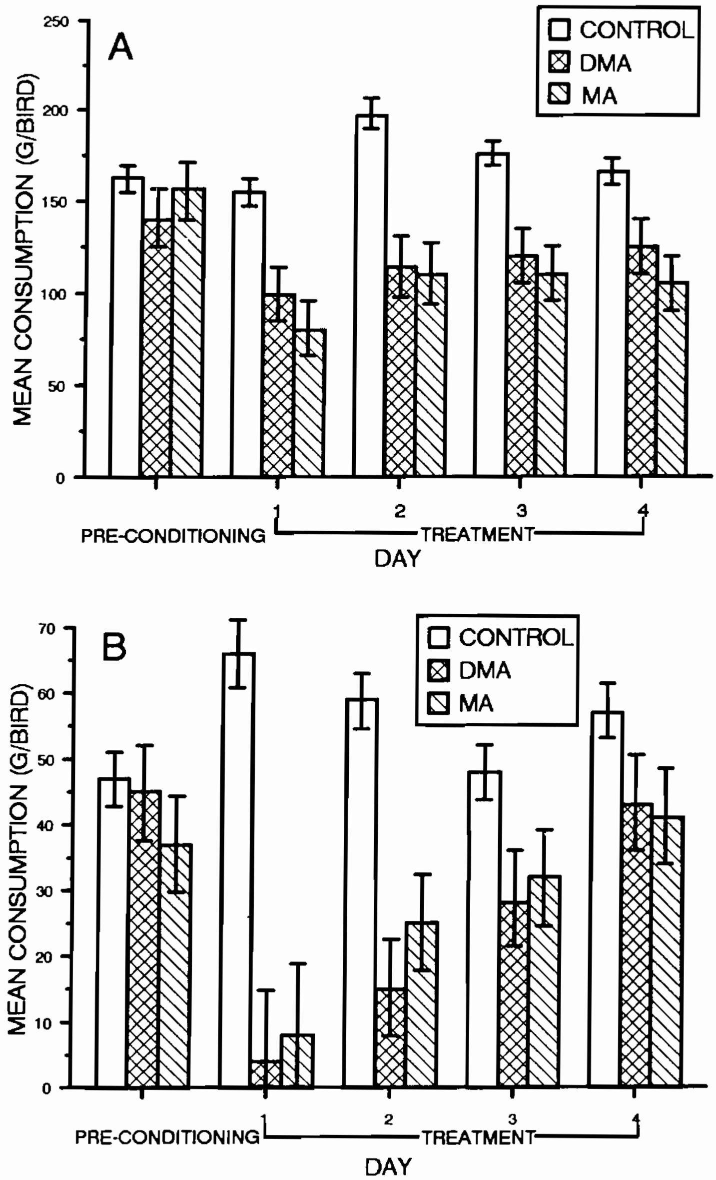

Fig. 1. Experiment 2: Mean consumption by 12 pairs of Canada geese (A) and 12 pairs of mallards (B) of 1.0% (g/g) dimethyl anthranilate (DMA)- or methyl anthranilate (MA)-treated shelled corn in a 1-choice test. Capped vertical lines represent standard errors.

there was for ducks (F = 7.63; 12,18 df; P = 0.0001).

For geese, all 3 treatments produced the same basic pattern of consumption (Fig. 2A). Average consumption over all treatments was reduced ($P \leq 0.005$) between the last pre-conditioning day and each of the treatment days, but was not reduced during the posttreatment days. Average consumption decreased between treatment days 2 and 3 ($P = 0.04$) but increased ($P = 0.03$) between treatment days 3 and 4 and also between treatment day 4 and posttreatment day 1 ($P = 0.005$).

There was no overall difference ($P = 0.20$) in treatment performance for ducks, but the treatment by day interaction ($P = 0.0001$) revealed differences in the response profile of treatments due to the different responses recorded in the posttreatment period (Fig. 2B). Consumption of MB-treated food steadily increased during this

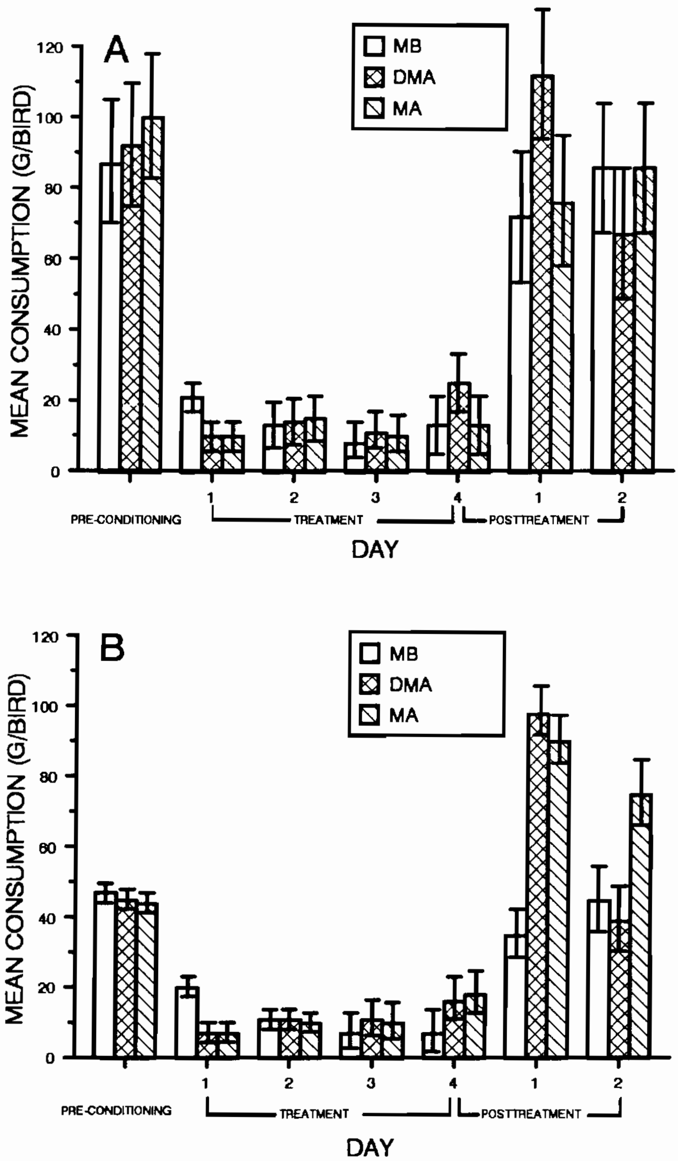

Fig. 2. Experiment 3: Mean consumption by 6 pairs of Canada geese (A) and 6 pairs of mallards (B) of 2.0% (g/g) dimethyl anthranilate (DMA)-, methyl anthranilate (MA)-, or 0.1% methiocarb (MB)-treated shelled corn in a 1-choice test. Capped vertical lines represent standard errors.

period, but both DMA and MA showed a sharp increase and then decrease during this time. Average treatment consumption was reduced ($P \leq 0.01$) between the last pre-conditioning day and all posttreatment days. However, there was a difference ($P = 0.0004$) among treatments between the last pre-conditioning day and posttreatment day 2 due to the large increase in consumption of DMA- and MA-treated food (Fig. 2B).

DISCUSSION

Degree of repellency of DMA, MA, and MB to geese and ducks was influenced by chemical, concentration, and bird species. The significant goose and duck avoidance of treated shelled corn at low concentrations (Experiment 1; 1%), and the consistent avoidance throughout the treatment period, suggests that no habituation to the repellency of DMA or MA occurred. However, ducks seemed to be relatively less sensitive to both anthranilate derivatives. These differences, albeit slight, may reflect species differences in the degree to which chemical (i.e., olfactory, taste, trigeminal) cues influence food consumption (Espaillat and Mason 1990).

Experiment 2 suggested that 1% DMA or MA acted as a repellent, but not enough to cause complete avoidance of treated diet in 1-choice tests. Although there were species differences in response, geese exhibited no changes in consumption during the treatment period, and ducks showed consistent increases in feeding over days. This may reflect species differences in chemical sensitivity, or perhaps, differences in feeding behaviors.

In Experiment 3, 2.0% DMA or MA and 0.1% MB were sufficient to cause almost complete avoidance of treated shelled corn during the treatment period. The return to baseline consumption during the posttreatment period suggests that there were no residual effects of the treatments. These findings are in apparent conflict with those of Conover (1985), who reported that free-ranging geese avoided MB-treated grass sites for extended periods of time. However, the durability of effects reported by Conover probably reflects the fact that geese left treated areas altogether (M. R. Conover, Utah State Univ., Logan, pers. commun.). In the present experiment, the penned birds could not abandon treated sites and were forced to sample the test diet during the posttreatment period. When free-ranging geese are tested under analogous conditions (i.e., lack of alternatives), they continue to sample plots and MB repellency declines (Conover 1989).

Analysis of the power of the hypothesis tests in Experiment 1 indicated that, despite small sample size, the tests had a very high probability of detecting differences as small as 5% because of the consistent responses of the birds in 2-choice situations. Thus, the lack of significant differences between MA and DMA implies that the compounds cause essentially equal levels of avoidance by birds when there is a choice of treated and untreated food. In the 1-choice Experiments 2 and 3, however, the probability of detecting meaningful differences among treatments was much less than 50%, and therefore the relative repellency of DMA, MA, and MB in this context remains unclear.

MANAGEMENT IMPLICATIONS

Both DMA and MA are effective goose and duck feeding deterrents when applied to otherwise palatable materials at concentrations between 1–2% (g/g). The relative repellency of these 2 compounds is an important economic consideration in the future development of waterfowl repellents, because MA is less expensive than DMA (P. Vogt, PMC Spec. Group, Teaneck, N.J., pers. commun.). Aside from economic considerations of efficacy, however, primary and secondary wildlife hazards could restrict the use of the MB against nuisance and depredating waterfowl populations (R. A. Dolbeer, Bird Sect. Res. Rep., U.S. Dep. of Agric., 1988). A recent survey of Animal Damage Control State Directors (D. L. Otis, Bird Sect. Res. Rep., U.S. Dep. of Agric., 1989) indicated that an unspecified chemical repellent would be used on about 40,000 ha of turf in the United States to alleviate Canada goose problems. In addition, the same chemical repellent potentially could be used to mitigate damage caused by an assortment of birds to various agricultural crops. Finally, either DMA or MA could perhaps reduce nontarget hazards associated with toxic liquid and pelleted agricultural chemicals by reducing or eliminating accidental ingestion by birds. Field evaluations of the repellency of MA on turf are planned.

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