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THE EFFECT OF COMMONLY USED BIOCIDES ON SLUGS

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Summary

A range of biocides, including 16 fungicides, 14 insecticides and 25 herbicides were tested, at the maximum recommended rate, in the laboratory for their toxicity to two introduced pest slugs (*Deroceras panormitanum* and *D. reticulatum*). Five of the fungicides, five herbicides and three insecticides were good ovicides. The most effective insecticides killed slugs only after ingestion although phorate was also a contact molluscicide. Methiocarb was an effective bait and also an ovicide. Three herbicides and three insecticides were tested in all pair combinations. The effect of combinations of biocides was not predictable from a knowledge of their separate effects.

INTRODUCTION

Slugs have the potential to be serious pests of glasshouse and horticultural crops as well as field crops and pastures. The most widely distributed pest species in New Zealand are *Arion hortensis*, *Milax gagates*, *Deroceras panormitanum* and *D. reticulatum*. Of these, *D. panormitanum* and *D. reticulatum* are the most important established pests (Barker 1979). Most of the available literature on the chemical control of slugs refers to control of *D. reticulatum* (Stephenson and Bardner 1976 and Crowell 1977).

In this study the two most common species in pastures and orchards were *D. reticulatum* (referred to as *Agriolimax reticulatus* in U.K. literature) and *D. panormitanum*. *D. panormitanum* is conspecific with *D. caruanae* which has a Mediterranean distribution in Europe and is rare in England, is present in California, and has been found on plants imported to New Zealand from Australia (Barker 1979). Crowell (1977) found that the effect of biocides was dependent on both the age and the species of slug. Because of this, and because of the lack of information on one of New Zealand's most common pest species, a range of biocides, including fungicides, herbicides and insecticides were tested for their action on the mature, juvenile and egg stages of both species of *Deroceras*. This work is part of an M.Sc. study on the biology and chemical control of slugs at Massey University, carried out by Mr J. van der Gulik.

METHODS

The slugs used for chemical control experiments were collected from the pastures and orchards around Massey University, Palmerston North. The slugs were kept, without food, for 48 hours before the start of the tests. Individuals were classed as adult or juvenile according to their extended length; *D. panormitanum*, adults over 2.5 cm, juveniles up to 1 cm; *D. reticulatum* adults over 3 cm and juveniles up to 1.5 cm. Eggs were collected from laboratory cultures of each species and 100 newly laid, undeveloped eggs were used for each test.

The biocides were presented in two ways, either incorporated into standard food bran (ingestion) or as a soil surface spray (contact). Adults and juveniles were used in ingestion tests and adults and eggs in contact tests. Table 1 shows the chemicals used in this work, the rate (a.i./ha) used in the contact tests and the % a.i. in the bran sites.

Ingestion tests

Bran baits were made up to contain 4% of the commercial formulation, 2 gm of

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TABLE 1: Biocides tested as contact and ingested poisons against the slugs *D. reticulatus* and *D. panormitanum*

	spray rate/ha	% a.i. in bait		spray rate/ha	% a.i. in bait
Fungicides			Herbicides		
benomyl	250 g	2.0	alachlor	3.5 kg	2.0
captafol*	280 g	1.6	amitrole* + ammonium thiocyanate*	4.4 kg	0.8
captan*	4 kg	0.4			
carbaryl + mancozeb	1.2 kg + 1.2 kg	0.8 + 0.8			
carbendazim	250 g	2.0	amitrole	4.0 kg	0.7
copper oxychloride*	3 kg	2.0	asulam*	3.1 kg	3.6
dichlofluanid*	1 kg	2.0	bentazone*	1.6 kg	1.6
dimethirimol*	375 g	0.5	chlorbufam + pyrazon	1.4 kg	1.9
dinocap*	189 g	0.9	chlormethazole	1 kg + 1 kg	0.8 + 0.8
maneb*	1.6 kg	3.2	chlormethazole	750 g	3.0
propineb*	1.4 kg	2.8	chlorpropham	1.2 kg	1.3
pyrazophos*	15 g	1.2	chlorthal-dimethyl*	12 kg	3.0
thiophanate	7.4 kg	3.2	2,4-D*	1.2 kg	0.8
thiophanate-methyl	450 g	3.2	2,2-DPA*	2.5 kg	3.0
thiram	1.6 kg	3.2	glyphosate*	2.2 kg	1.4
vinclozolin*	500 g	2.0	ioxynil	750 g	1.0
Insecticides			linuron*	750 g	2.0
arsenate of lead*	979 g	1.3	methabenzthiazuron*	1.4 kg	2.8
carbaryl	1.22 kg	3.2	metribuzin*	350 g	2.0
dazomet	495 g	3.9	MCPA	1.5 g	1.5
DDT*	930 g	2.0	paraquat	1.4 g	0.8
demeton-S-methyl	336 g	1.2	paraquat-diquat	540 g + 540 g	0.4 + 0.4
fensulfothion*	3.3 kg	0.4	picloram + 2,4,5-T*	150 g + 600 g	0.2 + 0.8
lindane*	1.4 kg	0.8	prometryn*	1.1 kg	2.0
maldison*	1.7 kg	2.0	propachlor	6.5 kg	2.6
methamidophos	600 g	2.4	propyzamide	1.5 kg	2.0
methiocarb	112 g	3.0	sodium chlorate*	290 kg	2.3
methomyl (liquid)	396 g	3.6	2,4,5-T	5.8 kg	1.4
methomyl (powder)	400 g	0.8	Molluscide		
mineral oil	30 ml	3.8	metaldehyde	6.0 kg	3.0
parathion-methyl	420 g	2.4			
phorate	2.2 kg	0.9			
rotenone*	127 g	.02			

* Biocide not significantly better than control

bait were used in each test. Slug pellets containing 3% metaldehyde were used as supplied by the manufacturer. Combined applications used the same rate of each biocide as was applied alone.

Adult slugs were tested in the laboratory in polystyrene boxes (47 x 31 cm) with a close fitting muslin lid. Juvenile slugs were tested in standard 15 cm plastic petri dishes. Each test box was provided with a covered refuge area and a flat container for bran. The bottom of the box was covered with a layer of moist sieved soil. The slugs were used in each test, with three replicates of each treatment (except compounds marked "i" in Table 2, in which there were 15 per test and two replications). Controls used unsprayed soil and natural bran. The number slugs killed after 10 days was recorded.

Contact tests

To test the contact effectiveness of biocides against adult slugs, the soil surface in the test boxes (excluding the refuge area) was sprayed with the biocide in water from a hand-held fine mist sprayer. The volume applied was 7.84 ml (=0.01ml/cm² or 1000 litres/ha.) and the maximum recommended rate per hectare of the commercial formulation was used (see Table 1). After spraying, ten slugs were placed in the refuge and 2 g of fresh food bran were placed in a container in the centre of the sprayed area. The number of slugs killed after 10 days was recorded (Table 2).

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TABLE 2: Biocides which showed molluscicidal activity. Mean % of slugs killed after 10 days exposure and mean % of eggs killed

Common name	<i>D. panormitanum</i>				<i>D. reticulatum</i>			
	BAIT		SPRAY		BAIT		SPRAY	
	Adult	Juvenile	Adult	Eggs	Adult	Juvenile	Adult	Eggs
A - Biocides with high toxicity								
<i>Fungicides</i>								
benomyl	33	10	0	100	10	0	0	100
carbaryl-mancozeb	46	13	0	14	40	67	0	10
thiophanate	10	-	10	100	40	-	0	100
thiophanate-methyl	20	-	10	100	0	-	10	100
thiram	0	-	0	100	20	-	0	100
<i>Insecticides</i>								
carbaryl	45	20	30	56	38	13	40	67
dazomet (i)	20	-	83	19	20	-	90	+
methamidophos	33	80	10	0	57	80	0	+
methiocarb	96	100	33	95	93	100	26	96
methomyl (liquid)	100	90	36	6	90	43	53	44
methomyl (powder)	97	93	10	82	97	100	10	94
phorate (i)	93	77	93	6	100	76	100	4
<i>Herbicides</i>								
alachlor	24	40	0	59	24	80	0	100
ioxynil	48	57	0	11	90	70	0	+
MCPA	18	67	0	27	26	77	10	+
paraquat-dichloride	50	100	0	100	60	90	0	100
paraquat-								
dimethylsulphate	63	90	0	100	67	83	0	100
propachlor	20	-	10	97	10	-	0	100
propyzamide (i)	30	-	10	100	20	-	0	100
2,4,5-T	40	33	33	+	57	18	63	11
<i>Molluscicide</i>								
metaldehyde	83	67	90	100	73	97	93	100
<i>Combinations</i>								
alachlor + carbaryl	13	26	63	74	3	26	30	88
alachlor + ioxynil	23	36	13	22	20	27	16	89
alachlor + methiocarb	86	60	43	100	80	67	8	100
alachlor + methomyl	83	46	83	29	77	50	56	97
alachlor + 2,4,5-T	16	23	57	26	9	13	53	100
carbaryl + ioxynil	26	30	57	66	63	33	53	47
carbaryl + methiocarb	100	73	97	97	100	90	86	69
carbaryl + methomyl	100	80	100	91	77	97	100	82
carbaryl + 2,4,5-T	63	26	73	64	67	9	100	60
ioxynil + methiocarb	83	33	26	88	93	80	46	57
ioxynil + methomyl	90	73	50	31	100	77	50	37
ioxynil + 2,4,5-T	97	26	26	6	97	20	50	+
methiocarb + methomyl	97	95	100	100	97	95	90	100
methiocarb + 2,4,5-T	77	77	75	96	90	100	70	49
methomyl + 2,4,5-T	97	67	83	25	93	49	93	68
B - Biocides with intermediate toxicity								
<i>Insecticides</i>								
demeton-S-methyl	33	30	10	+	35	50	0	+
maldison 1.7 kg/ha	23	50	10	+	9	63	0	+
parathion (methyl)	30	-	10	11	40	-	10	47
<i>Herbicides</i>								
chlormethazole	40	-	0	54	20	-	10	7
chlorpropham	18	33	0	57	44	57	0	41
methabenzthiazuron	30	20	0	+	20	50	0	+
paraquat-diquat	14	23	6	+	16	63	26	0

footnote (i) = 2 replicates of 15 slugs

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The ovidical effect of the biocides was tested using batches of 100 eggs taken from laboratory cultures of each species. There were three replicates for each species and one control set of 100 eggs for each treatment. The eggs were placed on two layers of damp filter paper in a standard 9 cm petri dish. All the biocides were diluted in water to 20 ppm (it was assumed that 1 g = 1 ml) and 4 ml of the solution added to each dish. The eggs were then covered with a single layer of filter paper. After 10 days a further one ml of solution was added to the dish and this was repeated after 20 days.

RESULTS

Table 2 shows the mean percentage of slugs killed after 10 days and the percentage of eggs killed. The number of slugs dying in the controls was less than 12% for both species and ages (Table 3). The mortality rate of the eggs is calculated in relation to the number of eggs hatching in the control for that egg batch,

$$\% \text{ killed} = 100 \times \frac{\text{No. of control eggs hatching} - \text{No. of treated eggs hatching}}{\text{No. of control eggs hatching}}$$

In some cases the number of eggs hatching in the treatment was greater than in the control, this seemed to be because pathogenic organisms such as moulds had been inhibited by the treatment, these cases are marked + in Table 2. A least significant differences method was used to divide the results into the groups. The variability of the control group was compared with that of a semi-random selection of chemicals killing between 30% and 80% (mid group) of at least one age group and species and this group was in turn compared with the variability of those chemicals killing more than 80% (top group) of at least one age group and species. A 1% level of significance was chosen, (Table 3). The chemicals which did not cause significantly more mortality than that in the control group are indicated * in Table 1 and Table 2 shows those chemicals which did cause significant mortality. Table 2 is divided into two parts (A) in which the mortality of at least one age group for one species was not significantly different from the best (over 80% mortality) and (B) in which while the mortality was better than the control it was not high. All of the 15 possible pairs of the three insecticides and 3 herbicides were in the highly effective group (Table 2A).

TABLE 3: The mean % mortality of slugs and eggs in the control and top groups and the least significant differences between these groups and the mid group

Common name	<i>D. panormitanum</i>				<i>D. reticulatum</i>			
	BAIT		SPRAY		BAIT		SPRAY	
	Adult	Juvenile	Adult	Eggs	Adult	Juvenile	Adult	Eggs
Control group	11.0	10.0	11.0	46.4	12.0	9.2	12.0	68.2
LSD 1%	30.3	30.1	30.3	17.8	30.4	38.8	30.4	13.1
top group	91.9	91.9	89.3	97.2	87.7	90.6	97.8	96.5
LSD 1%	30.3	30.3	30.4	12.9	30.3	30.3	30.3	17.5

Of the 69 biocides tested 36 had no effect on any age of either species, 23 biocides killed more than 80% of at least one age group and 10 chemicals had a significant but lower toxicity. Fungicides and herbicides tended to be effective against slug eggs whereas insecticides were most effective when ingested. Only metaldehyde and phorate were effective contact molluscicides when applied alone. The effectiveness of dazomet resulted from the reluctance of the slugs to cross the sprayed soil to their food, they remained in the refuge and died of starvation.

Under the test conditions only metaldehyde was highly effective against all ages of both species as bait and as a spray. Methiocarb was not effective as a contact molluscicide, although it did kill over 90% of the eggs of both species.

The effect of combinations of biocides was not predictable from the effects of each chemical alone. Methiocarb was highly effective against all ages of both species as

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bait and as spray when combined with carbaryl or methomyl, in fact any combination of two of these three biocides was more effective than any applied singly. However, alachlor, ioxynil and 2,4,5-T reduced the effectiveness of the three insecticides against at least one age of one species. The effectiveness of herbicides was also changed when they were applied in combination. Alachlor alone was an effective juvenile bait and ovicide for *D. reticulatum*, ioxynil alone had some activity as a bait against adults and juveniles of both species. The combination was only effective against *D. reticulatum* eggs. Similarly alachlor and 2,4,5-T combined with ioxynil was a good bait for the adults of *D. reticulatum*.

In general both species reacted in a similar manner to each biocide, the main points of interest are in the reaction of different age groups. For example, phorate did not kill eggs, carbaryl may be less effective against juveniles than adults, and methamidophos was more effective against juveniles.

DISCUSSION

The object of this study was two-fold, firstly to ascertain the similarity of *D. panormitanum* and *D. reticulatum* in their susceptibility to biocides and, secondly, to find out which of the commonly used biocides have molluscicidal activity at normal rates of application. The first point has been answered clearly; *D. panormitanum* reacts to biocides in the same manner as *D. reticulatum*. There may be some exceptions but generally, overseas references to *D. reticulatum* should be relevant to both species in New Zealand. Answers to the second point are less clear cut. Forty per cent of the biocides tested killed at least a proportion of both species of slug, perhaps the most important point to note is that five herbicides and five fungicides killed slug eggs very effectively. It was not within the scope of this study to test effectiveness in the field but it would seem reasonable to suppose that some of the 28 chemicals which killed slugs in the laboratory will also kill slugs in the field, as a side effect of their normal use.

The small number of chemicals used in combination show that the side effects of using more than one chemical cannot be predicted from a knowledge of their separate effects. In direct drilled crops, for example, it would be important to apply a herbicide which did not reduce the effect of any molluscicide. A biocide marketed primarily as a molluscicide must have a high kill rate and be applied in a manner likely to maximise its effect. This does not mean that chemicals applied to crops for other purposes must have a nil effect on slugs. Most brassica crops grown for local markets will have applied to them at least two fungicides, one insecticide and one herbicide. In many horticultural crops the total number of chemicals applied is greater than this. It would seem, from this study, that there is a good chance that some slug control is being achieved as a side effect of other control measures and that slug control could be increased if chemicals were selected with primary target, side effects and possible synergistic effects in mind.

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