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Laboratory trials of seven rodenticides for use against the cotton rat (*Sigmodon hispidus*)*

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SUMMARY

The efficacy of seven rodenticides for use against *Sigmodon hispidus* was investigated in the laboratory. The poisons (warfarin, coumatetralyl, difenacoum, brodifacoum, bromadiolone, calciferol and zinc phosphide) were all toxic at the concentrations normally used against *Rattus rattus* and *R. norvegicus* and all were palatable.

Trials are now needed to confirm the efficacy of these poisons in the field, but it seems likely that, if used in suitable bait formulations, they would all be useful for the practical control of *S. hispidus*.

INTRODUCTION

Sigmodon hispidus (the cotton rat) is a rodent found from the southern United States, through Central and South America to Peru (Ellerman, 1941; Walker, 1964). Although a mainly grassland inhabitant, it also lives in open forests, cactus patches, and fresh- and salt-water marshes (Clark, 1972). It nests in shallow burrows or under logs or rocks and breeds throughout the year, but at a slower rate in winter. Population peaks occur every two to five years (Schwartz & Schwartz, 1959) and most young breed for the first time at the age of two to three months (Clark, 1972). Although mainly vegetarian, insects and carrion are also eaten (Clark, 1972). Cotton rats cause serious damage to such crops as cereals, sugar cane, cotton, vegetables and fruit (Clark, 1972; Espinoza & Rowe, 1979) and will also attack trees, palm, citrus fruit and forestry seedlings (Meanly, 1957). Other forms of damage have been recorded including burrowing in river banks leading to breaching and flooding, and predation on eggs of ground-nesting birds.

Control of *S. hispidus* is carried out by preventive measures and by poisoning. The former includes destruction of nesting sites and cover, gassing of burrows (Espinoza & Rowe, 1979) and enclosing valuable crops with open ditches and metal barriers (Ludeman, 1962).

Poisoning is accomplished by placing bait such as oats or sweet potato treated with zinc phosphide (1·5 %), thallium sulphate (0·5 %) or strychnine under grass

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Table 1. *Results of no-choice feeding tests with five anticoagulants in medium oatmeal bait*

Poison and concentration	No. of days feeding	Sex	Mean body wt (g)	Mortality	Lethal dose of active ingredient (mg/kg) Mean	Lethal dose Range	Survived dose of active ingredient (mg/kg) Mean	Survived dose Range	Days to death Mean	Days to death Range
	3	M	172	1/5	49	—	55	46–65	6·0	6
		F	164	2/5	36	32–40	40	29–55	6·0	6
Warfarin 0·025%	4	M	156	2/5	81	75–88	74	68–82	5·5	5–6
		F	150	4/5	73	61–88	79	—	6·0	5–7
	5	M	186	2/5	68	63–73	57	43–63	6·0	6
		F	149	5/5	63	34–78	—	—	6·0	5–7
	6	M	167	5/5	90	66–117	—	—	6·4	5–8
		F	160	5/5	62	45–86	—	—	5·8	4–8
	1	M	192	0/5	—	—	29	25–36	—	—
		F	148	0/5	—	—	30	21–38	—	—
	2	M	163	0/5	—	—	59	49–69	—	—
		F	152	2/5	55	49–61	58	37–80	5·0	5
Coumatetralyl 0·0375%	3	M	188	4/5	86	70–97	71	—	6·3	6–7
		F	138	4/5	95	66–107	96	—	6·0	6
	4	M	142	4/5	115	97–125	100	—	5·5	4–6
		F	122	5/5	138	121–151	—	—	6·0	6
	5	M	149	5/5	135	119–160	—	—	5·2	4–6
		F	157	5/5	122	91–156	—	—	5·2	4–6
	2	M	190	3/10	8·1	6·3–11·1	6·0	4·5–9·8	5·7	4–8
		F	150	5/10	5·9	3·6–8·4	6·4	5·0–9·1	8·6	5–13
	3	M	124	7/10	14·5	11·1–17·5	15·8	13·3–17·7	7·7	6–9
Difenacoum 0·005%		F	115	10/10	12·5	9·1–16·6	—	—	6·8	5–10
	4	M	187	10/10	12·7	4·9–23·6	—	—	6·8	5–9
		F	132	9/10	15·5	6·5–22·6	10·5	—	6·8	3–9
	5	M	151	10/10	16·8	11·7–23·0	—	—	7·6	6–12
		F	132	10/10	18·6	12·6–24·7	—	—	6·9	5–8

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Brodifacoum 0·002 %	1	M	174	8/15	1·4	1·1–1·8	1·6	1·2–1·8	6·9	4–9
		F	141	9/15	1·5	0·9–1·9	1·5	1·0–2·0	7·9	3–13
	2	M	171	12/15	3·2	1·2–4·1	2·0	1·5–2·7	7·5	5–10
		F	150	12/15	3·0	1·8–4·5	1·7	1·6–1·8	7·1	6–10
	3	M	178	10/10	4·5	2·9–5·5	—	—	7·7	5–12
		F	150	10/10	4·7	3·7–5·8	—	—	8·1	6–9
Bromadiolone 0·005 %	1	M	153	2/10	4·4	4·2–4·6	4·4	3·2–6·7	5·0	4–6
		F	133	5/10	4·6	2·4–8·6	4·0	3·0–4·6	6·2	4–8
	2	M	176	6/10	9·6	4·9–18·9	6·1	5·7–6·9	7·8	7–10
		F	142	4/10	8·3	7·7–9·7	7·9	6·2–10·3	8·5	6–12
	3	M	197	8/10	8·6	0·8–14·3	7·1	7·0–7·2	6·8	5–8
		F	151	10/10	10·1	7·7–12·0	—	—	7·8	6–9
	4	M	161	10/10	16·3	11·1–21·5	—	—	7·2	5–10
		F	138	9/10	13·1	8·8–17·7	16·1	—	6·6	5–9
	5	M	190	10/10	14·1	8·8–19·6	—	—	6·5	5–8
		F	185	10/10	15·0	6·4–19·4	—	—	5·8	4–7

cover or near burrow openings (Ludeman, 1962). Fumarin and warfarin, both in dry grain baits at a concentration of 0·025%, are used in sugar cane fields, and also an endrin bait (Collado & Ruano, 1962). Marsh & Howard (1977) state that vacor and commercial anticoagulant baits are quite effective for control although not actually registered for this species.

None of the above statements on the use or value of rodenticides in controlling *S. hispidus* seems to be based firmly on published experimental data, either from field or laboratory investigations. The present laboratory study helps to make good this deficiency. It should be noted, however, that no attempt has been made to establish the optimum concentration of the poisons tested. The study was designed simply to establish quickly whether the concentrations generally recommended for use against commensal species, and therefore often commercially available, could be expected to control *S. hispidus* in the field.

METHODS

The *S. hispidus* colony, founded from animals obtained from the London Hospital Medical School and the National Institute for Medical Research, Mill Hill, consisted of monogamous pairings. Males were left in the breeding cages throughout. Young were weaned at three weeks of age, although Meyer & Meyer (1944) state that this occurs naturally at 10 to 15 days. At weaning the sexes were separated into colony cages and maintained on diet 41B (Oxoid, Ltd, London) and water *ad lib.* A few days before a test, animals were weighed and caged individually. Feeding tests were carried out as described for *Arvicanthis niloticus* (Gill & Redfern, 1977), the method being based on the guidelines for the development and biological evaluation of rodenticides prepared by the European Plant Protection Organization (EPPO, 1975). Bait consumption was measured daily with very few exceptions. The no-choice tests followed the method of the World Health Organization for determining susceptibility levels to anticoagulant rodenticides (WHO, 1976), the animals being given poisoned bait with no alternative food for varying numbers of days.

RESULTS AND DISCUSSION

The results of the no-choice feeding tests with five anticoagulants (Table 1) show clearly that all these poisons caused complete mortality in a reasonable time. Warfarin (0·025%) is the least effective, giving a complete kill after six days feeding, with coumatetralyl (0·0375%) achieving this after five days exposure. As has been found with *R. norvegicus* (Hadler, Redfern & Rowe, 1975; Redfern, Gill & Hadler, 1976; Redfern & Gill, 1980), the more recently developed poisons difenacoum (0·005%), brodifacoum (0·002%) and bromadiolone (0·005%) are more active against *S. hispidus* than warfarin, giving complete kills after five, three and five days' feeding respectively.

The dose/mortality data obtained were examined by probit analysis (Finney,

Table 2. *Lethal feeding period values (with 95 % fiducial limits) for five anticoagulants*

Poison and concentration	LFP 50	LFP 98
Warfarin 0·025 %	3·7 (2·8–4·3)	7·4 (5·7–19·2)
Coumatetralyl 0·0375 %	2·5 (2·0–2·9)	4·5 (3·7–7·6)
Difenacoum 0·005 %	2·2 (1·7–2·5)	4·3 (3·6–6·7)
Brodifacoum 0·002 %	0·9 (0·6–1·2)	3·3 (2·4–7·1)
Bromadiolone 0·005 %	1·5 (1·1–1·8)	5·5 (4·0–10·0)

'1): the value for two lethal feeding periods (LFP) percentiles are shown in ble 2. Adopting the WHO procedure, inspection of the upper 95 % fiducial limit the LFP 98 shows that a feeding period of 20 days on 0·025 % warfarin would required to detect resistance to that poison. For difenacoum, a seven-day test ›uld be needed, and for brodifacoum and bromadiolone, eight and ten days ›pectively. Further work to expand the basic data might well reduce the dura- ›n of these tests.

Similar no-choice feeding tests were carried out with calciferol and zinc phos- ıide (Table 3). With 0·1 % calciferol, 9/10 animals were killed after one day's :posure, and 10/10 after 2 days' feeding. There was a marked drop in bait con- ₒumption after 24 h, similar to that observed with *R. norvegicus* (Greaves, Redfern & King, 1974). The two tests with zinc phosphide were both for one day only; at 3 %, 9/10 animals were killed, the survivor ingesting 94·5 mg/kg of the poison. At 4 %, a complete kill was obtained.

The results of palatability tests in which *S. hispidus* were given a choice between poisoned bait and plain bait are given in Table 4. With the exception of warfarin, all poisoned baits were taken less well than the plain food, although in no case was the difference significant. Warfarin was significantly preferred to plain bait ($P = < 0{\cdot}025$).

The study has shown that each of the seven rodenticides, at the relevant concentration and under the conditions of the test, can give a complete kill of *S. hispidus*. It therefore seems reasonable to assume that, provided they are used in a sufficiently palatable bait, they will all give good control of the cotton rat in the field. However, field trials are now needed to test this assumption and to demonstrate which poisons are the most appropriate to use under practical conditions.

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Table 3. *Results of no-choice feeding tests with calciferol and zinc phosphide*

Poison and concentration	No. of days feeding	Sex	Mean body wt (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
Calciferol 0·1 %	1	M	212	5/5	49	34–61	—	—	3·8	3–6
		F	183	4/5	40	30–52	35	—	3·0	3
	2	M	244	5/5	66	56–73	—	—	3·2	2–4
		F	160	5/5	82	51–96	—	—	3·2	3–4
Zinc phosphide 3 %	1	M	168	5/5	77	45–97	—	—	1·0	1
		F	122	4/5	186	107–252	95	—	4·0	1–10
4 %	1	M	186	5/5	160	*–185	—	—	1·8	1–3
		F	125	5/5	207	157–281	—	—	1·0	1

* One animal died after eating a quantity of bait too small to measure.

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Table 4. *Bait consumption in* S. hispidus *given a choice between poisoned and plain baits*

Poison and concentration	Duration of test (days)	Mean body weight (g)	Mean daily bait intake (g)		No. of animals preferring poison	Significance (*P*) of Student's '*t*'
			Poison	Plain		
Warfarin 0·025 %	2	185	5·8	4·3	8/10	< 0·025
Coumatetralyl 0·0375 %	2	146	4·8	5·7	3/10	> 0·2
Difenacoum 0·005 %	2	142	3·8	4·9	3/10	> 0·2
Brodifacoum 0·002 %	2	181	4·2	6·4	3/10	> 0·2
Bromadiolone 0·005 %	2	206	5·7	7·0	6/10	> 0·2
Calciferol 0·1 %	1	200	2·7	3·7	6/10	> 0·5
Zinc phosphide 4·0 %	1	143	0·2	0·9	6/10	> 0·4

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