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The results and conclusions in this report are based on a review conducted over a six-month period. The results have been reported in detail and with accuracy. However, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Authentication

I declare that this work was done by myself with the aid of colleagues and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headlines

- Current methods of slug control in horticultural crops are likely to remain in use for the near future.
- The impact of restrictions on the use of baits containing metaldehyde may be minimised by using alternative active ingredients (ferric phosphate, methiocarb), or using slug-parasitic nematodes on high-value crops, or increasing the use of cultivations.
- Recent research is unlikely to produce novel, cost-effective methods of control for immediate uptake.

Background

This review was conducted at the request of the Field Vegetables Panel of the HDC.

Summary

Slug control in horticultural field crops can be obtained by the use of pellet baits containing metaldehyde, methiocarb or ferric phosphate, or by the application of slug-parasitic nematodes.

All three active ingredients available in slug baits are likely to be effective. Choice of pellet should therefore be made on the basis of palatability, durability, number of bait points/m^2, potential for effects on non-target organisms and other possible environmental effects. Label restrictions on the number of applications that can be made (methiocarb) or the total dose applied (metaldehyde, ferric phosphate) must also be taken into account.

Mollusc-parasitic nematodes are effective alternatives to bait pellets in the right circumstances but their use in field crops may be limited by the relatively high cost of application.

Current research is limited and, in the near future, may only provide further active ingredients for use in bait pellets, rather than any completely novel methods of control.

Financial Benefits

There are no financial implications from this review.

Action Points

Growers should review their current slug control methods in the light of the restrictions on use of pelleted baits. There would be implications for slug control if, for instance, metaldehyde was withdrawn as an active ingredient in slug pellets, and it is therefore recommended that the industry maintains a watching brief and supports, where possible, the development of new methods of slug control as and when the opportunity arises.

Science Section

Introduction

Slugs are a persistent cause of economic damage in horticultural crops. In circumstances favouring the pests they cause direct damage to the marketable parts of crops such as Brussels sprouts and lettuce by grazing the wrapper leaves and lower petioles respectively. Contamination of produce can also be a problem in leafy brassicas and lettuce when slugs, particularly the grey field slug *Deroceras reticulatum,* which is active above ground far more than other species, are hidden in the foliage at harvest.

Economic damage continues to occur, despite the use of available control methods.

The purposes of this review are: i) to examine current trends in the usage of molluscicides on salad crops and brassicas in the UK; ii) to review recent research carried out on behalf of the HDC at British universities and overseas; and iii) to assess currently-available control measures and those that may become available in the near future.

Trends in the usage of molluscicides on salad crops and brassicas in the UK

Information on the use of molluscicides in the UK is gathered during the periodic Pesticide Usage Surveys that are made on behalf of the Government's Advisory Committee on Pesticides (ACP). This is the only comprehensive data-gathering exercise of its kind in the UK. The data are published in the form of reports which are available to the public, and more detailed information may be supplied on request by the Pesticide Usage Survey Group, which is part of the Food and Environment Research Agency (FERA) of DEFRA. Pesticide Usage Surveys are not carried out on an annual basis and the most recent survey of pesticide usage on vegetables was completed in 2007, with the results reported in 2008 (Garthwaite *et al.* 2008).

It is difficult to provide an indication of the long-term trends in molluscide usage on vegetables in the UK, for two reasons. Firstly, appropriate surveys are well separated, and secondly, usage varies widely from year to year based on the activity of slugs rather than the whim of industry.

The data in table 1 are taken from the 2007 survey.

Table 1: Area of UK crop and proportion treated with molluscicides in 2007

Crop	**UK area in 2007 (ha)**	**% of crop treated with molluscicide**	**Total area treated (ha) (inc. repeats)**
Leafy Brassicas	27,969	18	16, 713
Lettuce, endive etc.	6,032	39	3,670

The proportion of the lettuce crop treated with molluscicides is much higher than that of the brassicas. This may reflect the fact that whilst all lettuces are more-or-less equally vulnerable to slug damage, so that treatment is widespread, brassicas vary in this respect. Brussels sprouts, for instance, are much more susceptible to slug grazing than cauliflower or calabrese, and winter cabbage is more vulnerable to contamination with slugs than cabbage grown in summer or the flowerhead brassicas, so that a relatively small proportion of the brassica crop may need treatment. However, when crops do need to be treated, it seems that brassicas require far more repeat treatments than lettuces. Calculations from the above data indicate that a mean of 3.3 treatments are given to treated brassicas, but only 1.6 are given to treated lettuce. This is a reflection of the number of treatments that need to be applied, for instance, to Brussels sprouts, which stand in the field for prolonged periods, including autumn/early winter when conditions are often conducive to slug activity. Slugs are also notoriously difficult to control on this crop, due to an abundance of crop debris that reduces the efficiency of pellet applications.

Almost all slug control treatments applied to vegetables, including brassicas and lettuce, involve the application of bait pellets containing one of three active ingredients, namely metaldehyde, methiocarb or ferric phosphate. The relative proportions of applications containing one of these active ingredients are summarised in table 2 below:

Table 2. Relative usage of different molluscicide active ingredients on vegetable crops, 2007

Crop	**Proportion (%) of applications made with pellets containing:**		
	Metaldehyde	**Methiocarb**	**Ferric phosphate**
All vegetables	84	10	6
Leafy Brassicas	86.7	8.6	4.7
Lettuce, endive etc.	54.3	22.4	23.3

In general, the great majority of pellet applications to vegetables, including leafy brassicas, are made with those containing metaldehyde. This probably reflects the cost of applications, with pellets containing metaldehyde being cheaper than the alternatives. However, the pattern of usage in lettuce is different, with relatively more applications of either methiocarb or ferric phosphate being made. Lettuce is a high-value crop, so that growers may be more able to afford the use of methiocarb-based baits, which tend to be more durable but more expensive than the cheaper metaldehyde products. Ferric phosphate may be preferred because it is has a lower mammalian toxicity than either of the other active ingredients and it is also approved for use in organic culture. Timing of application of pellets to vegetable crops may be influenced by the risk of contaminating the produce with the product as well as the activity of the slugs themselves. Applications to lettuce, for instance, may need to be made pre-planting and/or immediately post-planting to avoid contamination of the head.

Although treatment with poison bait is by far the commonest method of controlling slugs, there is also some use of the biological control agent *Plasmarhabditis hermaphrodita*, a nematode worm that invades the mantle cavity of slugs and snails and infects them with a lethal bacterium. A commercial product containing this organism was used on 310 ha. of brassicas (mainly Brussels sprouts, 228 ha. and cauliflower, 52 ha.) and 63 ha. of lettuce in 2007 (D. G. Garthwaite, pers. comm.)

The next survey of pesticide usage on outdoor vegetable crops in the UK is scheduled to take place in 2011. This will be the first survey since concerns were raised over the discovery of metaldehyde above the EU limit of 0.1 parts per billion in water courses used for drinking water. This survey may provide information on the impact of the guidelines issued by the Metaldehyde Steering Group in June 2009 which proposed a limit of 700g active ingredient/hectare/year (since introduced as an Amendment of Approval by the Chemicals Regulation Directorate of the HSE in May 2010) and a maximum of 250g metaldehyde/hectare/application.

Recent research relating to slug control.

Worldwide, research into the control of agriculturally-important molluscs seems to be in a relatively quiet phase. There has been no relevant international conference or symposium since 2003, when there was a joint BCPC/Malacological Society of London meeting at University College, Canterbury, Kent.

An HGCA project involving FERA and the University of Durham, entitled ‘New environmentally-friendly techniques for slug control based on orally-delivered fusion proteins containing specific molluscicidal toxins’, is ongoing (Fitches, 2010). This follows on from earlier work using fusion proteins for the control of insect pests. A fusion protein consists of 2 elements, combined. The first is a molecule (in this case a plant lectin, GNA, derived from snowdrop (*Galanthus*)) able to pass through the gut wall of the target invertebrate. This itself has little or no detrimental effect on the target. The second element is a peptide or protein that has specific toxicity to the target if it is able to penetrate into the haemocoel (‘blood cavity’). Examples are toxins from spider or scorpion venom, which are normally injected into the victim. These toxins have no effect if administered orally because they are broken down in the gut and are unable to penetrate the haemocoel. The combination of the lectin with the toxin, expressed using the yeast *Pichia pastoris*, produces the fusion protein, which is able to penetrate the gut wall and in doing so introduces the toxin directly into the haemocoel. Fusion proteins have been produced that, when introduced into the diet of insect larvae, increase mortality and severely restrict the growth of individuals. Whilst expression of functional mollusc-specific toxins has proved to be problematic and further work is required, some insecticidal fusion proteins have been shown to have some effect on the grey field slug *Deroceras reticulatum* in injection and feeding assays, suggesting potential for use in the control of slugs. If successful, fusion proteins for slug control will be incorporated in baits. They have the potential advantage over the conventional active ingredients used in current commercial baits that there should be no palatability problems, and they will also be more specific to molluscs than some conventional treatments, thus avoiding the detrimental effects on non-target organisms that current baits can have.

Although there are periodic reports in the scientific and popular press of novel chemicals with molluscicidal or repellent activity, these rarely come to market, and there have been very few objective experiments comparing the efficacy of these materials with the industry standards.

Extracts from 15 different lichen species were screened for antifeedant activity at Rothamsted Research (Clark *et al*., 1997). The most effective came from the species *Letharia vulpine.* The main active ingredient, vulpinic acid, gave protection against slug feeding when applied as a foliar spray to turnip plants and as a dressing to wheat seeds in laboratory experiments.

The toxicity of a number of natural products to the eggs of *Deroceras reticulatum* was tested by Iglesias *et al.* (2002). Carvone, saponin, extract of *Pongamia pinnata* and azadirachtin all killed eggs after periods of exposure ranging between two and 14 days. One of the most active products was azadirachtin, the active ingredient in neem, although West & Mordue (1992) had previously demonstrated that feeding behaviour of several slug species was not affected by the presence of azadirachtin at concentrations which deterred aphids from feeding. Carvone, a terpenoid derived from caraway seeds, was found to protect wheat seeds from damage as effectively as a seed dressing of methiocarb (Ester & Nijenstein, 1995), and has also been reported as a feeding deterrent in a study with the slug *Arion lusitanicus* (Frank *et al*., 2002). The highest concentration used (0.75ml litre^{-1} mulch) also caused 50% morbidity in a laboratory choice experiment.

Dodds *et al*., (1999) evaluated foliar extracts of 33 species of umbellifers (Apiaceae) for their effects on the feeding behaviour of *Deroceras reticulatum,* using an electrophysiological recording assay. Extracts of *Petroselinum crispum* (garden parsley), *Conium maculatum* (hemlock) and *Coriandrum sativum* (coriander) were identified as being the most neuroactive as well as the most antifeedant. A more recent paper (Birkett et al., 2004) identified the active principles from these extracts using coupled GC-MS and neurophysiological assay, and reported that one of the most potent actives was the toxic alkaloid γ-coniceine from *Conium maculatum*. However almost all the isolated neuroactive chemicals from the three species showed similar antifeedant activity, e.g. γ-coniceine from hemlock and myricetin from parsley reduced feeding by 70 $\pm$ 5.4% and 69 $\pm$ 4.3% respectively.

Hemlock is a well-known human poison and the isolation of an active ingredient with mammalian toxicity from this plant is not therefore surprising, but herbs such as parsley and coriander should be a better place to look for “safe” and selective actives. On this basis, other food plants have received attention as potential slug control agents. Tarragon (*Artemisia dracunculus*) herb extract incorporated into wheatflour pellets had antifeedant activity in starved *D. reticulatum* (Clark *et al*., 1997). Schüder *et al*., (2003) reported that garlic applied topically as a 2.5% or 5% solution showed promising activity for the control of slugs (*D. panormitanum*) and snails (*Oxyloma pfeifferi*) in UK nurseries. This built upon previous reports of the molluscicidal activity of garlic, where allicin was isolated as the active ingredient (Singh & Singh, 1995). Hollingsworth, Armstrong and Campbell (2003) reported the repellent and toxicant activity of caffeine on molluscs. Drench treatment using a 1% or 2% solution of caffeine caused 100% of slugs (*Veronicella cubensis*) to exit treated soil and the majority of individuals subsequently died. A 2% solution of caffeine applied to the growing medium of orchids killed 95% of orchid snails (*Zonitoides arboreus*), better control than that given by liquid metaldehyde, the standard treatment for this problem in the

USA. Caffeine solutions as low as 0.01% significantly reduced overall feeding by slugs. Hollingsworth and Armstrong (2003) also evaluated an extract of yucca for the control of *Zonitoides arboreus*, a snail pest of orchids in Hawaii, finding it to have contact repellency. Ali *et al*. (2003a, 2003b) demonstrated molluscicidal and repellent properties of extracts of African plants, including myrrh and opoponax. Bennison (2003), in work for the Horticultural Development Council, considered cinnamamide, an experimental repellent and antifeedant, to be a promising candidate material for slug control. It has not been possible to confirm a report (Luckhurst, E., *pers.comm*.) that a product made from crushed tea seeds is effective as a topical application and is available in New Zealand.

Despite the considerable research input into novel, plant-derived molluscicides, none have been developed to the point where they are available for use by professional growers. Given the economic impact of slug damage, there would appear to be a continuing opportunity for research into new antifeedants and molluscicides derived from plants to be developed. However, it is critical to gather information on toxicities (to plants, mammals and beneficial insects) at an early stage of the development process, as these may preclude the commercial exploitation of the compound. Caffeine, for instance, may be a less effective molluscicide than metaldehyde, is less specific and has a higher mammalian toxicity (Simms & Wilson, 2003). Information such as this is often lacking.

Brooks et al. (2003) showed that, *in vitro*, red clover was a suitable alternative food for *Deroceras reticulatum* in winter wheat, being both palatable to the slugs and least detrimental to wheat seedlings. Damage to seedlings when red clover was present was reduced to the same level as that in seedlings where metaldehyde was applied. To date, however, this work does not seem to have been translated to the field.

The success of the parasitic nematode *Plasmarhabditis hermaphrodita* as a biocontrol agent for slugs and snails in Europe has prompted a continuing search for similar biopesticides, particularly outside Europe, where *P. hermaphrodita* does not occur naturally. Though other slug-parasitic nematodes have been found, e.g. *Angiostoma* spp., none of these have the same potential as *P. hermaphrodita* and none have been developed commercially. A large number of other natural enemies of molluscs are known, including pathogenic bacteria, fungi and viruses; parasitic protozoa and microsporidia; parasitic and predatory Sciomyzidae (flies); predatory molluscs, flatworms and arthropods; and predatory invertebrates, including amphibians, reptiles, birds and mammals (Barker & Watts, 2002), but none of these have been successfully exploited. At the time of writing there do not appear to be any biopesticides for the control of molluscs under development worldwide (Gwynn, R., *pers. comm*.)

Periodically, the molluscicidal or deterrent effects of physical barriers are tested. Most recently, Bennison (2003) has reported the significant effects on molluscs of copper-impregnated ground-cover mattings (e.g. Tex-R, Landcsape Pro, Supercover Plus) used as root retardants and weed suppressants in horticulture. This same work also confirmed the molluscicidal effects of ureaformaldehyde and copper-based fungicides.

Currently-available pesticides for the control of molluscs

Molluscicides available in the UK

Ignoring cultural methods of controlling molluscs (e.g. manipulation of soil conditions, time of sowing), there are four alternatives available to commercial growers in the UK. Three of these consist of pellet baits incorporating a molluscicide, and the fourth is a biopesticide comprising a nematode worm and its symbiotic pathogenic bacterium.

i) Metaldehyde

Metaldehyde has been the mainstay of chemical control of terrestrial molluscs for at least 50 years, applied either as a liquid or in baits. It irreversibly damages the mucus cells of slugs (Triebskorn *et al.*1998). The liquid formulation has not been approved for use in the UK for many years but there are 46 proprietary bait products, from 11 manufacturers, currently available to professional growers (Lainsbury, 2010). These baits vary in the type of attractant base used, in the method of pellet manufacture and in the amount of active ingredient incorporated. The use of metaldehyde has come under close scrutiny since the discovery of residues of metaldehyde in raw water supplies intended for drinking, in late 2007, following the development of new advanced analytical techniques for detecting very low levels of trace substances in water. This has prompted the regulatory authorities to confirm an annual limit on the quantity of metaldehyde that can be applied per hectare (700g), and there have been some recent developments in metaldehyde baits as a result.

Metaldehyde baits are formulated on a cereal base, usually wheat bran or durum wheat. The latter is more expensive to use in manufacture but pellets made from durum wheat may be more palatable to slugs than those made from other cereal products and may also be more durable. Additives which may be used include attractants and feeding stimulants (proteins, carbohydrates), stabilizers and binders to improve wet resistance and durability, and fungicides. Repellents and colouring agents increase visibility in the field and help to deter accidental consumption.

Metaldehyde pellets may be manufactured by variations on either a ‘dry’ or ‘wet’ process. The former, which involves extruding the dry ingredients under pressure through a die, tends to produce dusty pellets of a non-uniform size, with poorer durability in the field, but is a cheaper process. In the latter process the ingredients are mixed into a paste, formed and then dried, which is more expensive but produces uniform, dust-free pellets with greater durability in the field. Reduction in dust improves operator exposure and environmental contamination, whilst uniformity is an aid to accurate field distribution of the pellets. Greater durability increases the time that pellets are available to slugs, improving efficacy and reducing the need for repeat applications.

The quantity of active ingredient included in a formulation is a balance between increasing mortality and decreasing palatability as the level of a.i. is raised (Bailey, 2002). Levels of metaldehyde lower than 1.5% generally result in a meal being completed before a lethal dose of the active ingredient has been absorbed, whilst levels above about 6% result in rejection of baits due to unpalatability. Formerly, metaldehyde baits generally contained 3-6% a.i., but with current restrictions on the overall level of metaldehyde that can be applied per annum, several products containing only 1.5% a.i. have been introduced. Managing the level of application of metaldehyde per unit area by reducing the level of a.i. in a slug pellet is seen as preferable to reducing the number of pellets applied per unit area. This is because the number of bait points has an influence on the efficacy of treatments, 25-100/m^2 being the optimum range for the control of the grey field slug *Deroceras reticulatum* (Hunter & Symonds, 1970, Howling & Port, 1989). Six applications per annum are possible using slug pellets containing 1.5% metaldehyde at 7.5 kg/ha, giving 60 bait points/m^2, whereas only three can be made when using a 3% pellet at the same rate.

ii) Methiocarb

Methiocarb is a carbamate pesticide that, when ingested by molluscs, acts on the nerve tissues, inhibiting acetylcholinesterase (Meredith & Lankford, 2005). The mode of action ensures that activity is practically unaffected by changes in environmental conditions, so that it works even under conditions of low temperature or high humidity.

There are currently 7 bait products containing methiocarb available to professional growers (Lainsbury, 2010). These range in concentration of a.i. between 2% and 4% and, as with products containing metaldehyde, there are variations in the composition of the base used in the baits and the method of manufacture, to provide choice in size of pellet (and hence number of bait points/m^2), durability and palatability.

Methiocarb has been used effectively as a slug bait for many years. Its main advantage is claimed to be that it is active in all environmental conditions. A disadvantage is that it is poisonous to other invertebrates and is more likely to affect non-target organisms, such as ground beetles, than metaldehyde.

iii) Ferric phosphate

Whilst baits containing metaldehyde or methiocarb have been available to growers for many years, those containing ferric phosphate as the active ingredient have only been approved relatively recently (2005) for use in the UK.

When ingested, ferric phosphate causes cellular pathological changes in the hepatopancreas and crop of slugs and snails and also interferes with oxygen uptake by haemocyanin, the respiratory pigment of haemolymph in molluscs.

Koch *et al.,* (2000) demonstrated that iron phosphate, as Ferramol, gave good control of slugs of the families Arionidae and Agriolimacidae in both the laboratory and the field. However, *Lehmannia valentiana,* a major pest in glasshouses in Germany (but not present in the UK), was not controlled. In Switzerland, Speiser and Kistler (2002) showed that iron phosphate reduced leaf loss of lettuce and increased the number of marketable heads whilst reducing numbers of the slug *Arion lusitanicus*. However, the reference treatment, metaldehyde, was more effective in preventing slug damage and reduced numbers of *A. lusitanicus, A. hortensis* and *Deroceras reticulatum*. In oilseed rape, iron phosphate reduced the percentage of seedlings with slug damage but did not affect the total number of seedlings per unit area. Further evidence for the efficacy of iron phosphate as a bait component for slug control is provided by Iglesias & Speiser (2001). Rae *et al*., (2009a) have since suggested that it can significantly reduce slug damage caused by the grey field slug, *Deroceras reticulatum*.

Iron phosphate was considered to be environmentally safer than metaldehyde (Bari, 2004). Edwards *et al.* (2009) used mesocosms to compare the effects on earthworms of an untreated pellet with baits containing metaldehyde, ferric phosphate or the chelating agents ethylene diamine triacetic acid (EDTA) and ethylene diamine succinic acid (EDDS) at both the recommended rate and five times greater. There was virtually no earthworm mortality over the 14 days of the experiment, and though there were considerable differences in earthworm weights, none of them differed significantly from the control.

Three products containing ferric phosphate are now approved for slug control in the UK, in all edible and non-edible outdoor crops. Two contain 1% w/w ferric phosphate and the other contains 2.97% ferric phosphate. Company literature suggests that ferric phosphate has an advantage over other molluscicides in that it has a lower mammalian toxicity and is broken down by micro-organisms in the soil to iron and phosphate, which are plant nutrients. Some organisations have approved the products for use in organic agriculture.

iv) Nematodes

The nematode *Phasmarhabditis hermaphrodita* is a biological control agent for slugs (Glen & Wilson, 1997). The formulated product contains the nematode in its aggressive juvenile form. The nematode responds to slug-associated cues such as slug mucus and faeces in order to locate potential hosts (Rae *et al.*, 2006, Rae *et al.,* 2009b) and infects them via the shell cavity at the back of the mantle (Wilson *et al.*, 1993). Once inside the slug the nematodes release symbiotic bacteria, which initially stop the slug feeding and then quickly kill it. The nematodes develop and breed within the cadaver and a new generation of infective juveniles is produced which disperse in search of further prey. The ability to stop slugs feeding quickly and the absence of residues is particularly valuable in horticultural crops where crop quality is of primary importance.

P. hermaphrodita is produced in liquid fermenters, harvested and formulated so that it can be stored until required. In the UK it is available as Nemaslug from Becker Underwood, for use in vegetable crops. The nematode is usually applied by spraying but it is also possible to apply it via most forms of irrigation equipment. Trickle irrigation has been used for some time and the nematode can now be applied through rain guns.

In Holland, parasitic nematodes were shown to have commercial potential for the control of *Deroceras reticulatum* in Brussels sprouts by Ester et al. (2003), and also gave better control of slugs than two applications of traditional pellets. Similarly good results in this crop were reported from Lincolnshire. Parasitic nematodes have also been effective in asparagus and in lettuce where they were again better than slug pellets, with no slugs found in the crop at harvest (Pennell, 2010). Work has also investigated their potential in potatoes where the ability of the nematode to move through the soil and reduce tuber damage can maximise yields of high quality potatoes. However, when used against *Arion* spp., *Cepaea nemoralis* and *Helix aspersa* on organic lettuce in Italy, *P. hermaphrodita* was ineffective (Gengotti *et al*., 2008), which the researchers ascribed to the large size of the individual molluscs encountered during the trials.

Successful use of parasitic nematodes for slug control in the UK to-date has been confined to high value horticultural crops such as Brussels sprouts. An estimated cost for parasitic nematodes is £110/ha which is significantly more expensive than molluscicide pellets (Ellis, S., *pers. comm*). Other factors, including low efficacy under unfavourable conditions, limited shelf life and the need to achieve correct timing of applications for optimum efficacy will also need to be addressed if parasitic nematodes are to gain a higher proportion of the slug control market in the UK.

Molluscicides available outside the UK

North-west Europe, and Britain in particular, are strongholds of economically-important slug activity worldwide. It is not surprising, therefore, that slug control methods have tended to be developed in these areas, and similar methods of control are used throughout the region.

In the USA, baits containing metaldehyde or ferric phosphate are used for the control of terrestrial molluscs, along with liquid formulations of metaldehyde or methiocarb. Bait pellets containing methiocarb are not currently available in the USA, and *Plasmarhabditis hermaphrodita* is also unavailable as a biological control agent since it is considered a non-indigenous organism (Anon., 2009). Current development seems to be focussing on a boric acid bait and a search for a native malacopathogenic nematode species.

In New Zealand, baits containing metaldehyde, methiocarb or ferric phosphate, as used in Europe, are registered for commercial use (New Zealand Food Safety Authority). There is also one registered bait that contains chelated iron (iron ethylene diamine triacetic acid, EDTA). Baits containing iron EDTA are also approved for use in Australia. These seem to provide an alternative route for poisoning molluscs with iron, rather than employing ferric phosphate.

Conclusions

Despite considerable and continuing research effort, poison baits will remain the most cost-effective method for controlling slugs and snails in horticultural crops for the foreseeable future, with only a minor role for mollusc-pathogenic nematodes.

Although there are alternative active ingredients available in the UK (currently metaldehyde, methiocarb or ferric phosphate, with the possibility of fusion proteins being added at a future date), in terms of effectiveness in controlling slugs, there is little to choose between them. If molluscs can be persuaded to feed on any of these baits, which may be a function of bait pellet composition and distribution rather than active ingredient, they are likely to succumb. The choice between bait pellets is therefore likely to be made with reference to a number of criteria including cost, number of bait points/m², pellet palatability/durability, effects on non-target organisms and perceived environmental safety.

The relatively recent addition of mollusc-pathogenic nematodes *Plasmarhabditis hermaphrodita* provides a useful alternative to the use of bait pellets in the right circumstances. However, the high cost of these nematodes and the need to apply them in the right conditions is likely to restrict their use to a few high-value horticultural crops, particularly those where baits are relatively ineffective, such as Brussels sprouts or asparagus.

Knowledge and Technology Transfer

No technology transfer activities have been carried out that relate to this project.

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