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Mint plant derivatives as blackbird feeding deterrents

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Naturally occurring plant constituents are potentially useful as avian feeding deterrents. In a series of cage trials, pulegone, a compound found in various species of mint, suppressed consumption of rice seed by red-winged blackbirds (*Agelaius phoeniceus*) more effectively than methyl anthranilate. Furthermore, pennyroyal oil, from which pulegone is obtained, was nearly as effective as pulegone itself. Brown-headed cowbirds (*Molothrus ater*) were more sensitive to pulegone than were redwings, but female boat-tailed grackles (*Quiscalus major*) were less sensitive. Because pulegone produces both sensory irritation and post-ingestive distress, it has potential for seed treatment and other bird deterrent applications. Published by Elsevier Science Ltd.

Keywords: bird repellent; blackbirds; pulegone; rice

Bird depredation in newly seeded rice is a serious problem for many growers in Louisiana, Texas, and other parts of the southeastern United States. Although regionwide quantification of economic loss has not been attempted, conservative estimates suggest over $8 million annual damage is caused in newly planted rice in Texas (Decker, Avery and Way, 1990) and Louisiana (Wilson *et al.*, 1989).

Various approaches are possible to reduce the impact of birds in newly planted rice. Lethal baiting of blackbirds at staging areas associated with winter roosts has proved effective in reducing populations (Glahn and Wilson, 1992), but no direct relationship has been established between reducing winter roost populations and reduced damage to rice. Delaying planting until mid-April, when most wintering blackbirds have migrated, can reduce losses (Wilson *et al.*, 1989), but later spring planting results in later harvest and compromises growers' ability to obtain a second, or ratoon, crop. A successful ratoon crop often determines whether the year's rice production will be profitable or not (Helton, 1995). Furthermore, because individual growers often plant several fields of rice, it is not possible to delay planting in all fields.

Bird deterrent seed treatments can protect newly seeded rice from bird damage (Holler *et al.*, 1982). Although a number of potentially useful materials have been identified (Avery and Decker, 1992; Avery, Decker and Fischer, 1994; Avery *et al.*, 1995) none is currently registered with the U.S. Environmental Protection Agency as a rice seed treatment.

Pulegone is a naturally occurring compound derived from oil of pennyroyal mint species *Mentha pulegium*, *M. longifolia* and *Hedeoma pulegioides* (Guenther, 1949). The bird deterrent property of pulegone was identified by Mason (1990) who found it to be several times more repellent to European starlings (*Sturnus vulgaris*) than methyl anthranilate (MA), a more well-studied compound that is an effective bird repellent in some situations. Pulegone was also repellent to northern bobwhites (*Colinus virginianus*) in captive feeding trials (Mastrota and Mench, 1995).

In this study, we investigated the relative deterrence of MA, pulegone and pennyroyal oil applied to rice seed. We chose MA as a standard because bird response to it has been well-documented in feeding trials. Our objectives were to (1) compare avian repellency of pulegone and MA applied to rice seed; (2) evaluate interspecific responses to pulegone applied to rice seed; and (3) compare pulegone repellency to that of pennyroyal oil from which pulegone is obtained.

Materials and methods

Test subjects

We captured birds in decoy traps in Alachua County, Florida and housed them by species in communal cages (1.2 × 1.2 × 1.7 m) in a roofed outdoor aviary 2–6 months prior to testing. The feeding trials occurred during November–December, 1994 and March–April, 1995. Birds had free access to water and maintenance food, F-R-M Game Bird Starter (Flint River Mills, Bainbridge, GA, USA). Each bird was banded and released following the study.

Seed treatment

We prepared rice seed in 700 g batches by stirring the rice in a stainless steel container while gradually pouring the chemical treatment. Because MA (99%

*To whom correspondence should be addressed purity, Aldrich Chemical Co., Milwaukee, WI, USA), pulegone (85% purity, Aldrich Chemical Co.) and pennyroyal oil (International Flavors and Fragrances, Inc., New York, NY, USA) are not water-soluble, we mixed them with propylene glycol prior to treating the rice. We applied a total of 15 ml of liquid to 700 g of rice, so the actual amount of propylene glycol used varied with the treatment rate. Rice for the 0% control group was treated with 15 ml of propylene glycol only. After mixing, the rice was air-dried under a fume hood for 3–4 hours and then stored in airtight jars until used.

Two-cup trial, red-winged blackbirds

Red-winged blackbirds were randomly assigned to individual cages (45 × 45 × 45 cm) and to eight-bird treatment groups 5 days prior to the 4-day trial. We tested pulegone and pennyroyal oil at 0.1, 0.5 and 1.0% (g chemical/g rice) and MA at 0.5% (g/g). There was also a control (0%) group. At 07.00 hours on each test day, we removed the birds' maintenance food, and at 08.00 hours presented each bird with two clear plastic cups each holding 25 g of unhulled rice. Prior to the first test day, we randomly assigned one cup to hold the treated seed, and then alternated the position of the treated and untreated cup daily. Aluminum pans placed below each cage caught spillage. We removed test cups at 11.00 hours and replaced the birds' maintenance food.

We evaluated rice seed consumption among treatments (8), days (4), and cups (2) in a three-way analysis of variance (ANOVA) with repeated measures on days and cups. We used Tukey's HSD test (Steel and Torrie, 1980) to isolate differences ($P < 0.05$) among means.

One-cup trial, red-winged blackbirds

We randomly assigned six red-winged blackbirds to each of seven treatments: 0.1, 0.5 or 1.0 (g/g) pulegone; 0.1, 0.5 or 1.0 pennyroyal oil; or rice seed treated with propylene glycol only. We housed birds in individual test cages 5 days prior to the start of the trial which consisted of one pretreatment and four treatment days. At 07.00 hours on the pretreatment day, we removed maintenance food and at 08.00 hours presented each bird with a clear plastic cup holding 25 g of unhulled rice. At 11.00 hours, we removed the test cups and spillage pans and returned maintenance food to each cage. We repeated this procedure on each of the next 4 days except that the test food cups held treated rice.

We evaluated rice consumption among the treatment groups in a two-way ANOVA with repeated measures across days. We applied Tukey's HSD test (Steel and Torrie, 1980) to isolate differences ($P < 0.05$) among means.

Interspecific comparison of pulegone repellency

We randomly assigned three female boat-tailed grackles and three brown-headed cowbirds (sexes combined) to receive rice seed treated with 0, 0.1, 0.5 or 1.0% (g/g) pulegone. We placed birds in test cages 5 days before the start of the trial and conducted this one-cup trial identically to that with the red-winged blackbirds. We evaluated rice consumption per gram of body mass in a three-way ANOVA with treatment and species as independent factors and repeated measures on days. To facilitate comparisons among the three species and control for body mass differences, we divided each treatment group's mean consumption on each test day by the mean consumption on the single pretreatment day. We then analyzed the resulting ratios in a one-way ANOVA within each treatment level for differences in species' response to pulegone.

Videotaped behavior

We videotaped selected individuals in one-cup trials with pulegone to provide behavioral information in support of consumption data. We taped a different red-winged blackbird on each of day 1 (1% group), day 2 (1% group), and day 3 (0.5% group). We taped one grackle (1% group) on days 1 and 2 and another on days 3 and 4. For taping, we chose birds with high consumption on the previous day.

Results

Two-cup trial, red-winged blackbirds

Rice consumption did not differ among treatment groups ($P = 0.629$), but cup ($P < 0.001$) and day ($P < 0.001$) each affected consumption of rice seed. Consumption from untreated cups ($\bar{x} = 2.31$ g cup^{-1}, SE = 0.08) exceeded ($P < 0.05$) that from treated cups ($\bar{x} = 0.44$ g cup^{-1}, SE = 0.05). Total consumption was greatest ($P < 0.05$) on day 3 ($\bar{x} = 1.56$ g cup^{-1}, SE = 0.14) and least on day 4 ($\bar{x} = 1.22$ g cup^{-1}, SE = 0.11).

A significant cup x treatment interaction ($P < 0.001$) reflected that consumption of untreated rice exceeded ($P < 0.05$) that of treated rice at each pulegone and pennyroyal level, but was equal between cups in the MA and control groups (*Figure 1*). Consumption of treated rice in the MA group exceeded ($P < 0.05$) that of the 0.5 and 1.0% pulegone and pennyroyal oil groups. A significant three-way interaction ($P = 0.004$) reflected that consumption of untreated rice exceeded that of treated rice in each pulegone and pennyroyal

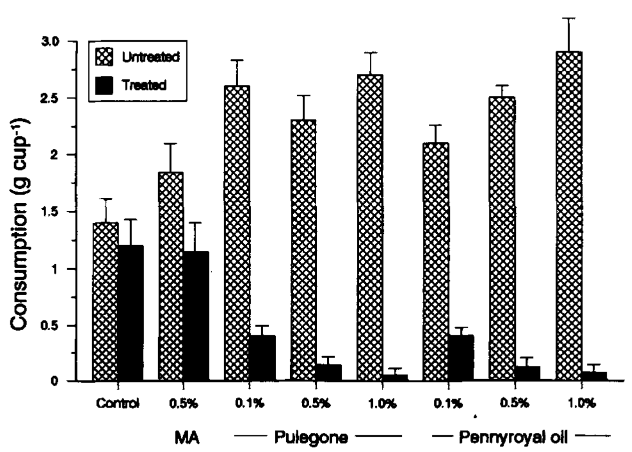

Figure 1. Mean daily consumption by individually caged male red-winged blackbirds of untreated rice and rice treated with methyl anthranilate (MA), pulegone or pennyroyal oil. Each bird received two cups of seed for 3 hours on four consecutive mornings. Capped bars indicate 1 SE

group on each day, but this pattern did not hold in the MA and control groups.

One-cup trial, red-winged blackbirds

Rice consumption varied among groups. Daily consumption by the control group exceeded ($P < 0.05$) all others except the 0.1% pennyroyal group (*Figure 2*). The 1.0% pulegone and pennyroyal groups consumed less ($P < 0.05$) than did the control and the 0.1% pennyroyal groups, but there were no differences ($P > 0.05$) among the other groups.

Interspecific comparison of pulegone repellency

Rice consumption by female boat-tailed grackles [$\bar{x}$ = 25 mg (g body mass)$^{-1}$, SE = 3.1] was equivalent ($P = 0.543$) to that of brown-headed cowbirds [$\bar{x}$ = 19 mg (g body mass)$^{-1}$, SE = 3.8]. For both species, consumption by the control group exceeded ($P < 0.001$) that of each of the pulegone treatment groups. Rice consumption differed ($P < 0.001$) among test days, being greatest on day one [$\bar{x}$ = 27 mg (g body mass)$^{-1}$, SE = 4.7] and least on day three [$\bar{x}$ = 18 mg (g body mass)$^{-1}$, SE = 4.7]. The significant interaction between treatment and test day ($P = 0.017$) reflected the decline in rice consumption across the test days in all but the control groups.

At 0% pulegone, rice consumption during the treatment period relative to pretreatment consumption did not vary ($P = 0.230$) among species (*Figure 3*). The 0.1% pulegone treatment reduced consumption more than 90% in cowbirds, whereas consumption remained substantially greater ($P < 0.001$) in red-wings and grackles. At the 1.0% treatment level, female boat-tailed grackles exhibited only an 80% reduction whereas consumption by cowbirds and red-wings was suppressed almost entirely ($P = 0.008$).

Videotaped behavior

Videotaped observations indicated that red-winged blackbirds and boat-tailed grackles were affected

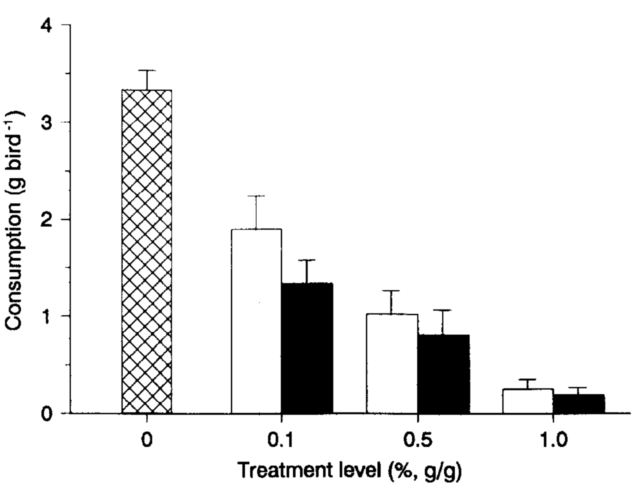

Figure 2. Mean daily consumption by individually caged male red-winged blackbirds given one cup of rice seed for 3 hours on each of four consecutive mornings. Rice was either untreated (cross-hatched) or treated with pulegone (solid bars) or pennyroyal oil (open bars) at the rate indicated. Capped bars denote 1 SE

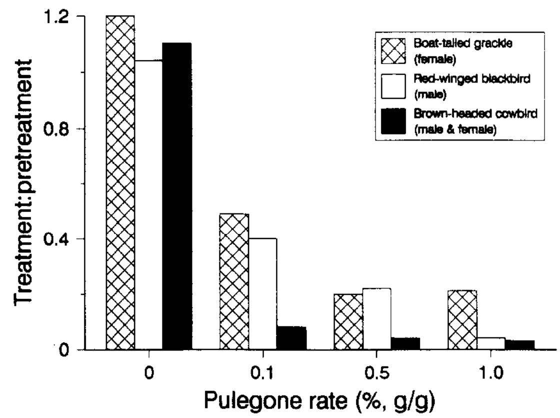

Figure 3. Ratio of mean consumption of pulegone-treated rice by three species of birds during four test days to their consumption of untreated rice during a single pretreatment session. Individually caged birds were presented with one cup of rice for 3 hours during each session.

rapidly by consuming rice treated with 1.0% pulegone. Both species exhibited feather ruffling and pronounced head-shaking. Whereas red-wings ate minimally after initial exposure, however, one boat-tailed grackle fed steadily for 10 min and then vomited 22, 23 and 47 min later. The other grackle, taped on days 3 and 4, did not exhibit overt signs of discomfort even after feeding bouts of 10 min (37 seeds), 9 min (44 seeds), and 4.2 min (32 seeds). With rice treated with 0.5% pulegone, the videotaped red-wing displayed initial sensory irritation (head-shaking) but then steadily ate treated seeds for 8 min. It then gagged but did not vomit, and continued to feed with no evident problem.

Discussion

Mason (1990) found that pulegone effectively deterred feeding by starlings at concentrations 5–10 times lower than methyl anthranilate. Using a different species, the red-winged blackbird, we have corroborated Mason's (1990) findings of the relative aversiveness of MA and pulegone. Furthermore, we showed that pennyroyal oil, the natural source of pulegone, was virtually as aversive as pulegone itself. Also, the range of pulegone repellency in three closely related species varied according to body mass. Brown-headed cowbird, the smallest species tested, was the most sensitive, whereas the least sensitive was the boat-tailed grackle, the largest species.

Videotaped observations of grackle and red-wing behavior indicate differential sensitivity to pulegone irritation. At the 1.0% pulegone treatment level, red-wings were inhibited from eating, probably due to the aversive sensory properties of pulegone, but grackles were not. One video-taped grackle vomited after eating 1.0% pulegone-treated rice. The video-taped red-wing was not deterred by aversive sensory stimuli at the 0.5% pulegone level, ate the treated seed, and became moderately sick. The illness was not sufficiently severe, however, to suppress subsequent feeding. Apparently, feeding is suppressed when the pulegone treatment is sufficient to produce sensory irritation. The levels of feeding suppression vary among species, and may be related to body mass or to differential sensory sensitivity.

Brown-headed cowbirds are very sensitive to volatiles (Clark and Mason, 1989) and their avoidance of pulegone-treated rice seed at the lowest test concentration probably reflects their sensitivity. Red-winged blackbirds are difficult to condition to olfactory stimuli in the laboratory, suggesting that perhaps they are less sensitive to volatiles than are cowbirds (L. Clark, personal communication). Only at the 1.0% pulegone treatment level was the red-wings' consumption of treated seed suppressed to levels approaching that of cowbirds.

Our findings confirm previous speculation that pulegone produces post-ingestional illness in birds (Mason, 1990). Pulegone's dual modes of action, sensory irritation and post-ingestive distress, suggest potential flexibility in its use as a bird repellent. Species such as the brown-headed cowbird that are sensitive to volatiles will be deterred at low application rates because of direct sensory (olfaction, trigeminal, taste) effects. In species less sensitive to direct sensory stimulation, such as the boat-tailed grackle, feeding suppression might be achieved through post-ingestive effects.

Pulegone is the primary constituent of pennyroyal oil (Guenther, 1949). In the pennyroyal oil we tested, there was approximately 80–90% pulegone (T. Primus, Denver Wildl. Res. Center, personal communication). The level of feeding deterrence obtained with pennyroyal oil was approximately 75% that of pulegone, and we attribute that to the pulegone in the oil. Pulegone costs approximately 10 times more than methyl anthranilate. Thus, although pulegone suppresses food consumption at much lower levels than does MA, it is not clear that pulegone is more cost-effective. Pennyroyal oil, however, is 2–3 times less expensive than pulegone (W. Schreiber, Int. Flavors and Fragrances, New York, personal communication) which should make it more cost-effective than MA and other candidate feeding deterrents such as methyl cinnamate (Avery and Decker, 1992) and cinnamamide (Watkins *et al.*, 1995). Furthermore, the inclusion of mint oil and peppermint oil on the list of compounds proposed by the US E.P.A. for exemption from requirements of the Federal Insecticide, Fungicide and Rodenticide Act could facilitate the availability of pennyroyal oil for use as a nonlethal avian feeding deterrent.

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References

Avery, M. L. and Decker, D. G. (1992) Repellency of cinnamic acid esters to captive red-winged blackbirds. *J. Wildl. Manage.* **56**, 800–805

Avery, M. L., Decker, D. G. and Fischer, D. L. (1994) Cage and flight pen evaluation of avian repellency and hazard associated with imidacloprid-treated rice seed. *Crop Prot.* **13**, 535–540

Avery, M. L., Decker, D. G., Humphrey, J. S., Aronov, E., Linscombe, S. D. and Way, M. O. (1995) Methyl anthranilate as a rice seed treatment to deter birds. *J. Wildl. Manage.* **59**, 50–56

Clark, L. and Mason, J. R. (1989) Sensitivity of brown-headed cowbirds to volatiles. *Condor* **91**, 922–932

Decker, D. G., Avery, M. L. and Way, M. O. (1990) Reducing red-winged blackbird damage to newly planted rice with a nontoxic clay-based seed coating. *Proc. Vertebr. Pest Conf.* **14**, 327–331

Glahn, J. F. and Wilson, E. A. (1992) Effectiveness of DRC-1339 baiting for reducing blackbird damage to sprouting rice. *Proc. East. Wildl. Damage Control Conf.* **5**, 117–123

Guenther, E. (1949) *The Essential Oils.* Vol. 3. R. E. Krieger Publ. Co., Huntington, NY

Helton, T. L. (1955) Rice farming healthy but trade worries persist. *Rice J.* **98**, 27–28

Holler, N. R., Naquin, H. P., Lefebvre, P. W., Otis, D. L. and Cunningham, D. J. (1982) Mesurol (R) for protecting sprouting rice from blackbird damage in Louisiana. *Wildl. Soc. Bull.* **10**, 165–170

Mason, J. R. (1990) Evaluation of d-pulegone as an avian repellent. *J. Wildl. Manage.* **54**, 130–135

Mastrota, F. N. and Mench, J. A. (1995) Evaluation of taste repellents with northern bobwhites for deterring ingestion of granular pesticides. *Environ. Toxicol. Chem.* **14**, 631–637

Steel, R. G. D. and Torrie, J. H. (1980) *Principles and Procedures of Statistics*, 2nd ed. McGraw-Hill Book Co., New York, 633 pp

Watkins, R. W., Gill, E. L. and Bishop, J. D. (1995) Evaluation of cinnamamide as an avian repellent: determination of a dose–response curve. *Pestic. Sci.* **44**, 335–340

Wilson, E. A., LeBoeuf, E. A., Weaver, K. M. and LeBlanc, D. L. (1989) Delayed seeding for reducing blackbird damage to sprouting rice in southwestern Louisiana. *Wild. Soc. Bull.* **17**, 165–171

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