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ABSTRACT: The bird repellent properties of methyl anthranilate (MA) and dimethyl anthranilate (DMA) are well-established. Nevertheless, development of means to reduce the amount of chemical needed to effect satisfactory repellency would reduce costs and make their use even more attractive. Thus, we evaluated the usefulness of a visual stimulus for increasing DMA repellency. We offered groups of captive European starlings (*Sturnus vulgaris*) untreated food and DMA-treated food, and to some groups we also presented a putatively repellent eyespot pattern. As expected, a DMA concentration of 1.4% (gig) reduced ($P = 0.001$) consumption of treated food compared to untreated; 0.3% DMA was ineffective. While, the presence of the eyespot pattern alone reduced food consumption by about 50%, pairing the eyespots with the DMA treatments did not improve the chemical's effectiveness at either level. Even though the eyespot pattern was initially aversive, prolonged exposure resulted in rapid habituation. Although visual scare devices using eyespot patterns are marketed for bird control, our findings suggest that alone they are probably of limited value against starlings. Instead, integrated approaches employing visual, aural, and chemical deterrents are needed.

Key words: bird repellent, dimethyl anthranilate, DMA, European starting, eyespots, feeding deterrent, *Sturnus vulgaris*

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European starlings and other bird species annually cause considerable economic loss in livestock feedlots (Glahn 1983, Besser 1985). Reduction of such losses may be possible through the use of methyl (MA) and dimethyl anthranilate (DMA), food additives that are aversive to birds (Glahn et al. 1989; Mason et al. 1984, 1985, 1991). Mason (1989) suggested that the repellency of anthranilate derivatives might be improved by the addition of distinctive colors. Because it may not always be possible to apply a color directly to the food source, we chose to examine this concept using an eyespot pattern as the visual stimulus. Moreover, because an eyespot pattern has been shown to deter starling feeding behavior (Inglis et al. 1983), we reasoned that the aversiveness of DMA might be enhanced by pairing the chemical with this type of prominent visual stimulus. The enhanced effect may reduce the amount of repellent needed to repel birds or may retard their habituation to the chemical.

Specifically, we wanted to determine the relative effectiveness over short time periods of DMA and eyespots in reducing food consumption by starlings, to determine if the effectiveness of DMA is enhanced when paired with the visual stimulus, and to document the responses of starlings to prolonged exposure to an eyespot pattern.

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METHODS

Testing Environment

We conducted the tests during winter in 4 outdoor enclosures (3 x 9 x 2 m). To provide birds with 2 distinct feeding stations, we divided each enclosure in half with a partition attached to one side of the enclosure and extending across to within 1 m of the opposite side. The partition extended from ground level to within 0.8 m of the top of the enclosure.

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An opaque screen attached to the sides of each enclosure prevented birds in one enclosure from observing feeding behavior in others. Several perches were provided in each enclosure, and roofing provided shelter from sun and rain. Water was available at all times. Study subjects were adult European starlings, trapped locally (Alachua County, Fla.) and held in captivity 2 weeks before testing.

Test Food

We prepared test concentrations of 0.3% and 1.4% a.i. (gig) on Purina Layena® Etts (Purina Mills, St. Louis, Mo.) by adding the appropriate amount of DMA (38% a.i., gig, in a starch matrix; National Starch and Chemical Co., Bridgewater, N.J.) to 1 kg of Layena and mixing for 5 minutes in a rotating tumbler.

Eyespots

We painted 8 pieces of waferboard (30 x 40 cm) white on both sides and added pairs of eyespots (16.5 cm outer diam) to 1 side of 4 boards. Each eyespot consisted of an inner 'pupil' (7.5 cm diam) painted black surrounded by an painted red. Throughout all trials the boards were suspended by string on the inside of the enclosures just above and 30 cm behind the food bowls. When the eyespot pattern was not being tested, the plain white side faced the birds. During tests of the visual stimulus, the eyespot pattern was turned toward the birds.

Evaluation of DMA-eyespot Combinations

We evaluated 5 treatments: eyespots alone, 0.3% (gig) DMA alone and with eyespots, and 1.4% DMA alone and with eyespots. Each treatment was tested against 4 separate groups of starlings (n = 4 birds/group). We tested starlings in groups because in the field this species normally feeds in flocks. At a given time, each of the 4 test enclosures received the same treatment. The sequence of testing the 5 treatments was determined randomly.

On the morning of day 0, starlings were removed from their group holding cages (1.3 x 1.3 x 2 m) and assigned randomly to the 4 test enclosures. At 1530, maintenance food was removed. On Day 1, at 0800, each test group received 2 ceramic bowls (9 cm deep) of food, one on each side of the partition. One bowl was designated at random as treated, the other as control. Each bowl held 150 g of maintenance food. Two other bowls, identical to the test food bowls, were placed outside the enclosures and their mass determined before and after feeding trials to determine moisture gain or loss. Consumption estimates were then adjusted to correct for the effects of moisture.

Over the test food bowls, we suspended 50 x 65 cm metal trays to reduce fouling by excrement and to protect from rain. At 0900, the bowls were removed and the birds remained "without food until 1000 when the 2 food bowls were again presented but with positions reversed. At 1100, test bowls were removed and their mass determined, and separate bowls of maintenance food were again provided until 1530. We then withheld food until 0800 the next morning.

On day 2, we applied the treatment following the same schedule as on day 1. Except for the eyespot only treatment, the treated bowl contained DMA-treated food. The control bowl always held untreated food. The treatment was applied at one feeding station (randomly determined) during 0800-0900 and then switched to the other side during 1000-1100.

Evaluation of Eyespots Alone

We conducted a follow-up evaluation of eyespots alone. Following 3 days' acclimation to the test enclosures, food consumption by 4 groups of starlings was measured over a 24-hour baseline period. Then eyespots were presented at the feeding station preferred during the 24-hour baseline period. The eyespots were left in place, and we measured feed consumption at 2, 24, 48, and 72 hours. We calculated preference ratios by dividing consumption from the bowl at the initially preferred feeding station, where the eyespot pattern was placed, by total consumption.

Analysis

For the DMA-eyespot evaluation, we replicated each of the 5 treatments 4 times, with a different group of 4 birds used for each replication. To assess the effects of the treatments on food consumption, we used a 3-way repeated measures ANOVA.

In the eyespot-only evaluation, we compared baseline preference ratios and those at 2, 24, 48, and 72 hours against the null value of 0.5 (indicative of indifference) using 2-tailed t-tests. Ratios below 0.5 indicated possible avoidance of the eyespot pattern.

RESULTS

DMA-eyespot Combinations

Overall, food consumption did not differ among treatments ($F = 1.01$; 4,15 df; $P = 0.43$). Consumption was greater ($F = 6.84$; 1,15 df; $P = 0.02$) on day 2 (x = 16.1 g/bowl) than on day 1 (x
= 14.0 g/bowl; Table 1). The birds ate nearly twice as much 67.87; 1,15 df; $P = 0.001$) from the untreated bowl (x 19.6 g/cage) as from the treated bowl (x 10.5 g/cage). The treatment x bowl interaction ($F = 8.56$; 4,15 df; $P = 0.001$) reflected the markedly reduced consumption ($P < 0.05$) from the treated bowl by the 1.4% DMA and 1.4% DMA plus eyespot groups relative to the other treatments (Fig. 1). The day x bowl interaction ($F = 78.98$; 1,15 df; $P = <0.001$) was due to consumption from the treated bowl being greatly suppressed (x 7.8 g/cage) on day 2 relative to the untreated bowl (x 24.4 g/cage). On day 1, consumption was nearly equal between bowls (13.2 vs. 14.8 g/cage).

Eyespots Alone

Each of the 4 test groups showed an immediate reaction to the presence of the eyespots and shifted their feeding to the untreated, and previously less-used, bowl (Fig. 2). By design, preference ratios over the 24-hour baseline period were greater ($t = 3.53$, $P = 0.039$) than the indifference value of 0.5. After 2 hours of exposure to the eyespot pattern, the preference scores shifted ($t = 6.28$, $P = 0.008$) below 0.5, indicative of an avoidance response. Thereafter, however, the effect waned and preference scores generally approached or exceeded 0.5.

Table 1. Mean food consumption by groups of 4 starlings during feeding trials with a chemical and visual repellent, at Gainesville, Florida, 1989. Food consumption did not differ among treatments ($P = 0.43$) but was greater ($P = 0.02$) on day 2 than on day 1.

Food consumption (g/bowl)

Day 1[a] Day 2

Treatment	x	SE	x	SE		
0.3% DMA	12.3	2.0	15.0	1.3		
0.3% DMA + eyespots			15.0	1.9	18.5	3.2
Eyespots	13.1	1.5	14.0	31		
1.4% DMA	150	2.4	15.5	45		
1.4% DMA + eyespots			14.8	2.3	17.6	53

[a]On day 1, all food was untreated; on day 2, treatment was applied to 1 of the 2 food bowls.

Fig. 1 Mean consumption by groups of 4 starlings (n = 4 groups/treatment) given 1 bowl of untreated food and 1 bowl of food with the indicated treatment. Treated food consumption was reduce ($P < 0.05$) relative to untreated food consumption in each treatment except 0.3% DMA.

Fig. 2. Responses of starlings to an eyespot pattern placed in front of their preferred food bowl. A preference ratio of 0.5 indicates indifference to the treatment. Baseline ratios were greater ($P = 0.039$) than 0.5, while the 2-hour values were lower ($P = 0.008$), indicating avoidance.

DISCUSSION

We recorded an immediate reduction in food consumption from the bowl where the eyespots were applied whether or not the chemical repellent was used. While the avoidance reaction did not persist, the neophobia is consistent with earlier findings (Inglis et al. 1983) that eyespot patterns can, in the short term, reduce feeding by starlings.

We conducted the combined stimulus trials over a brief period (2 days) because we were interested in evaluating repellency enhancement. We reasoned that if a visual repellent is to be effective, the effects will be most pronounced immediately after presentation. Because we did not detect enhancement of DMA repellency by the presence of the eyespot pattern on day 2, more lengthy evaluation of the combined stimuli was not justified.

Because the addition of the eyespot pattern to the 0.3% and 1.4% DMA treatments did not improve the chemical's repellency, we conclude that the effectiveness of the paired stimuli was determined by the stimulus that proved more effective when presented singly. The 0.3% DMA plus eyespot treatment was no more effective than eyespots alone, and the 1.4% DMA plus eyespots treatment produced results no different from 1.4% DMA alone. We suspect that our failure to find enhanced DMA repellency with the addition of the eyespot pattern might be due to a lack of connectivity between the 2 stimuli. The eyespot pattern is a novel, perhaps threatening, visual stimulus while DMA is an irritating food additive. When eyespots are augmented with another type of frightening stimulus, such as a distress call, the avoidance response is enhanced (Inglis et al. 1983). Similarly, combining a taste irritant (methyl anthranilate) with a novel visual stimulus (calcium carbonate) on the food itself enhanced repellency of the tastant (Mason 1989).

The starlings may not have recognized the eyespot/DMA combination as a unit, and so responded to each component separately. To form an effective combination with a taste repellent such as DMA, a visual repellent may need to be applied directly on the food, or at least be more closely associated with the feeding site than was our eyespot pattern.

MANAGEMENT IMPLICATIONS

The immediate reductions in food taken from the bowl with the eyespot pattern suggest that this visual device may have some utility in certain bird damage situations. Performance should improve in applications where additional mechanical and electrical devices can be used to augment repellency. Specific items for future consideration include combining eyespots with distress calls (lnglis et al. 1983) or developing a "pop-up" eyespot scarer to exploit the startle response of birds to visual stimuli (Vaughan 1983). In general, the integration of aural, visual, and chemical stimuli to produce repellent combinations superior to the individual constituents is a fertile area for additional research. This approach could have substantial importance if it results in lower effective application rates for chemical repellents such as MA or DMA.

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