Control of Slugs in the Australian Vegetable Industry

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Final Report

HAL Project VGO8152

Project Title: Control of Slugs in the Australian Vegetable Industry

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HAL Project : Control of Slugs in the Australian Vegetable Industry VG08152

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Summary:

The aim of this project was to develop a strategy for controlling slugs in processing vegetable crops based on existing information from previous Australian studies (mostly in broad-acre crops). Some field observations from Tasmanian crops were made to help develop the strategy. Relevant information has been collated and presented in a format that is appropriate for the end users of this research. This information includes:

- a guide to the most common species of slugs
- cultural or management options that can have a positive or negative impact on slugs
- the potential use of beneficial insects within an IPM system to help maintain a low population of slugs
- Why baiting does not always work
- How to control slugs using the tools that are currently available

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Media Summary

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Slugs feed on living plants and sometimes on other organic matter such as stubble or dead insects. They can be a problem in processing vegetables either because of direct eeding damage to plants, especially at crop establishment, but also as contaminants at harvest in crops such as processing peas. This latter issue is of particular concern to vegetable processors.

Slugs can invade a paddock from a weedy edge or can build up within a paddock because of favourable rotations such as pasture or irrigated lucerne. Some native predators of slugs can be important, especially in pasture phases, but they are easily affected by insecticides targeting other pests such as mites, caterpillars or aphids.

Once a paddock or farm has a serious problem with slugs they are very difficult to control. This problem is compounded if there are restrictions placed on baiting once the crop is established. With an essentially unlimited food supply (the crop), a perfect environment (moist, shelter) and few or no predators, slug populations can reach damaging levels.

The best option is to manage populations of slugs before they reach damaging levels and that usually means using methods in the crop(s) prior to a susceptible processing crop.

One of the key points in controlling slugs is for growers to be able to assess the level of slugs within a paddock, including the identification of slug species. The demonstration sites used for this project both indicate that the number of slugs can be greatly underestimated.

Technical Summary

Several species of slugs (Mollusca: Gastropoda) have been accidentally introduced into Australia and these now can be pests in a range of agricultural crops. These species include *Deroceras reticulatum,* (Grey field slug), *D. panormitanum,* (Chestnut slug) *Lehmannia nyctelia,*(Striped slug), *Lehmannia flava* (Great yellow slug), *Milax gaga*tes (Black keeled slug) and *Arion intermedius* (Hedgehog slug). *Limax maximus* (Leopard slug) is widespread but not usually a concern in agricultural systems and *Arion ater* (European black slug) is known only from a couple of isolated locations in wetter areas of Victoria and South Australia. Native slugs are not agricultural pests in southern Australia as they are restricted to native habitats.

Slugs feed on living plants and sometimes on other organic matter such as stubble or dead insects. They can be a problem in processing vegetables either because of direct feeding damage to plants, especially at crop establishment, but also as contaminants at harvest in crops such as processing peas. This latter issue is of particular concern to processors, and so the relative importance of slug species based on crop damage is not necessarily relevant. Instead, the mere presence of slugs is the criterion that matters.

Slugs can invade a paddock from a weedy edge or can build up within a paddock because of favourable rotations such as pasture or irrigated lucerne. These parts of the rotation are of particular concern because of the lack of tillage, which is known to disrupt slug populations. Some native predators of slugs can be important, especially in pasture phases, but they are easily affected by insecticides targeting other pests such as mites, caterpillars or aphids. This means that control of slugs needs to be considered in more than just a single crop.

Once a paddock or farm has a serious problem with slugs they are very difficult to control. All slugs are hermaphroditic which means that each individual slug has the potential to produce eggs, and some species can produce more than 1,000 eggs each. This problem is compounded if there are restrictions placed on baiting once the crop is established. With an essentially unlimited food supply (the crop), a perfect environment (moist, shelter) and few or no predators, slug populations can reach damaging levels.

The best option is to manage populations of slugs before they reach damaging levels and that usually means using methods in the crop(s) prior to a susceptible processing crop. Rather than let a population build up in a crop or pasture where damage is not of great concern and then attempt to deal with the pests in a susceptible processing crop, it is suggested that it is better to begin control measures ahead in the rotation. That is, look at slug control a year or more ahead of planting a crop such as processing peas.

One of the key points in controlling slugs is for growers to be able to assess the level of slugs within a paddock, including the identification of slug species. The demonstration sites used for this project both indicate that the number of slugs can be greatly underestimated. Rates of bait used will influence the results, and banding higher rates along perimeters (even outside the crop area) to deal with invading pests would be worthwhile.

Introduction

This project was commenced because there was a need by the processing vegetable industry to achieve better control of slugs. The processors wanted to achieve fewer complaints about slugs as contaminants in produce, and highlighted pea crops as being of particular concern. This project aimed to bring together information about slugs that was available from a range of sources and use it to develop a draft strategy for control of slugs in processing crops.

Several species of slugs (Mollusca: Gastropoda) have been accidentally introduced into Australia and these now can be pests in a range of agricultural crops. These species include *Deroceras reticulatum, D. panormitanum, Lehmannia nyctelia, Lehmannia flava, Milax gaga*tes and *Arion intermedius*. *Limax maximus* is widespread but not usually a concern in agricultural systems and *Arion ater* is known only from a couple of isolated locations in wetter areas of Victoria and South Australia. Native slugs are not agricultural pests in southern Australia as they are restricted to non-agricultural habitats.

Slugs feed on living plants and sometimes on other organic matter such as stubble or dead insects. They can be a problem in processing vegetables either because of direct deeding damage to plants, especially at crop establishment, but also as contaminants at harvest in crops such as processing peas. This latter issue is of particular concern to processors, and so the relative importance of slug species based on crop damage is not necessarily relevant. Instead, the mere presence of slugs is the criterion that matters.

All species of pest slugs listed above have been introduced from overseas and so they have escaped their natural enemies that would be found in their places of origin. There are some native Australian insects (carabid beetles) that will accept slugs as prey and these can exert a significant impact on slug populations (Horne 2005, Horne 2008, Nash *et al* 2008). These carabid predators of slugs typically have life-cycles of 1 or two years. They are easily killed by applications broad-spectrum insecticides such as synthetic pyrethroids, organophosphates, fipronil and importantly methiocarb-based molluscicides. This is in part because the beetles are scavengers as well as predators and so will feed on insects and slugs affected by the insecticides, even if they are not directly exposed to them. Therefore, in the long-term it is necessary to not use such insecticides in paddocks where sustainable control of slugs is desired as populations of carabids are slow to recover.

There are two scenarios where slugs need to be controlled; firstly, dealing with slugs in a paddock about to be planted (or already planted), and secondly, reducing the slug population in a paddock before a crop is planted and then keeping that population down. Obviously the second option is better but will take at least 2 - 3 years in most cases to lower the resident populations of slugs, and increase the size of populations of native predators of slugs.

In both cases, an assessment of risk of damage by slugs needs to be made before the crop is planted. This means taking into account the numbers of slugs and the species of slugs present. It is also important to look for other pest species that can cause identical damage to slugs (in particular European earwigs). Therefore, this project aimed to provide the processing vegetable industry with better means to identify the slugs present, how to assess risk and a strategy to better deal with slugs. A monitoring approach was proposed (outlined below) that was field tested by an agronomist from the advisory company, Serve-Ag Pty Ltd.

Materials and Methods

Existing information on slugs (Horne 2005, Horne 2008 and Page and Horne 2006) was utilised to formulate a draft strategy and guide to slugs. This strategy was then tested in the field.

Field sites in processing pea crops in Tasmania were chosen and the proposed strategy was implemented as a demonstration with support from IPM Technologies. The aim of the field work was to demonstrate monitoring methods, demonstrate how the proposed strategy would operate and provide some information on the type of slugs to be dealt with in a processing crop in Tasmania.

The crops most likely to be affected are processing peas and beans, and so the demonstrations were in these crops. A workshop run by IPM Technologies to outline the strategy and identify an agreed course of action regarding all pest control activities was

conducted at the commencement of the project, with participants from McCain, Simplot and Serve-Ag.

Ten tiles were placed in each paddock, 5 along an edge and 5 in the middle. The tiles were made of MDF and were 30 cm x 30cm. The tiles were used as shelter traps which is a standard method used for trapping and monitoring slugs as well as other species that are active on the soil surface including carabids. The tiles were checked throughout the season by an agronomist from Serve-Ag Pty Ltd and the species and number of slugs were recorded.

The aim of the monitoring was to identify which species of slugs were present, if they were through the whole paddock or moving in from an edge and were there other potential pests or beneficial species present. The tiles were also used to give an indication of the size of the population.

Results

Species found in Tasmanian trials

Only three species were recorded from the pea crops in this project. These were *Deroceras reticulatum* , *Milax gagates* and *D. panormitanum*. A fourth species, *Arion intermedius,* had been collected nearby in a previous study (Horne 2005). As an establishment pest *M. gagates* is the most damaging followed by *D.reticulatum* and then *D. panormitanum.* All species however have equal potential to be a problem as a contaminant.

At site 1 three species of slugs were identified, the highest number of slugs was recorded along one edge and a low level along the others. No slugs were recorded in the middle of the paddock . A low number of European earwigs and predatory carabid beetles were also found. At this site two applications of bait applied at a high rate was recommended along the eastern edge.

At site 2 two species of slugs were identified, the highest number recorded was along one edge that bordered a lucerne paddock in which the number of slugs was extremely high. This farm has a long history of slug problems possibly due to having lucerne in the rotation.

Irrigated lucerne is the perfect habitat for slugs as it is moist, provides good shelter and is undisturbed for a number of years. The damage slugs cause to lucerne is perceived to be low and so may not receive the rate of bait needed to keep the population down, particularly when a susceptible crop is to be grown following the lucerne. At site 2 a high rate of bait was recommended in the pea paddock along the lucerne border. Bait was not recommended in the lucerne because the population of slugs was so high that even baiting at the label rate would have had minimal impact. Consideration was given to the cost of baiting and in this case there was better value in only baiting the edge in the pea paddock. For this site a long term strategy is needed to lower the slug population over the whole farm particularly if lucerne is included in the rotation. No predatory beetles or earwigs were found.

Table 1: Site 1. Pea paddock Number of slugs, European earwigs and carabid beetles recorded.

Date	location	*Deroceras reticulatum*	*Milax gagates*	*Deroceras panormitanum*	European earwig	Carabid beetles
29/7/09	Eastern edge	42	2	2	2	0
	Bottom edge	0	0	0	0	0
	Top edge	11	11	5	0	1
6/8/09	Eastern edge	31	1	7	0	0
	Bottom edge	3	0	0	0	0
	Top edge	18	16	0	0	0
15/8/09	Eastern Edge	39	2	10	2	0
	Bottom edge	0	0	0	0	0
	Top edge	11	8	9	0	1

Table 2: Site 2. Pea paddock. Number of slugs, European earwigs and carabid beetles recorded.

date	*Deroceras reticulatum*	*Milax gagates*	*Deroceras panormitanum*	European earwig	Carabid beetles
2/7/09	7	5	0	0	0
27/7/09	0	0	0	0	0
16/9/09	8	6	0	0	0
12/1/10	4	5	0	0	0

Table 3: Site 2. Lucerne paddock. Number of slugs, European earwigs and carabid beetles recorded.

date	*Deroceras reticulatum*	*Milax gagates*	*Deroceras panormitanum*	European earwig	Carabid beetles
27/7/09	21	40	0	0	0
16/9/09	60	0	0	0	0
12/1/10	9	6	0	0	0

Slug Control Strategies

The sites chosen are good examples of the two possible control strategies.

Site 1 has the potential for the population to be maintained at a low level by the use of strategic baiting along the paddock edge.

Site 2 has a much more serious problem that will require a longer term strategy. Control of slugs in the pea crop relies on the management of the population over the whole farm.

What options are available?

The first point to consider is the range of control options that are available. These include:

1. Bait – The amount of bait that is required will depend on the number of individuals present, and as slugs can foul baits with mucus the efficiency of baiting is lessened as the population size becomes higher. The most common reason for baits to fail is that the rate used is too low.
2. Rotation - some crops favour slugs more than others by providing a good habitat and food source. Other crops that are in for long periods of time such as Lucerne, pasture, poppies and pyrethrum can bulk up populations simply because instead of the paddock being cultivated and baited every year it may only be one year in three.
3. Tillage – tillage can have a very big impact on slugs by removing their habitat and also by physically damaging them. Cloddy ground favours slugs by providing a habitat for them.
4. Burning- removes their habitat
5. Native predators- in most horticultural situations predators of slugs such as carabid beetles do not survive well. They are easily killed by broad –spectrum insecticides so it is only in situations where these are no longer used that there is the potential for predators to have an impact.

The species found will also influence the impact of different control strategies. The most common pest species, *D. reticulatum*, becomes active after any rainfall, while the other serious pest, *M. gagates*, is a true burrower and will only become active when the soil profile is wet.

There are two likely scenarios for a farmer wanting to control slugs and we discuss each of these here. In the two scenarios described, we outline the factors that should be considered in assessing risk and deciding on control options.

A. Dealing with a Problem Paddock immediately

1. Paddock History (previous problems with slugs)
2. Make sure it is actually slugs causing the damage (pests such as earwigs can cause identical damage symptoms).

   Monitor for slugs using ***direct searching*** (including looking for eggs and tiny stages) and ***shelter traps*** (tiles)
3. Identify the species of slugs (measure risk) and assess the level of the problem (High, medium, low).
4. Bait using EDTA-based baits using a high rate, split over two applications. Alternatively use Metarex® if high rainfall is expected.

B. Long-Term Strategy

1. Monitor for slugs, as above, in non-susceptible crops in Spring
2. Treat with baits in Autumn to prevent a build-up
3. Plant susceptible crops early, so that they do not sit in the vulnerable cotyledon stage for too long.
4. Avoid the use of broad-spectrum insecticides for any pests
5. Monitor for predators of slugs.

Factors to consider when Assessing risk:

(not Problem Paddocks where it is known there is a high level of slugs) –

Paddock History (do previous crops increase populations of slugs?)
Number of slugs found per trap (relative number to compare sites or years)
Species of slugs (*D. reticulatum* and *M. gagates* most damaging)
Life stage of slugs (small/adult)
Time of planting (will plants sit in the vulnerable cotyledon stage for long?)
Soil preparation (cloddy soils favour slugs)
Press wheels used or not (press wheels help reduce damage at establishment)
Predators present/not (carabid beetles can prey on small slugs)

Stubble retention/ burnt (retained stubble can improve the habitat for slugs and also beneficial species)

Seeding density (increased seedling density can help compensate for slug damage)

Insecticide use (broad-spectrum insecticides in previous crops will kill carabid beetles)

Value of crop (how much should be spent on crop protection?)

Baiting

Use EDTA baits or Metarex® if irrigated

Bait early (before crop is planted or seeds germinated) if adult slugs are present and active.

Apply baits twice if both *Milax* and *D.reticulatum* present

Not all slugs active at one time (2 baits better than one)

Use a high rate of bait per ha.

Border bait at a higher rate if slugs are likely to come in from an edge.

Slug Identification Guide

A draft guide to slugs found in agricultural crops in southern Australia is included with this report.

Discussion and Conclusions

This project summarises the strategy needed to improve control in processing vegetable crops. A key point is that control measures must consider all crops in the rotation and that a strategy may be required that takes several years. Another key point is that baiting should not only be considered in the crop at risk. Instead, looking to prevent the build-up of slug populations is better than trying to deal with high populations in a vulnerable crop.

It was not possible in a one year project to validate a strategy that includes rotation and multiple years of actions to impact slug populations but the strategy has been successful in other crops. It was possible to demonstrate the methods involved in assessing risk of slug damage and how to identify the different species of slugs.

The identification guide included with this report could be produced as a guide to slugs in horticulture (and other crops) in general. This would be a useful tool to assist in managing slug pests.

Validation of the draft strategy could also be undertaken as either a project or by farmer groups.

Communications/ Extension

The project plan, conduct and strategy have been developed with the input from agronomists with ServeAg, MCCain and Simplot.

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DRAFT STRATEGY FOR THE CONTROL OF SLUGS IN PROCESSING CROPS

By Jessica Page and Paul Horne, IPM Technologies Pty Ltd.

There are 4 main species of slugs commonly found in agricultural systems throughout Southern Australia. All of these species originate from different parts of Europe and have done very well at adapting to conditions here. All slugs are hermaphrodites, which means they change sex several times throughout their life. This characteristic gives each individual the ability to lay eggs. The number of eggs laid by each individual varies between species but can be as many as 1,000 or more, so a population can increase rapidly given the right conditions. Once a population is well established in a paddock they can be very difficult to control but there are tools that can be used to manage the population and keep it below a critical level. These tools can be divided into three groups - chemical control, cultural control and biological control.

Chemical Control

Baits – All commercially available baits kill slugs. There are slight differences in how rain-fast they are but they are all equally effective if a slug feeds on them. However once a bait is fouled with slime, other slugs may not feed on it. The biggest issue with baits is application rate. Slugs are not all active at the same time so it is very easy to underestimate the size of the population. What may seem like a high rate often isn't and you may be relying on a below-label rate to try and control a high population of slugs!

Below label rates will deliver low numbers of baits per square metre. For example, while Slugout at the label rate (20kg/ha) will deliver about 240 baits per square metre, a rate of 5 kg/ha would give only 60 baits/square metre and 2 kg/ha would give only 24 baits/ square

metre. Similarly, Multiguard at the top label rate of 16 kg/ha would deliver 40 baits/ square metre while 5 kg/ha gives 13 baits/ square metre while 2 kg/ha gives only 5 baits per square metre. Low rates are unlikely to give effective control if slugs are a problem.

Consider banding high rates of baits along edges where there are high levels of slugs.

Cultural Control

Rotation – Slugs do well in most crops but are not necessarily a problem in all crops. It is easy to bulk up a slug population without realising. Consider baiting the season before planting a susceptible crop or try to avoid planting a susceptible crop into a paddock that has not been baited for many years and has a very high population of slugs. Obviously there will be a problem if slugs are left to build up for several years and then control is attempted in a susceptible crop.

Cultivation – There are many cultural practices such as cultivation that can significantly reduce slug numbers by either physically damaging them or removing their food and shelter. Unfortunately many of these practices are undesirable for other reasons such as maintaining soil quality and health. They could be considered to help clean up a problem paddock but not used as a routine. Slugs do very well in cloddy ground so soil preparation is a very important tool.

Timing – If possible plant susceptible crops when they are more likely to grow beyond their vulnerable stage quickly. As an establishment pest most crops are safe once they have their true leaves. The situation you want to avoid is having plants sitting in the cotyledon stage over winter when slugs are most active. Also, timing of baiting should relate to the different slug species and life stages, and possibly in the crop before a susceptible one.

Biological Control

Predators – In Europe there are species of beetles that specialize in eating slugs, in Australia there are similar species that are generalist predators. These beetles are called carabids (Family Carabidae) or ground beetles and are very common throughout southern Australia. Carabids do very well in the same conditions that favour slugs such as stubble retention and minimum tillage so it reasonable to expect them to play a role in slug control. However, they are easily killed by the use of some insecticides (and some slug baits) and so are unlikely to be found in large numbers where broad-spectrum insecticides are used.

Important things to consider

Because slugs are long term residents within a paddock control or management of a slug population needs to be considered for the paddock and not for a specific crop. There are a range of tools available but on their own each one is limited, it is how they are used together that will give control. The best chance of controlling slugs will be when all of the options listed above are employed, and some of these will need to be considered several years ahead of the susceptible crop. Conversely, if only one tool (baits) are used then problems can be expected, and if low rates and poor timing of baiting are used then very poor results can be expected.

Earwigs- Not all damage is caused by slugs. European earwig damage is identical to slug damage so don't rely on symptoms alone. (Slug baits do not kill earwigs).

Monitoring – Shelter traps are the easiest method of monitoring for slugs. 30cm x 30cm tiles are good to use. Place five tiles about 2 metres apart in areas of a paddock that are of most

concern. It is important that it is moist underneath the tiles otherwise slugs will not find them attractive. Predatory beetles and earwigs will also shelter under tiles.

Slug Species (See separate ID Guide)

Deroceras reticulatum	Very damaging
Milax gagates	Very damaging
Deroceras panormitanum	Less damaging
Lehmannia nyctelia	Minor risk

However, if contamination is the concern rather than physical damage then all species can be of concern.

Summary:

1. Aim to use as many of the biological, cultural and chemical options as possible.
2. Make sure slugs are really the problem.
3. Use rates of bait appropriate for the level of pest slugs.
4. Target slugs according to species.

SLUG GUIDE ***Draft***

Deroceras reticulatum (Grey Field or Reticulated Slug). This is the most common species of slug found in agricultural systems across south-eastern Australia. It has a grey mottled appearance and has milky white mucus when poked with a pointy object. It shuts down in dry conditions but can be active even in summer in irrigated crops. It is very active on the surface and can lay up to 1000 eggs per individual.

Milax gagates (Black Keeled Slug). This species can tolerate long periods of dry conditions as it is a true burrowing slug. They are dark grey to black in colour and have a prominent ridge or keel along the length of their body. Each individual can lay up to 500 eggs which are often buried. They can cause more damage per individual than the other species.

Deroceras panormitanum (Chestnut Slug). This species is generally smaller than the Reticulated and the Black Keeled slugs and is less damaging per individual. They are brown in colour and have markings on their back that look like a thumb print; they also have a small keel on the tip of their tail. This species could be more important as a contaminant at harvest than as an establishment pest.

Lehmannia nyctelia (Striped Slug). This species is rarely a major pest and is possibly a scavenger as well as a plant feeder. It has a very different life cycle with eggs hatching late August. Their distribution is very patchy and they need good shelter such as rocks to survive over summer. Rarely a significant pest.

Lehmannia flava (Great Yellow Slug). Most commonly found around dairies. This is a large orange or yellow coloured slug. It has yellow mucus if poked with a pointy object. Unlikely to be a significant pest in horticultural crops.

Arion intermedius (Hedgehog Slug). This species can be a significant pest in other parts of the world, including New Zealand, but has only been found in very low numbers in Australia. It is a small slug compared to other the other species and can be distinguished by its yellow foot and dark antennae.

Limax maximus (Leopard Slug). Often found near houses feeding in places such as compost bins or dog food. This is a huge slug but is not a pest in Australian agriculture. It is a scavenger and is more suited to backyards than paddocks.

Arion ater (European Black Slug). This slug is not well established in Australia but isolated populations have been found in the Dandenongs in Victoria and near Mt Lofty in South Australia. It needs very moist conditions to survive and so is unlikely to ever be found in outdoor Australian agricultural systems. Adults are extremely large - about the size of a Lebanese cucumber.

Forficula auricularia (European earwig) is a common pest in crops as well as in the home garden. It can cause almost identical damage to that caused by slugs, especially to germinating seedlings or very young plants. They have wings folded up under wing covers and prominent forceps at the tip of the abdomen. Males and females have different shaped forceps.

Carabid beetles (Carabidae or ground beetles) are very often black with the body shape shown in the photo. They have prominent mandibles (jaws) at the front of the head. There are many different species of carabids but some of the common species in agricultural habitats eat slugs.