REP 1983-177

MODE OF REPELLENT ACTIVITY OF CONDENSED TANNIN TO QUELEA

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INTRODUCTION

Nonlethal chemical repellents are being vigorously investigated to control wildlife feeding in agriculture and silviculture and thus alleviate damages to food, feed, and fibre. Unfortunately, few effective avian repellents have emerged, partly because workers tend to be anthropomorphic in their basic assumptions about target species and repellent action (Rogers, 1978), and partly due to the lack of knowledge of the feeding behavior of the target species (McKey, 1974). Rogers (1978) advocated natural chemical defenses of plants against herbivores as starting points for studies dealing with repellent development.

Rogers (1978) defined repellents as a "compound or combination of compounds that, when added to a food source, acts through the taste system to produce a marked decrease in the utilization of that food by the target species." He separated repellents into primary repellents, where the animal reacts to the taste of the repellent alone, and secondary repellents, where the animal uses the taste of the repellent as a cue to other later physiological adverse effects. Most of the successful repellents have been secondary repellents (Bullard et al., 1983a,b), but few investigators have looked at the reasons behind the ineffectiveness of primary repellents in topical applications.

Condensed tannins, which would classify as primary repellents, are the active ingredient in bird-resistant sorghums (Harris, 1969; Tipton et al., 1970; McMillian et al., 1972). These compounds are found in a wide variety of plants (Haslam, 1979) and elicit their herbivore, antifeedant activity primarily through an astringent tactile stimulus (Bate-Smith, 1972; Arnold and Hill, 1972). Astringency, a contracting or dry feeling in the mouth, is caused by precipitation of protein in saliva and on mucosal surfaces (Bullard et al., 1981).

Although the anti-herbivore characteristics of tannins are well known in intact plants, very little is known about the use of extracted tannins as topically applied avian repellents on plants. Bullard and Shumake (1979) recently began appraising tannins as repellents against red-billed quelea (*Quelea quelea*), which has set the stage for further research on their utility in bird damage control. The object of the research on which we are reporting was to determine the mode of repellent activity of wattle tannin to quelea.

METHODS AND MATERIALS

Quelea were wild-trapped in Sudan, flown to the Denver Wildlife Research Center, and held for a 90-day quarantine and acclimatization period. During this period birds were provided water, grit, and a maintenance ration mixture of whole proso millet, whole Martin X sorghum, and Purina Game Bird Startena in a 2.4 X 4.8 X 2.1-m aviary. The birds were then transferred to 53 X 51 X 41-cm communal cages, where they were gradually adapted to the test foods over a one-week period before the individual cage testing.

After food adaptation, birds were transferred to individual cages where there was at least a four-day adaptation to their new quarters before testing. Two quelea were placed in a double (44 X 25 X 20-cm) cage that had been divided by wire mesh (one bird on each side of the divider). Quelea, a gregarious bird, appears to exhibit less stress when caged next to each other (Bullard and Shumake, 1979).

In all preference tests, the position of food cups was alternated daily to eliminate any position bias. Spillage was collected by means of boxes placed under the cages and was accounted for in food consumption calculations. Daily food consumption from the control and treated food was recorded for each bird. Repellency was expressed in terms of the percent by weight that the treated food made up of the total food consumed.

Test 1- R_{50} Determination by Less Preferred Alternate Food Method

This two-choice test was designed to find the concentration of wattle tannin that when coated on a preferred food would cause the bird to choose a lesser preferred untreated food. In field situations quelea have choices between foods of varying preference to them. The method we used was a modified version of Starr et al. (1964) to determine the R_{50} value that would repel quelea from a preferred food and to estimate the concentration of wattle tannin needed in field tests.

Seven groups of five individually caged birds were tested. Each bird was offered 5 g of hulled proso millet and 5 g of sorghum in separate food cups. Consumption of each grain was recorded for four days. Birds consuming more than 60% of the mean millet consumption and less than 10% of the mean sorghum consumption were retained for further testing.

From this last group, five birds were treated at each of five geometrically spaced dosage levels: 0.4, 0.52, 0.68, 0.88, and 1.14% wattle tannin. The test progressed for four days, during which time each group of birds was offered a choice between proso millet treated at one of the five dosage levels and untreated sorghum. A bird was considered to be repelled if more than 60% of the total amount of food eaten during the four days was untreated sorghum. The resulting data were analyzed by the method of Thompson and Weil (1952) for an R_{50} value and 95% confidence limits.

Results and discussion - Twenty percent of the birds were repelled at the 0.4% level of wattle tannin, and 80% at the 1.14% level (Table 1). An R_{50} value of 0.65% was calculated which when compared with a 0.0015 R_{50} for methiocarb [3,5-dimethyl-4(methylthio)phenol methylcarbamate] (Garrison, 1976), indicates methiocarb, a secondary repellent, to be far more effective.

This difference in quelea sensitivity points to the different modes of action of primary and secondary repellents. Obviously, the quelea responses to the postingestional effects of methiocarb were more pronounced than those to the chemosensory effects of wattle tannin. Although animals initially respond to the flavor constituents of food (Arnold and Hill, 1972; Rohan, 1972), they are more sensitive to the nutritional and toxicological consequences of their ingestion (Jacobs et al., 1978).

Test 2 - Repellent Effects with Varying Alternate Food

Test 2 was designed to examine the response of quelea to a wattle-tannin treatment in the presence and absence of an alternate reference food, specifically (1) how does the affected bird modify its feeding behavior in response to the treatment, and (2) do results from this and the previous test allow prediction of the performance of tannin under field conditions?

A test was designed that enabled assessing the pretest food consumption rates and comparing quelea preference for the treated food presented alone and in combination with an untreated food. Ten individually caged quelea birds were pretested for four days with untreated proso millet and then given a choice between untreated proso millet and 0.2% wattle tannin-coated millet for four consecutive days. This test was followed by another four-day test, when the birds were exposed to the 0.2% wattle-tannin treatment without untreated food.

Results and discussion - The feeding responses of this group of quelea before and during exposure to wattle tannin are shown in Figure 1. The influence of the preference test conditions on the bird response to the treatment was obvious. When an equally palatable alternative to the treated food was available, 0.2% wattle tannin conferred high protection to the treated food (Figure 1, curve-3). The latter was consumed at rates significantly less ($P < 0.01$) than preexposure consumption rates.

When no alternative food was available, the same birds readily ate the 0.2% wattle-tannin treatment (Figure 1, curve-2). The birds consumed the treated food at rates not significantly different from preexposure rates ($P > 0.05$).

To further highlight the influence that availability and nature of the alternative food might have on the preference response of quelea, we compared data from this test with the repellency data established in an earlier study (Bullard et al., 1983a; Figure 2). In the treated millet vs. untreated millet test (Figure 2-A), 0.2% wattle tannin produced a significant and consistent change in quelea feeding preference.

In contrast, when the treated food (millet) was offered with a less preferred food (sorghum grains), much higher wattle-tannin treatment levels (>0.6%) were required (Figure 2-C). Below 0.6% concentration the birds established weak and reversible preferential trends (Figure 2-B). Although differences in consumption were not significant ($P > 0.05$), the birds that initially avoided the tannin-treated millet readily consumed it. Therefore, under these conditions, over three times as much repellent is needed for the same effect when equally palatable alternate food is available. Apparently, birds that prefer millet over sorghum will tolerate a fairly high level of astringency rather than switch foods. In view of these results, it seems that wattle tannin is labile in terms of repellent activity.

Rogers (1978) believed that the only successful repellents are those that mediate their effects by means of the conditioned aversion route. Freeland and Janzen (1974) stated that food rejection is strongly linked to its postingestional consequences and the ability of the animal to form associative cues. Similarly, Alcock (1970) stated that punishing (emetic) prey were more highly protected from attack by predators than those which were merely distasteful, and hypothesized that in periods of limited food, distasteful prey could be exploited as a food source.

CONCLUSIONS

An astringent primary repellent, wattle tannin, conferred significant repellency to millet at 0.2% concentration when an equally preferred alternate food (untreated millet) was available. When no alternate food was available, birds readily consumed millet coated at that concentration. When a less preferred alternate food was available, over three times that concentration was required for repellency.

Because wattle tannin is not a conditioning repellent, satisfactory protection of the treated food source is highly unlikely under conditions when alternative food is unacceptable or scarce. When surface-coated formulations are extrapolated to the field (Elmahdi et al., in prep.) a 91 kg/ha application would be required to protect the crop. The potential for protection is somewhat better when an acceptable alternative food source is available. In this situation a 28 kg/ha (~0.2%) application should provide protection. Both treatment levels are too high, meaning the primary repellent wattle tannin is not effective at acceptable field levels.

ACKNOWLEDGEMENTS

We thank C. P. Breidenstein for statistical assistance. The research was conducted primarily with funds provided to the U.S. Fish and Wildlife Service by the Agency for International Development under PASA ID/TAB-473-1-67 "Control of Vertebrate Pests."

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TABLE 1. Repellency[1] response to wattle-tannin-treated millet vs untreated Martin X sorghum by *Quelea quelea* which prefer millet.[2]

Dosage level (%)	No. of birds	Total food consumed (g)		Percent millet preference Mean ± SD	Percentage of birds repelled
		Millet	Sorghum		
0.4	5	37.9	26.1	59.2 ± 16.4	20
0.52	5	30.2	33.9	47.1 ± 10.6	40
0.68	5	23.9	37.9	38.7 ± 5.9	60
0.89	5	24.9	40.9	37.5 ± 7.8	60
1.14	5	22.5	41.0	35.4 ± 8.3	80

[1]The percent preference is the percent by weight that treated millet seeds made up of the total millet plus sorghum seeds consumed (treated millet consumed ± control sorghum consumed = 100 percent).

[2]Birds that consumed 60% or more untreated millet in a four-day pretest against untreated sorghum.

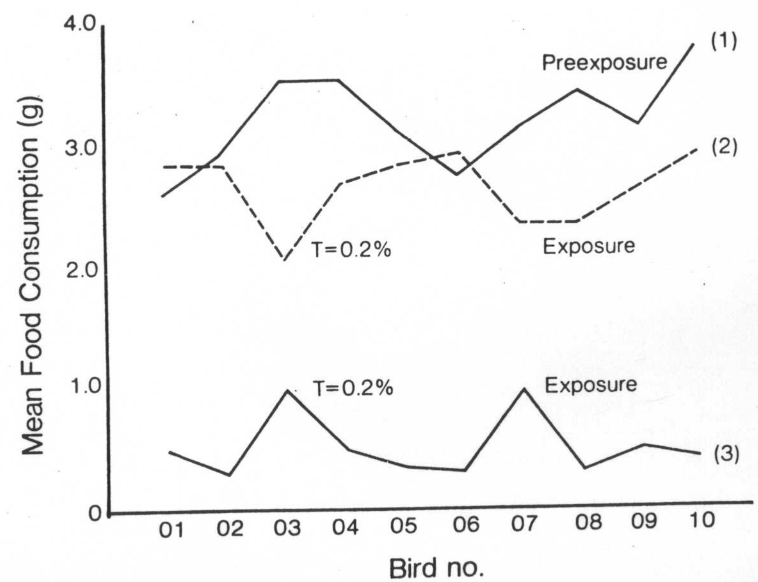

FIGURE 1. Feeding responses of quelea before and during a four-day exposure to wattle-tannin-treated millet presented in the absence (curve-2) and presence (curve-3) of untreated food (millet). "T" represents the dosage level of wattle tannin. Curves 2 and 3 represent the amounts of treated millet consumed.

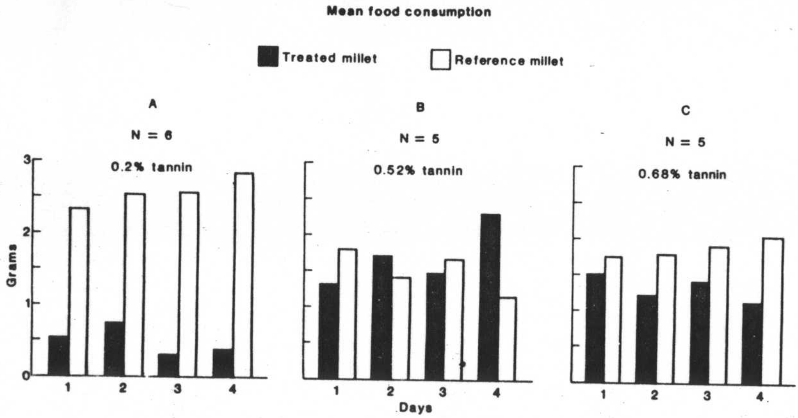

FIGURE 2. **Feeding responses of quelea to wattle tannin at different treatment levels, challenged with different reference foods. "A" refers to data recorded for Test 2. "B" and "C" refer to data recorded for Test 1. "N" represents the number of birds per test.**