LINCOLN UNIVERSITY

Te Whare Wānaka̱ O Aoraki̱

THE EFFICACY OF PASTE BAITS CONTAINING MICRO-ENCAPSULATED ZINC PHOSPHIDE FOR THE CONTROL OF POSSUMS

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1. Summary

1.1 Project and Client

This report summarises pen and field trials that investigated the efficacy of a new paste bait containing zinc phosphide (Zn_3P_2), for the control of the brushtail possum. The work was undertaken by Ray Henderson (Pest-Tech), James Ross (Lincoln University) and Chris Frampton (Lincoln University), and was funded by the Animal Health Board (Project No. R-80525).

1.2 Objectives

- To evaluate the palatability and efficacy of Zn_3P_2 paste on caged possums;
- To compare the efficacy of Zn_3P_2 and 1080 paste in replicated field trials; and
- To publish the results in an appropriate scientific journal.

1.3 Methods

Bait palatability was assessed in pen trials by comparing the consumption of Zn_3P_2 paste with that of RS5 cereal bait.

The efficacy of the Zn_3P_2 paste was assessed in replicated field trials. Throughout the field trials Zn_3P_2 bait was compared with the 'standard' paste containing sodium monofluoroacetate (1080). Possum density was estimated using the standard trap-catch index method.

1.4 Results

Both the Zn_3P_2 and 1080 paste baits were highly palatable (i.e., palatability exceeded 40%). There was no significant difference in the palatability of non-toxic Zn_3P_2 prefeed and toxic Zn_3P_2 paste.

The Zn_3P_2 bait was highly efficacious killing 97.8% of the captive and 96.6% of the wild possums. These results were very similar to the 1080 paste, which killed 100% of the captive and 96.6% of the wild possums.

1.5 Recommendations

We recommend that:

i) further research be undertaken to establish whether birds and bees interfere with the Zn_3P_2 paste formulation;

ii) the rate of loss of Zn_3P_2 from paste exposed to rain or that is buried be measured to define the time that paste is likely to remain toxic in the environment;

iii) these preliminary field trials are replicated in diverse habitats supporting high (>15 possums/ha) and low (<5 possums/ha) possum densities to ensure that Zn_3P_2 is effective at all control sites; and

iv) the risk to dogs by secondary poisoning should be determined.

2. Introduction

Six poisons are currently registered for possum control, with sodium monofluoroacetate (1080) being the most extensively used. This toxin can be incorporated into various bait types and has been shown to be an extremely cost-effective method of initially removing >90% of a possum population (Eason *et al.*, 1994).

As a result of ongoing non-target kills (especially domestic dogs) and increased public opposition to the use of 1080, it has become politically very difficult to use this toxin at some locations (Eason *et al.*, 1996). This is of concern as the achievement of conservation and disease goals requires ongoing control work and there is currently no other registered toxicant considered suitable for wide-scale distribution (Eason, 1996). Consequently, in the decade 1989-1999 the Animal Health board (AHB) extensively funded a programme of research to find an alternative to 1080 for the control of possums. Zinc phosphide (Zn_3P_2) was subsequently identified as a potential replacement for 1080.

3. Background

Zn_3P_2 (*trizinc diphosphide*) is considered to be a cost-effective and efficacious rodenticide (Sugihara *et al.*, 1995, Buckle, 1994). It is used extensively throughout Asia, Europe and America, and is one of few rodenticides that is registered by the USA Environmental Protection Agency for broadcast use (Mauldin *et al.*, 1997) as it has been shown to present a low risk to the environment and is unlikely to cause secondary poisoning of predators and/or scavengers.

Zn_3P_2 was previously considered for New Zealand possum control, however, it was disregarded because it has a distinctive 'garlic' odour that can cause taste and/or smell aversion to the bait (Eason *et al.*, 1994) and 'bait shyness' if sublethal amounts of Zn_3P_2 are consumed (Sterner, 1999). This issue has since been overcome by micro-encapsulating the toxicant (Henderson, 1999) and, therefore, Zn_3P_2 has the potential to be an effective alternative to 1080 for the control of wild possums in New Zealand.

4. Objectives

- To evaluate the palatability and efficacy of Zn_3P_2 paste on caged possums;
- To compare the efficacy of Zn_3P_2 and 1080 paste in replicated field trials; and
- To publish the results in an appropriate scientific journal.

5. Methods

Pen trials

Possums were captured and acclimatised to captivity at the Pest-Tech. (hereafter referred to as PT) animal facility. Only animals with stable or increasing body weight after 4 weeks of captivity were used for assessing bait palatability. Palatability was determined using a standard 'two-choice' test (Grote and Brown, 1971), in which a minimum of 10 individually caged animals were given paired trays containing 100 g of test bait and 100 g of non-toxic RS5 (Animal Control Products, Wanganui; hereafter referred to as ACP) cereal bait as the control. Palatability was then calculated as the percentage of test bait eaten relative to the total bait eaten (i.e. the test and control bait). A value of 50%, therefore, demonstrates that the test bait is of equal palatability to the control. Comparisons in bait palatability between treatments were made using a repeated-measures ANOVA.

ACP supplied the non-toxic apple prefeed and 1080 apple paste. PT manufactured the non-toxic prefeed and Zn_3P_2 paste bait.

The pen trials were conducted with the approval of the Lincoln University Animal Ethics Committee (Ref. No. #808).

Field trials

Field trials were undertaken as paired trials that compared the efficacy of Zn_3P_2 and 1080 paste. Replicates of the paired comparison were undertaken at widely separated locations (i.e., >10 km apart) to improve the confidence in results that were attained.

Paired trials were undertaken in contiguous field sites (each of 25–35 hectares) in Canterbury, which were forested by *Pinus radiata*. The pre-control population density was estimated using Victor No. 1 leg-hold traps (Warburton, 1996). Because of the small area at each field site (i.e., <40 ha), possums caught during the pre-poison estimates of possum abundance were released (all caught animals were marked to ensure independence). This trapping was done on two successive fine nights, using 10 trap lines that each contained 6 leg-hold traps. Trap lines were spaced so that there were no more than 6 traps/ha. Trap lines were spaced at least 150 m apart so that they were independent.

KK bait stations (Pest Management Services, Waikanae) were distributed at a density of 2–3/ha throughout each study site. Approximately 100 g of prefeed paste was placed in bait stations for 5 nights. Bait stations were then filled with 100 g of toxic paste (either Zn_3P_2 or 1080) and left in the field for a further 7 nights. The amount of toxic paste removed from bait stations was then calculated after 7 nights using electronic scales (Toltec Scales, Christchurch). At the completion of each trial, all remaining toxic bait was recovered and buried at least 50 cm below ground level.

A χ^2 test of independence was used to compare the number of bait stations fed from amongst the treatment groups and a repeated-measures ANOVA was used to test for significant differences in bait consumption between each block. Re-locating traps at the same sites as used for the pre-poison monitor and then trapping for a further two nights estimated control efficacy. The percentage kill was calculated as the decline in the number of possums caught per trap night post-poisoning. Precision on the kill estimates was calculated from the variance in catch rate between the trap lines (Warburton, 1996). Finally, the relationship between the rate of dehydration and 1080-paste consumption was analysed using a least-squares linear regression equation.
All field trials were undertaken with an Experiment Use Permit (No. 5635/1) issued by the Pesticides Board.

6. Results

Pen trials

Palatability of non-toxic paste

The non–toxic prefeed paste supplied by ACP was more palatable than PT prefeed paste ($F_{1,38}$ =5.08, P=0.03; Table 1). However, both products had palatability's exceeding 40%; the minimum palatability recommended for baits to be consumed in lethal amounts by most (i.e., >95%) possums (Henderson and Frampton, 1999).

There was no significant difference in the palatability of the non-toxic and toxic paste formulations ($F_{1,112}$ = 0.22, P=0.64).

Efficacy of toxic paste

Both products were highly efficacious and killed almost all possums in the pen trials (Table 1). Zn_3P_2 paste killed 87/89 (i.e., 97.8% kill) of the caged possums and although only 10 possums were exposed to the 1080 paste, it killed all of them (100% kill).

There was no significant difference in the palatability of the Zn_3P_2 and 1080 paste bait ($F_{1,72}$ = 0.5, P=0.82). This analysis also included a group of 16 possums exposed to Zn_3P_2 paste, which had been stored for 6 months (Table 1).

Table 1. Palatability and efficacy of non-toxic and toxic paste containing 1080 and zinc phosphide on populations of captive possums.

Bait type	Agency doing trial	No. possums	Mean wgt. (g) bait eaten (±SE)	Palatability (%)	Mortality (%)
Non–toxic trials					
Prefeed paste[1]	Pest–Tech Ltd.	20	80.4 (9.59)	65.8	N/A
ZP prefeed[1]	Pest–Tech Ltd.	20	48.6 (6.85)	50.8	N/A
Toxic trials					
ZP paste	Pest–Tech Ltd.	37	13.9 (1.9)	47.2	36/37 (97.3)
ZP paste[2]	Landcare Research	13	22.5 (8.9)	51.2	13/13 (100)
ZP paste[2]	Landcare Research	13	12.6 (4.8)	46.3	13/13 (100)
ZP paste[3]	Pest–Tech Ltd.	16	15.7 (4.1)	40.5	15/16 (93.6)
ZP paste[1]	Pest–Tech Ltd.	10	28.1 (7.78)	42.2	10/10 (100)
1080 paste[1]	Pest–Tech Ltd.	10	21.1 (3.22)	52.1	10/10 (100)

N/A = Not Applicable
1 This was the same batch of bait used in the field trials.
2 Earlier trial conducted at the Landcare Research Ltd captive animal facility (Henderson, 1999).
3 Bait stored for 6 months to measure potential decline of palatability over time.

Field trials

Consumption of non-toxic ‘prefeed’ and toxic paste

Lighthouse plantation

At the Lighthouse plantation substantially less prefeed was eaten in the Zn_3P_2 block than in the 1080 block (Table 2), despite both areas having similar pre–poison catch rates (Table 3). Regardless of the amount of prefeed consumed once the toxic bait was applied, possums visited and ate bait from a similar percentage of bait stations in the 1080 and Zn_3P_2 blocks ($\chi^2 = 0.22$, d.f.= 1, P=0.64).

At the Lighthouse plantation the 1080 paste (not interfered with by possums) dehydrated by an average of 8.8% of its initial weight. The extent of dehydration depended on whether bait stations were in sheltered positions or exposed to sunlight and wind (range: 0 - 23.4%). Coincidentally where dehydration was most prevalent, the consumption of 1080 paste was lowest ($F_{1,40} = 6.46$, P=0.01). After the weight of bait remaining in bait stations was corrected for dehydration the results indicated that at the Lighthouse plantation possums ate significantly less toxic paste from the Zn_3P_2 block (18.8g / bait station) compared to the 1080 block (56.0g / bait station; $F_{1,58} = 31.9$, P<0.001). There was no dehydration with the Zn_3P_2 bait and the consumption of this bait did not have to be adjusted.

Southbridge plantation

At the Southbridge plantation weight loss of the 1080 paste by dehydration averaged 16.1% (range: 0 – 24.8%). After the dehydration adjustment, the results were comparable to the Lighthouse plantation with a similar percentage of bait stations fed from in each block ($\chi^2 = 3.19$, d.f.= 1, P=0.07).

We changed the prefeed type at the Southbridge plantation because we were concerned about the low consumption of Zn_3P_2 paste at the Lighthouse plantation. Previous research has demonstrated that if the prefeed and toxic baits are different formulations, then consumption of the toxic bait is lower than if the prefeed and toxic bait are the same formulations (Thomas *et al.*, 1997). Accordingly, we switched to Zn_3P_2 prefeed to encourage the consumption of the Zn_3P_2 toxic paste later in the trial. This had the effect of increasing the consumption of Zn_3P_2 paste from 19g/bait station at Lighthouse plantation (where the prefeed and toxic pastes were different formulations) to 29g/bait station at Southbridge plantation (where prefeed and toxic paste were similar). However, significantly more 1080 paste (57 g/bait station) than Zn_3P_2 paste (29 g/bait station; $F_{1,78} = 29.9$, P<0.001) was still consumed.

Table 2. The amount of non-toxic and toxic bait (containing zinc phosphide and 1080) consumed in two paired-field trials.

Location of plantation (ha)	Toxicant	Prefeed type	Pre–feed eaten per hectare (g)	Toxic bait eaten per bait station ±95% CI (g)	Bait stations fed from by possums (%)
Lighthouse (25)	ZP	Apple paste	76	19 ± 6	40
Lighthouse (33)	1080	Apple paste	318	56 ± 11	37
Southbridge (29)	ZP	ZP prefeed	283	29 ± 6	43
Southbridge (29)	1080	Apple paste	345	57 ± 9	57

Control efficacy

Following the application of toxic paste for 7 days, most possums were killed at all four study sites. These results suggest that Zn_3P_2 paste has a similar efficacy to 1080 paste with no significant difference in the percentage kill (Table 3).

Table 3. The estimated percentage kill of possums, in paired-field trials comparing zinc phosphide and 1080 paste.

Location (ha)	Toxicant	Pre–poison catch (%)	Post–poison catch (%)	Percentage kill ± 95% CI
Lighthouse (25)	ZP	21.8	0.8	96.2 ± 7.7
Lighthouse (33)	1080	23.7	0.8	96.5 ± 7.1
Southbridge (29)	ZP	27.0	0.8	96.9 ± 6.2
Southbridge (29)	1080	18.6	0.8	95.6 ± 9.0

7. Discussion

In the trials reported here Zn_3P_2 paste bait was highly efficacious; killing 97.8% of the captive and 96.6% of the wild possums. Although earlier research demonstrated that baits containing Zn_3P_2 were of low efficacy (O'Connor *et al.*, 1999), in this study micro-encapsulating Zn_3P_2 mitigated any initial aversion to the taste and/or smell of the toxicant. A minor concern from the field trials was that the Zn_3P_2 paste was of lower palatability than the apple paste containing 1080. Therefore, following the field trials we enhanced the palatability of the Zn_3P_2 paste so that it is likely to be eaten in larger amounts by wild possums exposed to it in the future (Appendix 1).

The other reason that Zn_3P_2 was previously disregarded as a possum toxicant was due to concerns regarding the development of bait shyness following unsuccessful control operations (G. Hickling pers. comm. 2000). Previous rodent studies have demonstrated that the survivors of control operations will learn to avoid Zn_3P_2 bait even after a single exposure (Sterner, 1999). Furthermore, these rodents will refuse to feed on similar bait for a considerable period of time (i.e. up to 100 days; Prakash, 1988). However, 1080 is also a fast-acting toxin and rodent-bait shyness caused by sublethal doses of 1080 can last more than 200 days (Prakash, 1988) and up to 24 months for possums (Morgan *et al.*, 1995). Accordingly, so long as ‘best practise procedures’ are followed in all control operations (Henderson *et al.*, 1998), Zn_3P_2 should not be any less effective than 1080 for the ongoing maintenance control of possums.

The efficacy of the 1080 paste in this study (mean kill 96.6%) was considerably higher than in another recent study investigating the efficacy of 1080 ground-laid on spits on farmland (mean kill 68%; Henderson *et al.*, 1999). This is most likely a result of reduced rates of dehydration when bait was applied in sheltered sites within a forest, as compared to paste lying on earth spits on farmland where they are exposed to the drying effects of sunlight and wind. Previous studies have demonstrated that 1080 paste bait will dehydrate by approximately 10% per week in sunless and windless indoor conditions (Ross *et al.*, 1997). In this trial 1080 baits exposed to wind and sunlight (i.e., on the western and northern margins of each forested block) lost up to 25% of their weight during seven days. This level of dehydration had a significant effect on bait consumption with more 1080 paste eaten in sheltered areas than in exposed sites. In contrast, the Zn_3P_2 paste did not dehydrate as it contains no water and is made from organic compounds with high boiling points. This suggests that the Zn_3P_2 paste formulation will remain attractive to possums for longer periods in the field than the 1080 paste.

It is speculated that the high efficacy of the Zn_3P_2 paste is related to its mode of action and the biology of the possum. Zn_3P_2 releases highly toxic phosphine gas (PH_3) when it reacts with stomach acid (Sterner, 1999, Guale *et al.*, 1994). Previous studies have demonstrated that possums have a low stomach pH (2.5), which is likely to facilitate release of large volumes of phosphine gas (Duckworth and Meikle, 1995). However, the efficacy of Zn_3P_2 reported here is applicable only to this product, as other pastes containing this toxicant are likely to differ in palatability and/or toxin bioavailability.

A literature review of environmental toxicology suggests that the risk of Zn_3P_2 to fauna in the New Zealand ecosystem is likely to be low because:

i) any Zn_3P_2 residues in damp soil are readily hydrolysed to zinc ions, dissolved phosphorous and PH_3 (EPA, 1998);

ii) although fish are susceptible to phosphine (liberated in acid waters) Zn_3P_2 is insoluble in water and is therefore unlikely to be ingested by aquatic fauna (EPA, 1998);

iii) Zn_3P_2 residues or metabolites do not accumulate in the tissues of poisoned animals. Accordingly, any risk of secondary poisoning would be associated with the consumption of unreacted Zn_3P_2 in the digestive tract. Overseas studies have demonstrated that this is unlikely and the risk of secondary poisoning of New Zealand carnivores that scavenge on carcasses is, therefore, considered to be minimal (Hill and Carpenter, 1982, Joermann, 1998); and

iv) large mammals are less susceptible than small mammals (Table 4) and few non-target deaths of domestic livestock have been reported after the use of rodenticides containing Zn_3P_2 (Pank and Engeman, 1988, Apa *et al.*, 1991).

Table 4. LD_{50} of zinc phosphide for various species.

Species	LD_{50} (mg/kg)	Source
Trout (*Salmo irideus*)	0.5mg/L	(Kidd and James, 1991)
Quail (*Colinus virginianus*)	12.9	(EPA, 1998)
Possum (*Trichosorus vulpecula*)	13.0	(Henderson, 1999)
Kiore (*Rattus exulans*)	23.0	(EPA, 1998)
Roof rat (*Rattus rattus*)	20–40.5	(EPA, 1998)
Field mouse (*Mus muculus*)	32.3-53.3	(Buckle, 1994)
Norway rat (*Rattus norvegicus*)	27–40	(EPA, 1998)
Sheep (Ovis ovis)	60–70	(Clarkson, 1991)
Dogs (fed) (*Canis* spp.)	>100	(WHO, 1988)
Dogs (fasted) (*Canis* spp.)	<100	(WHO, 1988)
Mallard duck (*Anas platyrhynchos*)	67.4	(EPA, 1998)

In conclusion, this favourable research and the perceived low environmental risk (when compared to 1080) suggest that Zn_3P_2 paste bait should be registered for the control of possums.

8. Recommendations

We recommend that:

i) further research be undertaken to establish whether birds and bees interfere with the Zn_3P_2 paste formulation;

ii) the rate of loss of Zn_3P_2 from paste exposed to rain or that is buried be measured to define the time that paste is likely to remain toxic in the environment;

iii) these preliminary field trials are replicated in diverse habitats supporting high (>15 possums/ha) and low (<5 possums/ha) possum densities to ensure that Zn_3P_2 is effective at all control sites; and

iv) the risk to dogs by secondary poisoning should be determined.

9. Acknowledgements

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Appendix 1.

As detailed in the attached report, the average consumption of Zn_3P_2 paste per bait station was significantly lower than 1080. There are three possible explanations for this:

1) First, there were differences in animal behaviour between the field study sites. This may have contributed to the lower consumption of Zn_3P_2 at the Lighthouse plantation;

2) Second, Zn_3P_2 has a shorter intent period before the onset of poisoning symptoms than 1080 bait. Whilst we didn't evaluate the physiological or behavioural effects of Zn_3P_2 in this study, the pen trial data supports this hypothesis with an average 'observed' time to death of 3 hours for Zn_3P_2 compared to 7 hours for 1080 paste. This longer latent period before appetite suppression is likely to have contributed to higher bait consumption in the 1080 block; and

3) Third, possums are consuming more 1080 paste because it has an initial higher palatability (in sheltered bait stations) than the Zn_3P_2 paste. Whilst our analysis could not detect any significant difference in the palatability of the Zn_3P_2 and 1080 pastes, we consider this to be the most likely explanation.

For that reason, we have continued to work on Zn_3P_2 paste bait and have improved the palatability of the paste formulation. Preliminary pen trials indicate that it is more palatable than the previous toxic and non-toxic Zn_3P_2 formulations (Table 1) and is highly efficacious (100% kill; Table 5). However, due to individual consumption variability and small sample sizes, these differences in palatability are not statistically significant (Two-sample *t* test; $P>0.10$). In respective of this, we believe that the new Zn_3P_2 formulation is superior and recommend that it be used in all future field trial work.

Table 5. Palatability and efficacy of non-toxic and toxic paste containing zinc phosphide on populations of captive possums.

Bait type	**Agency doing trial**	**No. possums**	**Mean wgt (g) bait eaten (±SE)**	**Palatability (%)**	**Mortality (%)**
Non–toxic trials					
ZP prefeed	Pest–Tech Ltd.	32	49.55 (7.25)	60.4	N/A
Toxic trials					
ZP paste	Pest–Tech Ltd.	15	21.13 (5.37)	60.0	15/15 (100)