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Laboratory tests of seven rodenticides for the control of *Mastomys natalensis**

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SUMMARY

Laboratory feeding tests were carried out to assess the efficacy of seven rodenticides against *Mastomys natalensis*. The poisons (warfarin, coumatetralyl, difenacoum, brodifacoum, bromadiolone, calciferol and zinc phosphide) were all toxic at the concentrations normally used against *Rattus norvegicus* (Berk.), although several were unpalatable. Trials are now needed to demonstrate the relative efficacy of these poisons in the field, but it is likely that, given suitable bait formulations, they would all be useful as practical control agents.

INTRODUCTION

Mastomys (*Praomys*) *natalensis* (the multimammate rat) is the most widespread rodent in Africa, being found from the southern and eastern edges of the Sahara Desert to the Cape, and to Morocco in the north-west (Coetzee, 1975). It is a nocturnal, fossorial species, nesting in the deserted burrows of other rodents in preference to digging its own. It is a good climber but not a truly arboreal species (Coetzee, 1975). Breeding takes place all the year round with an increase coinciding with an abundant food supply in the latter half of the rainy season. It is found in a range of habitats including mixed savannah and forest clearing, and is also a commensal species living in houses, food stores, cattle enclosures and cultivated fields. Although it is basically a plant-eating rodent taking grain, grass stems and rhizomes, it is also omnivorous: Taylor & Green (1976) found remains of other rodents, termites, insect larvae and frogs in stomach contents.

M. natalensis is a serious pest of agriculture and attacks various crops, especially cereals, in the field and in storage. It damages sugar cane, rice, ground nuts, and is the only rodent to attack maize cobs on vertical stems (Taylor, 1968). Cotton is eaten as the seed, and in many later stages of growth (Schmutterer, 1969), and root crops such as cassava and yams are also taken. It also barks saplings up to a height of 2·5 m when other food is scarce (Gratz & Arata, 1975): similar damage has been reported with *Cupressus* (Taylor, 1968). As well as being

* Because there is a possibility that this species may really be several with different chromosome numbers (Tranier, M. 1974. *Mammalia* **38**, 558–60), the colony was karyotyped and found to have a chromosome number of 36. Our thanks are due to Mr C. V. Beechey, Medical Research Council Radiobiology Unit, Harwell, for the karyotype determination.

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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 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
Warfarin, 0·025%	4	M	62	2/5	74	72–75	92	84–97	4·5	4–5
		F	39	3/5	79	16–122	119	110–128	4·0	3–5
	5	M	64	3/5	94	78–88	82	77–86	5·3	4–7
		F	37	2/5	131	66–197	132	107–183	6·0	4–8
	6	M	59	2/5	77	63–90	123	95–144	5·0	4–6
		F	33	4/5	145	72–186	—	165	5·8	5–7
	8	M	57	4/5	110	88–133	—	150	5·8	5–7
		F	37	2/5	166	160–172	187	161–223	7·0	6–8
	12	M	70	4/5	172	87–259	230	—	9·8	4–12
		F	39	5/5	183	132–307	—	—	9·0	5–13
	13	M	68	5/5	136	40–251	—	—	9·6	6–13
		F	45	5/5	124	72–240	—	—	7·8	6–15
Coumatetralyl, 0·0375%	4	M	57	3/5	139	117–155	127	118–136	7·0	5–9
		F	44	2/5	173	94–253	167	159–181	5·0	3–7
	6	M	58	7/7	121	92–228	—	—	5·1	3–7
		F	45	1/3	245	—	204	165–243	12·0	—
	8	M	50	5/5	198	147–238	—	—	8·8	6–13
		F	40	5/5	285	150–377	—	—	8·8	6–10

Difenacoum, 0·005%	2	M	71	3/10	6·1	3·8–8·5	8·6	5·0–10·4	7·0	2–12
		F	44	3/10	11·7	8·8–13·9	9·8	6·0–13·4	8·0	6–11
	3	M	61	5/10	13·7	12·3–15·8	14·4	7·2–22·4	8·8	6–12
		F	40	8/10	16·6	5·3–18·8	21·3	20·0–22·5	8·4	4–12
	4	M	58	9/10	19·4	9·1–24·7	20·0	—	9·0	5–14
		F	41	10/10	24·8	12·3–26·9	—	—	7·7	5–14
	5	M	64	10/10	19·5	12·1–25·0	—	—	6·5	4–10
		F	37	10/10	23·4	14·4–30·4	—	—	7·0	4–12
Brodifacoum, 0·002%	1	M	67	2/10	2·1	1·8–2·4	1·8	1·4–2·0	10·0	7–13
		F	42	5/10	1·9	0·4–3·1	2·3	1·8–2·5	7·5	7–8
	2	M	65	8/10	3·9	3·1–4·3	3·6	3·5–3·6	8·4	7–12
		F	43	10/10	5·1	3·1–8·0	—	—	7·8	6–9
	3	M	72	9/10	4·9	3·6–6·6	4·4	—	8·4	4–15
		F	40	9/10	7·7	5·6–7·9	6·6	—	7·8	6–12
	4	M	59	10/10	7·7	4·3–10·4	—	—	8·2	2–15
		F	43	10/10	10·2	6·9–12·7	—	—	9·7	6–18
Bromadiolone, 0·005%	1	M	50	7/10	5·8	4·5–8·3	4·8	2·5	8·4	4–10
		F	32	8/10	8·5	7·1–12·0	8·8	8·6–8·9	9·3	4–17
	2	M	54	9/10	14·1	10·0–17·0	11·6	—	7·4	5–11
		F	44	10/10	12·9	4·7–18·0	—	—	7·9	4–12
	3	M	59	9/10	16·2	9·0–24·4	15·4	—	9·7	7–18
		F	36	10/10	20·7	8·0–31·0	—	—	10·6	4–18
	4	M	49	10/10	22·5	13·1–31·2	—	—	9·2	5–15
		F	33	9/10	27·8	15·9–37·7	40·9	—	8·4	5–13
	5	M	62	10/10	26·5	19·9–36·9	—	—	9·4	4–13
		F	43	10/10	32·0	21·8–42·3	—	—	10·7	6–16

one of the most important reservoirs of plague in Africa, it is the reservoir host in West Africa of the arena virus causing Lassa fever, a severe febrile illness of man (Gratz & Arata, 1975). Spirochaetosis is among other diseases carried.

There is very little published work on the control of *M. natalensis*. In a comparison of the two poisons in the laboratory, Vissault & Raban (1976) found that 0·005% chlorophacinone was more active against this species than 0·025% warfarin: after 3-day feeding tests, kills of 29/30 and 8/19 were obtained respectively. Schmutterer (1969) describes poison treatments in the Sudan, especially in the dry season, where 3% zinc phosphide and warfarin in crushed dura are used: the former is laid in fields and inside burrows, and the latter in villages. Taylor (1968) reports rapid and inexpensive control measures taken against *M. natalensis* in a wheat and maize growing area near Kitale in Kenya in 1962, using warfarin and zinc phosphide in cereal bait and endrin as a toxic spray.

The present paper describes the laboratory testing of seven rodenticides against *M. natalensis*: with the exception of bromadiolone, which has not yet been registered, all the poisons are currently recommended for use in the U.K. against *R. norvegicus* and *M. musculus*.

METHODS

The *M. natalensis* were drawn from a laboratory breeding colony, originally derived from animals obtained from the Hammersmith Hospital. Young were caged individually when at least 3 months old, sexual maturity in the laboratory being reached at a little over 9 weeks (Johnston & Oliff, 1954). Whenever possible equal numbers of males and females were used in each test, and the procedures were carried out as described for *Arvicanthis niloticus* (Gill & Redfern, 1977). With very few exceptions, bait consumption was measured daily.

RESULTS AND DISCUSSION

No-choice feeding tests with five anticoagulants

Tests were carried out with warfarin and coumatetralyl, and also with three more recently developed and considerably more active anticoagulants, difenacoum and brodifacoum (Sorex (London) Ltd) and bromadiolone (Lipha, France). Groups of *M. natalensis* were fed each poison for varying numbers of days in accordance with the World Health Organization method for determining susceptibility levels of anticoagulant rodenticides (W.H.O., 1976). The dose/mortality data (Table 1) were subjected to probit analysis (Finney, 1971), and values for two 'lethal feeding period' (LFP) percentiles obtained are shown in Table 2. The LFP 50 for warfarin (4·8 days) is in rough agreement with the finding of Vissault & Raban (1976) that 8/19 died after 3 days feeding. The LFP 98 (21·3 days) indicates that, compared with *R. norvegicus*, *M. natalensis* is not very susceptible to warfarin.

As has been found with *R. norvegicus* (Hadler, Redfern & Rowe, 1975; Redfern, Gill & Hadler, 1976) difenacoum and brodifacoum were considerably more toxic

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

Poison and concentration	'LFP' 50	'LFP' 98
Warfarin, 0·025 %	4·8 (2·4–6·2)	21·3 (12·9–177·5)
Coumatetralyl, 0·0375 %	4·1 (1·9–5·0)	8·4 (6·4–50·6)
Difenacoum, 0·005 %	2·5 (2·1–2·8)	4·8 (4·0–7·0)
Brodifacoum, 0·002 %	1·9 (0·8–1·5)	3·6 (2·7–7·0)
Bromadiolone, 0·005 %	0·5 (0·9–7·2)	4·3 (2·6–56·3)

to *M. natalensis* than warfarin or coumatetralyl, giving complete kills after 5 and 4 days feeding, and with LFP 98's of 4·8 and 3·6 days respectively.

The results with bromadiolone suggest that this poison is at least as effective as difenacoum and brodifacoum against *Mastomys*. Although the LFP 50 (0·5 days) is less than that for either of the other poisons, the LFP 98 (4·3 days) is greater than that for brodifacoum.

Adopting the W.H.O. procedure, inspection of the upper 95 % fiducial limit of the LFP 98 shows that poison feeding periods of 7 days would be necessary to detect resistance to difenacoum and brodifacoum. Until more work is done, the results of the tests with warfarin and bromadiolone preclude the derivation of useful tests for the identification of resistance to these poisons.

Comparison of the range of days to death in tests where there was complete mortality in both sexes shows that warfarin (6–15) and coumatetralyl (6–13) were very similar. Despite the shorter feeding periods required with difenacoum, brodifacoum and bromadiolone, the ranges of days to death were 4–12, 2–18 and 4–16 respectively. In the difenacoum test there was a marked fall-off in food intake on day 4 in about half of those rats still alive. With brodifacoum, however, apart from the one animal that died on day 2, there was no fall-off in poison consumption. In the 5-day bromadiolone test, most animals ate less on days 4 and 5.

No-choice feeding tests with calciferol and zinc phosphide

In similar tests with calciferol and zinc phosphide (Table 3), all animals were given 2 or 3 days pre-baiting with plain bait. With calciferol at 0·1 %, complete kills of *M. natalensis* were obtained after 1 and 2 days feeding. Despite a marked reduction in food intake on the second day, similar to that found with *Arvicanthis niloticus* (Gill & Redfern, 1977) and *R. norvegicus* (Greaves, Redfern & King, 1974), all *M. natalensis* tested died between days 5 and 8.

Tests with zinc phosphide lasted for 1 day: with 3 % active ingredient 6/10 animals were killed, but with 4 % there was complete mortality. All deaths occurred within 24 h.

Palatability of rodenticide baits

The results of choice feeding tests are given in Table 4. As symptoms of poisoning would have occurred before the end of the tests in several instances, thereby affecting bait consumption, feeding figures used in the calculations are shown in parentheses.

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

Poison and concentration		No. 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
Calciferol,*	0·1%	1	M	57	5/5	96	78–107	—	—	6·6	5–8
			F	36	5/5	119	108–137	—	—	5·2	5–7
		2	M	62	5/5	109	58–196	—	—	5·4	5–6
			F	43	5/5	116	71–174	—	—	5·4	5–6
Zinc phosphide,†	3%	1	M	50	3/5	244	173–353	219	0–219	1·3	1–2
			F	34	3/5	705	555–923	441	0–441	1·3	1–2
	4%†	1	M	51	5/5	208	116–308	—	—	10	—
			F	44	5/5	?	? –558	—	—	10	—

* Pinhead oatmeal/corn-oil bait. † Dry medium oatmeal bait.

Table 4. *Bait consumption and mortality in* M. natalensis *given a choice between poisoned and plain baits*

Poison and concentration	Mean body weight (g)	Duration of tests (days)	Mean daily bait intake (g)		Significance (P) of students 't'	Mortality
			Poison	Plain		
Warfarin, 0·025%	56	4 (2)*	2·4	3·6	0·025–0·05	2/10
Coumatetralyl, 0·0375%	53	4 (2)	3·6	2·7	0·05–0·1	7/10
Difenacoum, 0·005%	50	2 (2)	3·5	1·4	< 0·001	1/10
Brodifacoum, 0·002%	38	2 (2)	2·4	2·3	> 0·5	2/10
Bromadiolone, 0·005%	47	4 (2)	2·4	3·0	0·2–0·4	10/10
Calciferol, 0·1%	48	2 (1)	1·6	3·7	0·025–0·05	5/10

* Figures in parentheses indicate number of days for which figures of bait consumption used in calculations.

The acceptance of difenacoum, brodifacoum, bromadiolone and coumatetralyl was very good, with more poisoned bait being eaten than plain in each case. Warfarin and calciferol, however, were significantly unpalatable, but it is considered unlikely that this would be of importance in the field. In a similar test with 4% zinc phosphide the quantities of food eaten were too small for accurate measurement, but the kill after 1 day's exposure was 9/10.

CONCLUSIONS

It is concluded that each of the seven rodenticides is effective against *M. natalensis* in the laboratory, and that provided suitable bait-bases are used in the field, good control could be obtained. In developing countries where the availability of cereal bait-bases may be limited, those poisons giving complete mortality after a short feeding period will be especially suitable. For this reason, brodifacoum, difenacoum and bromadiolone might be preferred to the other anticoagulants. In the laboratory calciferol and zinc phosphide (4%) gave complete kills after feeding for 1 day, but the possibility of poison-shyness developing in the field must be considered. It is suggested that field trials be carried out to confirm the laboratory findings.

We are indebted to the Hammersmith Hospital for supplying the original specimens of *M. natalensis* , to Sorex (London) Ltd for pure samples of calciferol, difenacoum and brodifacoum, and to Lipha (Lyon, France) for pure bromadiolone. Mr H. Cumming managed the breeding colony, and Miss B. Anasuya conducted the laboratory testing.

REFERENCES

COETZEE, C. G. (1975). The biology, behaviour and ecology of *Mastomys natalensis* in Southern Africa. *Bulletin of the World Health Organization* **52**, 637–44.

FINNEY, D. J. (1971). *Probit Analysis*, 3rd ed. Cambridge University Press.

GILL, J. E. & REDFERN, R. (1977). Some laboratory tests of five rodenticides for the control of *Arvicanthis niloticus*. *PANS* **23** (1), 33–7.

GRATZ, N. G. & ARATA, A. A. (1975). Problems associated with the control of rodents in tropical Africa. *Bulletin of the World Health Organization* **52**, 697–706.

GREAVES, J. H., REDFERN, R. & KING, R. E. (1974). Some properties of calciferol as a rodenticide. *Journal of Hygiene* **73**, 341–51.

HADLER, M. R., REDFERN, R. & ROWE, F. P. (1975). Laboratory evaluation of difenacoum as a rodenticide. *Journal of Hygiene* **74**, 441–8.

JOHNSTON, H. J. & OLIFF, W. D. (1954). The oestrus cycle of *Rattus* (*Mastomys*) *natalensis* Smith as observed in the laboratory. *Proceedings of the Zoological Society of London* **124** (3), 605–13.

REDFERN, R., GILL, J. E. & HADLER, M. R. (1976). Laboratory evaluation of WBA 8119 as a rodenticide for use against warfarin-resistant and non-resistant rats and mice. *Journal of Hygiene* **77**, 419–26.

SCHMUTTERER, H. (1969). *Pests of Crops in North East and Central Africa*. Stuttgart: Gustav Fischer-Verlag.

TAYLOR, K. D. (1968). An outbreak of rats in agricultural areas of Kenya in 1962. *East African Agricultural and Forestry Journal* **34**, 66–77.

TAYLOR, K. D. & GREEN, M. G. (1976). The influence of rainfall on diet and reproduction in four African rodent species. *Journal of Zoology* **180**, (3) 367–89.

VISSAULT, J. & RABAN, A. (1976). Sensibilité de trois muridés africains au chlorophacinone et au coumafène. *Phytiatrie-Phytopharmacie* **25**, 101–6.

WORLD HEALTH ORGANIZATION (1976). Instructions for determining the susceptibility or resistance of rodents to anticoagulant rodenticides. *World Health Organization, Technical Report Series* No. 443.