Rejection of Dyed Field Rodent Baits by Feral Pigeons and Chukar Partridges

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Whole wheat grain bait, treated with sodium fluoroacetate, is used to control field rodents in Israel. However, this bait constitutes a potential primary non-target hazard to seed-eating birds. In the present study black-, red-, green- and yellow-dyed whole wheat and sorghum grains, as well as undyed ones, were offered to feral pigeons, *Columba livia*, and to chukar partridges, *Alectoris chukar*, in the laboratory during 4 days. Grains were offered either piled on trays, or scattered. Consumption levels varied significantly ($P<0.05$) among varieties. The pigeons preferred undyed grain; black and yellow grains were consumed the least. The partridges preferred the undyed and black grains to all the other colored grains. When no undyed alternative was offered, the pigeons preferred red and green, and the partridges – black wheat. The pigeons preferred wheat whole grain, and the partridges - sorghum whole grain. When the pigeons received sorghum, a disliked grain, no significant difference ($P>0.05$) was observed in the consumption of the differently dyed grains.
KEY WORDS: Dye aversion; field rodent bait; secondary hazards; *Columba livia*; feral pigeons; *Alectoris chukar*; chukar partridges.

INTRODUCTION

The Israeli field rodents *Microtus guentheri, Meriones tristrami* and *Mus musculus* cause damage to many kinds of crops (10). They are controlled with a whole wheat bait, dyed green and treated with 0.05% sodium fluoroacetate (ROSH-80®, Jewnin-Joffe Ltd.). Moran and Keidar (11) found that a distribution rate of 1.6 to 4.0 kg bait/ha, and a manual treatment of 0.2 g per burrow opening, controlled the field rodent populations effectively. Today a distribution rate of 2.5 to 3.0 kg/ha is registered for this purpose, as well as the above rate for manual treatment.

However, the possibility of poisoning non-target animals by toxic rodent baits must be considered and investigated. In the past, contrasting findings have been reported with granivorous birds. For example, Hegdal *et al.* (5) found a few seed-eating bird carcasses after an aerial application of 0.075% sodium fluoroacetate to control California ground squirrel (*Spermophilus beecheyi*) colonies; and Shlosberg *et al.* (14) reported the poisoning of wild birds after using 0.2% fluoroacetamide green wheat bait to control field rodents. On the other hand, Miller and Anderson (9), when monitoring the bird population after the distribution of sodium fluoroacetate pellets, found no significant decline in bird numbers, while the abundance of four bird species even increased significantly.

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Colored toxic baits have been used to reduce bait consumption by birds. Kalmbach (6) found that bobwhite quails (*Colinus virginianus*) were deterred by colored food. Brilliant red was the most repulsive, more than purple and blue. Congo red, orange and Victoria green had deterrent values midway between brilliant red and purple. Aversion was greater when an abundance of naturally colored food was available. In contrast, Mastrota and Mench (8) showed that many dyes were not effective in deterring food consumption by bobwhite quails. Males showed no evidence of avoiding feed of any color. Females avoided feeds dyed red, orange, blue, and blue-green, when undyed feed was present. When only dyed feed was available, females reduced their daily feed consumption in only one of six tests. The house sparrow, *Passer domesticus*, prefers undyed food when allowed a choice (6,13); yellow and shades of green were the most effective deterrents (6). Also chukar partridges (*Alectoris chukar*) showed a marked preference for uncolored grain (Kalmbach, 1943); adult partridges did not consume colored grain after a period of more than 24 h without food.

Dyeing of field rodent baits has been a common practice to safeguard seed-eating birds in California and elsewhere since the late 1940s (7). In California, a brilliant yellow dye was applied to repel birds from sodium fluoroacetate bait (5). In New Zealand, bait used for the control of brush-tailed possum (*Trichosurus vulpecula*) was colored green to make it less attractive to birds (15). Color coating of seeds was tested for reducing the consumption by granivorous birds (13).

In Israel, colored wheat baits were used, and accidental poisoning was thereby reduced many years ago (3). In 1964, the active ingredient of toxic bait against rodents was changed from thallium sulfate to fluoroacetamide; the bait was still dyed red. Three years later, the color was changed to brilliant green in order to differentiate between fluoroacetamide and thallium sulfate baits (1). Today there is a need to re-evaluate the efficacy of these dyes to deter Israeli granivorous bird species from consuming the rodent bait. The only game bird species in Israel is the chukar partridge. This bird feeds mainly on wild and cultivated seeds (2). Therefore, there is a risk of humans hunting and eating partridges that have consumed a large amount of poisonous grains in the field. The same risk exists for the feral pigeon (*Columba livia*), which is sometimes trapped for human consumption. Both the pigeon and the partridge are seed eaters, and their foraging behavior may represent the behavior of other seed feeders. The objective of this study was to assess the ability of various dyes to reduce consumption of toxic grains by chukar partridges and feral pigeons.

MATERIALS AND METHODS

Chukar partridges bred in captivity were kept in an outdoor aviary (10×10×3 m). One-year-old birds were housed in test cages for an acclimation period of 2 weeks. Feral pigeons were raised in a cage similar to the test cage. Two weeks before the start of the experiments, four birds of each species were selected at random and transferred to two 4.3×3.5×2 m (l×w×h) cages with a roof, a concrete floor, and a back wall with concrete roosting shelves. The experimental food trays were placed in the four corners of the cage, 80–100 cm from the walls. They were checked daily, every 24 h. No food other than the tested grain was offered to the birds; water was provided *ad libitum.*

Whole wheat and sorghum grains, dyed with brilliant colors: green (C.I. Basic Green 4), red (C.I. Basic Violet 10), black (C.I. Acid Black) and yellow (P.Y. 13), or undyed, were prepared for the experiments from the same stock of grain (Jewnin-Joffe Industry Ltd., Tel

Aviv, Israel). In one of the experiments (A4), millet and oats were also tested, to determine preference for different types of the cereal.

Two different series of experiments were conducted: In Series A, pigeons and partridges were offered piles of 50–200 g wheat grain in four green plastic trays (dimensions 14×10×4 cm). After 24 h, the remaining grains were weighed, and replaced by fresh grains. Series A included four experiments with whole wheat grains. In experiment A1 the birds were offered undyed, green, black and red grains. In experiment A2 the birds were offered undyed, red, green and yellow grains. In experiment A3 all the grains were dyed (green, black, red and yellow). In experiment A4 four types of undyed grain (wheat, sorghum, millet and oats) were offered. Each experiment was conducted twice, once on pigeons and once on partridges, and lasted 4 days. Each day, the position of the trays was transposed in a Latin square sequence.

Other groups of birds were selected and acclimatized for Series B experiments. The grains were placed in cardboard egg trays, in only 15 of the 30 depressions (*i.e.*, separated by empty depressions). A mixture of four or five grains of different colors was placed in each depression. The grains were scored after 30 minutes. Two experiments were run each day: one in the morning and the other at noon. Series B included four experiments, on pigeons only. The experiments consisted of two types of grain, wheat and sorghum, and two color sets: two experiments with undyed and dyed grain, and two with dyed grain only.

The data on consumption were recorded as weight of the grain consumed (Series A), or their number (Series B). Then the data were transformed to arcsin [sqrt (consumed/offered)]. The results of Series A experiments were subjected to ANOVA for Latin square design; the factors were day, side of cage, and treatment. The results of Series B were subjected to one-way ANOVA for randomized complete blocks; the factors were day and treatment. The significance of the differences between treatments in both series was analyzed by the Student-Newman-Keuls (SNK) test at 0.05 significance level (4).

The protection level (PL) of a dye was calculated according to the formula:

$$\frac{Average\ amount\ of\ dyed\ grain\ consumed\ in\ the\ experiment}{Average\ amount\ of\ grains\ that\ are\ consumed\ most\ in\ that\ experiment} \times 100$$

RESULTS

Series A

In the three experiments with the dyed wheat (A1, A2, A3) no significant differences ($P>0.05$) were found between the days of the test or between the sides (location) of the food tray in the test cage (Table 1). When different grains (wheat, sorghum, millet, oats) were offered to the birds (Fig. 1, experiment A4), a significant difference ($P<0.05$) between days was found only when pigeons were tested (Table 1). It was a result of a difference in daily consumption of the oat grain: 9.1 g on the first day, 29.3–35.5 g on the second to fourth days. No such difference in the consumption of the partridges existed in this experiment, and no significant difference between the sides of the tray location existed for both species.

TABLE 1. Effect of day of observation, side of the tray in the cage, and color of the wheat grain, on the consumption by feral pigeons and partridges in Series A experiments. Data was subjected to ANOVA for Latin square design after being transformed to arcsin [sqrt (consumed/offered)]

Exp.	Species	Details	F-ratio (3,12 df) and significance[z]		
			Days	Sides	Color
A1	Pigeons	undyed, black, red, green	0.9 ns	0.7 ns	13.3 **
	Partridges		0.3 ns	1.0 ns	11.8 **
A2	Pigeons	undyed, red, green, yellow	1.2 ns	3.6 ns	566.5 ***
	Partridges		0.3 ns	0.5 ns	27.0 ***
A3	Pigeons	black, red, green, yellow	0.6 ns	0.8 ns	25.0 ***
	Partridges		0.9 ns	0.8 ns	6.0 *
A4	Pigeons	wheat, sorghum, millet, oats	6.0 *	4.1 ns	23.6 **
	Partridges		0.9 ns	1.1 ns	50.2 ***

[z] One-way ANOVA for randomized complete blocks. ns - no significant difference ($P>0.05$) between the variables; ***, $P<0.001$; **, $P<0.01$; *, $P<0.05$.

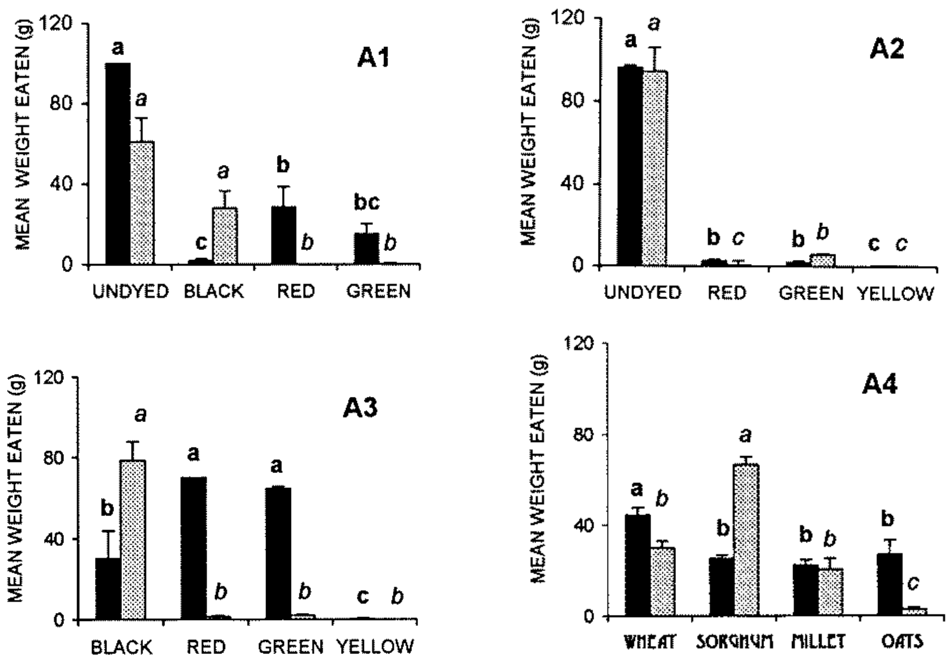

Fig. 1. Series A, Experiments A1, A2, A3: Average amount per day of dyed and undyed whole wheat grain eaten by partridges and pigeons in 4 days. A4: Average amount of different kinds of grain eaten by partridges and pigeons in 4 days. Bars represent standard errors. Means with a common letter do not differ significantly at $P=0.05$ according to the Student-Newman-Keuls test. Consumption data were transformed to arcsin [sqrt (consumed/offered)]. Black columns – pigeons; gray columns – partridges.

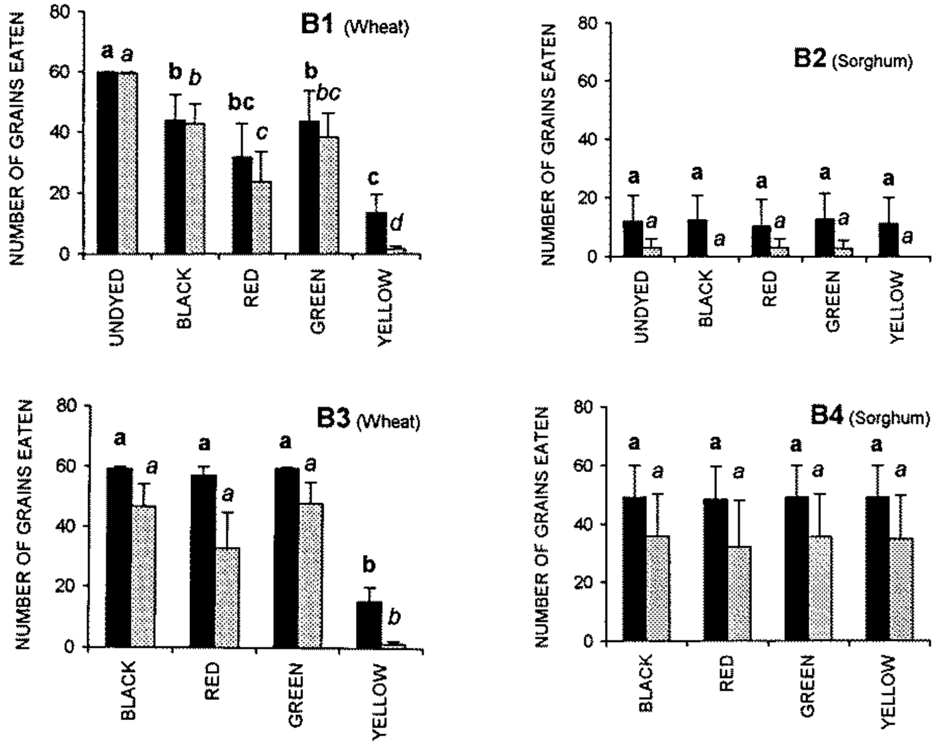

Fig. 2. Series B. Average number per day of whole wheat or sorghum grains eaten by pigeons in 4 days. In experiments B1 and B3, wheat grain; in experiments B2 and B4, sorghum grain. Bars represent standard errors. Means with a common letter do not differ at P=0.05 according to the Student-Newman-Keuls test. Consumption data were transformed to arcsin [sqrt (consumed/offered)]. Black columns – morning; gray columns – noon.

The consumption of grain as a function of its color differed significantly in all the experiments (mostly $P<0.01$) (Table 1). In experiment A1 the pigeons consumed significantly more undyed grain than any of the dyed grain; they consumed all of the former, whereas no difference existed between red and green grains, or between green- and black-dyed grains (Fig. 1). In the same experiment, with the partridges, there was no significant difference between the consumption of the undyed and the black grains. Both kinds of grain were consumed by the partridges to a significantly greater extent than the red and yellow grains, which were hardly touched. The partridges ate 0–0.1 g of the green grain per day during days 2–4, and 0–0.2 g red grain per day during the 4 days of the experiment. In experiment A2 (Fig. 1) no black-dyed grain was presented, and a tray of yellow grain was presented instead. In both bird species the consumption of the undyed grain was significantly much higher than that of the red-, green- or yellow-dyed grains, of which only negligible quantities were consumed.

In experiment A3 no undyed grain was offered to the birds (Fig. 1). The pigeons consumed significantly more of the red and the green than the black grain; the yellow grain was the least consumed: 0–1.2 g per day. All of the red grain offered was consumed. The partridges consumed significantly much greater amounts of the black grain than of the other colors. The amount of the red and green grains consumed was quite small: 0–2.9 g per day. No yellow grain at all was taken by the birds from its tray during the 4 days of experiment A3.

In experiment A4 the pigeons consumed significantly more of the wheat than of the other grains, with no significant difference among the three other types of grain. The partridges consumed significantly more of the sorghum than of the other grains, and significantly the least of oats.

Series B

In all the experiments of series B there were significant differences in the consumption between days (Table 2), in the morning as well as at noon. In experiment B1 (Fig. 2), in which wheat grain was tested, the pigeons consumed significantly more undyed than dyed grain. The results of the morning and noon feedings were similar. The undyed grain was consumed totally, in the morning as well as at noon. There was a significant reduction in the amount of the red-dyed grain consumed at noon, compared with the black grain. In the grains dyed black, green and red, consumption was less on the first day (2–23 grains), increased on the second day (23–37 grains), and was greatest on the third to fourth days (44–59 grains). The yellow dyed grain was significantly the least consumed, particularly at noontime. In the morning, the trend of daily change in consumption of the yellow grain was similar during the first 3 days only (4–29), as it was quite low on the last day (four grains). At noon, only a few (0–4) yellow grains were consumed.

TABLE 2. Effect of day of observation and color of the grain, on the consumption by feral pigeons in Series B experiments. Data were subjected to ANOVA for Latin square design after being transformed to arcsin [sqrt (consumed/offered)]

Exp.	Time	Details	F-ratio (df) and significance[z]	
			Days	Color
B1	Morning	Wheat: undyed, black, red, green, yellow	5.8 (3,12)*	12.5 (4,12) ***
	Noon		5.6 (3,12)*	32.5 (4,12)***
B2	Morning	Sorghum: undyed, black, red, green, yellow	367.4 (3,12)***	0.9 (4,12) ns
	Noon		5.1 (3,12)*	1.0 (4,12) ns
B3	Morning	Wheat: black, red, green, yellow	4.0 (3,12)*	66.8 (4,12)***
	Noon		8.4 (3,12)**	19.4 (4,12)***
B4	Morning	Sorghum: black, red, green, yellow	1132.1 (3,12)***	1.9 (4,12) ns
	Noon		467.9 (4,12) ***	1.5 (4,12) ns

[z] One-way ANOVA for randomized complete blocks. ns - no significant difference ($P>0.05$) between the variables; ***, $P<0.001$; **, $P<0.01$; *, $P<0.05$.

No significant difference between colors was found in experiment B2 (in which sorghum grain was tested) or between morning and noon. In this experiment the total amounts consumed were relatively small, compared with the other experiments. In the morning the pigeons did not eat the grains on the first 2 days. Then, on the third day of the experiment, they consumed 4–13 grains of the 60 offered. On the fourth day they consumed 36–37 grains. At noon the amounts were even smaller; they did not take black or yellow grain on any of the 4 days. The other grains – undyed, red- and green-dyed, were not taken on the first 3 days; on the fourth day they consumed 11–12 grains.

In experiment B3 yellow-dyed grain was consumed significantly less than the other dyed grains. In the morning the yellow grain consumption dropped gradually from 28 grains on the first day to six on the fourth; at noon, only 0–4 grains were eaten. No significant difference existed between the other colors (black, red and green). In most cases, the majority of the grain was consumed. In experiment B4, in which sorghum dyed grains were tested, no significant difference was found between the colors. In the morning, the amounts consumed were low on the second day (14–16 grains) and maximal on the other days of the experiment. At noon the consumption increased gradually, from nil on the first day to total consumption on the last (60 grains).

The PL was highest where the yellow dye was tested. In both species, PL was 98.2–100% in experiments A2 and A3, and 73.9–100% in the experiments of Series B (wheat only). When no yellow dye was presented, and undyed grain was offered (experiment A1), the level of protection was greater with black dye: for pigeons - 98.2%, and for partridges - 99.9%.

DISCUSSION

The merits of dyeing cereal bait were borne out in this study. Natural colored, undyed wheat was preferred by both pigeons and partridges. However, the rejection of the colors differed between the species. The efficacy of colors in repelling pigeons, when no undyed grains were offered, is ranked as follows: yellow $>$ black $>$ green $=$ red. In the case of partridges, when no undyed grain was offered, the black wheat grain was consumed.

Whereas the experimental technique of offering grain to the tested birds in hoppers, cups or dishes has been used in the past (6,8,13), it may lead to false conclusions. In the field, birds do not find cereal grains in piles, and do not choose between different colors. In field rodent control operations, the treated wheat grains, when not inserted into the burrow openings, are dispersed from an airplane or with a spreader (11). Then, two situations exist: (*a*) in cereal fields, natural-colored grains are either scattered or stored in the rodent burrows; (*b*) rodenticide-treated grains are spread in fields without competing natural-colored cereal grains (*e.g.* vegetable gardens and orchards). The birds can therefore notice the different colors of the mixed grains while foraging in the field, and pick certain colors when grains are scattered. When the wheat grain was offered to the pigeons in mixed color groups of grains (series B), the rank of rejection was yellow $>$ black $=$ green $=$ red $>$ undyed. This ranking was comparable to the results obtained in series A. For pigeons, when the less favored sorghum was offered, the color of the grain did not affect the number of grains consumed.

Clearly the yellow whole wheat grain is preferable as a bait, from the point of view of rejection. However, the use of the yellow hue, which is indistinct in comparison with undyed grain, is hazardous to both humans and livestock. More easily detectable colors must be used. Of these, black is the color most strongly rejected by pigeons, but not by partridges. The differences between these two bird species demonstrate the possibility of an interspecific variability in response to cereal bait color. This means that when one considers dyeing rodent baits for field use, one has to consider the response of the local bird species to different dyes. In Israel, because of the low repellency value of the black color to chukar partridges, only the green and red colors remain as valuable candidates for the rodent baits.

When a less preferred grain is used, such as sorghum, the deterence of the dye, would be even less. The 'rejection' from this grain may mask the phenomenon of dye rejection.

The high level of protection conferred by the yellow dye is notable. Still, one has to consider that is still only a cage test. There is no way to prevent totally the consumption of any grain. For example, in the morning the birds are hungry after the night feeding pause, and are eager to feed (as in the experiments of series B).

The variability in the consumption of the scattered grain between days may hint at aversion from a mixture of several colors, and may persist until the birds decide to pick the preferred color of grain. Because of the likelihood that piles of bait may attract seed-eating birds and create poisoning hazards, in Israel the label of the sodium fluoroacetate-treated bait (ROSH-80) states: "It is forbidden to spread ROSH-80 in piles. . . Spilled (bait) grains have to be collected..." (Israel Ministry of Agriculture License 682/90). The only legitimate method for field rodent control is to spread the bait grain (2.5–3.0 kg/ha), or to put it in burrow openings (12).

The use of green dye for sodium fluoroacetate rodent bait is reasonable. It adds to the safety of seed-eating bird species in the open field, where, in contrast to the test cages, the birds' free choice is more pronounced. Free choice may result in consumption of some of the undyed cereal grains spread in the field naturally. Only a few cases of poisoning of seed-eating birds by sodium fluoroacetate (and fluoroacetamide) bait have been reported (*e.g.* 14), although this bait has been in extensive use in Israel since 1964. In inspected incidents of bird poisoning in Israel, the poisoning was a result of misapplication (S. Moran, unpublished). When another chemical group of toxicants will be used in the field (see *e.g.* 12), there will be the option of dyeing the grain bait red and still retaining effective repellency.

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