A NOVEL BAIT FORMULATION FOR SLUG AND SNAIL CONTROL

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SUMMARY

A novel bait was developed which comprises an edible matrix, incorporating the molluscicide metaldehyde, applied as a coating to an inert core. In seven field trials in pastures and vegetables this bait gave control of slugs and snails equivalent to that achieved with standard extruded bait formulations.
Keywords: molluscicide bait, slugs, snails, pest control

INTRODUCTION

The chemical control of pest slugs and snails is usually reliant on the application of baits containing a molluscicide. Most commercial products comprise an extruded cereal-based bait containing 3-8% metaldehyde or methiocarb. Reductions in gastropod populations achieved with these baits are inconsistent and frequently poor (Godan 1983; Port and Port 1986). Therefore, much effort continues to be directed at improving the efficacy of metaldehyde baits in addition to searching for alternative molluscicidal agents.

The influence of metaldehyde concentration on the palatability and toxicity of baits to gastropods has received considerable attention in recent years (Wright and Williams 1980; Henderson and Parker 1986; Bourne *et al* 1988; Wedgwood and Bailey 1988; Howling and Port 1989). However, the active ingredient should not be considered in isolation from the other components of a bait when the objective is to improve bait efficacy. Bait composition, particle size, application rate, persistence, and the concentration and formulation of the active ingredient, all interact to affect the efficacy of baits against specific gastropod species. These fundamental issues of bait formulation, including ease of application by hand or machine, were addressed during development of the Agtech Bait (Barker *et al* unpubl.), the field efficacy of which is described in this paper.

The Agtech Bait was a joint development between Plant Protection Group, Ruakura Agricultural Centre, and ICI Crop Care, a division of ICI New Zealand Limited. It contains 1.8% metaldehyde by weight concentrated to 9% in the edible outer coating of the bait, which comprises 21% by weight. The bait core is inert. The bait is formulated to provide approximately 130 bait particles of 1.18 to 3.50 diameter per gram. The recommended application rate of 20 kg/ha gives 260 bait particles/m^2.

MATERIALS AND METHODS

Trials 1-3: Slug control in direct drilled pasture

Slug infested pastures in Bruntwood clay loam (Trials 1 and 3) and Horotiu sandy loam (Trial 2) were sprayed with glyphosate herbicide (Roundup 4 litres/ha) 14 days prior to direct drilling 3.7 kg/ha Pitau white clover and 13.3 kg/ha Ellett perennial ryegrass. In Trials 1 and 2 the Agtech baits were applied at 5, 10 and 20 kg/ha, either as broadcast treatments immediately after drilling, or drilled with the seed. Mesurol bait (Mesurol Snail and Slug Bait, 2% methiocarb) was applied at 10 kg/ha as broadcast and drilled treatments, and Blitzem (Blitzem Slug and Snail Bait, 2.7% metaldehyde) as a broadcast treatment at 30 kg/ha. In Trial 3 the bait treatments were broadcast

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immediately after drilling the seed: Agtech and Mesurol each at 10 kg/ha, and Blitzem at 30 kg/ha. In all trials these bait treatments, and an untreated control, were replicated four times in a randomised block design, with plot size 5 x 15 m.

Slug population density was assessed at 10 (Trials 1 and 3) and 11 (Trial 2) days post-drilling. Slug numbers per 3 m of drill row were counted by taking 30, 10 cm diameter soil cores, centred over the drill furrows, for each plot.

Trial 4: Slug control in established pasture

The Agtech baits were broadcast onto an established pasture at 5, 10 and 20 kg/ha. Mesurol and Blitzem baits were broadcast at 10 and 30 kg/ha respectively. Each treatment, including an untreated control, was replicated four times in a randomised block design, with plot size of 10 x 10 m.

Slug numbers on the plots 10 days post-treatment were estimated by counting slugs in four 30 x 30 cm quadrats per plot.

Trials 5 and 6: Slug control in vegetable crops

Enclosures measuring 47 x 89 cm x 40 cm high were sunk into the soil to a depth of about 10 cm to enclose 10 vegetable seedlings 1 day following transplanting (Trial 5, 'Triumph' lettuce on Horotiu sandy loam; Trial 6, 'Winter Cross' cabbage on Horotiu sandy loam). The enclosures consisted of galvanised sheet iron, with a barrier to slug escape fixed to the upper rim. Two 10 cm dia. x 10 cm deep holes, lined with a sleeve of PVC and supplied with a raised cover, were made in each enclosure between the seedling rows to provide a refuge for slugs released into the enclosures. Slugs collected locally were introduced into the enclosures at the following rates: Trial 5 — *Deroceras reticulatum* 12/enclosure, *D. panormitanum* 4/enclosure; Trial 6 — *D reticulatum* 9/enclosure, *D. panormitanum* 7/enclosure.

The Agtech baits were broadcast on the enclosed vegetable crops at 5, 10 and 20 kg/ha. Mesurol and Blitzem baits were broadcast at 10 and 30 kg/ha respectively. These bait treatments, and an untreated control, were replicated four times in a randomised block design.

Individual seedling plants were scored at 2-day intervals, post-treatment, for slug damage on a scale of 0-6 (0 = no damage, 6 = complete consumption of seedling), and the numbers of healthy, moribund (intoxicated) and dead slugs were recorded. At day 18 the surviving plants were harvested for foliar dry weight determinations.

Trial 7: Snail control in vegetables

Enclosures as described above were used to enclose 10 'Triumph' lettuce seedlings on Horotiu sandy loam. Twenty *Helix aspersa* were released into the enclosures which were covered with mesh to prevent snail escape.

Agtech baits, at 5, 10 and 30 kg/ha, Mesurol 10 kg/ha and Blitzem at 30 kg/ha were broadcast over the enclosed crop. Each treatment, and an untreated control, were replicated four times in a randomised block design.

At 4, 9 and 12 days after treatment, individual seedling plants were scored for snail damage on a scale of 0-6 (as above), and the numbers of healthy, moribund (intoxicated) and dead snails were recorded. At day 12 the surviving plants were harvested for dry weight determinations.

Statistical analysis

Numbers of slugs in soil cores, scores of plant damage, and plant yields were subjected to an analysis of variance using untransformed data. Proportions of slugs, snails and plants surviving after molluscicide treatment were analysed by generalised linear regression using a binomial distribution with a logit link.

RESULTS

Trials 1-3

The slug infestations comprised the following species (untreated plots): Trial 1 — *Deroceras reticulatum* 50%; *D. panormitanum* 39.6%; *Milax gagates* 8.4%; *Arion intermedius* 2%; Trial 2 — *D. reticulatum* 42%; *D. panormitanum* 49.1%; *M. gagates* 6.3%; *A. hortensis* 2.6%; Trial 3 — *D. reticulatum* 53.5%; *D. panormitanum* 30.2%; *M. gagates* 14.2%; *A. intermedius* 2.2%. Mortalities achieved with the molluscicide treatments were similar for all slug species, so data were pooled for analysis.

The level of slug control achieved with the broadcast Agtech baits at 10 and 20 kg/ha did not differ significantly from that achieved with broadcast applications of Mesurol and Blitzem (Table 1). When drilled Agtech baits at 10 and 20 kg/ha gave higher control ($P<0.05$) than achieved with Mesurol pellets (Table 1). Molluscicide applications in Trial 3 significantly reduced slug populations ($P<0.05$), with no significant differences between treatments (Table 1).

Trial 4

The slug population comprised one species, *D. reticulatum*. The Agtech baits reduced slug numbers ($P<0.01$), with a significant ($P<0.01$) rate effect (Table 1). The level of slug control for these treatments was similar to that achieved with Mesurol but significantly higher than achieved by Blitzem ($P<0.05$).

TABLE 1: Slug control effected by molluscicide baits in direct drilled (Trials 1-3) and established (Trial 4) pasture as influenced by formulation, application rate and placement.

	Application rate		Trial 1		Trial 2		Trial 3		Trial 4	
	kg bait/ha	kg ai/ha	No/ m²	% control	No/ m²	% control	No/ m²	% control	No/ m²	% control
Untreated	—	—	26.6	—	34.7	—	23.8	—	59.1	—
Agtech										
Broadcast	5	0.09	14.4	46	27.3	21	—		34.8	41
Broadcast	10	0.18	17.8	33	20.7	40	14.4	50	17.4	70
Broadcast	20	0.36	13.3	50	16.3	53	—		14.6	75
Agtech										
Drilled	5	0.09	26.6	0	29.4	15	—		—	
Drilled	10	0.18	14.4	46	21.0	39	—		—	
Drilled	20	0.36	12.8	52	17.9	48	—		—	
Mesurol										
Broadcast	10	0.20	11.7	56	17.8	49	15.5	35	30.6	48
Drilled	10	0.20	28.9	0	29.5	15	—		—	
Blitzem										
Broadcast	30	0.81	11.7	56	18.3	47	11.1	54	50.1	15
SED			4.23		3.91		3.97		8.27	

TABLE 2: Proportion of *Deroceras* slugs dead (±SE) 12 days after treatment, as influenced by molluscicide bait formulation and application rate.

	Application rate kg bait/ha	Trial 5				Trial 6			
		D. reticulatum		*D. panormitanum*		*D. reticulatum*		*D. panormitanum*	
Untreated	—	0		0.06	(0.06)	0.04	(0.04)	0	
Agtech	5	0.73	(0.06)	0.81	(0.10)	0.56	(0.08)	0.68	(0.09)
	10	0.81	(0.06)	0.88	(0.08)	0.61	(0.08)	0.86	(0.07)
	20	0.79	(0.09)	0.88	(0.08)	0.75	(0.07)	1.00	(0.00)
Mesurol	10	0.83	(0.05)	1.00	(0.00)	0.72	(0.07)	0.86	(0.07)
Blitzem	30	0.73	(0.06)	0.94	(0.06)	0.94	(0.04)	0.93	(0.05)

Trials 5 and 6

In both trials all molluscicide treatments reduced slug numbers ($P<0.001$), reduced slug damage to seedling vegetables ($P<0.001$) and increased plant yields ($P<0.001$) (Tables 2 and 3).

The level of slug mortality effected by the Agtech bait treatments in Trial 5 was not generally different from that achieved with the Mesurol and Blitzem (Table 2). The apparent rate effect was not statistically significant.

In Trial 6, *D. reticulatum* mortality for Agtech and Mesurol baits was lower than for Blitzem (Table 2). Mortality of both slug species achieved with the Agtech baits was subject to a significant bait rate effect (P<0.01).

Plant damage scores and yields were similar for all molluscicide treated plots and significantly different from that of untreated in both Trials 5 and 6 (Table 3). There was no consistent application rate effect on plant damage or yield for the Agtech bait.

TABLE 3: Ratings of slug damage on vegetable seedlings and seedling yields at 18 days post-treatment.

	Application rate kg bait/ha	Plant damage scores (0-6 scale)		Proportion of plants surviving		Yield (gm)/plot	
		Trial 5	Trial 6	Trial 5	Trial 6	Trial 5	Trial 6
Untreated	—	3.35	4.12	0.75	0.87	2.35	2.70
Agtech	5	1.75	2.02	1.00	1.00	5.28	4.30
	10	1.85	1.48	0.98	1.00	4.74	4.90
	20	1.90	1.00	1.00	1.00	4.66	4.67
Mesurol	10	1.52	1.10	1.00	1.00	4.72	5.00
Blitzem	30	1.95	0.80	0.95	1.00	4.12	4.85
SED		0.42	0.45	0.04	—	0.64	0.37

Trial 7

All molluscicide treatments reduced snail numbers (P<0.001), reduced snail damage to seedling vegetables (P<0.01) and increased plant yields (P<0.001) (Table 4). Blitzem was superior to all other molluscicide treatments in the level of snail control (P<0.001). Levels of snail control were increased with application rate of the Agtech baits (P<0.05).

Mean scores of snail feeding damage and plant yields for Agtech bait treatments were similar to those achieved with Mesurol and Blitzem (Table 4). Plant damage scores in the Agtech bait treatments were affected by application rate (P<0.001), which was reflected in the proportion of plants harvested (rate effect, P<0.001) and yield per plot (rate effect, P<0.01).

TABLE 4: Proportion of *Helix aspersa* dead, ratings of damage on vegetable seedlings and plant yields at 12 days after treatment, as influenced by molluscicide bait formulation and application rate.

	Application rate kg bait/ha	Proportion dead (standard error)		Plant damage scores (0-6 scale)	Proportion of plants surviving (standard error)		Yield/plot (gm)
Untreated	—	0.09	(0.03)	6.00	0		0
Agtech	5	0.29	(0.05)	4.38	0.50	(0.08)	1.40
	10	0.38	(0.05)	2.75	0.82	(0.07)	2.57
	30	0.42	(0.06)	1.35	0.95	(0.06)	3.44
Mesurol	10	0.51	(0.06)	2.92	0.78	(0.07)	2.12
Blitzem	30	0.69	(0.05)	1.85	0.92	(0.06)	3.01
				SED 0.61			SED 0.52

DISCUSSION

The core-based formulation of the Agtech bait is a departure from the extruded pellet type bait usually used for terrestrial gastropod control. A principal advantage over the extruded bait formulations is the small, robust, flowable nature of the bait particles which allows easy application through a range of equipment. The small bait particle size, and hence the high number of bait particles per unit weight, allows a uniform and dense coverage of treated areas.

In many row crops there is a need to apply molluscicide baits in the soil in the vicinity of sown seed. However, many extruded bait formulations flow poorly through granule dispensing equipment on seed drills and usually require mixing with the seed to allow in-row soil incorporation (Kelly and Martin 1989). For accuracy this application technique requires the seed and bait particles to be similar in size and flow characteristics. Furthermore, extruded baits often have poor durability in soil (Stephenson 1972; Barker *et al* 1984). In contrast, the Agtech bait has a particle size range and flow characteristic which allows accurate incorporation into soil, adjacent to seed, through conventional granule application equipment fitted to seed drills. In the trials reported in this paper, Agtech baits exhibited good durability and efficacy in soil.

In experimental plots, Hunter and Symonds (1970) found that 25-100 bait particles/m² were optimum for control of *D. reticulatum* using broadcast applications of an extruded bait formulation. Because the surface activity of slugs may be less in some species and be reduced by weather and microtopography conditions, Hunter and Symonds recommended increasing the number of baits per unit area for field use, either by higher quantities of bait per hectare or by smaller bait particle size. When Blitzem and Mesurol baits are applied at the recommended rates, 30 kg/ha and 10 kg/ha respectively, the average bait particle distribution for both products is 25/m², which may be suboptimal under some use conditions. In contrast, the Agtech bait broadcast applied at 20 kg/ha gives a much higher number of particles, 260/m².

When a molluscicide bait is evenly and densely broadcast over an area the effectiveness of the bait is dependent more on the quantity of molluscicide ingested by each animal than on slug activity or bait attractiveness. Wedgwood and Bailey (1988) and Bailey *et al* (1989) showed that metaldehyde shortened the period slugs fed at baits by interfering with the neural control of feeding and inducing paralysis in the gut musculature. Only at high concentrations of metaldehyde was aversion more important than the toxic effects in ending slug feeding at the baits. Wedgwood and Bailey (1988) concluded that, to increase the likelihood of a lethal dose being ingested, a bait formulation was needed that reduced the rate of absorption of the molluscicide from the alimentary tract. During development of the Agtech bait several formulations of metaldehyde were found to eliminate the aversion effects of high metaldehyde concentration and increase the amount of molluscicide ingested by slugs. Baits containing 9% formulated metaldehyde (in outer bait coat) consistently effected higher slug mortality in glasshouse and field trials than baits containing unformulated commercial grade metaldehyde at a range of concentrations (Barker *et al* unpublished) and this forms the basis of the Agtech bait.

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