Bayer CropScience

Expert Guide: Wireworm

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Introduction

Wireworms, the soil-dwelling larvae (grubs) of click beetles, are widely distributed throughout the UK. They have the potential to attack a wide range of crops including cereals, sugar beet, vegetables and soft fruit, but the most serious damage usually occurs on potato. Potato crops are particularly susceptible to attack as wireworm damage to tubers reduces crop quality rather than gross yield. Even low populations (less than 100,000 per ha) can cause an economic level of damage. Click beetles in the UK have long life-cycles, and wireworms in the soil take up to four years to complete their development, making them a very persistent problem.

High wireworm populations are usually associated with fields in long-term grassland as this undisturbed habitat is generally favourable for wireworm survival, and therefore crops grown in the first few years after ploughing out grass are most at risk of wireworm attack. Traditionally, most potato crops are grown in arable farming areas in eastern England where rotations that include long-term grass are uncommon. Consequently, wireworms were until recently regarded as a minor but locally important pest in mixed arable and livestock farming areas (e.g. western England and Wales) where grassland is still common. However, in the last few years, wireworm damage has become an increasing problem for all potato growers in England (including those in the east) and Wales and to some extent in Scotland.

More regular damage has also recently occurred in fields with no history of long-term grass. The reasons for this apparent shift in pest status of wireworms are not entirely clear. Contributory factors may include increasingly stringent quality demands from retailers and the renting of wireworm-infested grass fields as 'clean' potato land free of soil-borne disease and potato cyst nematode. There is also some evidence that long-term set-aside (one to five years fallow) provides a suitable habitat for wireworms.

Another common perception is that the long-term decline in soil residues of persistent organochlorine insecticides such as aldrin, lindane and DDT may also be allowing more wireworms to survive. Although residues of such insecticides are known to persist in the soil, there is no evidence of a causal link between long-term wireworm population changes and soil insecticide residues. Whatever the reasons, wireworms are a pest that potato growers in particular now have to take seriously.

Wireworm biology

Species

There are approximately 60 species of click beetle recorded in Britain, but only three species, *Agriotes lineatus, Agriotes obscurus* and *Agriotes sputator* (Plate 1) are responsible for the vast majority of attacks on crops. All three species are usually found together in the same field, although one species or another tends to be most numerous. Extensive survey work in the 1940s suggested that *A. obscurus* was the dominant species in northern England and mid- and North Wales, whereas in the Midlands and South Wales, *A. lineatus* and *A. sputator* occurred more frequently with a corresponding decline in the incidence of *A. obscurus*.

More recent (though less extensive) work has suggested that *A. obscurus* is dominant in the west, and *A. sputator* in the east. In terms of absolute damage risk in infested fields, differentiation of *Agriotes* species as larvae is not important as they all have a similar damage potential, but as new adult pheromone trapping techniques are species-specific (see below), an appreciation of the existence of different species is important.

Plate 1a - *Agriotes lineatus* click beetle

Plate 1b - *Agriotes obscurus* click beetle
Photo: Frank Koehler

Plate 1c - *Agriotes sputator* click beetle
Photo: Claus Weisenboehler

Other wireworm types can sometimes be found in both grass and arable fields, usually in mixed populations with *Agriotes* species, but rarely exceed 10% of the total population. *Athous* and *Corymbites* wireworms have been known to cause damage to potato and other root crops. The pest status of others e.g. species of *Adrastus, Brachylacon, Cryptohypnus, Dolopius, Hypnoidus, Selatosomus, Prosternon* are uncertain although all have been found in agricultural land. In general, the non-*Agriotes* species tend to be more common in marginal areas such as rough grazing land or at higher altitudes than fields normally used for arable production.

Life cycle

Click beetles (so-called because if you lay one on the palm of your hand, they will often spring into the air with an audible click) are active from late April to August, often with a peak of activity in May (Figure 1). Females lay their spherical (0.5 mm diameter) translucent eggs just below the soil surface, either singly or in small clusters, and usually within the protection of grassy or weedy ground which minimises the risks of desiccation. Eggs hatch in four to six weeks depending on temperature.

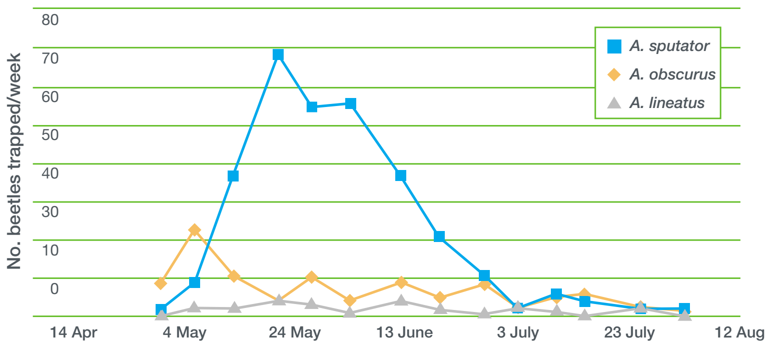

Figure 1 - Typical pattern of click beetle activity (as indicated by pheromone trapping). The numbers of individual species vary from field to field.

Young wireworms are initially white and about 1.5 mm long. They need live vegetable material to survive and grow, and are likely to die of starvation within 30 days in the absence of food. As they grow, their colour darkens to the shiny golden-brown typical of all wireworms (Plate 2).

Plate 2 - Wireworm

Wireworms mature very slowly, passing through one to three instars (moults) each year, and may remain in the soil for four or five years before pupating. Wireworms usually reach maturity in July to September, at which point they burrow deep into the soil and hollow out small pupation cells 5 to 30 cm below the soil surface. After three to four weeks they become adults, but usually remain in the cell over the winter before emerging in the spring.

Spatial distribution

Wireworm damage often appears to be patchy, suggesting that the distribution of wireworms, and possibly adults, in the field is also patchy. Areas of high infestation within fields usually tend to persist for consecutive years. Young wireworms may initially have a clumped distribution, with larger individuals becoming more randomly distributed. However, the worldwide evidence on this is conflicting, so there are no hard and fast rules.

Seasonal activity

In the UK, there are two main periods of wireworm activity, one in March to May and a second in September to October. The latter period of activity is when most damage to potato occurs. Laboratory experiments have shown that at least in *Agriotes* species, long periods of inactivity often precede a larval moult, and even once moulting has occurred, wireworms may remain inactive for some weeks. The proportion of time actually spent feeding by wireworms may be as little as 20%.

Extensive laboratory and field studies in Europe and North America have shown that high soil temperature and/or low soil moisture in the upper layers of the soil will drive wireworms down the soil profile. Although most wireworms are normally found in the top 10-20 cm of soil, they can move much deeper into the soil profile. Soil moisture in particular is critical to wireworm survival, and *Agriotes* species will move rapidly out of dry soil to seek more moist conditions. Soil temperatures below approximately 5°C appear to reduce wireworm activity under UK field conditions. (Figure 2).

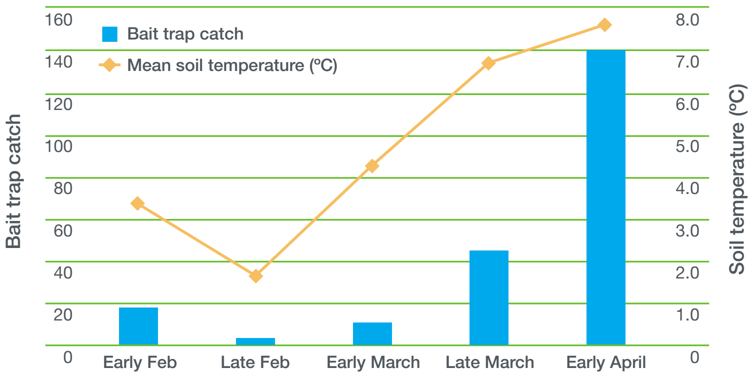

Figure 2 - Activity of wireworms (catches in bait traps) in relation to soil temperature.

Risk assessment

An essential part of a wireworm management strategy is effective methods of assessing the risk of wireworm infestation and if possible, the likely level of damage. This is primarily because insecticide treatments for wireworm control have to be applied at planting (either as seed treatments on cereals or as soil-applied granules on to potato land), and therefore an assessment of the likely damage risk has to be made well in advance of damage actually occurring to the crop.

A good working principle is to assess the risk as far as possible using site characteristics, then use more than one sampling technique at more than one time of the year to assess wireworm populations. This will invariably give a more accurate picture of the wireworm status of a particular field than relying on a single assessment.

Site characteristics

Undoubtedly the best indicator of wireworm presence or absence is the duration of grassland in the cropping history of individual fields. Approximately 60-70% of fields that have been in grass for more than 10-15 years are likely to have easily detectable wireworm populations (Figure 3). Other key factors that influence the likelihood of wireworm infestation in any particular field include climate, chemical and mechanical characteristics of the soil, cultivation history and past insecticide treatment.

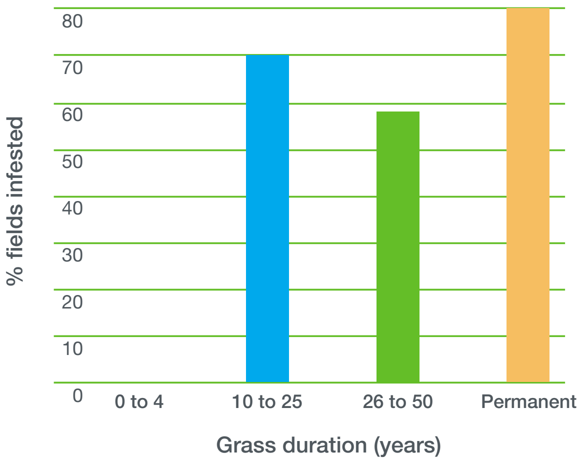

Figure 3 - Wireworm infestation incidence in relation to grass duration.

Results of wireworm surveys undertaken in the UK between 1939 and 1942 indicated that heavier alluvial soils such as reclaimed coastal marshes and estuarine deposits had high wireworm populations, whereas lighter and drier soils generally contained fewer wireworms. This suggested an association between high wireworm populations and those soils that were relatively moist throughout the summer. There was also a trend for wireworm populations to be higher in south-eastern England relative to more northern and western areas. However, such general trends are of relatively little value when assessing wireworm risk in individual fields (Plate 3).

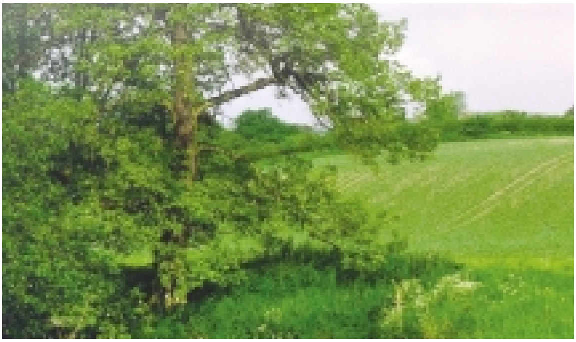

Plate 3 - ‘ideal’ wireworm site characteristics - south-facing, sloping, in river valley.
Photo: Bill Parker

There is a general perception that wireworm infestations can be associated with grass weed infestations, but this has not been substantiated experimentally. There is some evidence that sloping fields are more likely to be infested if they are generally south-facing (Figure 4).

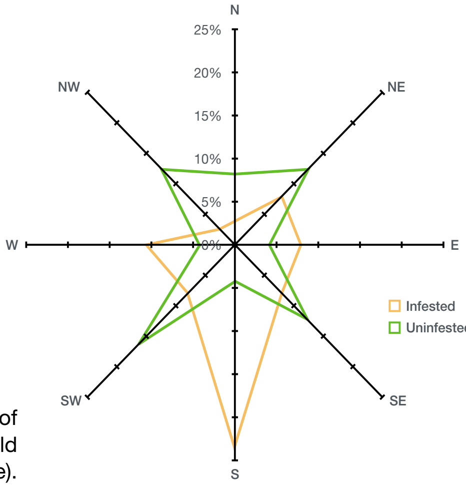

Figure 4 - Radar plot of likelihood of wireworm infestation in relation to field aspect (direction of slope).

Sampling for wireworms

There are a range of available risk assessment sampling techniques, and these can be conveniently categorised into those used to sample soil for wireworms, and those used to trap adult beetles. Sampling techniques ideally need to satisfy three criteria:

1. They should detect the pest population with an acceptable degree of accuracy.
2. They should not be too labour-intensive and take as little time as possible.
3. There should be a correlation between the sampling result and the risk of damage.

Wireworm sampling techniques do not necessarily meet all 3 of these criteria, but some come close.

Soil sampling

The standard method of soil sampling for wireworms is to take twenty 10 cm diameter cores to a depth of 15 cm. The twenty cores should be taken randomly along a W-shaped sampling transect covering between four and 10 ha. You end up with some large (and heavy!) bags of soil (Plate 4). Ideally, the soil samples need to be processed in a laboratory with the correct 'soil washing' equipment.

Plate 4 - Soil samples taken for assessing wireworm infestation.

Photo: Bill Parker

Although reasonably effective, this technique is very labour-intensive, and subject to significant sampling errors, particularly when wireworm populations are low. This is particularly critical for potato growers as the limit of detection of soil core sampling is approximately 62,500 per ha. Wireworm populations below this level are still capable of causing significant damage to potato crops. There is a reasonable relationship between wireworm population levels identified by soil sampling and subsequent damage to potato, but there is a good deal of variation, particularly at lower population densities (Figure 5).

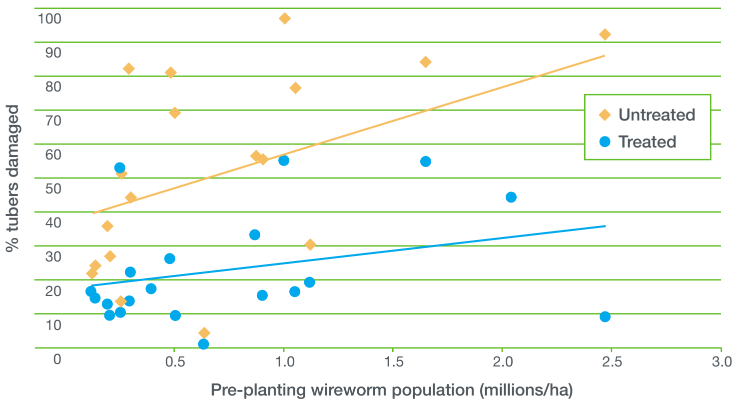

Figure 5 - Relationship between wireworm population assessed by soil sampling and subsequent damage to potato (treated and untreated).

Bait traps

Plate 5 - 'Bayer' wireworm bait trap

Bait trap systems utilise the principle that wireworms are attracted to the carbon dioxide (CO_2) given off by respiring seeds. A range of trap types is available, or can be constructed for everyday materials. The trap most commonly used in the UK is one distributed by Bayer CropScience (Plate 5), which consists of a cereal bait bag in a plastic pot drilled with wireworm-sized holes. The traps are soaked prior to burying in the field for 10-14 days. The grain in the bait bag sprouts and wireworms are attracted either into, or near to, the trap. Assessments are made by digging the trap up and examining the contents, and by looking for wireworms in the soil just outside the trap. Bait trapping works best in the spring when soil temperatures are rising and the field is not planted with any crop. Bait trapping is primarily a presence/absence test and the presence of even a single wireworm can represent a risk in the following potato crop.

Adult trapping

Because of the inherent inaccuracies of soil sampling or bait trapping for wireworms, systems for catching adult click beetles have recently been developed. The principle is that it is much easier to attract large numbers of beetles with an appropriate trapping system than trying to find wireworms hidden in a large volume of soil. The key point is relating the catch of adult beetles to the level of wireworm infestation in the soil, and hence assessing the risk of crop damage.

All adult trapping clearly needs to be done at a time when the beetles are most likely to be active (see Figure 1). As beetle activity does not usually start until after potatoes are planted, adult trapping techniques have to be used as an early warning system a year in advance of growing potatoes in a particular field.

'Plastic sheet' traps

This is a simple but unreliable way of catching adult beetles. In early May, lay a 0.5 m^2 sheet of plastic on bare soil and cover it with freshly-cut rye grass. Leave it for three days, then return and check the traps for click beetles by looking under the grass on the plastic sheet. This is an inferior approach to pheromone trapping.

Pheromone traps

Pheromones are insect ‘sex attractants’, usually a chemical released by females to attract males. By identifying and synthesising these compounds, lures can be produced which will attract male beetles into a specially designed trap. Such systems are now available for click beetles in the UK. As the pheromones are species-specific, at least one set of three traps is needed, one for each of the three main species found in the UK (*Agriotes obscurus, Agriotes sputator* and *Agriotes lineatus*). The trap containing the pheromone lure is placed on the ground (Plate 6) and is checked weekly in the period late April to early August. Ideally, the traps should be located about 30 m away from the field margin, with individual traps set about 40 m apart. The number of beetles caught throughout the season is usually related to the number of wireworms remaining in the soil (Figure 6), although occasionally this relationship is poor. The commercial use of these traps has yet to be fully evaluated.

Plate 6 - Click beetle pheromone trap.
Photo: Bill Parker

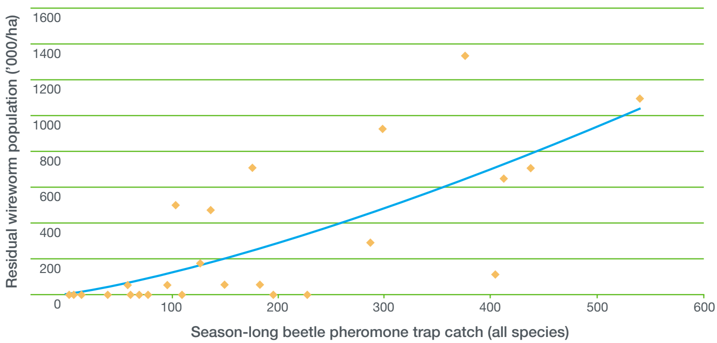

Figure 6 - Relationship between click beetle pheromone trap catches and residual wireworm populations.

Wireworm damage to potatoes

Type of damage

Wireworms tunnel into potato tubers leaving small, round holes on the surface and narrow tunnels running into the tuber flesh (Plate 7). Superficially, wireworm damage may be confused with slug damage as slug entrance holes are very similar to those made by wireworms. However, slugs often hollow out large cavities within the tuber flesh, whereas wireworms do not.

Plate 7 - Wireworm damage to potato tubers

Although damage does not affect yield, it causes a serious loss in tuber quality, which can render them unmarketable even when damage is relatively low. Wireworm holes may also provide access for slugs, or other soil organisms such as millipedes or bacterial rots. Wireworms may sometimes be blamed for damage caused by other organisms or physiological disorders. Wireworms also attack seed potatoes, but this seldom affects the growth of the plant. Finding wireworms feeding on seed tubers shortly after planting is common, but is not a reliable indicator of likely damage to daughter tubers.

Influence of population age structure on the severity of damage

Generally speaking, wireworms less than 5 mm long are not capable of significant damage. By the time they are a year old, wireworms became part of the effective or destructive wireworm population, and as they increase in age and size, they became more destructive. However. mature larvae that are about to pupate cease feeding and do not pose a damage risk. In practice, wireworm populations often consist of a range of ages, and it is rare to find a developmentally synchronised population.

Varietal susceptibility

There is some evidence to suggest that the susceptibility of potato varieties to wireworm damage is related to their glycoalkaloid content, and it may be possible to classify potato varieties into risk groups on this basis. However, glycoalkaloid content of tubers is subject to many environmental factors, and limited experimental work in the UK suggests that commonly grown varieties are all attacked by wireworms.

Damage progression

No definitive experimental work has been done on the development of *Agriotes* wireworm damage to potato tubers during the later stages of tuber bulking and subsequent skin-setting. Damage does tend to increase with time from mid-August onwards (c. 12 to 16 weeks post-planting), regardless of the initial population size (Figure 7). There is likely to be a strong interaction between variety, lifting date and insecticide use that may influence the intensity and timing of damage progression, but this has yet to be shown experimentally in the field.

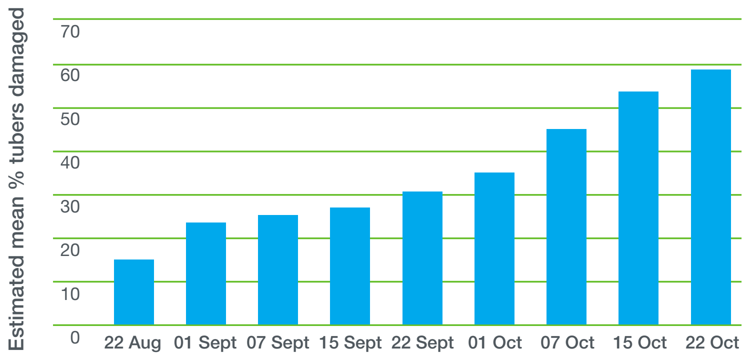

Figure 7 - Progression of wireworm damage to potato with time.

Control

Cultural control

The most effective method of preventing wireworm damage is to avoid growing potatoes in infested fields. This requires a degree of forward planning to allow the implementation of risk assessment methods (see above) well in advance of final decisions being made on field choice. Where potatoes are grown in an infested field, lifting the crop before wireworms start to actively feed on tubers in the late summer and early autumn can mitigate the level of damage or even prevent it occurring.

Populations of wireworms decrease quickly under arable cultivation and it is unusual for large numbers of wireworms to persist for more than three to four years after grassland is ploughed. However, complete elimination of the wireworm population does not necessarily occur, and the population may persist at a low level for many years.

The annual rate of reduction in wireworm populations can be highly variable, but is generally more rapid for fields that have grown crops for more than one year compared to those out of grass for less than a year. The rate of reduction is also often proportionately higher for fields with high wireworm populations, for example rates of reduction over two years can range from 37% for initial (moderate) populations of c. 250,000 per ha to 87% for initial (very high) populations of 4.5 million per ha.

The primary mechanism of population reduction under arable cultivation is through repeated disturbance of the soil. This decreases wireworm populations both by direct injury and from exposure to desiccation or attack by birds. Cultivation is likely to be most effective when wireworms are active in the upper layers of the soil profile. This is most likely to be in late summer or spring. Ploughing a grass field as late as possible also means that there is plenty of fresh organic material for the wireworms to feed on, which may distract them from feeding on the crop.

Previous cropping history and crop rotation can affect the level of wireworm infestation. Crops such as linseed, peas and beans are considered to be tolerant of wireworm damage as little damage occurs when these crops are grown in even heavily infested fields. However, this is probably a reflection of both husbandry practice (e.g. small seed and/or shallow drilling) and the ability of some plants to grow away from attack rather than true plant resistance.

Biological control

There are currently no commercial biological control agents available for controlling wireworms. Natural predation of wireworms by birds and predatory insects is known to occur, but probably rarely has a significant impact in terms of reducing the risk of damage in a particular field. Other natural control agents have occasionally been found in field populations, including nematodes and the insect pathogenic fungus *Metarhizium anisopliae*, some strains of which may prove to have a role as introduced biocontrol agents in time.

Soil amendments

Glucosinolates contained in cruciferous plant tissues are hydrolysed to a variety of biologically active products that are potentially useful for the control of soil-borne pests. Experiments done on using oilseed rape meal as a soil amendment in the USA were not particularly successful, but more recent work in Italy on novel green cover crops and de-fatted meals derived from them have shown more promise. Selection of the correct plant species is likely to be critical to success.

Insecticides

Historically, using insecticides to achieve effective, reliable control of wireworm damage to potato has proved to be difficult. There are two principal reasons for this. Firstly, wireworms are not generally found near the soil surface, so insecticides usually have to be applied pre-planting to ensure adequate incorporation of the active ingredient into the soil. Secondly, as *Agriotes* wireworm damage to potato tubers occurs late in the life of the crop, insecticides ideally have to be very persistent to ensure adequate control.

Investigation of organochlorine insecticides in the 1950s showed that aldrin and lindane, both highly persistent soil-acting organochlorine insecticides, provided generally satisfactory control either when applied as a conventional spray treatment to the soil pre-planting or as ‘aldrinated’ fertiliser. Aldrin remained the standard treatment for wireworms on potato in the UK until 1989, despite widespread concerns over the environmental impact of persistent organochlorine compounds.

Part of the reason for the longevity of aldrin recommendations in the UK was the lack of any significantly better alternatives, and a replacement product for aldrin, ethoprophos (as Mocap 10G) did not come forward until 1990. In general, worldwide studies have shown that organophosphorus (OP) insecticides such as ethoprophos and latterly (in the UK) fosthiazate as Nemathorin are more effective at controlling wireworms than carbamate soil insecticides such as carbofuran or aldicarb. However, even the leading treatment Mocap, does not provide perfect control of wireworm damage in potatoes (see Figure 5).

Newer products in different chemical groups have been shown to have activity against wireworms. These include the soil-acting pyrethroid tefluthrin, the related product cyfluthrin and imidacloprid (a chloronicotinyl) as in Secur seed treatments. Some of these (imidacloprid, tefluthrin) are available as seed treatments for sugar beet and cereals in the UK. Such products can have a role in a 'rotational' approach to the use of insecticides for controlling wireworms - i.e. applying insecticides at more than one point in the rotation. This approach affords the possibility of using insecticides for wireworm management that cannot be used directly on the potato crop, and are useful where there is a need for longer-term population suppression of persistent low wireworm populations.

Integrated control

Successful wireworm management requires forward-thinking to enable effective risk assessment to be done, and the use of a range of control methods. An ideal strategy would be:

1. Assess the risk of wireworm infestation (up to a year early for potatoes) using pheromone traps for adults in the late spring/summer.
2. Follow up with soil sampling in the autumn (October), and back this up with bait trapping in the following spring (late March).
3. Where any level of wireworm infestation is identified, avoid growing potatoes in that field if at all possible (high populations can also damage cereals; seed treatments are the best option for control).
4. If potatoes are to be grown, plant a variety that can be harvested early if possible (by the end of August).
5. Use an Approved insecticide at planting on potato if you have to grow the crop in a field known to be infested, but do not expect such treatments to give complete control – they only reduce damage.

Active ingredients and Trademark acknowledgments

Mocap 10G contains ethoprophos and is a trademark of Bayer. Nemathorin contains fosthiazate and is a trademark of Syngenta.

Always read the label: use pesticides safely.

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