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ABSTRACT: Possum control in New Zealand is dependent on the use of sodium monofluroacetate (1080) and cyanide. Although 1080 is highly effective, its use is restricted to government staff. Cyanide is available for a wider group of licensed operators, but cyanide "shyness" reduces its effectiveness. An acute toxicity programme has been set up to identify non-anticoagulant toxins that could be used safely by farmers. Dose-ranging studies showed that possums are susceptible to cholecalciferol, calciferol, gliftor, alpha-chloralose, and nicotine, but not to bromethalin. As lethal doses for these toxins have been ascertained, which of them are likely to be cost-effective and safe alternatives to 1080 now needs to be established. Bait palatability and field studies will then be undertaken with the most promising candidates.

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INTRODUCTION

New Zealand's native fauna was extremely rich in bird life and devoid of mammals before the arrival of man. Polynesian hunting followed by European colonisation and the introduction of a large number of exotic mammalian species had a devastating effect on native fauna and flora. Australian brushtail possums (*Trichosurus vulpecula*) were introduced between 1837 and 1922 to establish a fur trade. Possums spread rapidly, and there are now 60-70 million occupying forest and farm habitat throughout the country. The possum is regarded as New Zealand's number one animal pest, with an estimated cost to agriculture and forestry of NZ$35 million per annum (Cowan 1991).

Possums are a major cause of damage to native forest, with the extent of damage depending on the type of forest and how long possums have been present. There is no indication that possums have reached an ecological balance with vegetation in any forest type, and possum-induced changes in vegetation are disadvantageous for native birds and invertebrates.

Since the 1930s government control operations have attempted to reduce possum impact and restore habitat for native species. In recent years the New Zealand government and scientific community have renewed their efforts to improve control of the possum both because of their effect on indigenous forests and because of their role in the spread of bovine Tb to farm stock, first discovered in 1967. About 25% of the country is currently known to be occupied by Tb-infected possums. Control efforts to reduce forest damage and Tb incidence have been steadily increasing and now cost approximately NZ$8.5 M per annum.

Possum control is dependent on 1080 and, to a much lesser extent, cyanide. Large-scale possum control with aerially sown 1080 baits can be extremely successful, removing 85-95% of the population over areas of up to 20,000 hectares. However, the use of this toxin is restricted to government personnel, and it cannot be used by farmers for local ground control operations along boundaries between forests and farms. Cyanide can be used more widely by licensed operators; however, repeated use results in poison shyness. Although the need for alternative toxins has been recognised for many years, only limited progress has been made. Acute toxicity data exist for traditional toxins, including cyanide, arsenic, and strychnine, but all these non-specific toxins have disadvantages such as bait shyness, taste, or inhumaneness (Bell 1972).

Screening has shown that caged possums are not sensitive to a number of anticoagulant poisons, including pindone, flocoumafen, and brodifacoum (Agricultural Pest Destruction Council 1988, unpubl. report). No first-generation anticoagulants appeared effective, and possums had to be dosed with the second-generation anticoagulants for up to 10 days, to achieve a high mortality. Rodents only need a single dose of these potent new anticoagulants. The researchers concluded that although the possum had an efficient clotting system or a robust vascular system, there was resistance to the anticoagulants (J. Bell, pers. comm). In independent studies conducted in Western Australia, four possums were dosed with 16 mg/kg of pindone daily for 5 days, with no mortality (D. King, pers. comm).

Because of the apparent resistance of the possum to anticoagulants, we have focused our initial investigations on susceptibility to non-anticoagulant poisons. In this paper the susceptibility of the possum to cholecalciferol, calciferol, bromethalin, gliftor, nicotine and alpha-chloralose is reported.

METHODS

Materials

Cholecalciferol was supplied by Wellcome, Concorde, NSW, Australia. Calciferol was supplied by Sorex Ltd, Widnes, Cheshire, U.K., and bromethalin was supplied by Ciba-Geigy, Basle, Switzerland. As these three rodenticides were provided in oil-based concentrates, dose levels were adjusted by diluting the concentrates in corn-oil. Nicotine was obtained from Sigma, St. Louis, Missouri, USA, and gliftor was supplied by the China National Chemical Corporation, Nanjing, China. As gliftor was provided as an aqueous solution and nicotine is miscible in water, dose-levels of these two compounds were adjusted by dilution in water.

Animals and Dosing

Possums were caught in box traps and transferred to the Forest Research Institute animal facility where they were acclimitised before dosing. Food consumption and body weights were monitored before each study to ensure all animals were healthy. Possums were dosed orally under light ether or carbon dioxide anaesthesia. The animals were housed in individual cages both before and after dosing, and were allowed unimpeded access to food and water. Dose-levels were based on published toxicity data for each compound in other species where available. As there was limited mamma-

Table 1. Dose-ranging study for possums receiving cholecalciferol.

Dose (mg/kg)	Possum mortality per group
Control	0/3
50	2/3
100	6/6
200	3/3
400	3/3

ban toxicity data for cholecalciferol, a dose-ranging study using a wide-range of concentrations preceded an acute toxicity study. The possums were observed at regular intervals after dosing for 7 days for the short-acting poisons such as nicotine or alpha-chloralose, and for 35 days after dosing for the longer-acting poisons such as cholecalciferol.

The first dose-ranging study with cholecalciferol was conducted in multiple-housed animals in outdoor pens. The comparison of cholecalciferol and calciferol was carried out with individually caged animals in an animal house with temperature 15°C±10°C. The conditions were not ideal. Cages lacked nest boxes. All subsequent experiments were carried out in a new facility. Each possum was individually caged. Each cage had a nest box and the temperature of the animal house was maintained at 20°C±4°C (with a light dark cycle approximating natural conditions). The acute toxicity studies conducted in indoor controlled-environment conditions allow relative susceptibilities of the possum to the different toxins to be compared. All the experiments were conducted in accordance with National Animal Ethics Guidelines and had Animal Ethics Committee approval.

RESULTS

Possums are susceptible to cholecalciferol, calciferol, gliftor, alpha-chloralose, and nicotine but not to bromethalin.

The 20 male possums receiving doses of 4, 8, 16, or 32 mg/kg bromethalin all survived. Some animals in the highest dose group showed minimal clinical signs (slight tremor).

In the initial dose-ranging study with cholecalciferol, two of the three possums that received 50 mg/kg died. All six possums receiving 100 mg/kg died, as did the three receiving 200 and 400 mg/kg (Table 1). In the acute toxicity trial the susceptibility of the possum to cholecalcferol and calciferol were compared. All possums receiving 30, 60, or 120 mg/kg cholecalciferol or calciferol died. However, only half those receiving 15 mg/kg cholecalciferol died (Table 2). Intoxicated possums showed marked loss of weight and appetite. Most deaths occurred within 2 weeks.

Table 2. Acute toxicity of cholecalciferol vs calciferol in the possum.

Dose (mg/kg)	Cholecalciferol mortality per group		Calciferol mortality per group	
	M	F	M	F
0	0/3	0/3	ND	ND
15	2/3	1/3	ND[a]	ND[a]
30	3/3	3/3	3/3	3/3
60	3/3	3/3	3/3	3/3
120	3/3	3/3	3/3	3/3

[a]ND-not dosed, further comparative evaluations are scheduled.

All possums receiving alpha-chloralose at 400 mg/kg died, five out of six at 200 mg/kg, and one out of six at 100 mg/kg (Table 3). Death occurred within 2 to 48 hours and was preceded in some animals by several hours of unconsciousness.

All possums receiving 40 mg/kg of gliftor died, four out of six receiving 20 mg/kg, and one out of six receiving 10 mg/kg (Table 4). Deaths occurred within 1-5 days after dosing. All the possums were subdued and the most severely affected were lethargic for several hours before death.

All possums receiving 100 mg/kg of nicotine died, three out of six of those receiving 75 mg/kg, but none of those receiving 50 mg/kg (Table 5). Death took 2-5 minutes in the top dose group, and only slightly longer in the 75 mg/kg dose group.

DISCUSSION

Ideally, a toxin for possum control should be usable by farmers for ground control, should not be persistent in livestock or other non-targets that receive a sub-lethal dose. It should be degradable in soil and water. It should be humane and as far as possible be species-specific. It should be inexpensive and have an antidote. Such an ideal toxin will be difficult to identify, and we are screening potential toxins so that we can develop a short-list for further testing.

Of those tested to date, the possum appears susceptible to all but bromethalin. This is a comparatively new rodenticide that is thought to act on the central nervous system by uncoupling oxidative phosphorylation. As in most mammalian species, including rodents, cats, dogs, and primates, the LD_{50} ranges between 2 and 15 mg/kg (Spaulding et al. 1985),

Table 3. Acute toxicity of alpha-chloralose in the possum.

Alpha-chloralose (mg/kg)	Mortality (males only)
0	0/6
100	1/6
200	5/6
400	6/6

Table 4. Acute toxicity of gliftor in the possum.

Dose (mg/kg)	Mortality (males only)
0	0/6
10	1/6
20	4/6
40	6/6

Table 5. Acute toxicity of nicotine in the possum.

Nicotine (mg/kg)	Mortality M	F
0	0/3	0/3
50	0/3	0/3
75	1/3	2/3
100	3/3	3/3

the resistence of the possum even at doses of 32 mg/kg was surprising. However, one other species, the guinea-pig, has also been shown to be relatively insensitive to bromethalin (S. R. Spaulding, pers. comm.).

The acute toxicity data for cholecalciferol and calciferol indicates that the LD_{90} for both compounds is likely to be in the range 20-50 mg/kg. Further studies to identify which of these two compounds are most toxic to the possum are underway. These two compounds are of particular interest since the possum is thought to be susceptible to calcinosis from dietary calcium (Eason 1991), and both toxins act by mobilising stored calcium and increasing the absorption of dietary calcium, resulting in heart failure. Furthermore, their toxicity to birds is reported to be low. Cholecalciferol has an oral LD_{50} of >2000 mg/kg in the mallard duck.

The oral LD_{50} for alpha-chloralose in rodents is in the range 300-400 mg/kg. Cats are more susceptible (100 mg/kg) and dogs are more resistant (600-1000 mg/kg) (Cornwell 1969). Possums appear to be more susceptible than most mammals to this compound, being similar in sensitivity to the cat. However, because of the toxicity of this compound to birds, its use as a possum poison would have to be restricted to bird-proofed bait stations or target-specific baits. Our experiments were carried out at 20°C in a controlled environment. In the wild, particularly in winter, the possum could be more susceptible to this compound, since its toxicity is known to be temperature-dependent and enhanced by cold conditions (Cornwell and Bull 1967).

Gliftor is a rodenticide that is widely used in Russia and China. It has a mode of action similar to 1080 in that it appears to be metabolised to erythrofluorocitrate, with resultant inhibition of aconitate hydratase followed by citrate accumulation (Mead et al. 1991). In most rodent species, the LD_{50} ranges between 5 and 30 mg/kg. However, it is relatively non-toxic to birds (Mead et al. 1991) and is not expensive. The possum appears to be moderately sensitive to this compound, making it worthy of further investigation.

Nicotine was shown to be highly toxic to possums. It has been principally used as a fumigant insecticide, is inexpensive, and not persistent. Initial palatability studies indicate that baits containing nicotine are likely to be rejected by possums, but further palatability studies are planned to determine whether the adverse effect of nicotine can be overcome with 'masks.'

We will be undertaking palatability studies on all the toxins to which the possum appears susceptible. Palatability is as important as susceptibility, and we anticipate that some promising toxins might be detected and rejected by possums when applied to baits at lethal concentrations. As well as continuing the evaluation of non-anticoagulant toxins, we intend to re-evaluate the toxicity of anticoagulants in the possum and test the assumption, which is largely based on unpublished reports, that the possum is resistant to anticoagulants. This will be given a high priority since ICI made brodifacoum available for possum control in 1991, despite efficacy data suggesting considerable individual variation in the possums' response to anticoagulants and concern over the persistence of this toxin in livestock (Lass et al. 1985). If possums are shown to be susceptible to anticoagulants, it will be important to establish whether this extends to the first-generation anticoagulants. If it does, there could be some advantages in using compounds such as pindone or warfarin, which would be rapidly eliminated from any livestock exposed to a sub-lethal dose from a toxic bait. Furthermore, pindone and warfarin are considerably less expensive than brodifacoum. Ultimately, the cost-effectiveness of any alternative to 1080 will be a major consideration in the selection and evaluation process.

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LITERATURE CITED

BELL, J. 1972. The acute toxicity of four common poisons to the possum, *Trichosurus vulpecula.* N.Z. Vet. J.20(11): 212-214.

CORNWELL, P.B. and J.O. BULL, 1967. Alphakil - a new rodenticide for mouse control. Pest Control 35: 31-32.

COWAN, P. 1991. The ecological effects of possums on the New Zealand environment. Pp.73-89 in Symposium on Tuberculosis, Publication No. 132, Veterinary Continuing Education, Massey University, Palmerston North.

CORNWELL, P.B. 1969. Alphakil - a new rodenticide for mouse control. Pharm. J. 202:74-75.

EASON, C.T. 1991. Cholecalciferol as an alternative to sodium monofluoroacetate (1080) for poisoning possums. Proc. 44th NZ Weed and Pest Control Conf: 35-37.

LAAS, F.Y.; D.A. FORSS, and M.E.R. GODFREY. 1985. Retention of brodifacoum in sheep and excretion in faeces. N.Z. J. Agric. Res.28:357-359.

MAHMOUD, N. and R. REDFERN. 1981. The response of the Egyptian spiny mouse (*Acomys cahirinus*) and two other species of commensal rodents to anticoagulant rodenticides. J. Hyg. Camb.86: 329-334.

MEAD, R.J., M.G. FELDWICK, and J.T. BONN. 1991.1,3-Difluro-2-propanol: a potential replacement for 1080 in fauna management programmes in Australia. Wildl. Res.18:27-37.

OLIVER, A.J. and S.H. WHEELER. 1978. The toxicity of the anticoagulant pindone to the European rabbit, *Oryctolagus cuniculus,* and the sheep, *Ovis aries.* Aust. Wildl. Res. 5:135-142.

PAPWORTH, D.S. 1958. A review of the dangers of warfarin poisoning to animals other than rodents. R. Soc. Promot. Health J. 78: 52-60.

SPAULDING, S.R., R.B.L. VANHIER, and M.E. TARRANT. 1985. Toxicity and efficacy of bromethalin. Acta Zool.Fennical73: 171-172.