FAR FOCUS

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Integrated Pest Management

ISSUE 12

- Biological control
- Cultural control
- Chemical control
- Monitoring and decision making
- Cereal case study

ADDING VALUE TO THE BUSINESS OF ARABLE FARMING™

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FAR Focus 12
Integrated Pest Management

Contents

1. Introduction

The information enclosed in this FAR Focus summarises nine years of Integrated Pest Management (IPM) research in arable cropping over three consecutive projects. These projects were funded by the Ministry for Primary Industries Sustainable Farming Fund (MPI SFF) with co-funding coming from FAR, PGG Wrightson and Etec Crop Solutions. The research was carried out by Plant & Food Research with support from IPM Technologies Pty Ltd, Victoria, Australia. The first of these projects was entitled *Integrated Management of Slugs in Cropping Systems* (04/052) and its overall aim was to determine the potential for IPM strategies to control slugs under New Zealand's arable growing conditions. Information on the slug species present and their lifecycles was collected from nine farms in Canterbury. The project established which slug predators were present and a laboratory experiment investigating secondary poisoning of carabid beetles was also completed. The second project was entitled *Sustainable IPM Systems in Arable Crops* (07/010). This project had a data collection focus using paired paddocks to evaluate the impacts of the IPM approach alongside the conventional approach. The project tested the applicability of an extension model to influence adoption of IPM practices. The third project was entitled *Arable IPM Training and Transitional Support Programme* (10/002). This was a participatory project where farmers were educated and supported in the transition from routine broad-spectrum pest control to an IPM approach. This project also supported agronomists and advisers interested in offering this service to their clients.

This FAR Focus summarises the findings from these three projects under the following five sections:

- Biological control
- Cultural control
- Chemical control
- Monitoring and decision making
- A cereal case study (wheat)

Definitions

Routine use of broad-spectrum insecticides can result in insecticides being applied unnecessarily, the enhanced development of insecticide resistance and the loss of beneficial insects. This in turn can lead to pest outbreaks and increased dependence on insecticides. Integrated pest management (IPM) offers an opportunity to move away from a routine broad-spectrum insecticide-based approach to pest management. Over the past few years, the number of pest management options available to farmers has increased due to the greater availability of selective insecticides. Farmers may also be more familiar with natural enemies of the pests in question and may be more inclined to only use these insecticides when required.

IPM:

Combines biological (natural predators and parasites), chemical (selective molluscicides and insecticides) and cultural controls in a compatible way. Pest management decisions are based on pest:predator ratios which are monitored throughout the growing season. This approach to pest control aims to maximise the use of beneficial insects whilst minimising unnecessary insecticide use.

IPM is not:

Integrated pesticide management
Monitoring for pests and using insecticides according to pest levels is not IPM unless it also incorporates biological and/or cultural controls.

Insecticide resistance management
Such strategies are included within an IPM approach as they can prolong insecticide efficacy, but they are not IPM strategies if they are stand alone.

Stopping the use of insecticides
Although the aim of any IPM strategy is to minimise the use of insecticides, simply stopping the use of insecticides (conventional or organic) does not mean that IPM is being practised.

IPM is not a rigid one size fits all approach to pest control. Strategies implemented from farm to farm may vary, even though the IPM principles they are based on do not. This is due to a number of factors including farmer perceptions, management history and/or localised pest pressure. Strategies develop depending on circumstances and levels of experience, and these evolve as a farmer's perception and knowledge change over time.

2. Biological control

Key points:

- With IPM pests cannot be dealt with in isolation, as control measures for one pest may influence beneficial species that can contribute to the control of another pest.
- Some pests, such as aphids, have many natural enemies.
- Applying broad-spectrum insecticides while carabid beetles are active results in reduced numbers of these beneficial insects.
- Beetles can be killed by secondary poisoning when they eat slugs that have ingested broad-spectrum molluscicides such as methiocarb baits (EDTA and metaldehyde can be used).
- Predator populations will change to reflect pest populations with a slight delay.

Biological control is when natural enemies or beneficial species directly kill pest species by predation or parasitism. Predators feed and directly consume prey (of one or several species) whereas parasites lay their eggs inside their pest hosts, and the emerging larva consume their host over time.

A wide variety of beneficial predators and parasites contribute to pest control in arable cropping systems (Figures 2-17). Some are resident predators such as carabid beetles (Figures 14 and 15) that live in the crop all year round and play an important role in helping to control establishment pests (pests that inflict the most damage while the crop is getting established), while others are transient and only arrive in a crop if there is a pest present to eat (i.e. lacewings, Figure 4). Some pests, such as aphids, may be killed by a range of both transient and resident beneficial species including brown lacewings (Figure 4), hoverflies (Figure 7), ladybirds (Figure 10), carabid beetles (Figure 14 and 15), spiders (Figure 16), harvestmen (Figure 17) and parasitic wasps (Figure 11). In the case of slugs, carabid beetles (Figures 14 and 15) are the main contributors to biological pest control.

When broad-spectrum chemicals are withdrawn from a farming operation it may take a while for the resident beneficial populations to build up enough to contribute to pest control, whereas transient beneficial insects may fly into a paddock and maintain a presence if no broad-spectrum chemicals are being used (or if enough time has passed since it was applied). This is demonstrated in Figure 1 where monitoring results from three Waimate paired paddocks (IPM versus conventional pest management) have been pooled. A synthetic pyrethroid (lambda cyhalothrin) was applied to the conventional side of the paired paddocks in June and appeared to reduce the numbers of predator carabid beetles right through until harvest. The transient predators (data not shown) appeared in the crops at the end of October with no differences between the IPM and conventionally managed sites, suggesting that enough time had passed between June (when the synthetic pyrethroid inputs were applied) and spring (when the aphid beneficials arrived). Synthetic pyrethroids applied in spring, however, would be expected to reduce the transient species active at this time.

With an IPM approach pests cannot be dealt with in isolation, as control measures for one pest may negatively impact on beneficial species that could otherwise contribute to the control of another pest. This is demonstrated in Figure 1 where a synthetic pyrethroid sprayed to control aphids has compromised the population of carabid beetles which can contribute to the control of slugs.

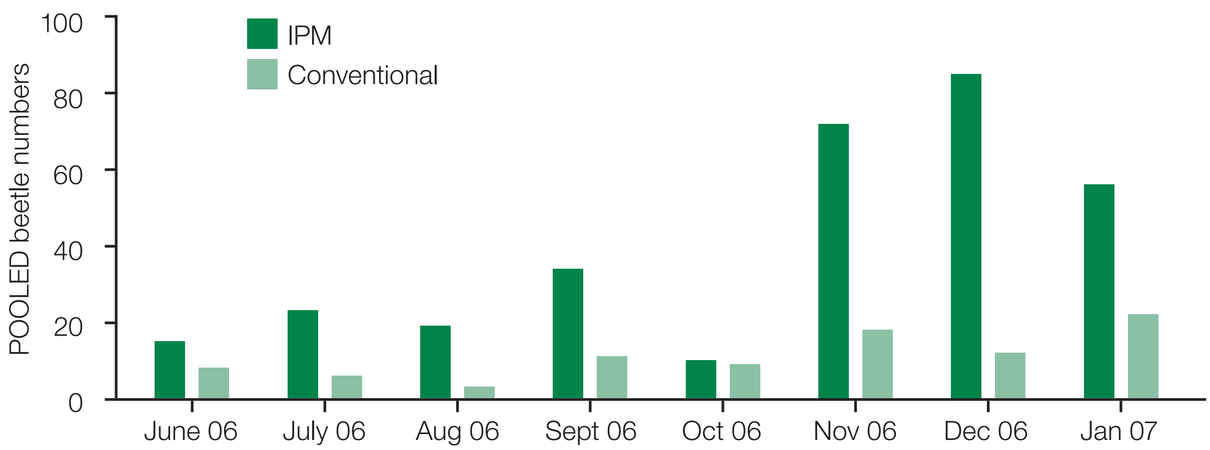

Figure 1. Beetle numbers from three IPM and conventional paired paddocks (three pitfalls traps per paired paddock).

Common predators and parasitoids in cereals

Transient - Brown lacewing (*Micromus tasmaniae*)

Figure 2. Lacewing egg.

Figure 3. Lacewing larva and aphids.

Figure 4. Adult lacewing.

Both adults and larvae are highly active predators of aphids and other soft-bodied insects. The adult lacewing is 7-10 mm long with brown lacy wings. The larvae are up to 9 mm long with a brown alligator-like appearance and move around a lot searching for prey. Eggs are less than 1 mm, smooth, white and oval. Single eggs are often placed on the plant surface close to aphid colonies or other suitable prey. They hatch within a week.

Transient - Hoverflies

Figure 5. Hoverfly egg.

Figure 6. Hoverfly larva.

Figure 7. Adult hoverfly and pupae.

Adult hoverflies hover in one place in the air and have yellow markings on a black body, similar to bees and wasps. They feed on nectar and pollen. Hoverfly larvae move around in the foliage of plants and feed on aphids and other soft-bodied insects. The larvae reach around 5 mm in length so are comparable to small caterpillar pests except they have no legs or head. Hoverfly eggs are white and oval, and are laid near aphid colonies so that there is food for the juveniles that hatch.

Hoverfly and lacewings eggs are very similar in size and shape, but when viewed under a magnifying lens, hoverfly eggs have a slightly dimpled surface.

Transient - Ladybird beetles (*Coccinella* spp.)

Figure 8. Ladybird eggs.

Figure 9. Ladybird larva.

Figure 10. Ladybird adult.

Most adults and larvae of ladybird beetles are highly active predators, with aphids being their main prey. Ladybird larvae look very different from adults. They can be up to 10 mm long, are highly mobile and have a greyish-black alligator-like appearance with yellow or orange bands or spots. Ladybird eggs are yellow, oval and about 1 mm in size. They are laid in batches on the underside of leaves or in the soil.

Transient - Parasitic wasps/parasitoids

Figure 11. The female *Aphidius* bends her abdomen under her legs and injects an egg into the aphid with her ovipositor (next to hoverfly larva).

Figure 12. Mummified aphid.

Figure 13. After the adult parasitic wasp emerges, an aphid shell with a circular hole is left behind.

Some parasitic wasps are species-specific and many actively search for aphids. The main parasitoid of aphids in cereal crops in New Zealand is *Aphidius rhopalosiphi*. The female lays an egg inside the aphid. When the egg hatches, the emerging larva consumes the aphid and eventually an adult parasitic wasp emerges, leaving behind an aphid shell with a circular hole.

Adult wasps are up to 3 mm long, black and can easily be mistaken for other flying insects. The most obvious sign of parasitoids is parasitised aphids, which become swollen and turn a dull brown colour. They are referred to as aphid mummies.

Resident - Carabid beetles

Figure 14. Some common carabid species in Canterbury are (L to R) *Megadromus antarcticus* (metallic green beetle), *Metaglymma monoliferum* and *Holcaspis angustula*.

Figure 15. *Megadromus antarcticus* (metallic green beetle).

Native carabid beetles (Carabidae) are generalist feeders that feed on pests such as slugs, aphids and caterpillars. The relatively long generation times of these beetles (1-2 years) means that a single synthetic pyrethroid application can reduce populations for many years. They are nocturnal predators so just because you don't see them, it doesn't mean they're not there.

Resident - spiders and harvestmen

Spiders and harvestmen are common generalist predators of insects in wheat crops. Some are soil- or foliage-dwelling whereas others spin webs in the vegetation. Spiders and harvestmen can be active throughout the year with highest numbers occurring in spring.

Figure 16. Wolf spider.

Figure 17. Harvestman.

Predator-prey cycle

Figures 18 and 19 show collective results from across two growing seasons in 14 Canterbury wheat paddocks. Monitoring was carried out every 2 - 4 weeks and the aphids and beneficial species were monitored using 4 pitfall traps and 1 sticky trap per paddock, as well as direct searching and sweep netting (4 - 5 sweeps, each around 10 m in distance per visit). The monthly averages of beneficial species (lacewings, carabid beetles, hoverflies, ladybirds and parasitic wasps) and aphids (winged and wingless) reveal typical pest-prey cycles. When numbers of pests are low then the numbers of beneficial species that eat them are low. This is usually followed by a pest increase which provides an increased food supply for the beneficial species. As a result of this the graphs show a peak in pests, a gradual build-up and subsequent peak of beneficial species and then a decline in both (as the beneficial species reduce the pest population, they are also reducing their own food supply so their own populations decline).

The time lag between pests reaching a peak to being controlled by the beneficial species is of particular relevance when using IPM (due to the damage that can be caused in the meantime). With experience, farmers are likely to become more confident that control will occur, but decisions still need to be made based on the pest-predator ratio and anticipated impact of the lag in time before control is reached. If economic loss is anticipated before the beneficial species achieve control, then the farmer may decide to intervene with a selective insecticide which will reduce the pest numbers with minimal effect on the beneficial species.

Figure 18 shows that on average, the aphid numbers from the 14 paddocks were lower than the beneficials over the autumn and winter months of 2011. At a paddock level, if a seed treatment had been used but aphids were still present after the crop had reached GS21 (and predator numbers were low) then a selective aphicide was recommended. If Figures 18 and 19 represent a single paddock, the lag between the aphids escalating at the beginning of October and the beneficial species catching up would not be a concern as long as the stage of development was past GS31 where the crop is no longer likely to be economically compromised by aphids transmitting *Barley yellow dwarf virus* (BYDV) (Thackray et al. 2005). Were this lag to occur in an individual paddock before the wheat crop had reached this growth stage, a selective aphicide would be recommended.

Figure 19 shows that aphid numbers remained low over the winter and then increased rapidly in October. Although the numbers of aphids were higher on average than the number of beneficial species over these months, each beneficial will eat many aphids and the pest/prey cycle proceeds along the expected trajectory with aphid numbers eventually diminishing below predator numbers.

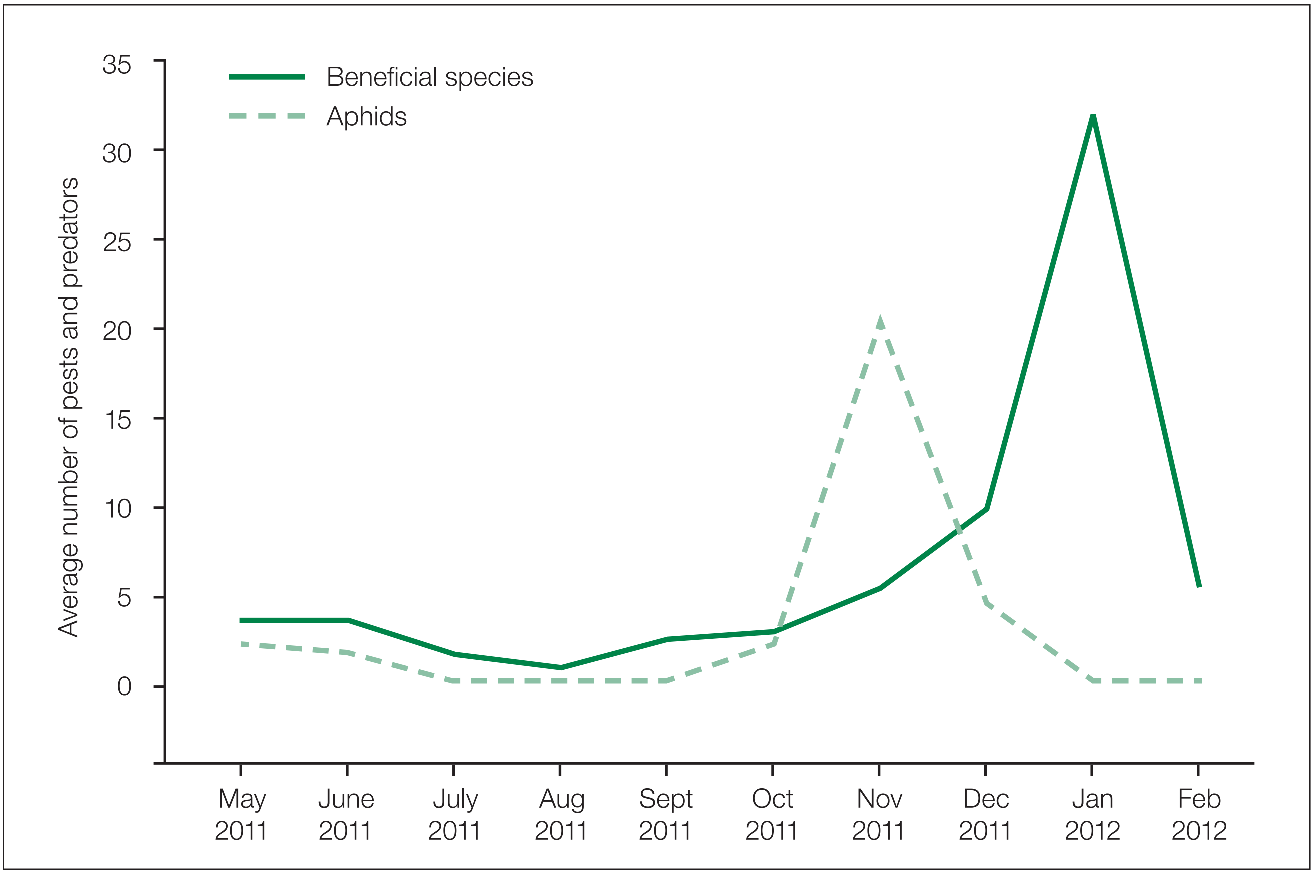

Figure 18. Monthly averages of beneficial and aphids (winged and wingless) from May 2011 to February 2012.

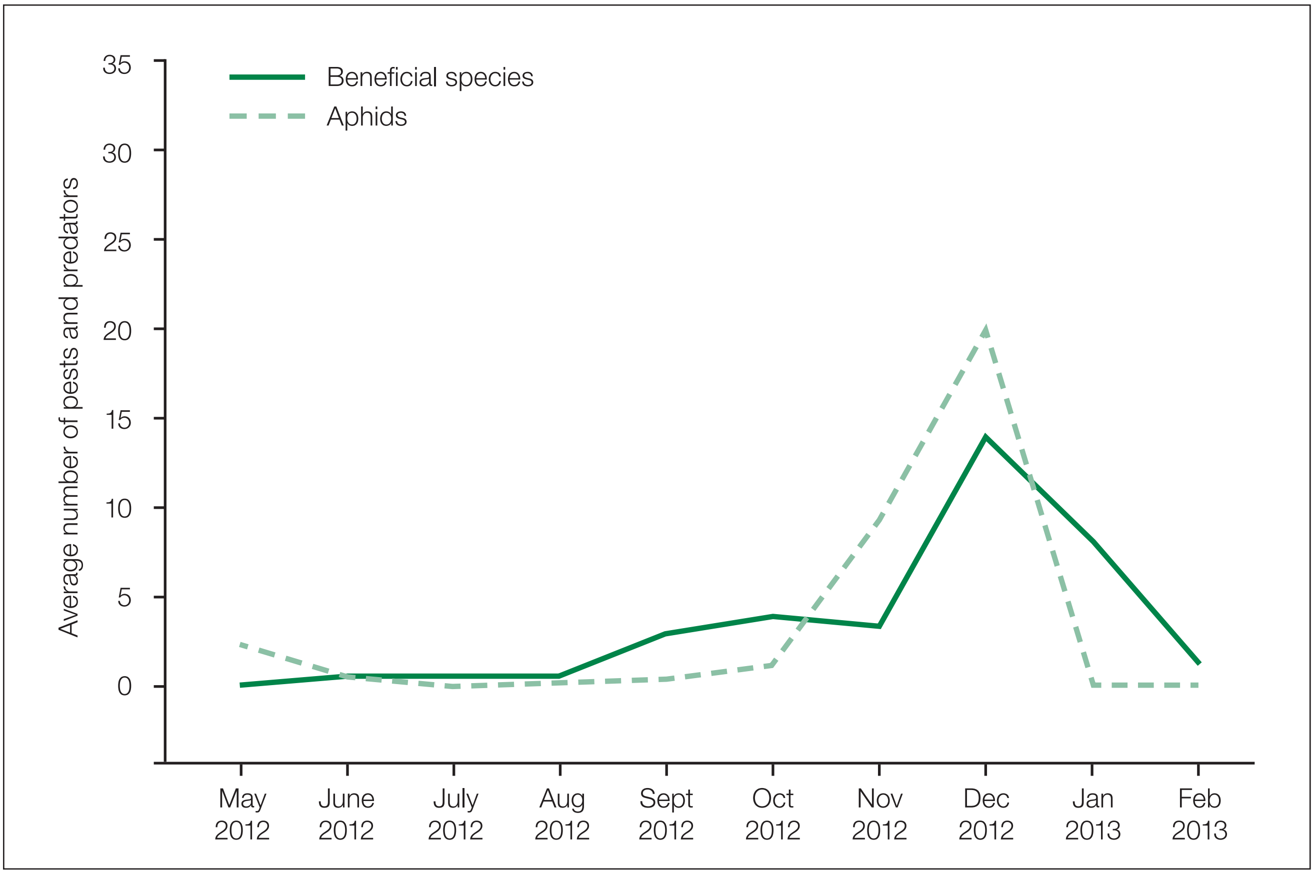

Figure 19. Monthly averages of beneficials and aphids (winged and wingless) from May 2012 to February 2013.

Another example of the pest-prey cycle can be seen in Figure 20. These results came from a paired paddock trial where an application of lambda cyhalothrin (Karate®) was made in late summer on the conventional pest management site, due to the build-up of aphid numbers and a concern that they would damage the head of the wheat. The insecticide was applied between the first and second leaf count (only to the conventional site) so at the second count there was a marked decrease in aphid numbers. A pirimicarb spray was not applied on the IPM site due to the large numbers of beneficial species also present (most predominantly ladybirds, lacewings and parasitic wasps). By the third count, aphid numbers were low at both the IPM and conventional sites even though no insecticide had been applied to the IPM site. No detectable yield differences were observed at harvest. These results show that beneficial species can have the same short-term effect as chemicals without the long-term negative effects of knocking back residential predators.

Confidence in recognising when to act on pest:prey ratios comes with experience, and will differ from farm to farm depending on perception of risk and personal experience.

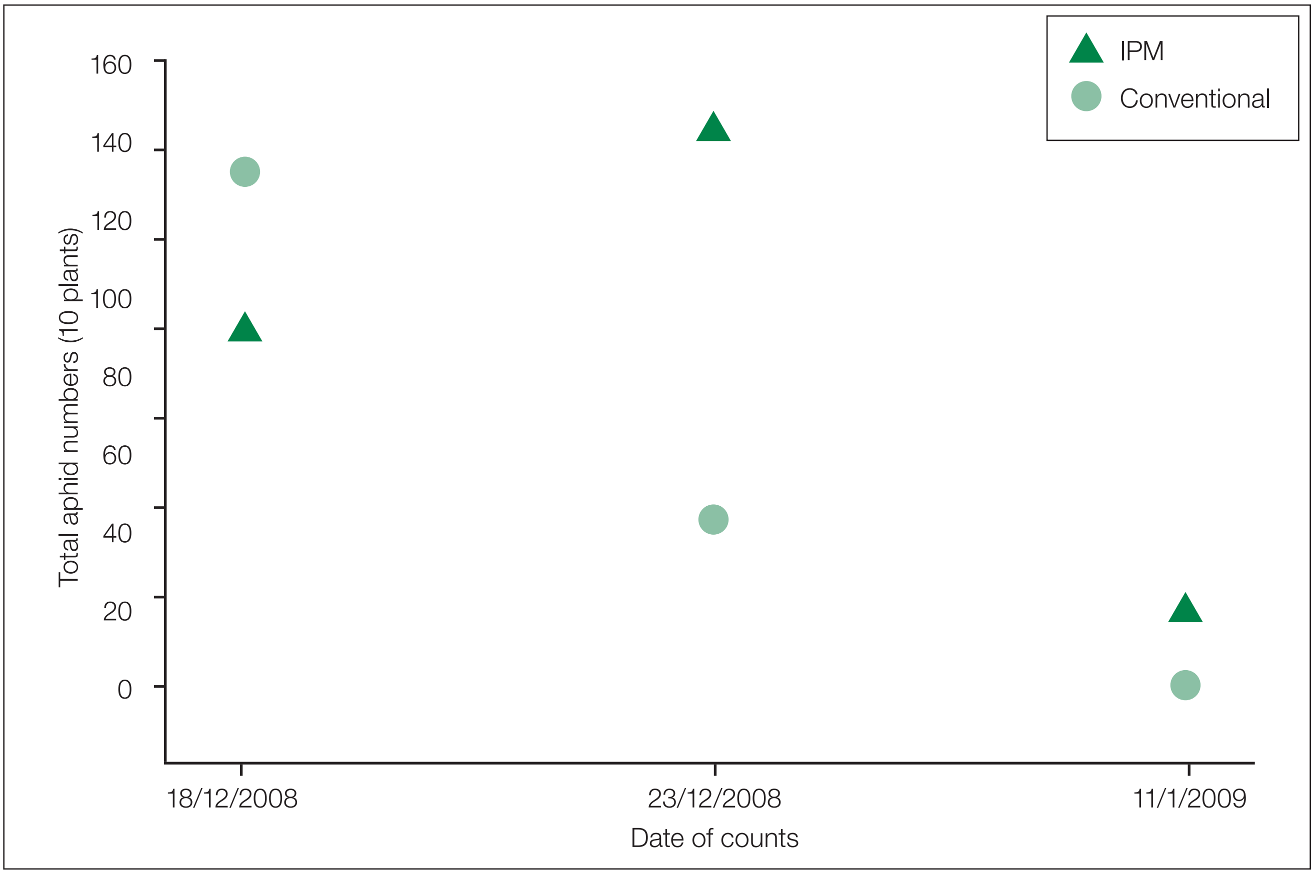

Figure 20. Aphid leaf counts over a 3 week period at a South Canterbury farm.

3. Cultural control

Key points:

- Examples of cultural controls are many and varied.
- Cultural controls are often the main control option in parts of the world where certain pesticides are no longer permitted.
- For slugs; cultivation, seed to soil contact and rolling are important cultural controls.
- For aphids; time of planting and weed management are important cultural controls.

Cultural controls include all management activities that can contribute to better pest control. They can be extremely varied but all work by either making the habitat worse for pest species or better for beneficial species. The combination of cultural control options implemented will vary from farm to farm depending on resources available and/or the farming system. For example, the cultural options available on a no-till farm will be different from those on a farm that cultivates. The no-till farmer may be implementing a cultural practice that makes the habitat better for beneficial species (i.e. by leaving more residue on the surface) whereas a farmer that cultivates may be inadvertently implementing a cultural practice that makes the habitat worse for the pest (i.e. physically destroying slugs through cultivating).

Crop rotation is an example of a well-understood and commonly implemented cultural control which is often factored into farming systems in order to break the cycle of increasing pest and disease populations. Similarly, variety selection has been used for centuries as a way to culturally control pests by selecting for resistance. Although there are currently no feed wheat varieties resistant to BYDV, this may change in the future.

A key cultural control for cereal aphids is to avoid planting at high-risk times by sowing later in the autumn (i.e. after May) to avoid aphid flights. This option is becoming less common due to concerns about yield loss with later sowing.

Soil preparation, a good quality seed and management of weeds that can harbour aphids are also important cultural controls. If the crop can be established quickly and the plants are growing well, problems with establishment pests, such as slugs, will be reduced.

In some parts of the world where molluscicides are not permitted, cultural controls are the main way of controlling slugs. In Denmark, for example, slug management is primarily obtained by having good soil-seed contact at sowing, grazing (where relevant), cultivation (where possible) and light rolling every 3-4 days until the crop is well established. Conditions need to be right as rolling is not effective when it is too windy or too wet.

Cultural controls can also be the most effective control measure for some pests even when chemical options are not restricted. An example of this is the Hessian fly, a pest of wheat and other cereals (barley and rye). It is very difficult to effectively control Hessian fly chemically due to the larvae being protected between the stem and leaf sheaths and the adults emerging at staggered time intervals. Flies emerge in spring from the stubble of the previous crop and therefore stubble management is a cultural control. Infested stubble must be destroyed, removed or buried where possible, and in no-tillage situations crop rotation with non-host crops is required.

4. Chemical control

Key points:

- Non-target mortality refers to the situation where a pesticide applied to kill one pest kills one or more other species in addition to the target.
- Although seed treatments may be used preventatively with an IPM approach, usually pesticides are applied only after monitoring indicates that they are needed and, where possible, only selective chemicals are used.
- A common outcome of implementing an IPM approach is the reduced routine use of insecticide applications.
- There was a 50% reduction in the number of insecticide applications in IPM-managed wheat crops monitored during the 2008-09 and 2009-10 growing seasons compared with conventionally managed sites.

IPM only uses pesticides after monitoring indicates that they are needed and, where possible, only uses selective chemicals. Synthetic pyrethroids such as lambda cyhalothrin or organophosphates are avoided where possible because their broad-spectrum effect means they will kill beneficial species as well as target pests.

Not all broad-spectrum chemicals kill beneficial species directly. Secondary poisoning of beneficial species occurs when they consume the pest which has come into contact with or ingested the insecticide or molluscicide. A laboratory trial was conducted as part of the *Integrated Management of Slugs in Cropping Systems* (04/052) project to investigate the effects of different types of slug bait on carabid species. It showed that when carabid beetles consumed slugs that had eaten metaldehyde slug baits (i.e. Metarex® and SlugOut®) or EDTA (i.e. Multiguard®) they were not poisoned whereas when they ate slugs that had consumed methiocarb (i.e. Mesurol®) baits they were poisoned.

Monitoring in Canterbury carried out since 2006 found several species of carabid beetles active in cereal crops. The extent to which beetles were present varied. Some farms had beetles present all year round, some had small numbers of beetles for short periods of the year and some had none. The history of molluscicides used on the farm is likely to be one of the reasons for the variation. For example, the farm with the lowest presence of carabid beetles was a direct drilled farm with a history of heavy methiocarb molluscicide use.

When choosing chemicals it is important to:

1. Make sure the pest is correctly identified.
2. Avoid routine use of insecticides - there must be a pest in sufficient numbers at a critical time.
3. Consider the effect of selected pesticides on beneficial species present (resident and transient).

A common outcome of implementing an IPM approach is the reduced routine use of insecticides. Whether the reduced number of insecticides results in increased gross margins will depend on the pest pressure each season. Although fewer chemical applications may be necessary, the benefits of this may be offset by selective insecticides often being more expensive than the broad-spectrum options. Additional costs of monitoring may also need to be accounted for. During the 2008–09 and 2009-10 growing seasons, data were collected from both conventional and IPM managed paired sites to determine the presence and abundance of key pests (slugs, aphids), diseases and beneficial species in wheat. There was an increasing trend in the number of beneficial species, a reduction in pests and a 50% reduction in the number of insecticide applications in the IPM-managed crops. The reduction in insecticide use was a result of the monitoring clearly determining that aphid pressure was low, so insecticides following seed treatment were not required. This was achieved without yields being compromised and, as a result, average gross margins were higher for the IPM-managed sites for these years.

Selective insecticides and non-target mortality

Non-target mortality refers to the situation where a pesticide applied to kill one pest kills one or more other species in addition to the target. Although non-target tests may have been done on earthworms or honey bees when the insecticide was registered, they are unlikely to have been carried out on the wide range of beneficial species that are present on farms (Page and Horne 2012). Using selective insecticides requires careful consideration of not only the pest in question but the beneficial species that may be present at the time the application is being considered. This is because even though newer insecticides are far less harmful to many beneficial species compared to the older broad-

spectrum insecticides, very few are harmless to all beneficial species. For example, pirimicarb (Pirimor) is a carbamate insecticide that is relatively selective when applied to control aphids. It does kill other species, especially parasitoid wasp species, but is highly volatile, so the effects on non-target species occur only for a very short time (Page and Horne 2012).

Information on what pesticides do to a range of beneficial species besides the target pest is required to begin to make changes to pest management. Two recommended websites are www.koppert.com and www.ipmtechnologies.com.au.

Insecticide resistance

Insecticide resistance describes the process whereby individuals within a population that survive a certain dose of pesticide (when other more susceptible individuals are killed) will be the only ones to pass their genes on to the next generation. Even when products are identified as being safe to the particular beneficials in a particular crop, if it is used too often resistance will develop in the pest population meaning that the best products for IPM will be lost (Page and Horne 2012).

5. Monitoring and decision making

Key points:

- IPM requires some degree of monitoring to be carried out to aid decision making so that insecticides and molluscicides are applied only when necessary.
- A farmer or adviser interested in implementing IPM is not expected to immediately know how to identify all pest and beneficial species at all the stages of the life cycle.
- As more experience is gained, decisions based on the same number of pest and beneficial species may change over time.
- What is happening at the paddock level is important and varies depending on localised conditions and pest predator ratios.

Using IPM does not mean relying solely on biological and cultural control, as there may be occasions when the lag between the pests doing damage and the beneficial species gaining control will require chemical intervention. There are also some pests for which no biological controls are available, such as Nysius (although the damsel bug may be important). Likewise, using IPM involves recognising the role of biological and cultural controls, not just alternative pesticides. What is essential is that some degree of monitoring is carried out to aid decision making so that insecticides and molluscicides are applied only when necessary.

If farmers are new to the IPM approach, the monitoring aspect may seem daunting. Support is often needed in the initial stages of implementing IPM until decisions can be made independently with confidence. Finding an adviser who has experience with IPM is not always easy but is a good place to start.

When taking the first steps:

1. Start with just a few paddocks.
2. Consider which crops and areas of the farm are more susceptible to pest damage.
3. Be attentive to the conditions that lead to rapid increases in pest numbers.
4. Pay the most attention if there are known times when the crop is vulnerable to pests.
5. Gain experience in identifying beneficial species.
6. Become comfortable with how best to monitor to suit your schedule and crops.
7. Gain confidence in using the results of monitoring to guide decisions.
8. Observe differences between IPM-managed paddocks and the rest of the farm.

Monitoring options

Sweep netting and **direct searching** following establishment of the crop are quick and simple once you know what you are looking for. They are a good way to detect colonies of winged and wingless aphids or leaf damage. A 10x magnifying hand lens can help with identification.

Figure 21. Sweep net.

Yellow sticky traps can be used to monitor for small flying insects such as aphids or brown lacewings, however they will not detect wingless aphids. These traps, which can be purchased from most farm service stores, can help detect sudden increases in a particular type of insect, which can lead to more timely decision making. They should be attached to bamboo (or similar) poles positioned so they sit just above the crop.

Figure 22. Yellow sticky trap.

Pitfall traps (any container dug into the ground flush with the surface and half-filled with diluted antifreeze as a preservative) will collect insects and other invertebrates that are active on the soil surface. They are a good way to see if there are any carabid beetles in the paddock (aphids can also be found on the surface).

Figure 23. Pitfall trap.

Tiles (anything that provides shelter, such as wooden tiles or sacks) can be used to monitor slug activity.

Figure 24. Wooden tile used to monitor slug activity.

For every action taken that influences pests or beneficial species a decision has been made which may have been based on adviser recommendations, standard routine practice or site specific monitoring. Site specific monitoring in a given paddock provides direct information about what is happening in the crop over the growing season and can directly inform decision making. Regional information can contribute to decision making but should not replace site specific monitoring.

For example, suction trap aphid counts can provide assistance, especially when considered alongside temperature, and are a good prompt to carry out site specific monitoring. However what is happening at the paddock level will depend on localised conditions and pest predator ratios so regional information is only one part of the story.

Different farmers will make different decisions when given the same set of pest numbers and crop types. Similarly, as a farmer interested in learning more about IPM becomes more familiar with the beneficial species of the pests in question, they might make different decisions with the same set of pest numbers and crop types over time.

A farmer or adviser interested in implementing IPM is not expected to immediately know how to identify all pest and beneficial species at all the stages of the life cycle, not to mention all the effects of insecticides on both target and non-target species. This knowledge will build up over time as long as the monitoring is carried out and there is reliable support available so that, with the aid of identification guides, cameras and email, problems can be addressed as they are encountered (Page and Horne 2012).

6. Cereal case study

When it comes to implementing IPM for a particular crop at a particular farm the three control options (biological, cultural, chemical) need to be integrated to build a strategy that accommodates the farming system as well as the farmer. One option for compiling a strategy is to make a table with a list of pests expected for the crop in question. In the column next to this identify any possible beneficial species for each pest. In the next column identify any cultural/managerial options that could either encourage beneficial species associated with the pest or discourage the pest itself (or both), then add a column for any chemical support. The chemical list should prioritise options that will have the least effect on the beneficial species that may be present, but also include non-IPM compatible options for pests where there are no alternatives available. An example of such a table can be seen in Table 1. This was put together by farmers at a farmer meeting in Ashburton, September 2012 (facilitated by Dr Paul Horne from IPM Technologies Pty). It may include pesticides that may not be registered for the pests or crops in question.

Note that for an IPM strategy to be most effective, this information needs to be captured before the crop has been sown, as some of the cultural controls may need to be carried out as early as in the previous crop. Deciding to implement IPM once a pest problem has been recognised limits options available and the optimal use of all cultural, biological and chemical options in an integrated way is more likely to be replaced with sole reliance on the chemical option (Page and Horne 2012).

Table 1. An example of an IPM strategy table for cereals put together by farmers at an IPM workshop, 2012.

Pest	Beneficial	Cultural	Chemical	Monitoring
Slugs	Carabid beetles	Tillage Press wheel Rolling at night	Metaldehyde EDTA	Use tiles or sacks to monitor slug numbers and assess risk
Grass-grub	Carabids Pathogenic fungi	Rotation	Seed dressing	Soil sampling before planting
Aphids	Parasitic wasps Ladybirds Brown lacewings Hoverflies	Grassy edge/weed volunteers and green bridge mgt Later sowing date	Seed dressing Pirimor[1] Chess[2]	Suction Traps Direct search Sticky traps
Caterpillars	Parasitoid wasps Damsel bugs Carabids	Control weeds prior to sowing	BT[3] Others if required	Pheromone traps Sampling Direct search
Hessian Fly	Parasitic wasps	Burying infected residue Burning Baling	Seed dressing	Direct search

[1] Rate needs to be increased when temp below 18 degrees. Ideal time to spray is in the morning when it is going to be sunny. Will kill adult parasitic wasps flying, but not juveniles (protected in maggot stage inside host).

[2] Should be applied in conditions where it won't dry too quickly on the leaf (as translaminar).

[3] If Bt used need to be aware that it is UV degraded, target first instars (won't kill eggs or adults), requires a high water volume with neutral pH, requires a wetting agent, needs 24 hrs without rain/irrigation and needs to be used before expiry date.

Two key pests that are likely to appear on the pest list for wheat are slugs and aphids. The following is a more detailed review of these pests from an IPM perspective.

Slugs

Slug species

Figure 25. Grey field slug (*Deroceras reticulatum*).

Figure 26. Brown field slug (*Deroceras panormitanum*).

Figure 27. Keeled field slug (*Milax gagates*).

All of the pest species of slugs present in arable crops are of European origin. The two most common slug pests of arable crops in the South Island are the grey field slug *Deroceras reticulatum* (Figure 25) and the brown field slug *D. panormitanum* (Figure 26). The adult grey field slug will vary from 35-50 mm in length. The brown field slug is smaller and the adult will vary from 25-30 mm in length. The grey field slug causes twice the damage of the brown field slug (per individual). The keeled slug (*Milax gagates*, Figure 27), though less common, is also very damaging. The adult keeled slug will vary from 35-50 mm in length. The grey field slug can easily be identified as it is the only species that produces milky white mucus when disturbed (disturb by stroking with finger nail or stick). The brown field slug is a uniform brown colour with no distinctive markings. The keeled slug is usually very dark with a sharp ridge, or keel, running along its back (see FAR Arable Extra 59).

Slugs are a serious pest of winter wheat, especially during establishment and if the previous crop was peas, ryegrass or brassica seed. Autumn is an important time for slug damage as autumn-sown crops are at the vulnerable growth stage for longer than spring-sown crops and slug numbers are generally high.

Slugs are active at night and depend on moisture for activity, survival and reproduction. They are at their most damaging in wet weather. Under the right conditions they are continuous breeders with population peaks in spring and autumn (which coincides with drilling). Areas on the farm with higher soil moisture contents or heavier clay soils are likely to be at greater risk.

Biological control

Carabid beetles (Figure 14 and 15) feed on a range of pests and can contribute to the natural suppression of slugs. Monitoring in Canterbury has found three different species of carabid beetles within arable crops that prey on slugs at various stages of their lifecycle. Though the presence of the beneficial carabid beetles was variable, overall there were peaks in their numbers in spring and autumn that coincided with peaks of new generations of slugs and periods of crop vulnerability.

Cultural control

There are a range of cultural options available to contribute to slug control including the use of intensive grazing (where appropriate), rolling after drilling and good seed - soil contact (if soil conditions permit). In a consolidated seed bed slugs cannot damage the growing points of cereals (as they are below ground). Crops are also more likely to compensate for shredding and windowing feeding damage to the leaves once established if nutrients are not limiting. If cloddy seed beds are an issue then increasing sowing depth can help. Cultivation prior to sowing tends to kill many slugs, with slugs more likely to be a problem in heavy soils with cloddy seed beds. As cultivation is not an option where direct drilling is practised it is especially important to have good seed-soil contact to minimise slugs entering the drill slots to feed directly on the seed. Burning is also a possible cultural control option. Although it may provide some control of slugs, it may be undesirable for other reasons (such as removal of predator beetle habitat), or may not be suitable due to the previous crop or current crop selection.

Chemical control

As carabid beetles are generalist predators, the extent to which they will predate on slugs may vary depending on other food sources. Consequently, implementing IPM does not mean that biological control of slugs is guaranteed.

There are several types of baits available - although they all kill slugs they differ in cost, ease of application, longevity and impacts on non-target organisms. Slug baits that do not result in secondary poisoning to generalist beetle predators are recommended. Secondary poisoning occurs when the beetles which eat a slug that has ingested a pellet are also killed. Baits with methiocarb as the active ingredient result in secondary poisoning to predator beetles whereas baits with EDTA and metaldehyde as active ingredients do not (Figure 28).

Timing of bait application is critical and applying baits for peace of mind when slugs are not active is a waste of money. In the right conditions slug populations will recover rapidly (from baiting, cultivation, a period of dry weather). Spring and autumn is when slugs are most active and therefore when slug baits should be applied. Baiting in the previous crop may need to be considered if monitoring shows high numbers and a slug sensitive crop is being planned. Work in Oregon has found that baiting under the following conditions increases efficacy:

- Applying the bait at dusk
- Not applying the bait if windy or too cold (below 8°C)
- Not applying the bait if it is raining or too wet.

Another thing to consider is the trade-off between how rain-fast the baits are and the concentration of baiting points. The more rain-fast baits have the active ingredient embedded in the bait (i.e. Metarex®) but if there are very high slug numbers then the number of baiting points may be a more important consideration. Table 2 shows bait points per square metre for two common metaldehyde slug baits and an EDTA bait (Multiguard®). Rates used are label rates and where there are two rates shown, this refers to the low and high rate on the label.

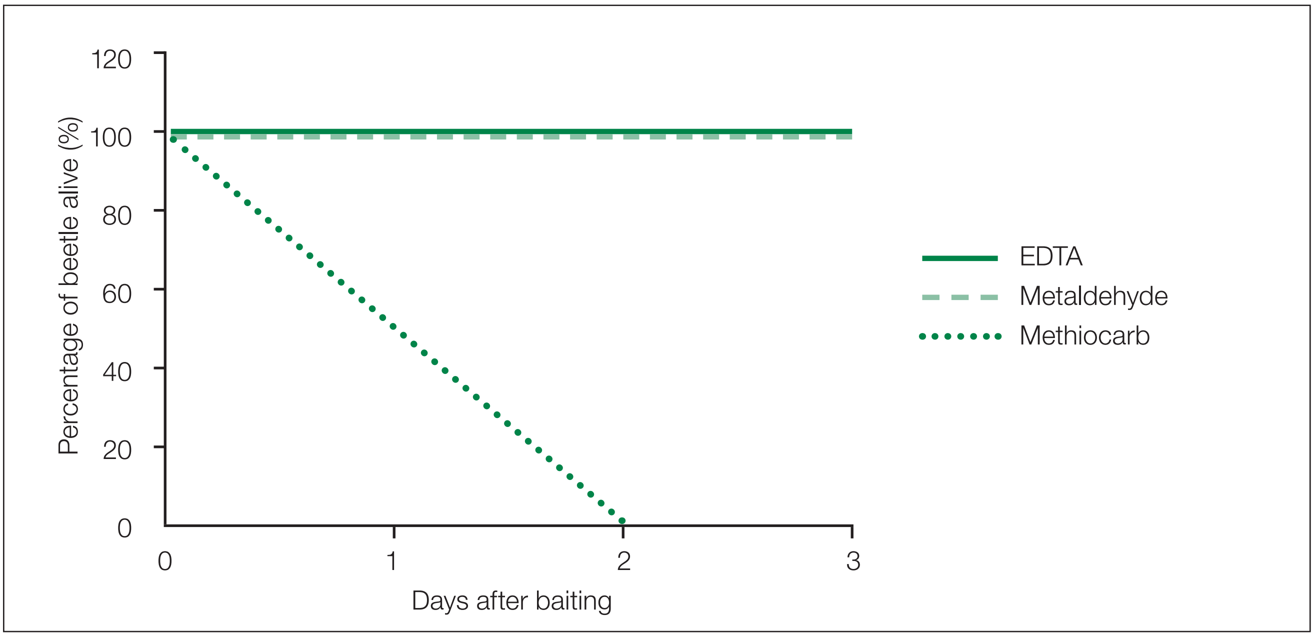

Figure 28. Percentage of beetles surviving after consuming slugs which had fed on three types of slug bait.

Table 2. Bait points per square meter and cost per hectare for four molluscicides.

Bait	Active ingredient	Label Rates (kg/ha)	Bait points/m²	Cost ($/ha)*
SlugOut	Metaldehyde	10 15	112 168	86 129
Metarex	Metaldehyde	4 8	24 48	75 150
Metarex Micro	Metaldehyde	4 8	44 88	82 165
Multiguard	Iron EDTA	5	13	76

* Price will vary between suppliers; these figures were obtained in New Zealand February 2015.

Monitoring

Crops are most vulnerable to slug damage during establishment because slugs attack and hollow out seeds and bite off young seedling plants at ground level. Monitoring of slugs is therefore essential before the crop is sown to determine background slug levels and should continue until the crop is well established (6-8 weeks), especially in moist conditions. The best way to establish if you have a slug problem is to put out wet sacks or tiles (Figure 24).

Slug damage is likely to be more serious in direct drilled crops, as surface residue and drill furrows provide favourable conditions for slugs.

The following key points are essential:

- Knowing which crops are more susceptible to pest damage
- Knowing which areas on your farm are most problematic
- Recognise the conditions that lead to pest numbers increasing rapidly.

Slug activity is moisture and temperature dependent. Just because numbers are low at drilling doesn't mean that there won't be population explosions within that window of vulnerability. Warning bells should go off when any of the following occurs:

- The field is drilled during a period of generally wet weather
- Wet weather delays sowing in a prepared seed bed
- The seed bed tilth is coarse and cloddy, and further consolidation is not possible following sowing
- The crop is slow to emerge or to grow through the early vulnerable stages and symptoms of slug damage are seen
- If slug damage was an issue in the previous crop.

Aphids

Figure 29. Cereal aphid (*Rhopalosiphum padi*) winged and wingless.

Figure 30. Rose grain aphid (*Metopilophium dirhodum*) winged and wingless.

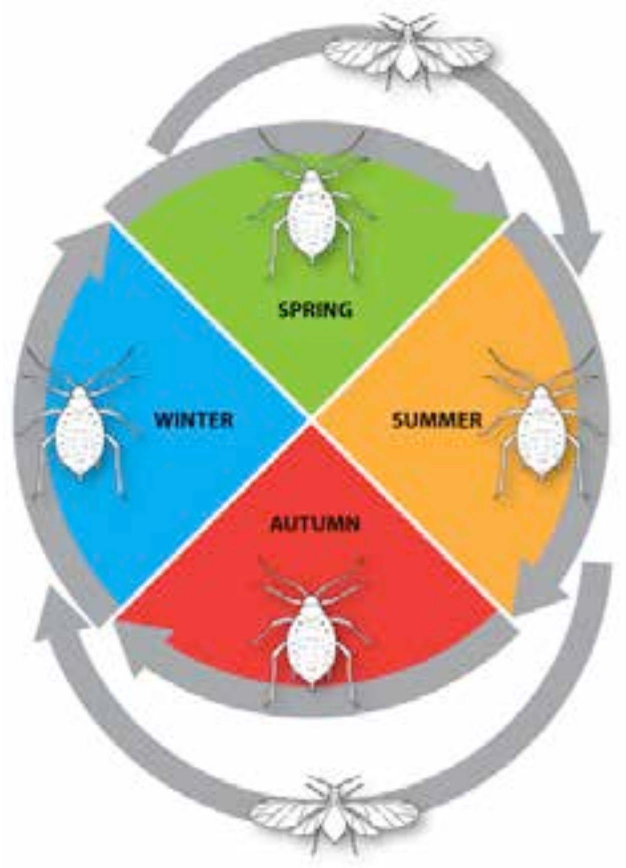

Figure 31. Lifecycle of cereal aphid *Rhopalosiphum padi*.

Aphids are small soft-bodied insects, typically yellow-green, dark green, dusky brown or blackish. The most common cereal aphid is *Rhopalosiphum padi*, commonly referred to as cereal aphid or bird cherry-oat aphid (Figure 29). The rose grain aphid (*Metopilophium dirhodum*) is also common (Figure 30). Both are responsible for transmitting BYDV, a major cause of cereal yield losses in New Zealand (see page 27). Figure 31 shows the life cycle for the cereal aphid *R. padi*. In parts of the northern hemisphere this aphid has an egg stage for over-wintering but in New Zealand the only change of form is from winged to wingless where young are born alive in an all-female population. Winged aphids fly into cereal crops from pasture grasses or other crops, and start colonies of wingless aphids. When plants become unsuitable or overcrowded, winged aphids reproduce and migrate to other plants or crops.

In Canterbury, cereal aphid flights usually peak in autumn from mid-March to mid-June and in spring from September to November. These flights will start new colonies of wingless aphids which will prosper in mild winters and may be responsible for secondary spread of BYDV in autumn sown cereals (Burnett 1984).

Biological

Aphids are a key food source for a large number of insects such as brown lacewings (Figure 4), hoverfly larvae (Figure 6), ladybirds (Figure 10), parasitic wasps (Figure 11), carabid beetles (Figures 14 and 15), spiders (Figure 16) and harvestmen (Figure 17). Hoverflies and ladybirds tend to lay eggs only where there are aphids present, as their larvae depend largely on aphids. Parasitic wasps, which contribute to aphid control very effectively, can be hard to detect so the best way to determine their presence is by observing if the aphids have been parasitised. Look for swollen aphids that have turned a dull brown colour (Figure 12) or aphid shells with a circular hole that the emerging wasp has left behind (Figure 13).

Cultural

The main cultural control for aphids in cereals is choosing to plant later so the crop will emerge after autumn aphid flights are over, i.e. late May or early June. The crop will still be in danger from infection of BYDV in spring, but, because older plants are less severely affected, the losses will be minimised (Thackray et al. 2005). However increasingly earlier planting has become common in order to try and achieve higher yields.

Chemical

Natural enemies limit aphid populations, so when using an IPM approach to control pests it is important to carefully integrate suitable chemicals that, where possible, do not disrupt these predators. This means avoiding synthetic pyrethroids and organophosphates. Insecticide seed treatments, especially for early sown crops, should be considered to reduce aphid populations and minimise BYDV spread up until the start of tillering (GS21). If aphids are found in the crop and natural enemies are absent (especially during stage 2 described below) then selective aphicides are recommended, i.e. pymetrozine or pirimicarb (apply pirimicarb on the morning of a sunny day; if weather is cold and cloudy, higher rates are required).

Monitoring

Sticky traps are useful to determine if there are aphids active in and around the crop, especially while the crop is establishing and too small for direct searching or sweep netting (see page 18). Once the crop is well established, sweep netting and direct searching are the best way to detect colonies of aphids, natural enemies and leaf damage. The amount of sweep netting and direct searching carried out will vary from person to person depending on their level of confidence and direct experience. As part of the SFF project, 4-5 sweeps, each around 10 m in distance, were conducted per visit.

Figure 32 illustrates an example of a low aphid pressure season for an autumn sown wheat crop. Figure 33 illustrates an example of a high pressure season for an autumn sown wheat crop. There are a number of factors that influence aphid pressure such as (1) climatic conditions (warm and mild conditions result in greater aphid reproduction and survival than cold, wet and windy conditions), (2) the action of natural enemies, (3) the action of pathogens, (4) host plant condition, (5) cultural measures such as time of planting and (6) the action of chemicals (Wellings and Dixon 1987).

Three crop growth stages are identified with different monitoring requirements.

Stage 1: This is generally the first month to six weeks after the crop is sown. If the crop has not had a seed treatment then monitoring needs to determine if aphids are flying or are present in the crop and if beneficial predator species are active. The low-pressure scenario depicted in Figure 32 shows that the crop is sown after aphid flights have finished. The high-pressure scenario depicted in Figure 33 shows an example where there are still active aphid flights while the crop is establishing.

Stage 2: This is generally considered the high-risk period; once seed treatments are no longer active and before the crop reaches GS31. It is important to note that once the crop reaches GS31 it does not mean aphids are no longer vectoring BYDV, rather there is just a decline in sensitivity. Monitoring needs to determine if there is evidence of wingless aphid colonies building up over a mild winter or if there are any early spring aphid flights (and if there are beneficial species active). Sticky traps will not detect whether there are wingless aphids in a crop so direct searching and sweep netting should be carried out. The low-pressure scenario depicted in Figure 32 shows wingless aphid numbers are low and spring flights are not detected in the crop until after GS31. The high-pressure scenario depicted in Figure 33 shows a year where action is required as wingless aphids have spread and spring flights of aphids can be found in the crop prior to GS31.

Stage 3: Even though it is assumed that there is greater tolerance for aphids post GS31, monitoring should be continued to see if aphids are causing any direct feeding damage. Cultivar sensitivity to BYDV may need to be considered if aphid numbers are high even if the crop is past GS31. Predator activity is also likely to be high, depending on choice of sprays.

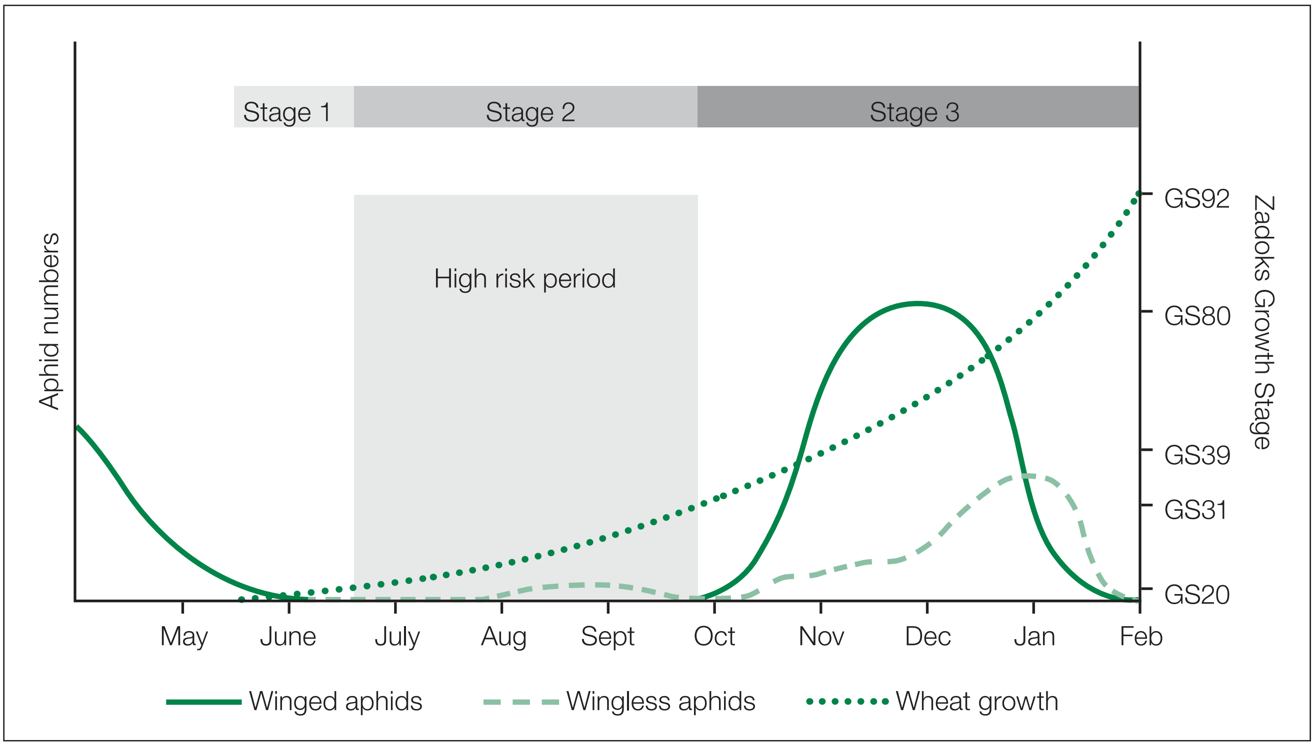

Figure 32. Example of low aphid pressure (winged and wingless) in autumn-sown wheat.

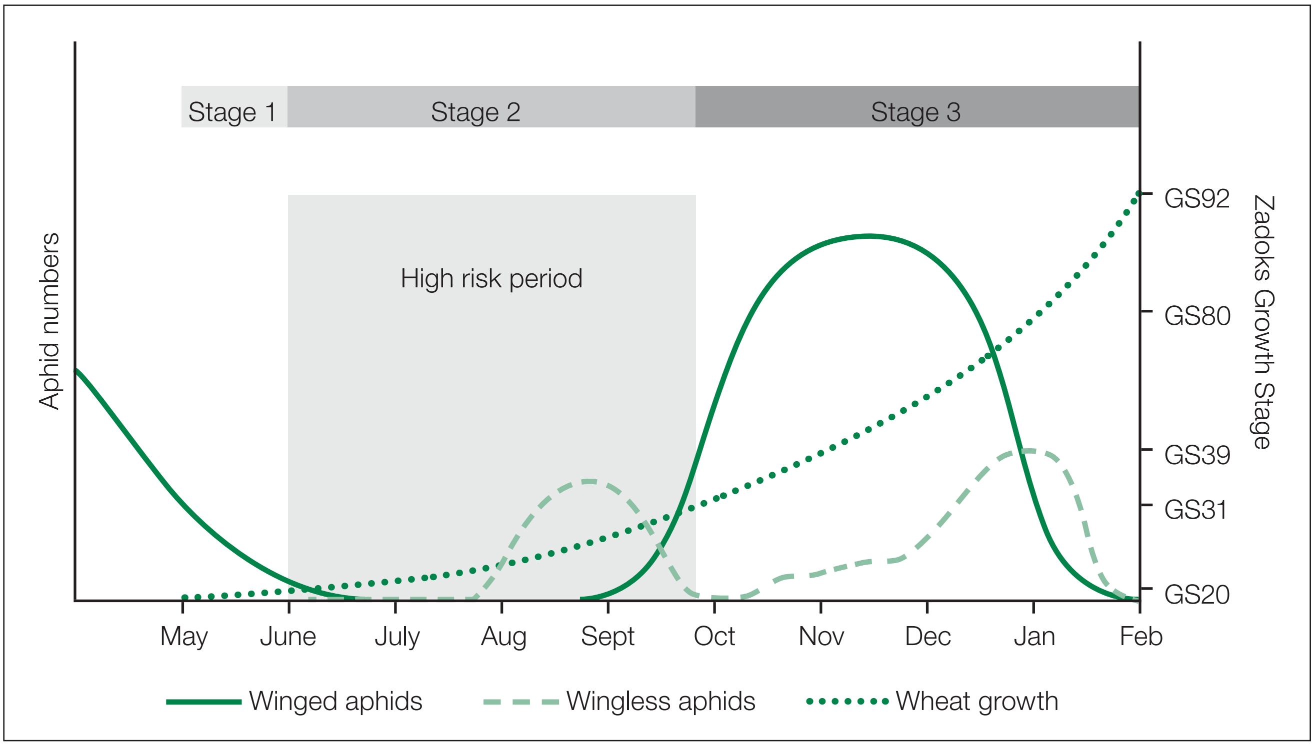

Figure 33. Example of high aphid pressure (winged and wingless) in autumn-sown wheat.

Barley yellow dwarf virus (BYDV)

BYDV is a disease in cereals and grasses caused by a virus infection. The virus is transmitted by aphids that fly into the crop (primary infection) and by their offspring within the crop (secondary infection). BYDV can be a big problem when autumn and winter temperatures are mild, due to prolonged aphid survival and reproduction in crops. BYDV damage is most serious in plants infected at early growth stages. Such autumn infections of BYDV tend to show symptoms of yellowing and reddening of leaves and stunted plant growth (Figure 34). Symptoms caused by BYDV can differ with cultivar and they can be confused with nutritional disorders (which is in fact what the virus does to the plant). It is also possible that spring infections of BYDV may show different symptoms depending on cultivar and stage of infection.

Figure 34. Typical leaf yellowing and reddening symptoms of *Barley yellow dwarf virus* on flag leaves in wheat.

During the 2008–09 and 2009-10 growing seasons, when data were collected from both conventional and IPM-managed paired sites, there was a trend towards increased numbers of beneficial organisms, a reduction in pests and a 50% reduction in the number of insecticide applications in the IPM-managed crops. There was also negligible *Barley yellow dwarf virus* and negligible crop yield differences between the two approaches. Adopting IPM requires:

- Taking small steps and being prepared to learn as you go.
- Building an understanding of how best to integrate biological, cultural and chemical controls that best suit you.
- Considering the broader 'costs' associated with broad-spectrum chemicals (e.g. the effect on generalist predators).

Further reading

FAR Arable Extra No. 59: March 2006. Slug predator identification WEEDS, PESTS & DISEASES.

FAR Arable Extra No. 66: May 2007. Slug Management Using IPM. WEEDS, PESTS & DISEASES.

Horne P, Page J 2008. Integrated pest management for crops and pastures. Australia, CSIRO PUBLISHING.

FAR Arable Extra No. 87. March 2010. Arable IPM - Making the most of beneficial predators. WEEDS, PESTS & DISEASES.

Page J, Horne P 2012. Controlling invertebrate pests in agriculture. Australia, CSIRO PUBLISHING.

Information on what pesticides do to a range of beneficial species can be found on line at:

www.ipmtechnologies.com.au

www.koppert.com

The best place to get a sweep net from is: Australian Entomological supplies.

www.entosupplies.com.au/equipment/field/nets

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Burnett, P. (1984). New Zealand pest and beneficial insects, Lincoln University College of Agriculture.

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Thackray, D. J., et al. (2005). "Role of winter-active aphids spreading *Barley yellow dwarf virus* in decreasing wheat yields in a Mediterranean-type environment." Crop and Pasture Science 56 (10): 1089-1099.

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