

Field vegetables

Project FV 225

Slug control in field vegetables

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As pellets alone will not control slug numbers or necessarily prevent damage to crops, an integrated long term approach to slug population management is essential. This factsheet will help to improve growers' understanding of how slugs live, how to assess their risk to crops and how best to manage their long term control.

Background

Slug populations and their economic significance

Slug populations have increased on arable land in the past twenty years, in part due to the increased area sown with oilseed rape, but also due to the ban on straw burning. In addition, the increased rotations with areas of non-cropped set aside land have resulted in fewer soil cultivations which is known to improve slug

survival. It is estimated that slugs cause £8 million of damage to vegetable crops each year in the UK despite the application of vast numbers of molluscicide pellets.

Type of damage

Slugs can attack and cause damage to vegetable crops at varying stages of their development. Attack in the early stages can result in plant loss by direct feeding on seedlings. At later

stages, feeding can lead to cosmetic problems such as holes and grazing damage (Figure 1). Faecal and slime contamination to mature crops makes them unmarketable whilst the presence of live or dead slugs in harvested produce will lead to rejections. The tolerance for feeding damage varies from zero in salad crops to small permitted tolerances in other crops like Brussels sprouts. The level of crop damage caused by slugs is directly related to their numbers and activity.



1 Slug feeding damage to Brussels sprout buttons

Main slug species and their behaviour

The species of slugs causing most damage to vegetable crops in the UK include the field slug *Deroceras reticulatum* (Figure 2) and the garden slugs *Arion hortensis* and *Arion distinctus* (Figure 3). *D. reticulatum* was found at 10 of the 11 sites sampled in slug experiments on lettuce and Brussels sprout crops (FV 225). As the same species are commonly found in arable crops, results from slug research in the arable sector can be used for devising management strategies for horticultural crops.

The field slug; *Deroceras reticulatum*

D. reticulatum can be variable in colour but is often light grey or fawn. It grows to 5 cm in length (when extended), producing a milky white mucus when irritated. It is the predominant species and most troublesome given its activity at temperatures close to freezing, when it will continue to be active in damp weather. Breeding is generally at its height in April and May with another peak occurring from September to October. However, if weather conditions are favourable, they will breed throughout the year. Populations tend to have a mixed age structure, so damage occurs whenever conditions are favourable for activity. In optimum conditions *D. reticulatum* can start to lay eggs within 16 weeks of hatching, but it more often takes longer.

The garden slugs; *Arion hortensis* and *Arion distinctus*

A. hortensis and *A. distinctus* are generally smaller than the field slug (*D. reticulatum*). The body is dark and the foot (underside) is yellow or orange. They produce yellow or orange mucus. Peak egg hatching for these *Arion* species occurs in the late spring. Young slugs can develop rapidly to produce a further generation within the year. *Arion* species are only active at temperatures above 5°C.

Reproduction and activity

Female slugs may produce up to 500 eggs over several weeks, laying them in small batches in crevices, worm-holes or between clods or at the base of plants. Eggs develop slowly during the winter, but will hatch within a few weeks when the soil temperatures start to rise.

The number of active slugs found at any one time and place is dictated by both the slug population density and the suitability of the weather for activity (activity-density). Rapid reproduction and growth is enhanced by mild, moist weather conditions, sufficient food supply and ample shelter. Such conditions prevail in the spring and early autumn, making crops like lettuce and Brussels sprouts more vulnerable at these times of year.

Slug movement occurs most frequently at night, but they will return

to their resting site by dawn if weather conditions are unfavourable. They do not travel far from where they were hatched, often taking only a circular route of a few metres in search of food.

Food preferences

Slugs prefer soft, nutritious tissue provided by young ground plants rather than more fibrous material. A damp environment combined with succulent food is essential for their survival, so leafier crops that provide ground cover are often preferred. However, when choice of food is limited, even unpalatable material is grazed. Having found a palatable food source, slugs remember its location and repeatedly commute from resting areas just to feed. Preference for certain vegetable varieties is clearly seen in the differential damage they cause within variety trials.



2 Field slug; *Deroceras reticulatum*



3 Garden slug; *Arion distinctus*

Assessing the risks to crops

Because the risk of damage from slugs is so high, growers should always assess slug populations on land regularly used in crop rotations as well as rented land. The earlier the assessment is made, the more time is available to incorporate effective control measures before a susceptible crop is established. Action should be taken before and during the establishment of a susceptible vegetable crop.

Things to consider

For all cropping fields, consider the six factors listed below which can increase the risk of attack. Each will either raise concerns or allay fears about the risks of slug attack.

1. Prolonged damp weather in the spring and autumn

The level of feeding and mating activity are dependent on temperature, light, moisture and soil structure. Slugs are most active during damp warm nights with temperatures between 5°C and 20°C, but will continue feeding throughout daylight hours on dull, damp days. High humidity and low wind speed also favour slug activity, but are less important than surface moisture and temperature.

2. Heavy clay soil types

Slugs tend to be more numerous on heavy, damp soils that are difficult to cultivate. Such soils remain cloddy (Figure 4) and provide more shelter than friable, frequently cultivated soils. The skin of slugs is soft and covered in mucus, which makes them susceptible to desiccation. If they remain in dry soil conditions they will die, but they can survive by moving down the soil profile by up to 2 metres, in search of moist soil. Be aware however that soils that are excessively wet, will in fact reduce the abundance of slugs.

3. Slug damage in previous years

Does the field have a recent history of slug damage? If so, where the crop rotation remains the same with no differences in cultivation practice,

then the risk remains high, especially if the soil has a clay texture.

4. Crops most sensitive to slug damage

Potatoes, celery, carrots, asparagus, long season brassicas such as Brussels sprouts, winter and spring cabbage, lettuce and spinach tend to be the most susceptible vegetable crops. Early planted crops like lettuce and salad crops (under covers and in the open) are known to be very vulnerable, especially if palatable to slugs (Figure 5). This is particularly so when the crop is grown under fleece or polythene covers, where warm, damp and occasionally weedy conditions prevail.

5. Crop rotations dominated by crops providing shelter or containing green fallow crops

Crops that follow oilseed rape,

cereals, potatoes, longer season ware brassicas, peas and beans are more susceptible to attack. New plantations that follow crops that have been growing for lengthy periods are also more susceptible. The effect of reduced soil disturbance tends to reduce slug mortality, thus increasing slug populations and the resulting risk of damage.

6. Small fields surrounded by dykes, wasteland, hedgerows or green fallow

Plants within 3 metres of field boundary vegetation are more prone to damage due to higher concentrations of slugs closer to the headland. However, except for headlands, populations of slugs are generally fairly evenly distributed across fields depending on levels of soil moisture. Be aware that irrigation will favour slugs by maintaining high soil moisture levels.



4 Slugs tend to be more numerous on heavy, damp and cloddy soils



5 Early planted lettuce crops are particularly vulnerable

Corrective action

If any of these factors indicate a high risk, the following action can be taken during and after the life of the preceding crop to minimise slug numbers:

- Apply herbicides to reduce weeds as a food source in the growing crop and ensure all crop residues are fully dried on the soil surface before being incorporated.

- During prolonged wet periods, if damage has been seen, apply pellets at the optimum time.
- Be prepared to use multiple cultivations as a tool to reduce numbers when time and soil conditions permit. Cultivations will move the soil, cause direct physical damage and leave slugs and their eggs exposed to environmental stress and predators.

Having taken this action, slug populations should be monitored and estimated, to determine which if any further control measures are required.

Monitoring for slugs

The most effective time to monitor for slugs is when the weather is warm and the soil damp. Sampling slugs in fields is best done using refuge traps consisting of upturned plastic plant pot saucers (Figure 6), baited with Chicken Layers Mash (a very palatable chicken feed), or other cereal based food (not slug pellets). These traps will provide an indication of slug activity during the preceding night.

Project FV 225 developed thresholds for slug populations in lettuce and sprout crops. For lettuce, if any slugs are found on the boundary or in any part of the field prior to planting, then treat. In sprout crops, one slug per trap is sufficient to justify treatment. If no slugs are found, continue to trap. It is interesting to note that for arable

crops, the threshold for treatment is 4 slugs caught.

Be aware that when soil conditions are dry and slugs are not actively seeking food, trapping will have little value in determining the threat to the crop.

How to monitor

Place no less than 10 traps at least 5 metres apart across the area to be monitored in the afternoon or evening, on a day when the soil surface is moist. In standing crops, place the traps just to the side of tramlines and mark with canes to allow them to be located. Bait traps with 20 ml (2 heaped 5 ml teaspoons) of Layers Mash positioned centrally under the saucer. Provide slugs with access to the bait under the saucer by leaving a gap between the saucer lip and the soil surface. Place a weight on the saucer in windy conditions to prevent it blowing away.

Return to the traps in the morning while the soil surface is still moist. Trapping in optimum conditions (10–18°C by day and no less than 5°C at night) should ensure a representative sample. Count the number of slugs present in each trap and note any slime trails. The number of slugs caught across the field gives an indication of the potential threat to the crop.



6 Upturned plastic plant pot saucers baited with chicken layers mash are ideal for slug monitoring

Commercial monitoring services

A service provided by Bayer CropScience called 'Slugwatch' (www.bayercropscience.co.uk/slugMap.html) monitors slug activity in fields at a number of marker locations in the UK on a monthly basis. The results may be used to alert growers to trap or apply treatments in their own fields.

'The Slug Population and Activity' model is an additional aid which is available within Morph 4.1 obtainable from www.warwick.ac.uk/go/morph.

It can help growers decide how a particular slug population will change over the following weeks, either with or without control measures such as applications of slug pellets or cultivations.

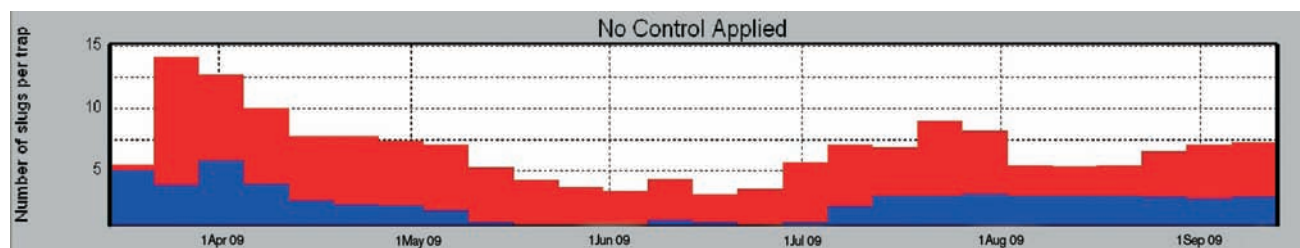
Slug populations vary both between and within fields and for effective control, growers need to know how quickly a number of slugs found in traps may become a threat to crops.

SLUG for MORPH (MORPH 4.1) uses the number of slugs found in traps and predicts how that population will change over time

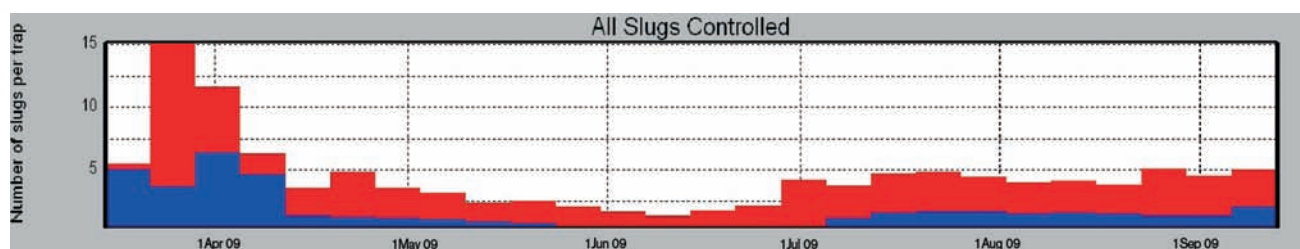
(Example 1). The number of slugs found in traps (active slugs) is used to estimate the total slug population (active and non-active, red and blue respectively). How the population will change is estimated from average weather conditions and the timing of control measures.

Example 1 SLUG for MORPH model output displaying forecasted active (red) and non-active (blue) populations of slugs using different criteria

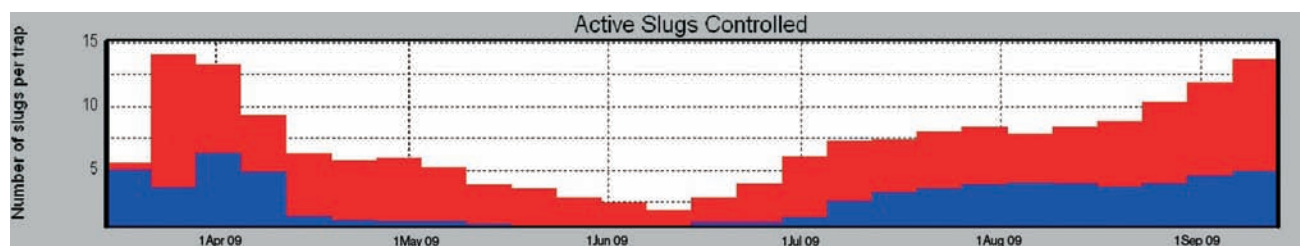
1. This first graph shows 'No Control Applied' with the population forecast to decrease in mid summer and increase in the autumn.



2. This second graph shows 'All Slugs Controlled' eg by cultivation in the spring.



3. The third graph shows 'Active Slugs Controlled' eg by application of slug pellets.



Decision support trees for Lettuce and Brussels sprouts

As part of the HortLINK project FV 225 (Hort 219), decision support

trees for the monitoring of slugs were developed for lettuce and Brussels sprouts (Diagrams 1 and 2). They provide an example of the action that can be taken to reduce the impact of slugs to the following crop. In future,

these decision support trees could be modified to provide guidance for action in other field vegetable crops.

Diagram 1 Lettuce crop decision support tree

Late January/ February

When conditions are suitable, monitor slugs using at least 10 baited saucer traps spread through the area.

Are there any slugs in the traps ?



Yes

Treat with slug pellets when conditions are suitable and apply herbicide.



No

Apply herbicide only.

Before cultivations

When conditions are suitable, monitor slugs using at least 10 baited saucer traps spread through the area.

Are there any slugs in the traps ?



Yes

Double cultivate.



No

Single cultivate.

After planting

Use standard pellet practices during the growth of the crop when conditions are suitable.

Diagram 2 Brussels sprouts crop decision support tree

March/April

When conditions are suitable, monitor slugs using at least 10 baited saucer traps spread through the area.

Is there more than 1 slug per trap?



Yes

Treat with slug pellets when conditions are suitable and apply herbicide.



No

Apply herbicide only.

Before cultivations

When conditions are suitable, monitor slugs using at least 10 baited traps spread through the area.

Is there more than 1 slug per trap?



Yes

Double cultivate.



No

Single cultivate.

After planting

Continue monitoring with traps at two week intervals. Apply pellets if (i) slugs have been detected in traps and (ii) no pellets have been applied in previous two weeks. Application of pellets should only be done when conditions are suitable. Brussels sprouts crop decision support tree.

Control of slugs

An integrated approach to slug control, using several different techniques, is more successful than relying solely on molluscicide pellets. It should be recognised however that complete eradication of slugs is unlikely, even when all methods are employed at the optimum time. The aim should be to achieve as high a level of protection as possible.

Cultural control

The first step is to minimise weed growth in preceding crops and seedbeds, thereby reducing sources of food and shelter.

Repeated seedbed cultivations will increase mortality depending on machine action, soil type, timing of cultivation, depth and intensity. Firm consolidated seedbeds reduce slug activity by making it harder for them to move around and reducing safe resting places.

Exposing slugs and eggs to freezing temperatures leads to death while in hot dry conditions, slugs die of desiccation.

Beetle banks

The establishment and management of beetle banks in field margins as habitats for carabid beetles (eg *Pterostichus melanarius*) (Figure 7) has been shown to reduce slug numbers by slug predation, mainly from June to September. However their usefulness in protecting crops directly from damage is questionable.

Predatory nematodes

The application of predatory nematodes *Phasmarhabditis hermaphrodites* (Nemaslug, marketed by Becker Underwood) to horticultural crops in advance of expected damage from slugs, can be successful if conditions remain wet during and after application. The nematodes actively seek out slugs, parasitizing them (Figure 8) and within a matter of days, prevent them from feeding. They subsequently cause death, which takes place

within 2 weeks. In ideal conditions nematodes will provide a reduction in damage for about 6 weeks after application.

The use of the nematodes is expensive, so they tend to be most viable for high value crops such as asparagus. They are also extremely useful in crop situations where it can be difficult to target the slugs effectively with molluscicide pellets. Mature lettuce crops or prolonged

crops of Brussels sprouts are typical examples.

Application

- The nematodes can be applied either at sowing or any time during the life of the crop.
- They are best applied in dull weather, in the evening and before rain.



7 Carabid beetle (*Pterostichus melanarius*)



8 Infected slug showing *P.hermaphrodita* nematodes (inset)

- Three applications of 50,000 nematodes per sq metre have been shown to give good control in asparagus and Brussels sprouts (see Table 1 opposite).
- In experimental work, this application rate to Brussels sprouts provided similar control to that achieved by using 6 applications of metaldehyde pellets at 448 grams of active ingredient per hectare. However, growers should seek guidance from experienced crop agronomists when choosing optimum rates.

Control with molluscicide pellets

By far the most common and most effective method of controlling slugs is through the use of molluscicide 'slug pellets'.

Two main groups of active ingredients are approved for use in the UK including metaldehyde and carbamate types such as methiocarb. Recent approval has also been gained for ferric phosphate. Equally good results can be achieved with all types of pellets. To be effective, slugs must feed on the pellets (Figure 9), but if they ingest insufficient poison, they can recover. Feeding stimulants have been added to some pellets (eg Metarex) to ensure sufficient is ingested to ensure paralysis occurs.

Metaldehyde products (various) paralyse the mouthparts and destroy the mucus-producing tissues, leading to excessive secretions and death. Metaldehyde is known to be safer than methiocarb to some non-target organisms including earthworms and predatory carabid beetles. However, it is still classified as toxic. The active ingredients break down into carbon dioxide and water.

Methiocarb (various products) acts on slugs' nerve tissue and inhibits production of acetyl cholinesterase, which leads to paralysis. One advantage of methiocarb over metaldehyde is its ability to continue working at low temperatures, offering control in winter growing crops.

The third type of molluscicide pellet iron (ferric) phosphate (Ferramol or Sluggo) is relatively

new to the market. It is the least toxic for pets, wildlife and humans. Ingestion leads to feeding inhibition and later death. There is no excessive production of mucus. Iron phosphate is approved by some organic certification bodies.

Pellets are formulated using either bran (dry) or pasta (wet), the latter being more expensive as it withstands wet weather for longer.

Optimum timing for maximum activity against slugs

The most effective time to apply pellets is when slugs are known to be active and just before the crop is at a slug sensitive growth stage.

For some vegetable crops like lettuce and celery, this phase lasts for the whole of the growing period, so protection is required from planting through to harvest. Where fields are at risk and it has not been

possible to double cultivate the soil before planting, pellet application before a lettuce crop is planted could be justified.

Laying covers or applying irrigation after planting will provide an ideal environment for slug activity. Early control is therefore essential if slugs are suspected. However, be aware that applications made too far in advance of the crop, may provide time for slug populations to recover if weather is favourable.

With other crops, like Brussels sprouts, the sensitive phase is at the seedling stage and as soon as the harvestable buttons start to develop. With this crop, applications should be limited to the sensitive phases only.

Achieving the best results

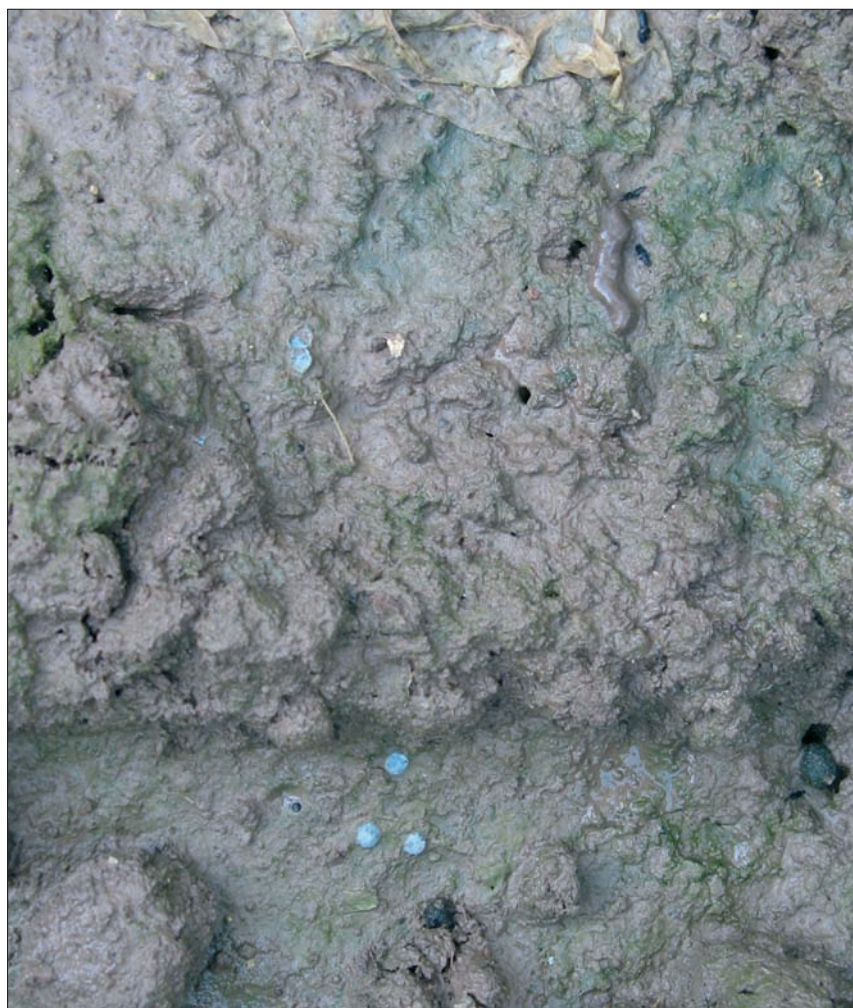
- Pellets broadcast on the soil surface will poison significantly more slugs than when incorporated into



9 Slug ingesting molluscicide pellet

the soil, as the slugs find them more easily. Similarly, don't apply pellets to cloddy soils before heavy rain as the pellets will be washed down the soil profile and not be found by the slugs. Be aware that pellets contaminated with soil following rain showers remain attractive to slugs and have no adverse effect on poisoning.

- When applied in ideal conditions, pellets will reduce slug populations and feeding activity for a number of weeks after use.
- Some molluscicide pellets can withstand more rain than others making them more suitable in wetter weather. However, after prolonged heavy rain, all pellets are rendered ineffective within days (Figure 10). The slug populations will recover more quickly in wet conditions or more slowly if conditions are dry.
- When choosing the most appropriate product, select a pellet that will be reasonably durable for the forecasted weather, taking into account irrigation events and harvest intervals. Mini pellets at



10 Slug pellets are rendered ineffective within days of prolonged rain

Table 1 Summary of molluscicides currently approved for use in field vegetables with recommendations for slug control

Active ingredient/ Product	Product type	Rate per hectare depending on crop*	Duration of treatment (days)*	Harvest interval (days)*
Methiocarb (Various products)	Pellet	Please consult product labels and, in the case of metaldehyde, the Metaldehyde Stewardship Group Guidelines available at: www.pelletsarepesticides.co.uk		
Metaldehyde (Various products)	Pellet			
Ferric phosphate (Various products)	Pellet			
<i>P.hermaphrodita</i> nematodes (Nemaslug)	Spray			

* Always read individual product labels before using a molluscicide

** 21 days if the weather dry

*** 6 weeks plus if the weather wet.

half rate applications at frequent intervals may be more appropriate if the pellet is not expected to last. Be guided by an experienced crop consultant as to the best choice of product for different weather conditions.

- Although slugs can locate previously encountered food sources, they do need to be within a few centimetres of food to detect it and they will search in a random manner. For this reason pellets must be distributed evenly on the soil surface to allow slugs to encounter them as soon as possible before feeding on the crop.
- If slugs are most numerous at the field margin, consider applying a band of pellets around the boundary (within the crop or on surrounding bare soil **BUT NOT** in watercourses), to deter movement into the crop.
- The spreader should be calibrated regularly for the specific pellets being used and applications made when the wind speed is low and the foliage dry, to reduce lodging of pellets in the crop.
- Protection for salad crops close to harvest is best achieved with

inter-row applications to minimise contamination of the crop.

- Choose an application distance that allows pellets to be thrown as close as possible to matching tramline spacing.
- Care must be taken when applying pellets near watercourses – just one metaldehyde slug pellet (5% active ingredient), could be enough to contaminate 10,000 litres of water to above 0.1 ug/litre. (10,000 litres is the volume of water in a 33 metre stretch of a 1 metre wide, 30 cm deep ditch.
- Table 1 lists details of all molluscicides currently approved (December 2008) for use in field vegetables.

Alternatives to molluscicide pellets

A number of other control options are available to growers, some of which are currently under investigation.

- Salt – slugs are sensitive to salt which can be applied to tolerant crops like asparagus when it appears through the ground. It should be applied to the rows in two doses of 2 tonnes/ha or four

applications of 1 tonne/ha. The application of salt to the soil is prohibited in organic production to control slugs.

- HDC Project FV 295 is investigating the use of carbon dioxide pre and post harvest as a muscle relaxant, to aid the removal of invertebrate contaminants in salad crops. Initial results would indicate when enhanced carbon dioxide levels are applied to slugs at levels above atmospheric CO₂, increasingly less force is required to dislodge them from produce.
- When used for control of insect pests such as aphids, thiacloprid (Calypso, Biscaya etc) may offer some incidental control of slugs as it is known to act as a slug repellent.

Guidance for operators applying slug pellets

- Slug pellets should only be used when there is a genuine risk of slug damage, not as a routine insurance policy.
- All users of slug pellets must hold a Certificate of Competence if they were born after 31 December 1964 or are providing a commercial service (eg contractors or applying on land that does not belong to their employer).
- Calibrate your applicator before use and according to product and rate to be applied.
- Know your applicator spread width and switch off when turning on headlands.
- Test bait using chicken layers mash.
- Do not apply slug pellets if heavy rain is imminent.
- Fill hoppers in field away from margins/water courses/hard surfaces.
- Clear up pellet spills immediately – no matter how small.
- Clean the applicator after each day's use.
- Do not contaminate drains or watercourses when cleaning the applicator.
- Application equipment should be stored under cover.
- Do not leave packaged product in field unattended.
- Dispose of packaging and contaminated PPE through a licensed waste contractor.
- Only apply pellets in conditions that you would spray in.
- Do not contaminate surface waters, ditches or drains during application – used deflector plates.
- **ALWAYS READ THE LABEL AND USE PESTICIDES SAFELY.**

Action points for growers

- Plan how you intend to control slugs at least a year before planting a susceptible crop and apply appropriate measures well in advance of cropping.
- Assess slug levels in preceding crops by looking for signs of damage, slime trails or trapping.
- Bury trash from previous crop residues after repeated disc cultivating.
- Remove weeds that act as a food source by double cultivating to control slug numbers prior to crop establishment. The use of stale seedbed or herbicides will also help. Prepare fine, clod free, consolidated seedbeds.
- Trap to monitor for slug activity before and after crop establishment.
- When slugs are active, pellets are effective at reducing slug numbers but will not give full control.
- Make your application just before the susceptible crop stage when optimum weather conditions prevail. Repeat treatment when new feeding damage is observed, when traps indicate an increase in activity or if pellets disintegrate/go mouldy.
- If the soil surface is rough, do not apply pellets before heavy rain as they will be washed in and have less chance of being encountered by actively feeding slugs.
- Nematodes may help to reduce slug numbers to a similar level as pellets but moist conditions during and after application are required.
- Slug pellets are pesticides so care needs to be taken when applying near watercourses to reduce contamination. Use deflector plates where fitted.

Further information

Further information on protecting water, the environment and responsible use of slug pellets:

BCPC Publication

'Spreading Fertilisers and Applying Slug Pellets' BCPC Publications,

7 Omni Business Centre,
Omega Park,
Alton Hampshire
GU34 2QD
www.bcpc.org/bookshop

The Voluntary Initiative
www.voluntaryinitiative.org

Commercial slug monitoring services:
Slugwatch Bayer CropScience
www.bayercropscience.co.uk/slugMap.html

Slug Population and Activity Model
Warwick HRI
www.warwick.ac.uk/go/morph

Acknowledgements

HDC is grateful to Dr Gordon Port (Newcastle University) for reviewing this Factsheet.

Additional information: