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Evaluation of brodifacoum against *T. indica*, *M. hurrianae* and *R. rattus*

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SUMMARY

Brodifacoum was evaluated in the laboratory against the two gerbils, *Tatera indica* and *Meriones hurrianae* and the house rat, *Rattus rattus*. The acute oral LD_{50} for these rodents was found to be 0·10 mg/kg, 0·083 mg/kg and 0·77 mg/kg respectively. Feeding tests with 0·002 % and 0·005 % brodifacoum produced a 100 % mortality after a 3-day feeding period in the gerbils and after a 4-day period in *R. rattus*. The anticoagulant is toxic at both the concentrations to all three species but is less palatable in comparison to plain baits. Results of this laboratory evaluation indicates that 0·002 % brodifacoum-treated bait can be effectively used against *T. indica*, *M. hurrianae* and *R. rattus*.

INTRODUCTION

The Indian gerbil, *Tatera indica* is one of the predominent rodents in the crop fields all over the Indian sub-continent and the desert gerbil, *Meriones hurrianae* constitutes 60 % of the rodent population in the Thar desert. These gerbils are significant pests being responsible for the majority of damage to crops (Barnett & Prakash, 1975). Consequently, large scale control operations using zinc phosphide, the only acute toxicant available indigenously are being organized in India. Zinc phosphide has the serious drawback of inducing poison aversion among rodents (Prakash & Jain, 1971; Prakash, Rana & Jain, 1975). Thus operations cannot be repeated for some time and 2–3 days of pre-baiting are required to overcome aversion to new food (Mathur & Prakash, 1980*b*). In addition the compound is toxic to the non-target species.

Rattus rattus, a universally distributed species is being managed with warfarin baiting which requires very long periods of feeding to achieve effective control.

During the last few years emphasis is being laid on the use of anticoagulant rodenticides for the control of field rodents in the Indian sub-continent. Many of them have been found to be effective against a large number of rodents in Pakistan (Greaves & Rehman, 1977; Rehman, 1979) and India (Prakash & Mathur, 1979; Mathur & Prakash, 1979, 1980*a*).

In the present study we report the results of our laboratory evaluation of brodifacoum (3-(3-4′bromo(1-1′Diphenyl) 4 yl-1,2,3,4-tetrahydro-1-napthalenyl-4-hydroxy-2H-1 benzopyran-2-one) against *T. indica*, *M. hurrianae* and *R. rattus*.

MATERIALS AND METHODS

The animals

The Indian gerbil, *T. indica indica* Hardwicke and Desert gerbil *M. hurrianae* (Jerdon) were live trapped at Jodhpur (Lat. 26° 18′ N Long. 73° 01′ E) in crop fields and grasslands. The house rat, *R. rattus rufescens* Gray were trapped from houses and godowns. These animals had no prior experience of feeding on any anticoagulant or toxic poisons. After capture the rodents were sexed, weighed and were lodged individually in the cages for three weeks prior to the initiation of experiments. Sick animals and pregnant females were discarded. Usually equal number of males and females were taken for each test. Average body weights (g) $\pm$S.E. of the animals were: *T. indica*, 127.50$\pm$5·97, *M. hurrianae*, 67·0$\pm$3·43 and *R. rattus*, 102·50$\pm$5·80.

Oral toxicity

Technical brodifacoum of 91·5% purity was dissolved in polyethylene glycol, 300, at concentrations ranging from 0·06 to 2·0 mg/kg. The doses were calculated according to the body weight of the animals and were orally administered. Only acute toxicity tests were carried out.

Feeding trials

Feeding trials were conducted using 0·1% commercial premix of brodifacoum which was added to whole pearl millet (*Pennisetum typhoides*) to provide 0·005 and 0·002% baits.

Feeding experiments were carried out with both 'no-choice' and 'choice' tests. In the former only poisoned bait was provided for a fixed number of days. In the 'choice' tests an alternative unpoisoned bait (same food in which poison was given) was provided in a separate container the position of which was altered with the poisoned one each day. After the completion of the feeding period, the animals were fed on laboratory diet for three weeks and symptoms and time to death were observed. Water was available *ad libitum*.

The trials were conducted as recommended by WHO (1970) for determining susceptibility of rodents to anticoagulants. The median lethal feeding periods and their 95% fiducial limits were calculated by probit analysis (Finney, 1971).

RESULTS

Oral intubation

Table 1 gives the LD_{50}, its 95% fiducial limits and the slopes of the probit regression line for each of the three species tested. No significant difference between the days to death for the three species was found.

No-choice feeding tests

In no choice feeding tests with 0·002% and 0·005% brodifacoum 100% mortality was observed after a 3 days feeding with both concentrations to *T. indica* and *M. hurrianae* and after 4 days feeding to *R. rattus*. Mortality started on day 2 and continued up to day 13. However, maximum deaths occurred at 3–6 days. In

Table 1. *Acute oral LD_{50} (mg/kg) of brodifacoum for* T. indica, M. hurrianae *and* R. rattus

Species	Acute LD_{50} (95% confidence limits)	Slope of the probit regression time $b \pm$ S.E.	Days to death	
			Mean	Range
T. indica	0·10 (0·08–0·17)	4·53 ± 0·56	7·2	5–12
M. hurrianae	0·083 (0·05–0·13)	5·57 ± 0·61	7·8	3–13
R. rattus	0·77 (0·40–1·28)	2·75 ± 0·25	6·3	2–20

Table 2. *Lethal feeding periods (LFP) for three rodents and their* 95% *fiducial limits*

Species	Conc. of poison (%)	Slope of the probit regression line $b \pm$ S.E.	Mean (95% confidence limits)	
			LFP_{50} (days)	LFP_{98} (days)
T. indica	0·002	2·70 ± 0·15	0·69 (0·32–1·48)	2·34 (1·10–5·0)
	0·005	2·92 ± 0·18	0·64 (0·32–1·39)	2·10 (1·25–4·16)
M. hurrianae	0·002	2·80 ± 0·14	0·79 (0·50–1·26)	2·52 (1·55–4·18)
	0·005	2·81 ± 0·15	0·74 (0·36–1·55)	2·23 (1·26–4·17)
R. rattus	0·002	2·76 ± 0·14	0·76 (0·40–1·51)	3·02 (1·35–6·76)
	0·005	2·81 ± 0·15	0·68 (0·38–1·23)	2·76 (1·59–4·79)

general there was no significant fall-off in the bait consumption in no-choice tests in *T. indica* but with *M. hurrianae* and *R. rattus* the consumption of the bait on day 3 and day 4 respectively was significantly lower ($P < 0·001$) than that on the first day.

Baseline susceptibility

Table 2 gives the lethal feeding periods (LFP_{50} and LFP_{98}) and their 95% fiducial limits for 0·002% and 0·005% brodifacoum treated baits. For an expected 50% kill less than 1 day and for 98% mortality 2–3 days feeding is required. Values did not differ significantly with respect to sex, species or concentration.

Palatability of rodenticidal baits

The poisoned bait is in general less palatable in comparison to the plain bait and in some instances the difference is highly significant (Table 3). Among *M. hurrianae* and *R. rattus* 0·005% brodifacoum-treated bait was significantly less palatable ($P < 0·05$ and $< 0·001$ respectively) than the 0·002% bait.

DISCUSSION

The results presented here indicate that the oral LD_{50} values for *T. indica* and *M. hurrianae* are lower than that for *R. rattus*. In addition higher values have been obtained for *R. norvegicus* (0·26 mg/kg; Redfern, Gill & Hadler, 1976) and female and male *R. argentiventer* (0·18 mg/kg and 0·16 mg/kg respectively; Lam, 1980). Thus brodifacoum is more toxic orally to gerbils than to rats.

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Table 3. *Bait acceptability and mortality in gerbils and house rat given a choice-test between plain and brodifacoum treated bait*

Species	Conc. of brodifacoum (%)	Duration of test (days)	Mean daily bait intake (g) (Mean ± S.E.) Poison (1)	Plain (2)	Significance (P) of student's '*t*' between (1) and (2)	Mortality	Mean days to death
T. indica	0·002	3 (2)*	2·77 ± 0·36	4·30 ± 0·59	0·05–0·02	12/12	6·5
	0·005	3 (2)	2·80 ± 0·52	3·28 ± 0·47	> 0·5	12/12	6·9
M. hurrianae	0·002	3 (2)	1·68 ± 0·45	4·83 ± 0·51	< 0·001	12/12	7·7
	0·005	3 (2)	0·94 ± 0·20	3·00 ± 1·01	0·02–0·01	12/12	9·2
R. rattus	0·002	4 (2)	2·70 ± 0·40	4·31 ± 0·55	0·01–0·005	10/12	8·9
	0·005	4 (2)	1·11 ± 0·25	4·73 ± 0·49	< 0·001	11/12	6·6

* Figures in parenthesis indicate the number of days for which bait consumption is analysed.

With *T. indica*, 100% mortality was achieved by feeding 0·002% brodifacoum for 3 days. Although similar results are achieved with other anticoagulants, a higher concentration and feeding for a longer period are required; 0·0375% coumatetralyl for 6 days, 0·0075% chlorophacinone for 7 days, 0·025% warfarin and 0·005% difenacoum for 14 days (Greaves & Rehman, 1977; Prakash & Mathur, 1979; Rehman, 1979). Brodifacoum is also more toxic than 0·0075% chlorophacinone to *M. hurrianae* since the latter compound had to be fed for 7 days to achieve 100% mortality (Prakash & Mathur, 1979). A 100% kill in *R. rattus* was observed with a number of anticoagulants (Chaturvedi *et al.* 1979; Girish, Singh & Krishnamurthy, 1974; Mathur & Prakash, 1979; Mukthabai & Krishnakumari, 1976) but brodifacoum required the shortest feeding time and smallest dose. These studies indicate that brodifacoum is more effective for the control of the species studied than any other anticoagulant evaluated.

The susceptibility of *T. indica* and *M. hurrianae* is similar to that of *M. shawi* (Hoppe, unpublished observations) with which 100% mortality is also obtained after 3 days feeding on 0·005% brodifacoum bait. The results with *R. rattus* are comparable with that for *Mastomys natalensis* (Gill & Redfern, 1979). In both the studies 100% mortality is observed after feeding on 0·002% brodifacoum treated bait for 4 days and lethal dose ingested and days to death are also very similar. It appears that a number of other rodent species are more susceptible to this anticoagulant than *T. indica*, *M. hurrianae* and *R. rattus*, namely *R. norvegicus*, *R. rattus* and *Mus musculus* (Redfern *et al.* 1976), *Bandicota bengalensis* (Brooks, Htun & Naing, 1980) and *Rattus argentiventer* and *Bandicota indica* (Lam, 1980; Tongtavee, 1980) in which a 100% mortality is achieved after 1–2 days of feeding. However, *Funambulus pennanti* required 6 days feeding (Mathur & Prakash, 1980*a*) on 0·005% brodifacoum bait for a complete kill and is the least susceptible to this anticoagulant.

Inspection of upper 95% fiducial limits of LFP_{98} for *T. indica* and *M. hurrianae* indicates that 5 days feeding on 0·002% brodifacoum would be a suitable test to detect resistance to brodifacoum and 7 days for *R. rattus*. The difference in the test times of the two gerbils and the rat indicates that the former are more prone to develop resistance than the latter and *M. natalensis* (Gill & Redfern, 1979) and *B. bengalensis* (Brooks, Htun & Naing, 1980).

Brodifacoum bait was found to be less palatable to the three rodent species than the plain bait but not to an extent that a lethal dose can not be ingested. Similar results are reported for *R. rattus* and *M. musculus* (Redfern, Gill & Hadler, 1976) and *R. argentiventer* (Lam, 1980).

On the basis of the results obtained in this study, it is recommended that brodifacoum at 0·002% concentration can be used for controlling the rodents, specially the bait-shy residual population after a zinc phosphide operation. This recommendation is being evaluated in field trials.

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REFERENCES

BARNETT, S. A. & PRAKASH, I. (1975). *Rodents of Economic Importance in India*, pp. 1–175. New Delhi: Arnold–Heinemann, London: Heinemann.

BROOKS, J. E., HTUN, P. T. & NAING, H. (1980). The susceptibility of *Bandicota bengalensis* from Rangoon, Burma to several anticoagulant rodenticides. *Journal of Hygiene* **84**, 127–135.

CHATURVEDI, G. C., PATEL, M. J., THAKORE, K. M. & THAKORE, M. T. (1979). Preliminary trials with bromadiolone – an anticoagulant rodenticide. *Indian Journal of Rodentology* **1** (1 & 2), 56–58.

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

GILL, J. E. & REDFERN, R. (1979). Laboratory tests of seven rodenticides for the control of *Mastomys natalensis*. *Journal of Hygiene* **83**, 345–352.

GIRISH, G. K., SINGH, KARAN & KRISHNAMURTHY, K. (1974). Studies on rodents and their control. Part IX. Susceptibility of *Rattus rattus* to some anticoagulants. *Bulletin of Grain Technology* **12**, 11–13.

GREAVES, J. H. & REHMAN, A. B. (1977). The susceptibility of *Tatera indica*, *Nesokia indica* and *Bandicota bengalensis* to three anticoagulant rodenticides. *Journal of Hygiene*, **78**, 75–84.

LAM, Y. M. (1980). Laboratory evaluation of brodifacoum for the control of the rice field rat, *Rattus argentiventer* (Robinson & Kloss). *Malaysian Agricultural Research and Development Institute, Rice Research Branch*, Information paper no. 13, 13 pp.

MATHUR, R. P. & PRAKASH, I. (1979). Comparative efficacy of three anticoagulant rodenticides on desert rodents. *Pest Control* (In the Press).

MATHUR, R. P. & PRAKASH, I. (1980*a*). Laboratory evaluation of anticoagulant treated baits for the control of the Northern palm squirrel, *Funambulus pennanti* Wroughton. *Journal of Hygiene*, **85**, 421–426.

MATHUR, R. P. & PRAKASH, I. (1980*b*). New food reaction among desert rodents. *Saugetierkundliche Mitteilungen* **28**, 28–30.

MUKTHABAI, K. & KRISHNAKUMARI, M. K. (1976). Responses of *Rattus* species to anticoagulant poisoning. *Comparative Physiology and Ecology* **1**, 129–135.

PRAKASH, I. & JAIN, A. P. (1971). Bait shyness of two gerbils *Tatera indica indica* Hardwicke and *Meriones hurrianae* Jerdon. *Annals of Applied Biology* **69**, 169–172.

PRAKASH, I. & MATHUR, R. P. (1979). Efficacy of cholorphacinone in controlling Indian desert rodents. *Pesticides* **13** (6), 44–46.

PRAKASH, I., RANA, B. D. & JAIN, A. P. (1975). Bait shyness in three species of *Rattus*. *Zeitschrift fur Angewandte Zoologie* **62**, 89–97.

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**, 419–416.

REHMAN, A. B. (1979). Effect of difenacoum on Indian gerbils. *Pest Control* **47** (9), 31.

TONGTAVEE, K. (1980). Efficacy tests of different rodenticides on some species of rats in Thailand. *Proceedings of Ninth Vertebrate Pest Conference*, pp. 143–145. California: Fresno.

WORLD HEALTH ORGANIZATION (1970). Provisional instructions for determining the susceptibility or resistance of rodents to anticoagulant rodenticides. *World Health Organization Technical Report Series* no. 443, 140–147.