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Calcium carbonate enhancement of methiocarb repellency for quelea

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Abstract. Methiocarb causes illness when present in food below levels at which it can be detected by some birds. Thus, sensory cues added to food have been used as repellent enhancers. Because white contrasts with most plant colours, various calcium carbonate ($CaCO_3$) combinations were experimentally surface-coated on to wheat, rice, white sorghum or red sorghum. In paired preference tests, quelea, *Quelea quelea* L., consumed more control than treated (2% $CaCO_3$ + 0·05% methiocarb) for all four grains. However, $CaCO_3$ alone was not repellent. Most importantly, birds that had been conditioned to avoid the methiocarb-cue treatment avoided 2% calcium carbonate treatments on all four cereal grains. In concentration tests, 0·008% (~1·12 kg/ha) methiocarb and 0·32% (~44·8 kg/ha) $CaCO_3$ were the lowest levels affecting repellency. The enhancement properties of $CaCO_3$ as a visual cue were illustrated in that concentrations of 0·32% and above were repellent whereas those below were not.

Introduction

Bird depredations on agricultural crops are not new but they are increasingly in conflict with man's interests. Especially serious are the losses to graminivorous weaver-birds in the subSaharan region of the African continent. Losses in East Africa alone exceed US$15 M annually (Elliot and Beesley, 1979; Kitonyo and Allan, 1979; Bruggers, 1980). Most of this damage is caused by the red-billed quelea, *Quelea quelea*, which has been known to attack fields of sorghum and millet in the drier parts of Africa since time immemorial (Ward, 1973).

Hundreds of millions of birds have been killed by various means (toxicants, explosives, etc.) during the past three decades without reducing quelea populations to tolerable levels (Fumilayo and Akande, 1979). The high cost, possible contamination, and low success of such activities has led some to question their continuation (Ward, 1973) and to consider a more ecological approach (Jackson and Park, 1973). The goal became one of crop protection rather than simple reduction of pest populations (Fumilayo and Akande, 1979; Ward, 1979).

Chemical repellents have been considered to be a reasonable alternative. Repellents have been defined by Rogers (1978) as compounds or a combination of compounds that, when added to a food source, act through the taste system to produce a marked decrease in the utilization of that food by the target species. They can be either primary, in which an animal responds to the taste of the chemical, or secondary (conditioned aversion), in which taste of the repellent is associated with adverse post-ingestional effects (Rogers, 1978). In both situations the treated crop is avoided, however, secondary repellents are currently considered to be more reliable (Bullard *et al.*, 1983). The chemical methiocarb (3,5-dimethyl-4-(methylthio)phenol methylcarbamate—Mesurol®) has proven to be an effective, nonlethal, broad-spectrum repellent to pest birds in numerous agriculture situations. In Africa, methiocarb has protected ripening wheat, rice, millet and sorghum against bird attack (De Grazio, 1974; Bruggers, 1977; Ruelle and Bruggers, 1979).

However, current field application rates for this purpose are generally higher than those for other pesticides, making the cost prohibitive for low-income farmers. Because birds have difficulty in tasting methiocarb, higher levels are used than actually needed to induce its characteristic soporific effect (Bullard *et al.*, 1983, 1984). Fortunately, studies at the Denver Wildlife Research Center have indicated that inexpensive chemicals can be added as sensory cues (tactile, visual, or olfactory) to formulations, making them effective at lower methiocarb concentrations and thus lower application costs (Bullard *et al.*, 1983; Elmahdi, 1982).

In a previous study (Bullard *et al.*, 1984) the visual cue calcium carbonate exhibited outstanding characteristics on sunflower applications. It is important that birds readily detect that a food has been treated and the colour white is more easily distinguishable from various plant pigments than any other dies or pigments tested. Calcium carbonate often serves as a pigment extender in white paints and contrasts with plants better than most other colours. Our objective was to determine the potential of calcium carbonate ($CaCO_3$) as a visual cue for quelea to associate with the post-ingestional effects of methiocarb and to develop a suitable cue-methiocarb ratio for field applications.

Materials and methods

A laboratory testing regime developed by Bullard and Shumake (1979) was followed in this study. Individually caged birds were exposed to the test substances that were surface-coated on wheat grains, and offered to the birds on a two-choice preference basis in a series of four tests.

Quelea, imported from Africa and kept indoors in a 2·4 × 4·8 × 2·1 m aviary to acclimatize them to captivity, were allowed free access to water, grit, and a maintenance ratio mixture of whole millet seeds, whole grain sorghum, and Purina game bird chow. One week before the individual caging, birds were transferred to 53 × 51 × 41 cm communal cages and were adapted gradually to the test foods. Finally, the birds were transferred to double cages (44 × 25 × 20 cm), where they were separated by a wire-mesh partition and further adapted to the untreated test foods for 4 days before initiation of the tests. During this period, their food consumption was recorded; those that had a daily consumption of 3–5 g were retained for testing.

Six naive birds (three males and three females) were used in all the tests. Each of the six birds was given 10 g each of the treated and the untreated (control) wheat daily for 6 days. The positions of food cups were alternated daily to eliminate position bias. Spillage was collected by means of boxes placed under the cages and accounted for in food consumption calculations. Daily food consumption from the control and treated food was recorded for each bird. A preference score was calculated for each bird by using the formula:

Percentage preference

$$= \frac{\text{Treated food consumed (g)}}{\text{Treated + control food consumed (g)}} \times 100$$

A mean percentage preference was calculated and used to compare different treatment levels. To make data more uniform, they were transformed by the formula $Y = \text{ARCSIN } Y/100$. The percentage preference data were treated statistically by analysis of variance (ANOVA). Preferences at the different treatment levels were compared by using the Duncan's Multiple Range Test (MRT). Comparisons between consumption of treated and control foods in individual tests were done by paired t-tests.

The test formulations were prepared by surface-coating the test substances on the cereal grains (wt/wt). This was done by mixing 1 ml of water and weighed amounts of the test compounds with 100 g of the test food in a beaker. The mixture was then air-dried and presented to the birds.

Results

Test 1. Potential of $CaCO_3$ as a colour cue

The objectives of this test were to investigate the potential of $CaCO_3$ as a colour cue and to determine if crop preference would affect repellency. A formulation containing a visually apparent level of $CaCO_3$ (2%) and a concentration of methiocarb known to be marginally repellent (0·05%) alone (Elmahdi, 1982) was chosen and surface-coated on wheat, rice, white sorghum and red sorghum.

Paired t-test results of individual tests indicated that there was a significant difference between quelea consumption of treated and control foods for each of the four crops ($P < 0{\cdot}001$). However, by ANOVA the mean preference scores among the four crops were not significantly different ($P > 0{\cdot}05$). The highest preference (least repellency) among the four test crops was for wheat (Table 1).

Test 2. Repellency of $CaCO_3$ alone on whole wheat and white sorghum

Paired preference tests were conducted on both 2% $CaCO_3$-treated wheat and white sorghum grains. Paired t-test results of individual tests indicated that there was a significant difference in the consumption of treated and nontreated wheat ($P < 0{\cdot}001$) but not white sorghum ($P > 0{\cdot}20$). The mean preference scores were 72·8 and 37·0 respectively (Table 2).

Test 3. Association of colour cue with sickness

This experiment was designed to test whether the quelea would associate the white colour of $CaCO_3$ with the 'unpleasant' experience of methiocarb-induced illness. Two per cent $CaCO_3$ was coated on the four cereal grains. After 10 days (simulating normal spray intervals) quelea used in the initial test (Table 1) were re-exposed for 2 days (a precaution against memory losses) to test materials (2% $CaCO_3$ + 0·05% methiocarb) before testing 2% $CaCO_3$ treatments only. Although the birds' intake rates of both control and treated ($CaCO_3$) food varied for the four

Table 2. Total food consumption and preference responses of quelea (N = 6) *to 2% $CaCO_3$-treated wheat and white sorghum grains*

Crop	Consumption (g) (mean + S.D.)* Control food	Treated food	P (t-test)	Percentage preference (mean ± S.D.)†
Wheat	4·53 ± 1·39	12·86 ± 1·49	<0·001	72·83 ± 9·15[a]‡
White sorghum	14·13 ± 4·48	8·78 ± 5·88	>0·20	37·00 ± 24·05[b]

* Average consumption (g) per six birds per day.

† The percentage preference is the per cent by weight that the treated food made up of the total food consumed (treated food consumed plus control food = 100%).

‡ Means followed by the same letter are not significantly different (Duncan's Multiple Range Comparisons).

Table 1. Summary of preference responses and total food consumption of quelea (N = 6) *determined in a series of two-choice preference tests on four cereal grains coated with 2% $CaCO_3$ + 0·05% methiocarb*

Crop	Consumption (g) (mean + S.D.)* Control food	Treated food	P (t-test)	Percentage preference (mean ± S.D.)†	P (two-way ANOVA)
Brown rice	19·5 ± 4·2	0·39 ± 0·18	<0·001	2·02 ± 1·05[a]‡	
Wheat	19·35 ± 3·9	0·82 ± 0·81	<0·001	4·15 ± 4·34[a]	>0·05
Red sorghum	23·9 ± 2·3	0·35 ± 0·23	<0·001	1·47 ± 1·0[a]	
White sorghum	22·1 ± 6·02	0·21 ± 0·11	<0·001	0·91 ± 0·45[a]	

* Average consumption (g) per six birds per day.

† The percentage preference is the per cent by weight that the treated food made up of the total food consumed (treated food consumed plus control food = 100%).

‡ Means followed by the same letter are not significantly different (Duncan's Multiple Range Comparisons).

Table 3. Food consumption and preference responses of quelea (N = *6) determined in a series of two-choice preference tests on four cereal grains coated with 2% $CaCO_3$. Quelea were previously exposed to 2% $CaCO_3$ + 0·05% methiocarb*

Crop	Consumption (g)* (mean + S.D.)* Control food	Treated food	*P* (*t*-test)	Percent preference (mean ± S.D.)†	*P* (two-way ANOVA)
Brown rice	18·10 ± 3·29	1·43 ± 1·45	<0·001	7·22 ± 7·07[bc]‡	
Wheat	15·82 ± 5·43	6·76 ± 3·77	<0·10	31·03 ± 18·58[a]	<0·01
Red sorghum	18·48 ± 3·94	3·24 ± 2·07	<0·01	15·04 ± 10·20[b]	
White sorghum	17·88 ± 1·85	0·36 ± 0·40	<0·001	1·82 ± 1·81[c]	

* Average consumption (g) per six birds per day.

† The percentage preference is the per cent by weight that the treated food made up of the total food consumed (treated food consumed plus control food = 100%).

‡ Means followed by the same letter are not significantly different (Duncan's Multiple Range Comparisons).

crops, *t*-test results of individual tests indicated significant differences between consumption of treated ($CaCO_3$) and control cereals (Table 3). Overall, there was a significant difference in quelea percentage preference for the $CaCO_3$ treatment among the four crops ($P < 0·01$; ANOVA). The mean percentage preferences were separated using Duncan's MRT. Preference for treated wheat (31·03) and red sorghum (15·04) were the highest and were significantly different from each other. The birds' preferences for treated brown rice (7·33) and white sorghum (1·82) were significantly different from those to treated wheat but were not significantly different from each other. Also, quelea preference response to treated rice was not significantly different from that to treated red sorghum.

Test 4. Determination of optimum methiocarb-cue formulation

According to the residue data obtained by Grass *et al.* (1981), four methiocarb levels (0·0015, 0·008, 0·016 and 0·24) were selected for this phase (A). Each of these four methiocarb levels was combined with 2% $CaCO_3$ with the objective being to find the lowest methiocarb level which, in combination with the visual cue, would confer statistically significant repellency.

The paired *t*-test results (Table 4) on this experiment indicated that the 0·0015% methiocarb level was the only one that did not induce avoidance ($P > 0·20$). Two-way ANOVA indicated a highly significant treatment effect ($P < 0·001$) for mean percentage perference over all treatments. Percentage preference decreased as methiocarb concentrations increased. Mean separation by Duncan's MRT indicated that the 0·008% methiocarb was the lowest concentration to elicit the repellent response.

In phase B, the threshold level of methiocarb from phase A was tested without cue. Percentage preference and *t*-test results (Table 4) indicated that although that level is capable of inducing conditioned aversion, that without the cue it was not effective in producing avoidance to the treated food.

Experiment C was designed to determine the efficacy threshold for $CaCO_3$ as a visual cue. Four $CaCO_3$ dose levels (0·16, 0·24, 0·32 and 0·40%) also were selected according to Grass *et al.* (1981) residue data. Each was combined with 0·008% methiocarb and surface coated on wheat grain. Quelea were then given a choice between this formulation and untreated control.

Within individual tests, paired *t*-test results (Table 4) indicated that cue enhancement of methiocarb repellency

Table 4. Food consumption and preference responses (N = *6) for various methiocarb-cue variations on whole wheat grains. Foods offered in a two-choice test for 6 days*

Experiment	Field equivalent (kg/ha)* Methiocarb	Cue	Consumption (g) (mean + S.D.)† Control food	Treated food	*P* (*t*-test)	Percentage preference (mean ± S.D.)‡
A. Methiocarb variations						
0·0015% methiocarb + 2% $CaCO_3$	0·22	280	8·74 ± 2·95	10·58 ± 3·42	0·20	54·92 ± 9·82[a]
0·008% methiocarb + 2% $CaCO_3$	1·12	280	12·17 ± 3·53	4·36 ± 1·10	<0·01	27·72 ± 10·62[b]
0·016% methiocarb + 2% $CaCO_3$	2·24	280	13·65 ± 2·63	1·70 ± 0·73	<0·001	11·27 ± 5·16[c]
0·024% methiocarb + 2% $CaCO_3$	4·48	280	16·46 ± 2.52	0·88 ± 0·34	<0·001	5·03 ± 1·62[c]
B. Threshold methiocarb alone						
0·008% methiocarb	1·12	—	5·73 ± 0·81	4·83 ± 0·91	>0·20	45·61 ± 5·66[a]
C. Cue variations						
0·008% methiocarb + 0·16% $CaCO_3$	1·12	22·4	9·58 ± 4·5	6·96 ± 3·78	>0·20	42·67 ± 20·69[b]
0·008% methiocarb + 0·24% $CaCO_3$	1·12	33·6	8·34 ± 2·29	8·19 ± 3·28	>0·20	49·16 ± 18·02[a]
0·008% methiocarb + 0·32% $CaCO_3$	1·12	44·8	11·95 ± 2·29	5·57 ± 2·27	<0·001	31·11 ± 6·55[bc]
0·008% methiocarb + 0·40% $CaCO_3$	1·12	56·0	13·25 ± 2·25	4·44 ± 2·29	<0·01	24·73 ± 10·57[c]

* Calculations conducted on basis of residue data.

† Average consumption per six birds per day.

‡ The percentage preference is the per cent by weight that the treated food made up of the total food consumed (treated food consumed + control food = 100%). Means with the same letters are not significantly different (Duncan's MRT).

($P < 0{\cdot}05$) occurred only at the 0·32% and 0·40% $CaCO_3$ levels. Two-way ANOVA gave a highly significant treatment effect ($P < 0{\cdot}001$) over all treatments for percentage preference. Percentage preference tended to decrease as $CaCO_3$ levels increased. Mean separation by Duncan's MRT and paired *t*-test results both indicated that 0·32% calcium carbonate was the lowest level at which cue enhancement of methiocarb occurred. This appears to be the efficacy threshold for both methiocarb and $CaCO_3$.

Discussion

These studies help substantiate earlier findings (Bullard *et al*., 1983) that sensory cues enhance the repellent properties of methiocarb formulations. In Test 1, with a marginally effective methiocarb level, the birds' consumption from all treated foods was negligible compared to the control beginning the first day of the test (Figure 1).

These results contrast with other reported paired preference observations involving methiocarb without a cue. For example, Rogers (1978) reported that at least two exposures are necessary for formation of a conditioned aversion in red-winged blackbirds when offered methiocarb-treated food. Also, because methiocarb has negligible taste properties, quelea usually are confused when the food cup positions are alternated and thus consume unexpected amounts of the untreated food (Bullard *et al*., 1983). Hence, it seems in these tests that the white colour of the $CaCO_3$ enabled quelea to detect methiocarb-treated food in spite of the alternation of the food cup positions.

Test 2 indicated that $CaCO_3$ itself has no taste repellency to quelea. With the lower palatability of wheat, the white cue may have influenced the increased consumption. Since $CaCO_3$ powder was removed from unconsumed treated seeds one might suspect that with this cereal the mineral qualities of $CaCO_3$ were important. With the more palatable white sorghum, food intake from the $CaCO_3$-treated seeds was much lower initially but an increased trend made consumption for the two nearly equal by the end of the test period. If the birds used in this test had previous exposure to treated white sorghum, the initial avoidance may be attributed to familiarity (Bullard and Shumake, 1979). However, during the adaptation period they had fed on nontreated red sorghum. The increased consumption during the second half (Figure 2) indicates adaptation and/or a mineral effect for $CaCO_3$.

In Test 3, when quelea, initially tested on the 2% $CaCO_3$ and 0·05% methiocarb combination, were offered a choice of grains treated with $CaCO_3$ or untreated grains 10 days later, they generally discriminated against the treated grain. This indicates that quelea can associate a visual cue with illness induced aversion. Quelea avoided the $CaCO_3$-methiocarb formulations during the 2-day exposure period indicating that this precaution may not have been necessary. This is consistent with another study conducted earlier (Shumake *et al*., 1977). Since these grains treated with $CaCO_3$ were shown in Test 2 to have no taste repellency on quelea and since the birds used in this test were

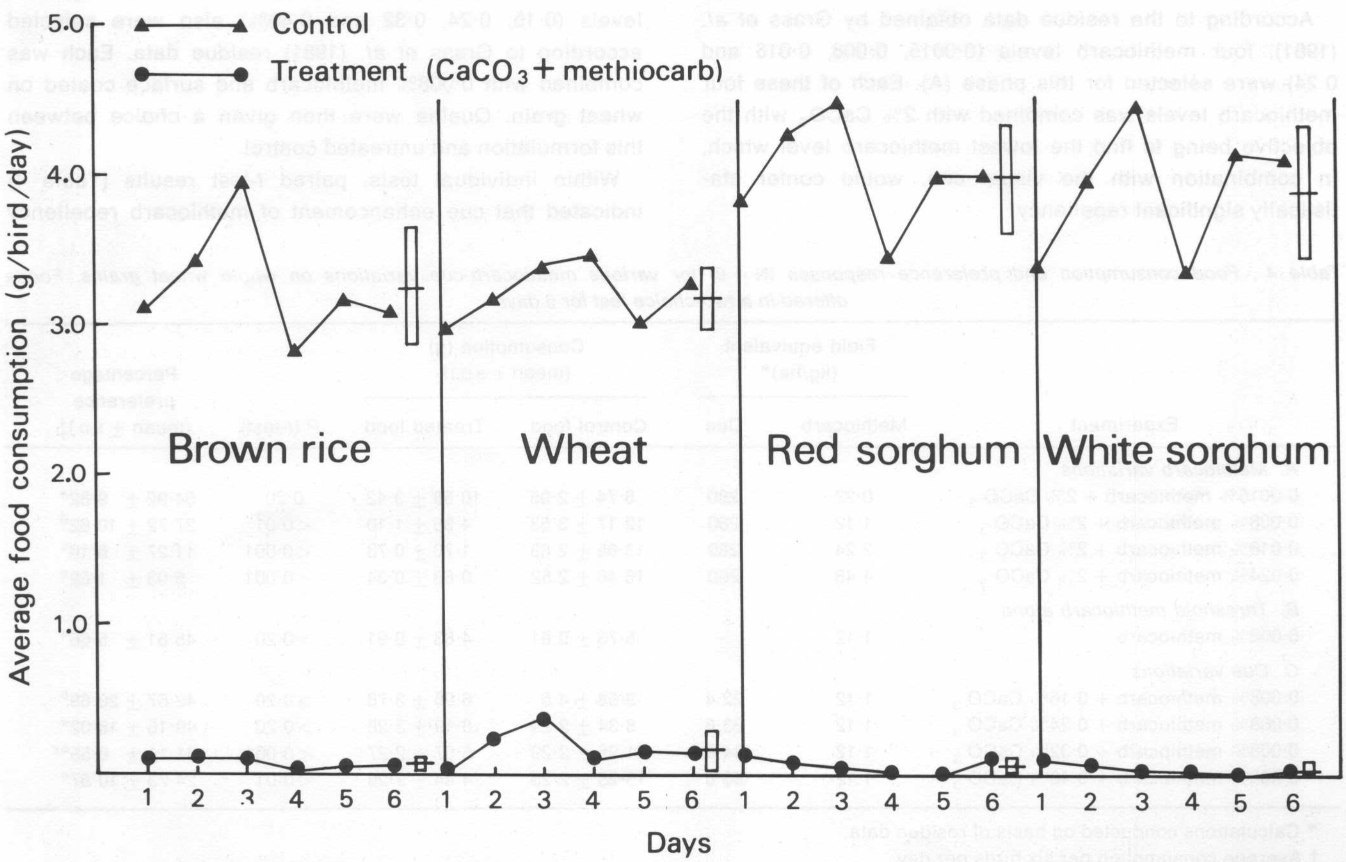

Figure 1. Food consumption during 6-day tests by four groups of quelea. Each group of six birds was presented with 2% $CaCO_3$ + 0·05% methiocarb. Rectangles (to the right of the curves) indicate 1 S.D. on each side of the mean.

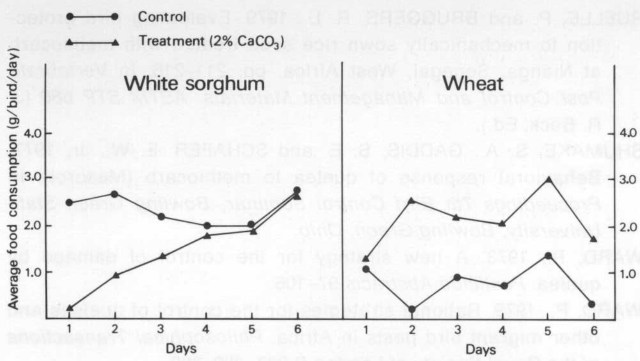

Figure 2. Average daily food consumption of quelea ($N = 6$) from control and 2% $CaCO_3$-treated wheat or white sorghum in 6-day choice tests.

previously exposed to a combination of $CaCO_3$-methiocarb treatment, it would be reasonable to assume that the birds were able to relate the white colour of $CaCO_3$ with the previous methiocarb-induced illness in all four test grains. These results were consistent with Wilcoxon *et al.* (1971) who demonstrated that quail can associate a purely visual cue with a long-delayed illness without mediation of peripheral mechanisms, such as taste.

The preferences for the four cereal grains, though less than 40%, were quite variable (Table 3). Quelea preferences for the treated rice and white sorghum were very low, approximating those of the four $CaCO_3$-methiocarb treatments in Test 1. This further indicates that the birds were visually responding from the methiocarb-induced sickness experienced in the previous exposure.

The quelea, thus, can associate a mere visual cue with a previous 'unpleasant' experience. This phenomenon, due to the current high prices of bird repellents, may have desirable economic implications. Second sprayings of the inexpensive cue-only formulation may work for a local flock of birds. Among unevenly maturing local sorghum varieties cultivated by low-income farmers, individual plants reaching the susceptible milk and dough stages can be spot-sprayed by the repellent-cue combination, while those which are relatively late in attaining this stage can be sprayed by the cue chemical only. The latter strategy can cease if and when the birds are conditioned to avoid the field.

Our efforts to determine the optimum methiocarb-cue formulation in Test 4 was probably the most informative study. These experiments helped substantiate earlier findings (Bullard *et al.*, 1983) concerning the mode-of-action of sensory cues enhancement in methiocarb formulations. In our study, 0·008% methiocarb (~1·12 kg/ha) alone was not repellent to quelea but when detectable quantities of $CaCO_3$ as visual cue was added to the formulation, avoidance became significant (Table 4). Thus, 0·009% methiocarb is a high enough level to elicit the soporofic effect, but apparently the birds are not able to detect its presence unless a sensory cue is added. Under this test paradigm where cups are rotated daily, birds apparently become confused as indicated by the consumption data (Elmahdi, 1982). Moreover, this 'confusion' response which might have been confounded by the time-delay in affectation of methiocarb (Rogers, 1974), resulted in an overall reduced food consumption.

These studies give the first published indication of the lowest levels of a methiocarb-cue formulation that would be effective. Our projection based on calculations from Grass *et al.* (1981) is that 1–12 kg/ha methiocarb plus 44·8 kg/ha $CaCO_3$ levels or higher should be effective if properly applied. We must caution from Table 4 data that this level of methiocarb and $CaCO_3$ would be about minimum.

These studies have provided further insight into the mechanism of sensory-cue enhancement of methiocarb repellency. Threshold concentrations for both methiocarb and cue in combination have also been established. It was revealed that repellent protection of cereal grain grops from birds can be cost effective. Alternate methods of application, such as direct head spraying of sorghum or millet, edge or strip treatments etc., are being studied as means of reducing application costs even further.

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References

BRUGGERS, R. L., 1977. *Summary of repellent trials in West Africa*. FAO Unpublished Report. RAF/73/055. pp. 8.

BRUGGERS, R. L., 1980. The situation of grain eating birds in Somalia. pp. 5–16. In *Proceedings of the 9th Vertebrate Pest Conference, Fresno, California* (J. P. Clark, Ed.).

BULLARD, R. W. and SHUMAKE, S. A., 1979. Two-choice preference testing of taste repellency in *Quelea quelea*. pp. 178–187. In *Vertebrate Pest Control and Management Materials, ASTM STP 680* (J. R. Beck, Ed.). American Society for Testing and Materials.

BULLARD, R. W., SCHAFER, E. W., Jr and BRUGGERS, R. L., 1984. Tests of the enhancement of avian repellent chemicals with sensory cues. *Vertebrate Pest Control and Management Materials, ASTM STP* (in press).

BULLARD, R. W., BRUGGERS, R. L. and KILBURN, S. R., 1983. Sensory cue enhancement of the bird-repellency of methiocarb. Submitted to *Crop Protection*.

DE GRAZIO, J. W., 1974. Vertebrate damage control research. *Quelea bird problems in African agriculture*. Unpublished Trip Report 11 January–25 February, Denver Wildlife Research Center. pp. 25.

ELLIOT, C. C. H. and BEESLEY, J. S., 1979. Qualitative and quantitative assessment of bird damage in Tanzania. *UNDP/FAO Proceedings 1st Technical Meeting RAF*/77042. 27–31 August 1979, Nairobi, Kenya. (Unpublished).

ELMAHDI, E. M., 1982. *Sensory cue enhancement of methiocarb repellency to the African weaver-finch* (Quelea quelea). M.S. thesis, Bowling Green State University, Ohio.

FUMILAYO, O. and AKANDE, M., 1979. Nigeria: The problem of bird pests. *Span* **22**(1), 30–32.

GRASS, G., HASSELMAN, C., PELLISIER, C. and BRUGGERS, R., 1981. Residue analysis of methiocarb applied to ripening sorghum as a bird repellent in Senegal. *Bulletin of Environmental Contamination and Toxicology* **26**, 393–400.

JACKSON, J. J. and PARK, O., 1973. The effects of fenthion on a nesting population of quelea during experimental control by aerial spraying. In *Proceedings 6th Bird Control Seminar, Bowling Green State University, Bowling Green, Ohio* **6**, 53–73.

KITONYO, F. M. and ALLAN, R. G. 1979. Quantitative and qualitative assessments of bird damage in Kenya. *1st Annual Technical Meeting of Food and Agriculture Organization/United Nations Development Programme RAF 77/042*. 27–31 August, Nairobi, Kenya. pp. 4.

ROGERS, J. G., Jr, 1974. Responses of caged red-winged blackbirds to two types of repellents. *Journal of Wildlife Management* **38**(3), 418–423.

ROGERS, J. G., Jr, 1978. Repellents to protect crops from vertebrate pests: Some consideration of their use and development. pp. 150–165. In *Flavor Chemistry of Animal Foods* (R. W. Bullard, Ed.). ACS Symposium Series (67).

RUELLE, P. and BRUGGERS, R. L., 1979. Evaluating bird protection to mechanically sown rice seed treated with methiocarb at Nianga, Senegal, West Africa. pp. 211–216. In *Vertebrate Pest Control and Management Materials. ASTM STP 680* (J. R. Beck, Ed.).

SHUMAKE, S. A., GADDIS, S. E. and SCHAFER, E. W., Jr, 1977. Behavioral response of quelea to methiocarb (Mesurol). In *Proceedings 7th Bird Control Seminar, Bowling Green State University, Bowling Green, Ohio*.

WARD, P., 1973. A new strategy for the control of damage by quelea. *Pesticide Abstracts* 97–106.

WARD, P., 1979. Rational strategies for the control of queleas and other migrant bird pests in Africa. *Philosophical Transactions of the Royal Society of London B* **287**, 289–300.

WILCOXON, H. C., DRAGOIN, W. B. and KRAL, P. A., 1971. Illness-induced aversions in rat and quail: relative salience of visual and gustatory cues. *Science* **171**, 826.