Effects of simulated rainfall on two contrasting metaldehyde slug baits

M.J. Wilson[1], D.J. Wilson[1], G. Burch[1] and B. Cotching[2]
[1]AgResearch Limited, Ruakura Research Centre Private Bag 3123, Hamilton 3240, New Zealand
[2]Ravensdown Ltd, PO Box 16081, Hornby, Christchurch 8441, New Zealand

Abstract

Slug pests can cause considerable damage to horticultural, pastoral and arable crops, particularly at crop establishment. There is a competitive market for slug baits, most of which use the active ingredient metaldehyde. However, for this single active ingredient there are many products of contrasting formulations, pellet sizes and application rates. While there is anecdotal evidence that some commercial products break down under heavy rainfall, this has not been confirmed experimentally. The efficacy of high and low rates of two contrasting commercial slug baits (large vs. small pellets) was compared under high and low simulated rainfall regimes. Plots were shielded from natural rain such that simulated rainfall could be controlled. The baits were assessed for their ability to protect forage brassicas from slug damage, and both plant establishment and slug grazing damage were recorded. The two baits performed differently under the differing rainfall regime experiments. In the low rainfall experiment carried out at the beginning of summer there was little slug damage, all baits significantly reduced slug damage but there were no significant differences among bait treatments. In the high rainfall experiment carried out at the end of summer there was considerably more slug damage, and the low rate of the small bait pellets did not significantly reduce slug damage, unlike the other three bait treatments.

Additional keywords: *Deroceras reticulatum,* mini-plots, rape, establishment

Introduction

Slugs damage a large range of crops throughout the world (Barker, 2002a). Despite a favourable climate and a general abundance of slugs, very little research in New Zealand has focused on slug damage and slug control, and most that has, has concentrated on slugs damaging clover in pasture (Barker, 2002a; Wilson and Barker, 2011).

Slug problems are becoming increasingly prevalent as increasing areas of cropped land are sown by direct drilling (Rae *et al*., 2005). While for some crops e.g., potatoes, a degree of slug resistance is available in some varieties but for many other crops, e.g., forage brassicas, all varieties are damaged by slugs. In Europe, a nematode parasite is available as a biological control for slugs (Rae *et al*., 2007), but this is not yet available in New Zealand. Where susceptible crops are established by direct drilling, growers rely on molluscicide pellets (slug baits) to minimise slug damage. Slug baits contain one of three active ingredients: methiocarb, metaldehyde or chelated iron phosphate (Henderson and Triebskorn, 2002; Rae *et al.*, 2009). Methiocarb is a broad spectrum biocide and its use is generally discouraged because of known non-target effects on beneficial insects (Bailey, 2002). Both metaldehyde and chelated iron phosphate baits are more specific, but the latter are not widely available in New Zealand. Most New Zealand growers therefore, use one of the many available metaldehyde baits. It has been suggested that numerous factors including weather, availability of other food sources and bait persistence can influence the efficacy of baits (Bailey, 2002). However, most data provided on efficacy of bait formulations is anecdotal. The patchy nature of slug populations, and annual variations within slug populations associated with climate, makes it is difficult and/or expensive to reliably obtain significant differences in slug damage in full scale field experiments. While these problems can be overcome in "laboratory" investigations using containers, the results of container experiments do not readily apply to field situations. The aim in the current work was to develop a mid-size outdoor system for systematic testing of slug bait efficacy, and to test the system by investigating the effect on slugs of two contrasting metaldehyde formulations, one using large pellets (ENDURE®, Ravensdown Fertiliser Co-operative Ltd) and one using small pellets (SlugOut®, Nufarm Technologies USA Pty Ltd). In addition to pellet size, the pellet formulations are quite distinct. The large pellets are homogenised pasta baits, with the active ingredient being distributed throughout the pellet, whereas in the small pellets, the active ingredient is applied as a surface coating to an inert chip.

This work aimed to investigate the effect of simulated rainfall on efficacy of baits. Because the increased irrigation also influences seed germination, plant growth, slug activity and slug survival, two separate experiments were carried out, one with low irrigation and one with high irrigation such that plants were all at similar growth stages at all assessment dates.

Materials and Methods

General Methods

Experiments were carried out using plastic crates 95 x 114 x 50 cm deep (surface area = 1.083 m^2) filled with loam soil to serve as plots. A 7.5 cm wide strip of P90 sand paper was attached around the upper inside edge of each plot to deter slugs from crawling out of the plots and a 20 cm diameter plastic plant pot saucer was placed in the centre of each plot as a shelter for slugs. The shelter was surmounted with an 18 x 18 x 19 cm deep plant pot to support bird-excluding nets that covered the plot. Because the aim was to investigate different levels of irrigation (= simulated rainfall) plots were placed outside but under a veranda to exclude natural rainfall.

Deroceras reticulatum (Müller) slugs, the most widespread and common pest species in New Zealand, were used in the experiments and were collected from pastures near Ruakura, Hamilton.

Slugs were introduced to the plots in open Petri dishes placed under the central shelter and allowed to crawl out and settle into their environment themselves to minimise handling. This introduction of 20 slugs per plot occurred three days before the low irrigation experiment commenced and one day before the high irrigation experiment commenced. Petri dishes were removed the following day. Carrot discs were added with the slugs to provide food prior to germination of test plants.

On the start day of the experiments, four narrow furrows, approximately 2 mm deep, were made lengthways in each plot and 20 rape (*Brassica napus* L.) seeds, cv. Spitfire were planted in each furrow (80 seeds/plot). The furrows were then gently filled by hand to cover the seeds. Slug baits were evenly spread over the plots by hand immediately after sowing. Each experiment comprised four replicates of five treatments with bait rates reflecting the manufacturer's label specifications for both minimum and maximum dose rates (Table 1).

Low irrigation experiment

This experiment started on 28 November 2013 and finished on 9 January 2014. During this time, the average mean air temperature was 17.7°C with an average minimum of 10.7°C and an average maximum of 28.8°C. Plots were watered thoroughly prior to the start of the experiment then received 5 mm irrigation every 3 days applied with a garden hose and spray attachment. Because several dead slugs were found on the surface of many plots, a further six slugs were added to each plot on (28 November 2013). Plant establishment and yield were assessed on 9 January, 2014 when all plants had reached four true leaves.

High irrigation experiment

This experiment started on 29 January, 2014 and 4 March, 2014. During this time, the average mean air temperature was 18.9°C with an average minimum of 11.2°C and an average maximum of 30.2°C. Plots were irrigated heavily for the first five days (5 mm per day) applied as two separate drenches of 2.5 mm, at least one hour apart to avoid water ponding on the soil surface followed by a further 5 mm every 2 days. Plant numbers and weight assessments were made on 4 March, 2014 when all plants had reached the four true leaf stage.

To assess the effect of the slug baits in both experiments, the number of established rape plants, percentage established rape plants showing slug damage, number of dead slugs on soil surface and plant dry matter per plot were measured. Data were analysed using ANOVA and significant treatment means were separated using Fisher's Protected Least Significant Difference test.

Results

Low irrigation experiment

There were significantly fewer dead slugs found on the soil surface of untreated plots compared with pellet-treated plots (P=0.021, Table 1). However there were no significant differences among the four pellet treatments (Table 1). Similarly, there was a significantly greater percentage of plants showing visible slug grazing in the untreated plots (P<0.001) but there were no significant differences between pellet treatments. There were no differences among treatments in total numbers of plants established by the end of the experiment (P=0.462) or plant dry matter per plot (P=0.114) (Table 1).

Table 1: The effects of high and low doses of small and large slug pellets on mean values per plot of cumulative numbers of dead slugs found in plots over fourteen days (no more were found after this period), numbers of plants established recorded nine weeks post-treatment, percentage of plants with slug grazing damage recorded at three weeks post treatments and plant dry weight recorded nine weeks post-treatment in the low irrigation experiment.

	Numbers of dead slugs	Numbers of. established plants	Plants with slug damage (%)	Plant dry weight (g)
Untreated Control	3	75.2	14.62	18.4
Large pellets 4 kg/ha	10.25	77.2	5.33	22.3
Large pellets 8 kg/ha	8	71.5	8.37	14.1
Small pellets 10 kg/ha	7.5	75.2	6.04	24.2
Small pellets 15 kg/ha	10	81.5	6.92	20.9
$LSD_{(0.05)}$	4.31	NA	3.57	NA
F-probability	0.021	NS	<0.001	NS

High irrigation experiment

There were significant differences in numbers of dead slugs found on the soil surface associated with treatment (P<0.001). Significantly fewer dead slugs were found in untreated plots than all bait treatments, except the low dose of the small pellets (Table 2). Most dead slugs were associated with the low rate of the large pellets, which had significantly more dead slugs than both rates of the small pellets (Table 2).

There were significant differences in the percentage of rape plants damaged by slugs associated with treatment (P=0.008). Smaller percentages of plants were damaged in all molluscicide treatments than in the untreated controls with the exception of the low rate of small pellets (Table 2) and there were also significant differences among molluscicide treatments. Plots treated with the low dose of the large pellets had least damage and this was significantly less than plots treated with the low rate of the small pellets (Table 2).

Treatment had a significant (P=0.022) influence on the number of established plants per plot (Table 2). The low rate of large pellets and the high rate of small pellets had significantly more plants than the untreated plots. The two different rates of large pellets did not differ significantly, whereas there was a substantial difference between the high and low rates of the small pellets.

Data for plant weights in the first replicate block were excluded from the analysis, as these plants received less light and were much smaller than in the remaining three blocks. There was also some evidence of stem base disease inhibiting plant growth in this block. Analysis of the remaining three blocks showed that treatment effects on plant dry weight per plot were very nearly, but not quite significant (P=0.055).

Table 2: The effects of high and low doses of small and large slug pellets on mean values per plot of cumulative numbers of dead slugs found in plots over seven days (no more were found after this period), numbers of plants established recorded five weeks post treatment, percentage of plants with slug grazing damage recorded at three weeks post-treatments and plant dry weight recorded five weeks post-treatment in the high irrigation experiment.

	Numbers of dead slugs	Numbers of established plants	Plants with slug damage (%)	Plant dry weight (g)
Untreated Control	0.25	52.8	71.1	2.73
Large pellets 4 kg/ha	5.25	67.0	11.1	6.16
Large pellets 8 kg/ha	4.5	59.0	22.7	7.19
Small pellets 10 kg/ha	1.5	54.2	45.8	4.71
Small pellets 15 kg/ha	3.25	74.0	23.7	5.33
$LSD_{(0.05)}$	1.99	13.35	30.55	NA
F-probability	<0.001	0.022	0.008	NS

For these data, greatest plant weights were recorded for the two rates of large pellets. All molluscicide treated plots had higher plant weights than untreated.

Discussion

While both bait products use metaldehyde as an active ingredient, the formulations and application rates in terms of baits per unit area are quite different. The small pellets are much smaller than the large pellets (approximately 0.0084 g versus 0.033 g per pellet respectively). This means there are more bait points per unit area and increased likelihood of slug encounter associated with small baits, but the much greater surface to volume ratio of these may make them more susceptible to breakdown under wet conditions. Furthermore, in the small pellets the active ingredient is concentrated at the pellet surface, which may also inhibit activity under high rainfall. However, there are no controlled experiments testing the extent to which this may happen. The current experiments set out to investigate the effect of light versus heavy simulated rainfall on pellet efficacy, but the very low levels of slug damage recorded in the low irrigation experiment make it difficult to draw firm conclusions about the relative efficacy of these two pellets under drier conditions.

It should also be noted that because the high and low irrigation regimes were tested in separate experiments, it is not possible to directly attribute relative differences among treatments to the irrigation regime alone, as other factors, e.g., ambient temperature may have affected bait efficacy.

There was very little slug damage in the low irrigation trial. Slugs had been difficult to collect during the hot, dry November, and many had been stored at 4°C for several weeks before the start of the experiment. Thus, slugs were probably stressed at the beginning of the experiment and the warm temperatures and dry conditions imposed by the low irrigation scheme probably caused high slug mortality and hence low damage. While significantly more slugs were found dead on the soil surface in pellet-treated plots, it is likely slugs in untreated plots too had died, but in their resting place within the soil rather than on the soil surface. There was a much greater range of slug damage in the high irrigation experiment and some evidence that the application rate of small pellets was important, with the low dose of small pellets failing to provide protection under the high irrigation regime. The same was not true for large pellets for which by the end of the experiment there were no significant differences between high and low rate application.

It is interesting that while slug activity was higher in the high irrigation experiment, numbers of dead slugs recorded in the plots were lower. This may imply that slugs that ingested the metaldehyde and become partially paralysed may have recovered. Martin and Forest, (1969) concluded that under wet conditions many slugs poisoned by metaldehyde can recover. However, under field conditions, moribund slugs would be subject to predation by both vertebrate and invertebrate predators, and would be much less likely to recover. The experimental setup in this work therefore may underestimate the efficacy of the molluscicides.

It should also be noted that because the high and low irrigation regimes were tested in separate experiments, it is not possible to directly attribute relative differences among treatments to the irrigation regime alone, as other factors, e.g., ambient temperature may have affected bait efficacy.

The newly developed box plot system presented in this work offers a good compromise between laboratory/glasshouse experiments and full scale field trials. Good replication can be achieved using uniform slug populations under outdoor conditions, and rainfall can be controlled. However, that is not to say that the system is a perfect mimic for field conditions and differences may well have affected the results in this work. Most noticeably, the slug population consisted of a relatively low number of adult slugs. The plot biomass was similar to biomass recorded in New Zealand pastures (Barker, 2002b) but slug numbers were much lower reflecting the fact that juvenile and adult slugs usually co-exist. The lower slug numbers found in this work may reduce the reported effects of increasing the number of bait points. In future experiments, the intention is to increase numbers of slugs per plot, firstly to make numbers more representative of field populations, and also to increase damage levels. Even in the high irrigation experiment, only an approximately 30% reduction in plant establishment was recorded, whereas in severe field infestations, >80% loss of establishment can be recorded.

Slugs are an important crop pest in New Zealand that have been largely ignored by the New Zealand research community. The experimental set up described here offers a technique that can be used to investigate slug impact and control and contribute to reversing this situation. There are many important issues arising from this work relating to slug problems and control using bait pellets. For example, significant differences in plant numbers were detected, but not total plant weight. What degree of slug damage is needed to reduce crop yield? The data from this work suggested that under high rainfall the smaller pellets were less effective, but at present it cannot be determined if this is an issue with pellet size, or formulation. Thus, there is much more research that needs to be done before sound advice to growers based on scientific experimentation can be given.

References

Bailey, S.E.R. 2002. Molluscicidal baits for control of terrestrial gastropods. pp. 33-54. *In:* Molluscs as crop pests. Ed. Barker, G.M. CABI Publishing, Wallingford.

Barker, G.M. 2002a. Molluscs as crop pests. CABI Publishing, Wallingford. 468 pp.

Barker, G.M. 2002b. Gastropods as pests in New Zealand pastoral agriculture, with emphasis on Agriolimacidae, Arionidae and Milacidae. pp. 361-423. *In:* Molluscs as crop pests. Ed. Barker, G.M. CABI Publishing, Wallingford.

Henderson, I. and Triebskorn, R. 2002. Chemical control of terrestrial gastropods. pp. 1-31. *In:* Molluscs as crop pests. Ed. Barker, G.M. CABI Publishing, Wallingford.

Martin, T.J. and Forest, J.D. 1969. Development of Draza in Great Britain. *Pflanzenshutz-Nachichten Bayer* 22: 205-243.

Rae, R.G., Robertson, J.F. and Wilson, M.J. 2005. Modern developments in slug control. *Outlooks on Pest Management* 16: 27-30.

Rae, R.G., Verdun, C., Grewal, P.S. Robertson, J.F. and Wilson, M.J. 2007. Biological control of terrestrial molluscs using *Phasmarhabditis hermaphrodita* – progress and prospects. *Pest Management Science* 63: 1153-1164.

Rae, R.G., Roberston, J.F. and Wilson, M.J. (2009). Optimization of biological (*Phasmarhabditis hermaphrodita*) and chemical (iron phosphate and metaldehyde) slug control. *Crop Protection* 28: 765–773.

Wilson, M.J. and Barker, G.M. 2011 . Slugs as pasture pests. *Grassland Research and Practice Series* 15: 125-128.