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# The response of the Egyptian spiny mouse (*Acomys cahirinus*) and two other species of commensal rodents to anticoagulant rodenticides

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## SUMMARY

The response of *Acomys cahirinus* to three anticoagulant rodenticides was investigated in the laboratory. In contrast to the other commensal rodents *Rattus rattus* and *R. norvegicus*, this species appears to be naturally very resistant to warfarin, difenacoum and brodifacoum. It is considered unlikely that anticoagulant poisons would be effective in the field for the control of *A. cahirinus*.

## INTRODUCTION

*Acomys cahirinus* (Desmarest), the Egyptian spiny mouse, is a predominantly commensal species (Setzer, 1959) living mainly in the richly agricultural land associated with the River Nile. Although not found in the coastal zone, it is common in the delta region and up the Nile valley into the northern part of Upper Egypt, but becomes less common further south (Rifaat *et al.* 1969).

Setzer (1959) considers that *A. cahirinus* and *A. dimidiatus* are distinct species, but Ellerman & Morrison-Scott (1951) list them as subspecies. While the former is found living in houses and cultivated fields immediately adjacent to villages, *A. dimidiatus* lives among rocks on arid hillsides (Setzer, 1959).

*A. cahirinus* causes damage to stored grain, vegetables and fruit crops. There is no reliable information on the extent to which the species transmits human diseases, but it is frequently infested by endoparasites which may infect people and by ectoparasites which may transmit rodent-borne diseases to man (Abdou, 1969; Rifaat & Arafa, 1972).

As *A. cahirinus* is very commonly associated with *Rattus rattus* and *R. norvegicus* in village and urban infestations, the present study was undertaken mainly to check whether some of the anticoagulants that are normally used against these last two species could also be expected to control *A. cahirinus*. At the same time it was also desirable to confirm that the responses to anticoagulants of *R. rattus* and *R. norvegicus* were similar to those of animals caught elsewhere.

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Table 1. *Mortality and bait consumption of* Acomys cahirinus *given a sole diet of various anticoagulants in medium oatmeal bait*

| Number of days feeding | Sex | Mean body weight (g) | Mortality | Lethal dose of active ingredient (mg/kg) | | Survived dose of active ingredient (mg/kg) | | Days to death | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Mean | Range | Mean | Range | Mean | Range |
| 0·025% Warfarin | | | | | | | | | |
| 2 | M | 29 | 1/5 | 29·2 | — | 29·2 | 25·0– 32·5 | 6·0 | — |
| | F | 29 | 2/5 | 54·2 | 34·1– 74·3 | 30·5 | 28·7– 31·4 | 5·0 | — |
| 3 | M | 28 | 1/10 | 41·0 | — | 53·6 | — | 12·0 | — |
| | F | 33 | 3/10 | 44·8 | 30·1– 59·5 | 59·9 | 38·2– 75·0 | 9·3 | 7–12 |
| 4 | M | 25 | 2/5 | 63·1 | 56·0– 70·2 | 65·2 | 64·8– 65·9 | 6·5 | 6–7 |
| | F | 34 | 2/5 | 53·5 | 45·0– 61·9 | 55·6 | 37·1– 76·0 | 8·0 | 6–10 |
| 5 | M | 29 | 2/5 | 69·5 | 54·5– 84·4 | 73·5 | 67·5– 85·0 | 13·5 | 13–14 |
| | F | 32 | 4/5 | 55·6 | 25·0– 82·0 | 70·7 | — | 9·5 | 7–13 |
| 6 | M | 33 | 3/4 | 99·8 | 93·4–105·2 | 91·7 | — | 10·7 | 7–14 |
| | F | 32 | 3/5 | 65·1 | 59·6– 68·9 | 84·0 | 81·9– 86·0 | 10·7 | 9–12 |
| 7 | M | 32 | 0/5 | — | — | 106·2 | 104·2–185·3 | — | — |
| | F | 30 | 4/5 | 126·5 | 98·8–172·0 | 174·3 | — | 7·0 | 5–9 |
| 10 | M | 30 | 4/5 | 181·0 | 162·1–200·1 | 294·4 | — | 12·5 | 9–16 |
| | F | 34 | 4/5 | 124·8 | 83·1–201·9 | 228·4 | — | 6·3 | 4–10 |
| 12 | M | 30 | 14/19 | 134·4 | 39·8–291·0 | 210·4 | 142·0–309·7 | 9·5 | 6–20 |
| | F | 32 | 17/20 | 155·5 | 52·1–260·5 | 200·9 | 173·3–242·7 | 10·5 | 5–21 |
| 16 | M | 33 | 3/4 | 146·5 | 50·9–291·5 | 205·5 | — | 13·0 | 8–22 |
| | F | 34 | 4/5 | 147·6 | 43·1–274·2 | 200·8 | — | 13·0 | 5–24 |
| 18 | M | 26 | 4/5 | 193·1 | 94·4–275·5 | 295·5 | — | 16·5 | 8–29 |
| | F | 35 | 3/5 | 157·9 | 48·1–272·4 | 198·4 | 139·7–257·1 | 13·7 | 5–24 |
| 24 | M | 28 | 4/5 | 155·2 | 108·6–208·9 | 462·0 | — | 12·3 | 8–19 |
| | F | 29 | 5/5 | 252·4 | 163·9–337·1 | — | — | 17·4 | 10–25 |
| 28 | M | 29 | 3/5 | 196·2 | 175·8–208·0 | 568·3 | 525·7–610·9 | 9·7 | 8–11 |
| | F | 29 | 2/5 | 226·9 | 218·9–235·6 | 617·9 | 532·4–698·1 | 17·0 | 12–22 |
| 0·005% Difenacoum | | | | | | | | | |
| 5 | M | 40 | 3/5 | 17·9 | 10·5– 22·6 | 21·3 | 20·7– 21·8 | 10·7 | 6–15 |
| | F | 35 | 2/5 | 23·1 | 18·9– 27·2 | 19·9 | 17·6– 23·0 | 12·5 | 12–13 |
| 7 | M | 29 | 4/5 | 27·7 | 21·4– 33·4 | 30·7 | — | 7·8 | 7–10 |
| | F | 26 | 4/5 | 25·1 | 16·2– 35·4 | 41·3 | — | 8·0 | 5–10 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | M | 31 | 3/4 | 34·7 | 29·6– 43·9 | 41·8 | — | 11·3 | 9–14 |
| | F | 31 | 5/5 | 29·0 | 13·8– 43·6 | — | — | 12·0 | 4–23 |
| 10 | M | 32 | 4/5 | 38·8 | 31·9– 46·3 | 39·7 | — | 11·3 | 9–13 |
| | F | 30 | 3/4 | 36·7 | 24·1– 50·3 | 41·3 | — | 11·7 | 8–15 |
| 12 | M | 29 | 1/4 | 12·5 | — | 37·9 | 34·0– 44·4 | 8·0 | — |
| | F | 33 | 4/5 | 26·9 | 18·6– 31·4 | 33·7 | — | 16·0 | 11–21 |
| 14 | M | 23 | 5/5 | 25·7 | 9·3– 40·4 | — | — | 10.2 | 2–19 |
| | F | 26 | 2/5 | 31·8 | 23·4– 40·2 | 33·4 | 25·4– 42·3 | 14·0 | 13–15 |
| 16 | M | 29 | 2/5 | 34·6 | 18·4– 50·7 | 49·2 | 40·3– 59·2 | 12·5 | 8–17 |
| | F | 27 | 5/5 | 29·2 | 31·4– 71·1 | — | — | 15·0 | 11–24 |
| 20 | M | 25 | 8/9 | 47·7 | 16·7– 74·6 | 111·4 | — | 18·4 | 5–34 |
| | F | 29 | 9/10 | 44·0 | 17·1– 96·6 | 63·0 | — | 12·4 | 6–25 |
| 24 | M | 28 | 4/5 | 92·8 | 30·7–132·8 | 132·8 | — | 23·0 | 7–32 |
| | F | 34 | 5/5 | 58·5 | 32·8– 80·4 | — | — | 16·8 | 11–23 |
| 0·002% Brodifacoum | | | | | | | | | |
| 2 | M | 27 | 3/5 | 4·5 | 3·7– 5·1 | 4·3 | 4·2– 4·3 | 6·0 | 7–10 |
| | F | 32 | 4/5 | 4·4 | 4·0– 5·2 | 4·0 | — | 7·5 | 6–12 |
| 4 | M | 33 | 2/5 | 6·1 | 5·8– 6·3 | 5·1 | 4·1– 5·9 | 10·0 | 6–14 |
| | F | 32 | 5/5 | 5·6 | 4·9– 6·0 | — | — | 10·8 | 8–14 |
| 8 | M | 27 | 3/4 | 13·6 | 10·3– 16·1 | 11·6 | — | 17·3 | 16–18 |
| | F | 30 | 3/5 | 8·9 | 6·1– 11·7 | 10·3 | 9·6– 10·9 | 7·0 | — |
| 10 | M | 28 | 3/5 | 19·9 | 16·7– 22·0 | 16·9 | 15·1– 18·7 | 14·3 | 11–20 |
| | F | 31 | 4/5 | 6·7 | 4·6– 9·7 | 14·7 | — | 6·3 | 4–8 |
| 11 | M | 27 | 4/5 | 12·8 | 6·8– 15.6 | 18·1 | — | 12·0 | 6–17 |
| | F | 29 | 3/3 | 11·2 | 9·0– 14·8 | — | — | 10·0 | 6–15 |
| 14 | M | 23 | 4/5 | 17·8 | 5·4– 27·8 | 27·5 | — | 13·3 | 5–20 |
| | F | 24 | 4/5 | 17·7 | 7·7– 25·8 | 25·0 | — | 13·0 | 6–20 |
| 18 | M | 31 | 9/10 | 21·0 | 10·3– 41·8 | 35·4 | — | 15·6 | 6–32 |
| | F | 31 | 8/10 | 18·8 | 9·4– 32·7 | 38·6 | 32·7– 44·4 | 16·8 | 8–29 |
| 20 | M | 27 | 4/5 | 25·6 | 10·3– 39·8 | 44·8 | — | 16·3 | 12–22 |
| | F | 29 | 5/5 | 22·7 | 5·1– 35·5 | — | — | 13·6 | 7–20 |
| 22 | M | 28 | 4/5 | 30·4 | 15·6– 39·8 | 44·8 | — | 18·0 | 7–26 |
| | F | 32 | 4/5 | 17·1 | 13·2– 21·2 | 41·5 | — | 12·3 | 10–12 |
| 23 | M | 28 | 5/5 | 18·2 | 15·1– 24·3 | — | — | 8·8 | 7–10 |
| | F | 30 | 5/5 | 27·2 | 9·9– 45·3 | — | — | 20·4 | 5–39 |
| 24 | M | 28 | 4/5 | 25.2 | 16·6– 35·5 | 37·3 | — | 11·8 | 7–19 |
| | F | 27 | 4/5 | 31·1 | 21·1– 43·0 | 49·8 | — | 16·8 | 9–29 |
| 25 | M | 30 | 5/5 | 28·3 | 11·7– 52·7 | — | — | 10·6 | 6–26 |
| | F | 29 | 5/5 | 26·2 | 11·5– 45·0 | — | — | 13·8 | 7–26 |

## METHODS

The *A. cahirinus* and *R. rattus* were live-trapped in houses in Combera and Kafre Hakim, two villages approximately 10 km west of Cairo. The *R. norvegicus* were caught on a rubbish tip on the outskirts of Cairo. Animals were transferred to individual cages in the laboratory, dusted with a pyrethrin-based insecticide and fed on diet 41B (Oxoid Ltd, London) and water *ad lib*. After a minimum period of seven days, animals were weighed and sexed, and assigned to groups in preparation for feeding tests.

'No choice' feeding tests, in which poisoned bait only is presented after an initial period of feeding on the plain bait-base, were carried out. In accordance with the World Health Organization method for determining the resistance or susceptibility to anticoagulant poisons (WHO, 1976), groups of animals were exposed to poison for varying numbers of days. Daily records were made of bait consumption and mortality. At the end of the prescribed poisoning period, the animals were again maintained on diet 41B. Survivors were observed for 14 days after the withdrawal of poison.

'Choice' tests were also carried out on *A. cahirinus* to investigate the relative acceptance of anticoagulant baits and plain food.

Medium grade oatmeal was used as the bait-base in all feeding tests. Poisoned baits were prepared by mixing the required quantity of active ingredient with fine flour to give a 'master-mix' containing the poison at a concentration 20 times that of the final bait. The master-mix was then added to the bait-base at the rate of 1 part to 19, thereby giving the correct concentration of poison in the final bait.

## RESULTS AND DISCUSSION

The results of no choice tests (Table 1) demonstrate clearly that *A. cahirinus* shows very great variation in response to anticoagulants. In a 2-day test with 0·025% warfarin, one animal died after ingesting 29·2 mg/kg of poison, while in a 28-day test another survived after eating 698·1 mg/kg. Similar variation is apparent with 0·005% difenacoum and 0·002% brodifacoum, but as might be expected with these more active compounds, the range is less extreme.

Brodifacoum was the only poison to give a complete kill within the range of days chosen (23 and 25 days), although with 24 days exposure the mortality was only 80%. With warfarin only 50% died in a 28-day test, and with difenacoum 90% after 24 days feeding.

When the dose/mortality data were subjected to probit analysis, the following values for lethal feeding periods (LFP) 50 and 98 were obtained: 0·025% warfarin, 5·40 and 153·5 days; 0·005% difenacoum, 3·15 and 146·1 days; and 0·002% brodifacoum, 0·88 and 291·4 days. The heterogeneity of the data did not permit the estimation of fiducial limits.

Choice tests against plain bait (Table 2) showed that both 0·025% warfarin and 0·005% difenacoum were significantly unpalatable to *A. cahirinus* ($P = < 0·001$ in both cases). There was no significant difference ($P = > 0·2$) between the consumption of plain bait and 0·002% brodifacoum.

Table 2. *Bait consumption of* Acomys cahirinus *given a choice between poisoned and plain baits for 2 days*

| Poison and concentration | Mean body weight (g) | Mean bait intake per animal (g) | | No. of animals preferring poison | Significance (P) of Student's 't' |
|---|---|---|---|---|---|
| | | Poison | Plain | | |
| Warfarin 0·025% | 34 | 1·0 | 6·0 | 1/20 | > 0·001 |
| Difenacoum 0·005% | 32 | 1·7 | 4·1 | 2/20 | > 0·001 |
| Brodifacoum 0·002% | 31 | 1·6 | 1·4 | 10/20 | > 0·2 |

Table 3. *Results of laboratory tests in which anticoagulant rodenticides were fed to* Rattus rattus *and* R. norvegicus *caught in Cairo, with comparable data for animals caught in the U.K.*

| | No. of days feeding | Mortality | |
|---|---|---|---|
| | | Cairo | U.K. |
| *Rattus rattus* | | | |
| (*a*) 0·025% Warfarin | | | |
| | 6 | 6/10 (60%) | — |
| | 8 | 26/30 (87%) | — |
| | 10 | 30/30 (100%) | 9/12 (75%)[1] |
| (*b*) 0·005% Difenacoum | | | |
| | 3 | 29/30 (97%) | 30/30 (100%)[2] |
| | 4 | 58/59 (99%) | — |
| | 7 | 10/10 (100%) | — |
| (*c*) 0·002% Brodifacoum | | | |
| | 2 | 9/10 (90%) | 29/30 (97%)[2, 3] |
| | 3 | 20/20 (100%) | 30/30 (100%)[2] |
| *Rattus norvegicus* | | | |
| (*a*) 0·005% Warfarin | | | |
| | 1 | 12/18 (67%) | 7/26 (27%)[4] |
| | 2 | 15/19 (79%) | 23/42 (55%)[4] |
| | 3 | 17/20 (85%) | 41/43 (95%)[4] |
| | 4 | 20/20 (100%) | 22/23 (96%)[4] |
| | 5 | — | 11/11 (100%)[4] |
| (*b*) 0·005% Difenacoum | | | |
| | 2 | 9/9 (100%) | 17/20 (85%)[5] |
| (*c*) 0·002% Brodifacoum | | | |
| | 2 | 9/9 (100%) | 20/20 (100%)[3] |

[1] Bentley & Larthe (1959).
[2] Redfern & Gill (Unpublished data).
[3] Redfern, Gill & Hadler (1976).
[4] Pooled data from: (*a*) Drummond & Wilson (1968). (*b*) Greaves (unpublished data).
[5] Redfern & Gill (1978).

The failure of each of these anticoagulants to give a complete kill of *A. cahirinus* in a reasonably short time in the laboratory indicates that, at the concentrations tested, they would be ineffective for the practical control of this rodent. Furthermore, the killing of the more susceptible animals in an incompletely successful treatment might raise the level of tolerance of the population and rapidly make the poisons even less effective.

The data in Table 3 indicate that the responses to warfarin, difenacoum and

brodifacoum of *Rattus rattus* and *R. norvegicus* caught in Egypt are similar to those of animals caught in the U.K., thereby confirming that anticoagulant poisons would also be effective for these species in Egypt.

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