

I SPY

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Introduction

In its simplest form, integrated pest management (IPM) is a control strategy in which a variety of biological, chemical and cultural control practices are combined to manage and prevent pests (invertebrates) from reaching damaging levels in crops. The integration of a range of effective, economic and sustainable pest management tactics to deal with pests replaces the reliance on any single control method to give stable long-term pest control.

IPM principles involve a sound understanding of pest biology, natural enemies of pests and host crop phenology to allow rational use of a variety of control tactics. These control strategies generally fall into the categories listed below.

Biological control

- The conservation or release of natural enemies (predators, parasites and pathogens) that feed on or attack pests (e.g. control of canola aphids by ladybird and lacewing predators).

Cultural control

- Tactics such as crop rotation, trap cropping, crop hygiene, removal and destruction of weeds (e.g. 'green bridge') and diseased plants, planting/harvest date selection, site selection, cultivar and variety selection and nutrient management. The incorporation of nectar-producing plants to encourage natural enemies.

Mechanical/physical control

- The use of barriers such as windbreaks and physical disturbances of the system (e.g. mowing, grazing, ploughing and inter-row cultivation).

Genetic

- The use of crop varieties bred or genetically developed for pest resistance/tolerance.

Pesticides

- Strategic chemical applications that are justified by monitoring and use of valid pest threshold levels.
- Where applicable, the use of selective chemical options that are specific to target pests and relatively harmless to natural enemies (e.g. pirimicarb for aphids, Bt for caterpillars and pesticide baits for beetle pests) should be used in preference to broad-spectrum insecticides.
- Spray application techniques (e.g. correct timing, nozzle selection and coverage).

The sole reliance on chemical control for pest management is NOT a sustainable long-term solution. IPM does not mean the abandonment of pesticides but aims to reduce the frequency of pesticide applications.

Pesticides within an IPM framework are tools used to assist in pest control when biological and cultural control methods are insufficient.

IPM advantages

- Natural enemies are encouraged to help maintain pests.
- Maintaining chemical effectiveness by reducing (or delaying) the risk of pests developing resistance to insecticides.
- Reduced chemical contamination of produce and environmental damage.
- Reduced use and dependence on chemicals.
- Increased health benefits to producers, their families, staff and consumers by decreased pesticide usage.
- Development of more robust cropping systems that do not rely solely on one method of control.
- Potential to save money and time spent applying pesticides.

IPM disadvantages

- More complex than using chemical control alone.
- Requires a time commitment for regular crop monitoring.
- Requires an understanding of the ecology of the cropping system, the ecology of the pests, their natural enemies and the surrounding environment.
- Lack of economic threshold information on many pests and the control their natural enemies provide, can lead to uncertainty of acceptable damage levels or risk to crops associated with IPM strategies.
- Potential crop damage associated with the transition to an IPM system.



The IPM decision-making process

IPM principles are well documented, but when and how to intervene remain the key questions for most growers and advisers. To successfully implement good decision-making practices in an IPM framework one must gain confidence in, and adopt, a new set of tools for the decision-making process. This involves a whole-systems approach that extends beyond simply killing pests when they appear.

A sound understanding of the following is required:

- pest and beneficial identification skills;
- pest and beneficial lifecycles, biology and ecology;
- effective crop monitoring or scouting skills that provide specific information on pest and beneficial activity;
- effects of pest damage on crop yield and quality utilising economic thresholds as the front line for pest control decisions;
- the impact of different control tactics on pest populations and their natural enemies.

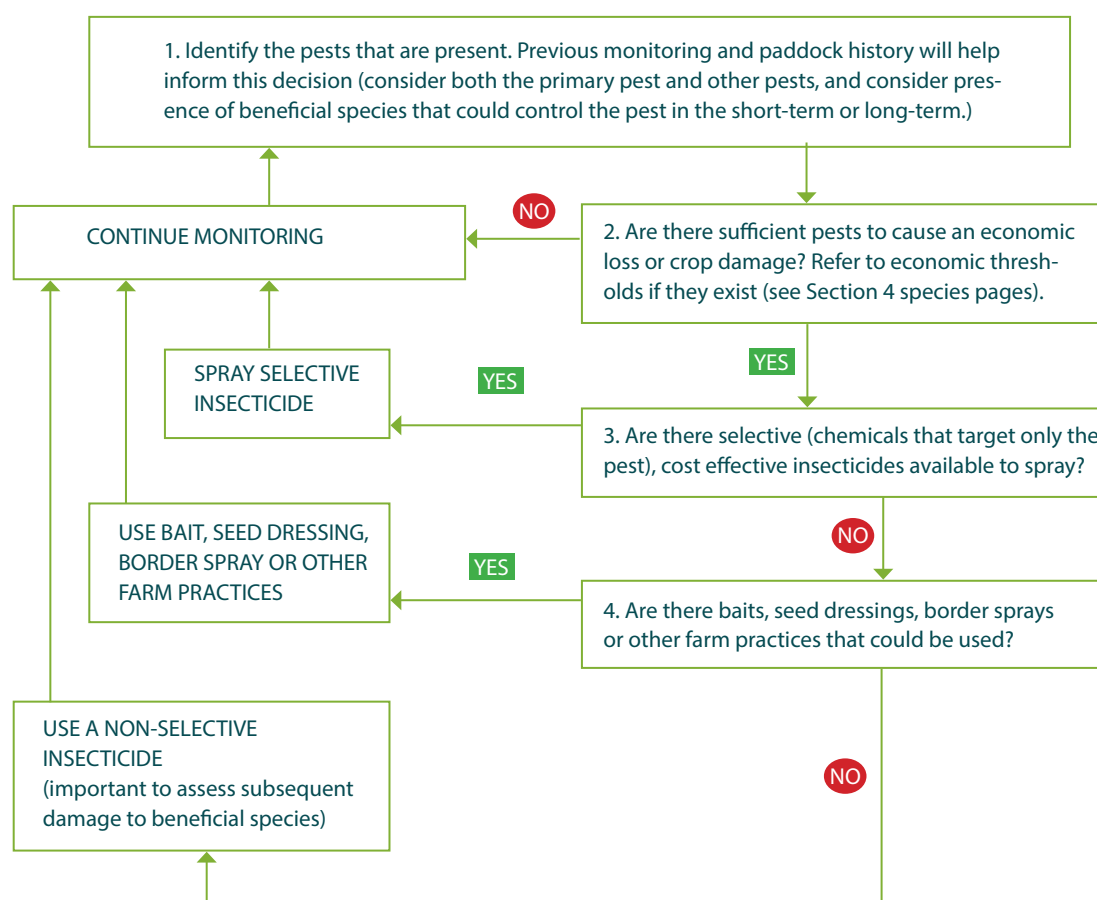
A change in mindset on how to tackle pests, coupled with the development of a new set of decision-making tools is critical for sustainable pest management.

One of the most difficult parts of any IPM program is deciding when and what action to take.

Flow charts with set pathways, like the one below (**Figure 5.1**), provide a good start to help you develop a decision-making process and a flexible program that can be modified to suit any crop-production system. It is important to accept that longer time-frames may be required to achieve pest control through the adoption of IPM methods (i.e. actions may need to be put in place a year or two prior to receiving the benefit).

Another resource is the **“Best Bet” IPM strategies**, which have been developed to highlight the crop stages with increased risk of pest pressure, and summarise the range of activities available to mitigate the risk of damage. They are available at: <http://ipmguidelinesforgrains.com.au/workshops/resources/#bestbet>

Figure 5.1 Flow chart for IPM decision making



Forward planning is essential to maximise the pest control options available. If control of the pest problem is only addressed in the year of sowing, the options and ability to minimise the effect on beneficial species through different treatment options is greatly reduced. For example, if a seed dressing is not used, then pest control options are further reduced to just in-crop spraying.

Source: Modified from Cam Nicholson IPM brochure Grain and Graze Project.

Biological Control

All pest populations are regulated to some degree by the direct effect of other living organisms. Beneficial species (natural enemies) play a vital but often unseen natural biological control role in cropping systems. The concept of integrated pest management (IPM) is based on naturally-occurring levels of biological control agents or a deliberate effort to increase these levels.

Biocontrol agents may be arthropods (insects, mites, spiders) and disease-causing microorganisms and pathogens (bacteria, fungi, protozoa, nematodes and viruses).

Many invertebrate natural enemies are highly mobile and will move from crop to crop if left unsprayed. They can help keep pest populations under control but the degree to which they can be used will vary with crop type, area and time of year. Broad-spectrum insecticides generally have harmful effects on beneficial invertebrate populations.

Major characteristics of beneficial organisms and pathogens:

- They kill, reduce reproduction, slow growth, or shorten the life of pests.
- Often host specific i.e. will attack only target pest species or are specific to a life stage.
- Their effectiveness may depend on environmental conditions or host abundance.
- The degree of control may be unpredictable.
- They are relatively slow acting and may take several days or longer to provide adequate control.

Biological control is more easily implemented in intensive forms of agriculture (such as tree crops or horticulture) where the maintenance of biological control agents and the expenditure of resources to monitor and maintain high levels of biological control are economically justified.

In extensive and discontinuous broadacre agricultural systems it is more difficult to utilise biological control, but natural agents are often seasonally abundant and can reduce pest damage in crops and pastures. Pest attack would be more frequent and severe without them in our systems. While it may not be viable to employ all biological approaches and all components of IPM, we can improve the management of beneficial organisms that naturally occur.

There are several different approaches to using biological control agents, including:

Classical biological control

This involves the deliberate introduction and establishment of imported (exotic) natural enemies to control established pests. In Australia, there have been many parasitoids (e.g. aphid wasp parasitoid *Aphidius ervi*) and predators (e.g. predatory mite of lucerne flea, *Bdellodes lapidaria*) imported and established in broadacre agriculture. There are also a number of weed biocontrol agents that have been released (e.g. the flea beetle, *Longitarsus echii* for Paterson's curse weed control).

This control approach must adhere to the Biological Control Act (1987) and takes years before biocontrol agents can be released.

Inundation or seeding biocontrol agents

Commercially available biocontrol organisms can be either mass-released (inundative) to have an immediate impact or released early (seeded) into the system so they can breed up with the pest. These approaches are more suited to intensive forms of agriculture, high value crops, small areas and those with market requirements for low or no pesticide use.

Natural biocontrol

Naturally occurring beneficial populations do their own thing, provided they are not sprayed with broad-spectrum insecticides. The preservation of natural enemies already in the system is the most effective approach likely to be used in broadacre systems. Therefore, various strategies (e.g. cultural techniques) that preserve and enhance natural enemies should be favoured, such as providing alternate food sources (e.g. nectar sources, non-pest hosts) and refuge habitats (e.g. remnant vegetation).



Biological agents

GENERALIST predators

Predators (adults and immature forms) are mainly free-living species that consume a large number and range of prey during their lifetime and are therefore often regarded as generalists rather than specialists.

Characteristics of generalist predators

- Generally larger in size than their prey.
- Consume many prey (often attack immature and adult prey).
- Males, females, immatures and adults all may be predatory.
- Can be transient (e.g. ladybirds) or residential (e.g. predatory mites).
- Have different approaches to how they find and kill their prey (e.g. mantids sit and wait and may also be camouflaged while ladybird beetles actively search for prey).
- Modification of their body parts in keeping with their predatory style (e.g. well developed mouthparts and legs, streamlined bodies or other modified structures to enhance prey capture).

Main predator groups: spiders (*Arachnida*), predatory mites (*Acarina*), lacewings/antlions (*Neuroptera*), beetles (*Carabidae*, *Coccinellidae*, *Staphylinidae*), hoverflies (*Syrphidae*) and true bugs (*Hemiptera*).

SPECIALIST parasites and parasitoids

Parasite - an organism that lives in or on the body of another organism (the host) during some portion of its lifecycle (e.g. parasitic mites). They mostly do not kill the host.

Parasitoid - invertebrate that oviposits externally on, or internally in a host, where eggs hatch and larvae feed and develop into adults, eventually killing the host (e.g. some flies and wasps). See **Figure 5.2** for a schematic diagram of a parasitoid and its host.

Characteristics of parasitoids and parasites

- They are highly specialised and host specific, often with a prolonged and specialised relationship with one or a few hosts (i.e. will attack only one species or a particular genus).
- They tend to be smaller than their host.
- Only the female searches for the host to deposit eggs.
- They are often very susceptible to chemicals, particularly the adults.
- Can be gregarious or solitary.

In broadacre agriculture, most biological control agents in this category are parasitoids.

Main parasitic and parasitoids groups: wasps (e.g. *Braconidae*, *Ichneumonidae*, *Trichogrammatidae*, *Scelionidae*, *Mymaridae*, and *Chalcidoidea*), and flies (e.g. *Tachinidae*, *Calliphoridae* and *Sarcophagidae*).

It is important to know what parasitoids look like, and which pests and life-stages they attack.

Evidence of parasitism

Ways to determine if parasites or parasitoids are present:

- look for evidence of an 'exit hole' in the host caused by the parasitoid (e.g. aphid parasitoid or 'mummified' aphid bodies);
- dissect samples (can be difficult if an insect is very small);
- rear individuals of the pest in an insect proof jar to see if any parasitoids emerge;
- observe deformed caterpillars or wasp cocoons surrounding caterpillars.

RESIDENTIAL or TRANSIENT modes

Residential: Permanently living within the system and most relevant at crop establishment. Usually have limited dispersal capabilities.

Pests include mites, cockchafers, wireworms, snails and slugs.

Beneficials include predatory mites, carabid beetles and native earwigs.

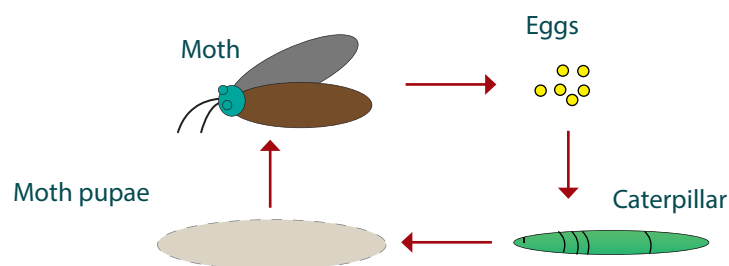
Transient: Mobile species that do not permanently reside in a system and generally have shorter generation times compared with residential species. Beneficial species will often follow the movements patterns of prey in and out of crops.

Pests include aphids and moths.

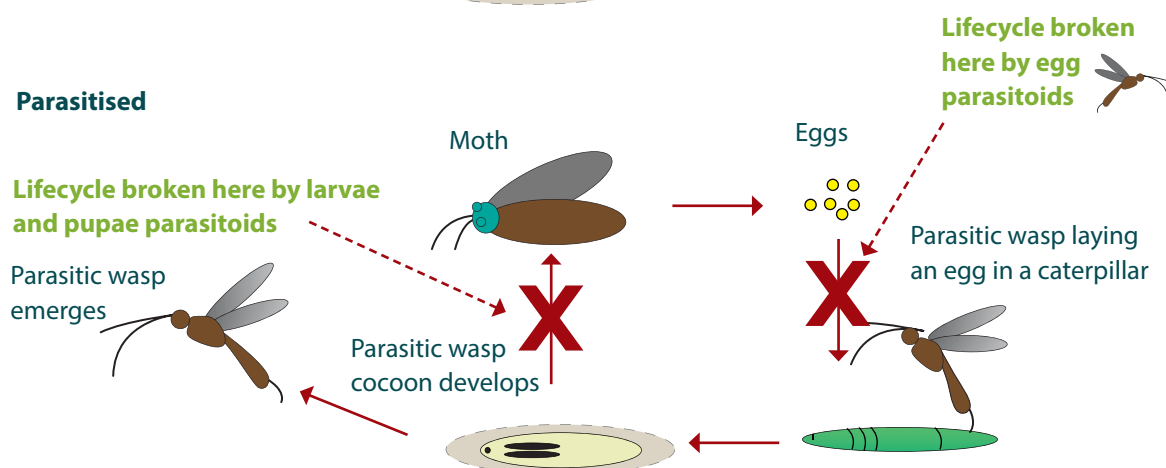
Beneficials include ladybirds, lacewings, and parasitic wasps.

Figure 5.2 Schematic moth lifecycle and associated parasitoid (wasp)

Un-parasitised



Parasitised



Source: C. Paull (SARDI)

Disease-causing micro-organisms and pathogens

Fungi: Fungi are the most common diseases of insects. Fungal spores that come in contact with insects germinate under certain conditions and fungal hyphae penetrate the insect's skin (cuticle), often releasing toxins. The fungus grows inside the insect body and leads to its eventual death. Useful genera: *Beauveria*, *Entomophthora*, *Hirsutella*, *Metarhizium*, *Nomuraea* and *Verticillium*.

The disadvantages of fungi include:

- sporulation and germination require ideal conditions (adequate moisture and humidity) to affect control in the field of large pest populations;
- difficult to mass produce consistently for commercial use and have a limited storage life. *Metarhizium* is available for locust control.

Viruses: Many viruses infect and kill insects. This occurs mainly via viral proteins damaging the insect's gut lining. Several useful naturally-occurring viral groups include: the nuclear polyhedrosis viruses (NPVs), granulose viruses (GVs), cytoplasmic polyhedrosis viruses (CPVs), and entomopoxviruses (EPVs). NPV is available commercially.

Bacteria: Bacteria rarely kill insects but one species, *Bacillus thuringiensis* (Bt), and variants of the strain have been widely used as a biocontrol agent.

Bt is mainly used against caterpillar pests (Lepidoptera) but is also active against some beetles (Coleoptera) and mosquito larvae (Diptera). It is formulated as a dust or as granules and then applied as an aqueous spray. The bacteria need to be applied when pest larvae are young as there is a delayed killing action. Bt toxins are also produced in some genetically modified crops such as cotton and corn. Check out the Bt checklist on page 13 in this section.

Nematodes: Nematodes are microscopic invertebrates with a smooth, cylindrical body and no legs. They actively search for their host, then enter the body through natural openings where they release bacteria that digest the insect. The nematodes then feed on the bacteria/insect slurry. Eventually the dead insect bodies rupture and release further nematodes. Some nematodes are commercially produced as a dehydrated cellulose mixture, which is rehydrated before use in high value crops.



Conservation and enhancing natural enemy numbers

An effective strategy in broadacre systems is the conservation and enhancement of beneficial species that occur in paddocks naturally. The abundance of beneficial species is affected by host pests, sugar sources, mating partners, overwintering sites, shelter, climatic conditions and insecticide usage. Preserving or enhancing these requirements will ultimately lead to an increase in their overall effectiveness.

Practical techniques that could help to conserve and enhance beneficial effectiveness include:

- tolerating some pest damage early in the season;
- delaying spraying if large numbers of beneficials are present and pest damage is below economic threshold levels;
- leaving some areas unsprayed if these areas are harbouring beneficial species;
- using selective insecticides (where available) that are less harmful to beneficial species (e.g. pirimicarb for aphid control);
- using appropriate timing and application of pesticides (i.e. using registered rates when economic pest damage is about to occur and not as 'insurance' sprays);
- spraying late evening to minimise direct exposure of foraging bees;
- using beneficial insect attractants (e.g. food sprays) in high value crops;
- using refuge areas (e.g. shelterbelts with shrubs/trees) or nursery crops which help to conserve sources of natural enemies;
- maintaining habitat diversity on farm by using a mixture of crops and preserving bushland;
- using insect resistant crop varieties.

There is a growing awareness of the utilisation of **'ecosystem services'** for long-term sustainability of some agricultural systems and the ability of these services to generate economic and ecological benefits. Extensive research overseas has demonstrated the value of manipulating landscape features to assist in pest control (see cultural control in this section).

The impact of biocontrol agents on pest populations

Determining the effectiveness of biocontrol agents can be difficult and is often underestimated, as their actions are not as immediate as those seen with insecticide use. It is also very difficult to assess and quantify the amount of prey taken, since biological agents tend to destroy their hosts leaving little evidence of their actions.

Under changing environmental conditions and crop management practices, pest and beneficial organisms are rarely stable but oscillate to different degrees. The response time of biological control agents is often too long for the control of pest populations approaching economic levels and those increasing quickly in numbers (e.g. a migratory moth flight with a large egg-lay event in a paddock).

Look for trends in monitoring data

Monitoring numbers of pest and beneficial species over time by sampling crops can provide an estimate of the impact that natural enemies may be having. For example, large numbers of ladybirds, lacewings or hoverfly larvae picked up in sweep net sampling of canola crops indicates that these beneficials are feeding on pests, within the crop.

Research in broadacre grain crops will hopefully develop and utilise beneficial / pest ratios similar to those used in the cotton industry.

Food webs

Pests and natural enemies are part of a complex food web of potentially many hundreds of species. Individuals interact with others in a variety of ways and can use resources from many habitats across the landscape (see case study on shelterbelts in this section on page 21).

For example, adult lacewings use flowering plants as a source of nectar and pollen and may also eat honeydew exuded from other insects. Easy access to these resources improves an adult lacewing's lifespan and their ability to produce eggs. Spiders can consume a wide variety of non-pest and predatory species and these can be valuable food resources prior to pest populations developing in fields.

Field crops, despite being widespread across a landscape, are extremely temporary habitats so it is important that natural enemies can find all the resources they need from other habitats across the landscape, such as perennial vegetation patches.

Table 5.1 Beneficial species commonly observed in broadacre crops

Beneficial		Mode of mobility	Prey or host		Monitoring method	Field prevalence
Name	Life stage		Name	Life stage		
Carabid beetles O: Coleoptera F: Carabidae Various species	Larvae and adults	Resident	Ground-dwelling pests. Slugs, caterpillars, European earwigs, true wireworms, false wireworms and moth larvae	Larvae, nymphs and adults	Shelter traps or night observation	All year in either adult or larval forms
Predatory mites O: Acarina F: Various families and species e.g. snout mites <i>Bdellodes</i> species	Nymphs and adults	Resident	Redlegged earth mite, blue oat mite and lucerne flea	Nymphs and adults	Direct search, suction samples and pitfalls	Autumn to spring
Native earwigs O: Dermaptera F: Labiduridae e.g. <i>Labidura truncata</i> and some other native species	Nymphs and adults	Resident, some capable of flight	Caterpillars, mites, lucerne flea and some pest earwigs	Larvae, nymphs and adults	Direct search under wood, rocks, etc., shelter traps	All year
Spiders O: Araneae F: Various families and species	Nymphs and adults	Resident, some are carried by winds as juveniles	Flies, crickets, lucerne flea, aphids, caterpillars and moths Most invertebrates including other predators	Larvae, nymphs and adults	Direct search, suction samples and pitfalls	All year for most species
Hover flies O: Diptera F: Syrphidae	Larvae only	Transient	A range of soft-bodied insects, but prefer aphids	Nymphs and adults	Direct search and sweep net	Predominantly spring to autumn
Brown lacewings O: Neuroptera F: Hemerobiidae	Larvae and adults	Transient	Various moth pests Aphids, thrips and mites	Larvae and eggs Nymphs and adults	Direct search and sweep net	Predominantly spring to autumn
Green lacewings O: Neuroptera F: Chrysopidae	Larvae only	Transient	Various moth pests Aphids, thrips and mites	Larvae and eggs Nymphs and adults	Direct search and sweep net	Predominantly spring to autumn
Predatory bugs Nabids, damsel bug O: Hemiptera F: Nabidae	Nymphs and adults	Transient	Various moth pests Aphids, leafhoppers, mirids and mites	Larvae and eggs Nymphs and adults	Direct search and sweep net	Predominantly in spring
Shield bugs O: Hemiptera F: Pentatomidae Various species	Nymphs and adults	Transient	Various moth pests	Larvae and eggs	Direct search and sweep net	Predominantly in spring
Assassin bugs F: Reduviidae Various species	Nymphs and adults	Transient	Various moth pests, other bugs and wasps	Larvae, nymphs and adults	Direct search and sweep net	Predominantly in spring



Table 5.1 Beneficial species commonly observed in broadacre crops (continued)

Beneficial		Mode of mobility	Prey or host		Monitoring method	Field prevalence
Name	Life stage		Name	Life stage		
Ladybird beetles O: Coleoptera F: Coccinellidae Various species	Larvae and adults	Transient	Various moth pests, aphids, leafhoppers, thrips and mites	Eggs, larvae, nymphs and adults	Direct search and sweep net	Predominantly in spring
Parasitic wasps						
Wasp parasitoids (medium-large, 10-20 mm) F: Ichneumonidae <i>Diadromis</i> spp. and <i>Diadegma semiclausum</i>	Adult	Transient	Diamondback moth	Larvae	Direct search and sweep net	Predominantly in spring
<i>Netelia</i> spp. <i>Heteropelma</i> and <i>Lissopimpla</i> spp.	Adult	Transient	Armyworms, cutworms and native budworms	Larvae	Direct search and sweep net	Predominantly in spring
<i>Ichneumon</i> sp.	Adult	Transient	Native budworm and some armyworms	Larvae	Direct search and sweep net	Predominantly in spring
Wasp parasitoids (small <5mm) F: Braconidae <i>Cotesia</i> spp. and <i>Apanteles</i> spp.	Adult	Transient	Moths including armyworm, cutworm and native budworm	Larvae	Sweep net and rearing out host larvae	Predominantly in spring
F: Aphidiinae (various species)	Adult	Transient	Aphids	Nymphs and adults	Look for aphid mummies	Predominantly spring to autumn
F: Trichogrammatidae	Adult	Transient	Moth larvae (wasps are species specific)	Eggs	Eggs will not hatch & often turn black	Predominantly spring
Diseases of insects Fungal diseases • <i>Bacillus</i> spp. • <i>Nomuraea rileyi</i> • <i>Beauveria bassiana</i> • <i>Zoopthora radicans</i> • <i>Metarhizium</i> spp. • <i>Pandora</i> sp. • <i>Conidiobolus</i> sp.	N/A	N/A	Moth larvae, aphids and grasshoppers. Some are species specific	Most effective on young larvae and nymphs	Look for diseased larvae/ fungus on bodies of pests	High pest populations or through spray applications
Viral diseases Nuclear polyhedrosis	N/A	N/A	Moth larvae	Most effective on young larvae	Look for dead larvae in 'V'- shape	High pest populations or through spray applications

Cultural, physical and other control of insects

Cultural farming management practices and the use of mechanical or physical techniques are incorporated into an IPM framework. These management practices can minimise pest attack by altering the habitat to achieve partial or complete pest control.

Cultural practices and techniques for pest control have been used in agriculture for centuries and their effectiveness is frequently underestimated or not fully utilised. Examples include plant varietal selection, time of sowing, crop rotation, crop hygiene and cultivation/fallow.

Other practices or tactics aim to alter paddock habitat to promote beneficial species and encourage their survival. These areas are relatively new in broadacre and need to be further researched and developed.

Host plant availability

Most insects have preferred hosts (oligophagous) and some are host specific (monophagous). By manipulating plant host availability, pest populations can be suppressed or controlled. Seasonal variations will naturally provide a wide range of host availability options for insects.

Destroying host plants using chemical fallowing or a cultivation fallow for several weeks prior to crops being sown will greatly reduce the populations of many pests by depriving them of a food source. Complete fallow periods (no green material) of about two weeks are sufficient to starve-out many pests.

Changing farming practices in some cropping areas has seen the introduction of lucerne, millet, grain, sorghum and other summer host plants into the farming system. These plants will increase the feed availability and survival of some insect pests. Examples include aphids, *Helicoverpa* spp., *Sitona* weevil, Rutherglen bugs and African black beetle.

Managing host weeds for some pests is also important. For example, the vegetable weevil, prefers to feed on capeweed. They can often be found in high densities in pastures or areas of paddocks where capeweed is dominant. Use of selective herbicides and grazing to manage capeweed in pastures prior to sowing canola will help to reduce weevil numbers below damaging levels.

Sampling pre-season weeds for the presence of insects will provide an indication of potential pest pressure that may affect crop seedlings at germination.

Removing the 'green bridge'

The term 'green bridge' describes the role of weeds and crop volunteers in helping pests cross from one cropping season into the next. Late summer and early autumn rainfall is an important trigger for the establishment of the 'green bridge' in parts of Australia where winter cropping dominates. Availability of summer/early autumn weeds within regions can provide pests with a food source that enables them to develop and increase.

Pest populations can then infest any subsequent crops sown early in the season, when pests transfer from dying weeds (e.g. following herbicide sprays) to new seedlings. The most damaging situations usually occur where pest populations have had several weeks or even months to increase in number prior to crops being sown. These seasonal situations are usually accompanied by high temperatures that provide fast developmental rates for pests.

While individual farmers will benefit from efforts to eradicate the 'green bridge' on their properties, effective control requires neighbours to work together to remove volunteers and weeds simultaneously. Weeds should be controlled early. Plants along fencelines, around sheds and roadsides should all be targeted as potential hosts for pests. Seasonal conditions provide an indication of the 'green bridge' risk from year to year.

Examples of pests that can use 'green bridges' are lucerne flea and *Bryobia* mites. These species will have an early hatch from their over-summering diapause state and increase rapidly if good rainfall provides abundant weed growth. Snails and slugs will also emerge from their summer resting phase to commence development when green hosts are abundant. Aphids and Rutherglen bugs are solely reliant on the availability of host plants to over-summer (i.e. survive between seasons). The abundance of these plants available during summer/early autumn will determine the level of their carry-over between seasons. Seasons with dry summer/early autumn periods often result in lower pest pressures.

Reduced pest pressure can also occur in seasons where 'false breaks' enable insect activity on weeds following early rainfall, before prolonged hot dry weather destroys those weeds.

The risk of viral diseases such as barley yellow dwarf virus (BYDV) or wheat streak mosaic virus (WSMV) is also increased in years with a 'green bridge'. Virus survival between seasons will increase if hosts such as volunteer cereals and their disease-carrying vectors are given the opportunity to increase. Aphids will transmit BYDV and wheat curl mites carry WSMV from diseased hosts into new season crop seedlings if seasonal conditions allow for their development.



Host plant susceptibility and resistance

Some cultivated agricultural plants have been selected by breeders or genetically modified for their resistance or tolerance to specific insect pests.

Plants are known to have at least three categories to defend themselves from insect attack:

- antibiosis – the eating of particular plants adversely affects the biology of the feeding insect;
- antixenosis – the plant has characteristics that deters insects from feeding;
- tolerance – plants are able to withstand or quickly recover from insect damage.

High levels of malic acid in most varieties of chickpeas is very effective at deterring most insect pests (apart from the native budworm) as well as beneficial species. Some varieties of narrow-leafed lupins (e.g. Yorrel and Tallerack) are susceptible to feeding damage by aphids, while others (e.g. Tanjil and Wonga) are considered resistant. These host susceptibility characteristics are important when considering pest management options.

Canola is very susceptible to damage by insects and is often treated with prophylactic insecticide sprays to avoid anticipated damage. The small cotyledons of canola and exposed growing tips make it most vulnerable to damage. Pulse crops with exposed growing points are also vulnerable, but to a lesser extent, as their cotyledons are more robust and fleshy. Cereal crops with concealed growing points (within their stems) are far less vulnerable to insect attack and can tolerate high levels of defoliation before plant death occurs or spraying is economically justified.

Genetic engineering techniques have enabled foreign genes, such as insecticidal toxins, to be inserted into the molecular structure of some agricultural crop species. For example, the toxins of *Bacillus thuringiensis* (Bt) have been incorporated into some transgenic varieties of cotton and canola.

Testing of cultivars of transgenic peas that have resistance to the pea weevil has provided promising results in WA. Research and development of crop cultivars with tolerance against pests is less likely while effective and cheap insect control is available.

The susceptibility characteristics of crop types are important when considering pest management options.

Stubble retention, minimum tillage and changing farming systems

Increased stubble retention within cropping systems has occurred over recent decades largely as a result of:

- higher yielding crops;
- increased use of minimum or no till cultivation;
- fewer or no grazing animals in the farming system;
- reduced burning of stubble.

Stubble retention has favoured the increase of some pests, such as the bronzed field beetle, weevils, slugs and snails, which now have a higher pest status. Bronzed field beetle larvae can reach very high numbers in some paddocks and have caused significant damage to canola in some seasons. This is exacerbated by poor control with insecticides.

Some farmers have addressed excessive stubble through burning stubble in autumn, cultivation to incorporate stubble into the soil, baling and removing straw following harvest and widely dispersing straw behind headers.

Changes in tillage practices have also favoured the increase and survival of some residential beneficial species such as carabid beetles, predatory mites and spiders. However, the benefits of some of these natural enemies has been reduced by the over-use of 'insurance' spraying with broad-spectrum insecticides.

Changing farming systems have resulted in a 'changing pest complex' with some newer pests becoming more troublesome and other pests becoming less problematic. For example, the increasing use of swathing as part of the harvest system has meant that vagrant insects sheltering in swaths have contaminated grain samples. Examples of these grain contaminants include the bronzed field beetle, vegetable beetles and weevils.

Grazing

Grazing management is an effective technique to alter the populations of a number of pasture pests. The carry-over benefits of grazing management will also have a large bearing on pest populations in pasture/crop rotations. Pests affected by grazing strategies include redlegged earth mites, lucerne flea, slugs, snails, weevils and other beetles such as false wireworms, cockchafers and African black beetle.

Redlegged earth mite populations are dramatically reduced by grazing winter/spring pastures to 'feed on offer' levels of below 2.5t/ha. This reduction is due to the altered pasture habitat and micro-environment providing a harsher environment for mite survival, as well as direct ingestion by stock. Grazing to these levels has the added advantages of:

- greater pasture utilisation by increased animal production;
- changing pasture composition to favour legumes and decreasing grasses;
- increased legume (sub clover) seed production.

Intensive spring grazing of selected pasture paddocks that will be cropped in the following season is routinely carried out by many cereal farmers, with the major objective of minimising grass seed production and carryover. Less well understood is the added bonus of minimising the seasonal carry-over of some pests.

The benefits of grazing can be equivalent to spraying pastures with insecticides. For example mite populations have been reduced from approximately 50,000/m² to less than 102 mites/m² in grazing trials at the South Stirlings (WA).

Crop establishment in paddocks following pastures that have been intensively grazed in spring to prevent large pest carry-over will be less reliant on seed dressings and foliar insecticides.

Chemical control of insects and resistance issues

Pesticide usage and IPM

Pesticides within an IPM framework are the support tools used to assist control when biological and cultural methods are insufficient. Although chemical control is still an important part of an IPM strategy, there needs to be a shift from using non selective broad-spectrum pesticides to more selective alternatives, if available. Broad-spectrum or 'hard' chemicals (e.g. most organophosphate, carbamate and synthetic pyrethroid insecticides) have an impact on a wide range of non-target organisms.

In contrast, selective or 'soft' pesticides are active on specific pest types (e.g. pirimicarb for aphids, Bt for caterpillars) and are effective management tools that facilitate – rather than disrupt – the natural biological control that already exists. By specifically targeting particular pests, they allow beneficial species to remain in the system to help further suppress other pests.

Start to take a whole-systems approach – get to know your pest and beneficial invertebrates and the role they play. Start to change your tactics – have a closer look at alternative control strategies. Think about 'softer' chemical options and strategic use of broad-spectrum pesticides.

Chemical pesticides such as insecticides, acaricides and molluscicides are categorised into various groups according to their mode of action and chemical composition. They are also referred to by the different formulations available (for example: WG = water dispersible granules, EC = emulsifiable concentrate). Formulations refer to how the chemical's active ingredient is prepared with other substances and made available to the end user. It is partially dependant on the chemical's physical properties and influences the mode of application. The effectiveness of a pesticide is based on its chemical nature, effect on the target pest and the environment in which it is applied.

Chemicals should preferably be applied in conjunction with general IPM principles. By law, all chemicals must be used in accordance with current label instructions. This includes the rates applied and adhering to withholding periods for grazing, harvesting and fodder production.



Selective insecticides

The terms 'soft' or 'selective' are frequently applied to pesticides (active ingredient) that kill target pests, but have minimal impact on non-target organisms.

In practice, there are varying degrees of 'softness' and some insecticides are selective or safe for one group of natural enemies but not another (see **Table 5.2**).

Unfortunately, soft chemical control options are not available for all pests and selective pesticides are not always expected to provide 100 % mortality of the target pest, but aim to suppress population numbers so that biological and cultural methods can regain control.

In addition to foliar applications, other soft options include coating seeds with insecticide (seed dressing) prior to sowing. The chemical is translocated into the new growing shoots where it provides control of plant feeding pests. This control option delays application of foliar sprays giving beneficial insects time to build up and smaller quantities of chemical are applied per hectare. Seed dressings may not give sufficient protection against large numbers of pests. For example, insecticide seed dressings on canola may not be effective against very large populations of redlegged earth mites.

The routine application of insecticide seed treatments should not be practiced (i.e. using treated seed every year across all paddocks). As with foliar applications, pests can develop resistance to chemicals expressed through seed treatments. The use of the seed treatments should be reserved for paddocks where moderate levels of pests are expected.

Insecticide resistance and tolerance

Resistance occurs when applications of insecticides remove susceptible insects from a population leaving only individuals that are resistant. Mating between these resistant individuals gradually increases the proportion of resistance in the pest population as a whole. Eventually this can render an insecticide ineffective, leading to control failures in the field. Resistance can be due to a trait that is already present in a small portion of the pest population or due to a mutation that provides resistance. The main mechanisms of resistance are target site insensitivity, metabolic resistance, penetration resistance, altered behaviour and cross-resistance.

Bt checklist

- Spray as late in the day as possible to minimise UV breakdown of product.
- The lack of Bt persistence in the field means it must be applied as a uniform spray to leaf surfaces where young insect pests are actively feeding.
- Target the small larvae, < 5 mm long (Bt is less toxic and effective on larvae > 5 mm).
- Avoid applying if rain (or overhead irrigation) is expected within 24 hours after spraying.
- Use a wetting agent.
- Use a high water volume.
- Make sure your water is not too alkaline. A pH of 6.5 to 8.0 is ideal.
- Make sure you use the appropriate strains and formulations suitable for the target pest.
- Spray out within a few hours of mixing.

Management of resistance is essential to ensure that valuable insecticides remain effective. One of the objectives of IPM is to help manage insecticide resistance by reducing the overall use of insecticides. This reduces the number of selection events. Insecticide resistance has evolved in many important pest species within Australia including the cotton bollworm, diamondback moth, whiteflies, several species of aphids and mites as well as many grain storage pests.

Many pest species possess natural tolerances to several chemicals which is unrelated to developed insecticide resistance. The exact reasons for these differences in tolerance levels between species are unknown. Body size and plant hosts have been suggested as factors for varying levels of susceptibility to chemicals observed in some species. For example, *Balaustium* and *Bryobia* mites are difficult to control in the field with insecticides used to control other mites, such as the redlegged earth mite and blue oat mite. Laboratory assays have discovered these pests have not developed resistance following extensive exposure to insecticides, but rather have a naturally high tolerance to multiple chemical classes.

Table 5.2 Impact of insecticides on natural enemies in crops

INSECTICIDES		TOXIC EFFECT ON SPECIFIC NATURAL ENEMIES									
Active Ingredient	Persistence	Hymenoptera ¹			Predatory beetles ²	Predatory bugs ³	Lacewings	Spiders	Thrips ⁴	Toxicity to bees ⁵	Predatory mites
		Egg parasitoids	Larval & pupal parasitoids	Ants							
<i>Bacillus thuringiensis</i> (VRP)	very short	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NP virus	very short	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
pirimicarb	short	H	L-H	VL	L	L	L	VL	L	VL	L
indoxacarb	medium	VL	H	VH	H ⁷	L	VL	VL	VL	H ⁶	VL
<i>Metarhizium anisopliae</i>	short	L	L	L	L	L	L	L	L	L	-
spinosad	medium	H	M-H	H	VL	M	VL	VL	H	H ⁶	M
fipronil	medium	M	VH	VH	L	M	L	M	VH	VH	VH
methiocarb	medium	VH	VH	-	VH	VH	VH	-	-	VH	VH
methomyl	very short	VH	H-VH	H	H	H	H	M	H	H ⁶	H
organophosphates	short-medium	VH	H-VH	VH	H	H	M	M	H	H	H
carbaryl	short	H	H	-	H	H	H	-	H	H	VH
synthetic pyrethroids	long	VH	H-VH	VH	VH	VH	VH	VH	VH	H	VH
paraffinic oil	short	VL	-	H	VL	VL	VL	L	VL	VL	-
spinetoram	unknown	-	-	-	-	-	-	-	-	H	-
sulfoxaflor (full rate)	medium	H	-	VH	H	L	H	L	H	-	-
chlorantraniliprole	long	L	-	L	L	VL	VH	VL	VL	-	-
clothianidin (low)	medium	M	H	VH	M	L	H	M	VL	-	-
clothianidin (high)	medium	H	VH	VH	H	M	H	M	VL	-	-
thiamethoxam	medium	H	-	VH	H	M	M	VL	H	H	-
abamectin	medium	M	H	H	L	M	VL	M	M	H	-
amorphous silica	short	-	-	M	L	M	L	L	VL	-	-
dimethoate (low)	short	M	-	H	M	M	M	L	M	H	-
emamectin	medium	M	-	VL	L	H	L	M	M	H	-
thiodicarb	long	M	-	M	VH	M	VL	M	H	M ⁶	-



VRP = Various Registered products

Overall impact rating (% reduction in natural enemies following application):

■ VL (Very Low) less than 10%	L (Low) 10-20%	M (Moderate) 20-40%
H (High) 40-60%	■ VH (Very High) > 60%	A dash (-) indicates no data available

Persistence of pest control: short = < 3 days; medium = 3-7 days; long = > 10 days

Pyrethroids may include alpha-cypermethrin, beta-cyfluthrin, cyfluthrin, bifenthrin, esfenvalerate, deltamethrin, lambda-cyhalothrin and gamma-cyhalothrin.

Organophosphates may include dimethoate, omethoate, profenofos, chlorpyrifos, methidathion, parathion-methyl, diazinon, fenitrothion, maldison, phosmet and methamidophos.

¹Toxicity ratings for hymenoptera are for adults only.

² Predatory beetles include ladybeetles, red and blue beetles, and other predatory beetles. Toxicity ratings for predatory beetles are for adults only.

³ Predatory bugs include big-eyed bugs, minute pirate bugs, brown smudge bugs, glossy shield bug, predatory shield bug, damsel bug, assassin bug, and apple dimpling bug.

⁴ Effects on thrips are for populations found on leaves. This is relevant to seedling crops, where thrips damage leaves, and to mid-late season when thrips adults and larvae help control mites by feeding on them as well as on leaf tissue. Note that flowers are a protected site, so live adult thrips may be found in flowers even after crops have been treated with products that would control them on leaves

⁵ Data Source: British Crop Protection Council. 2003. The Pesticide Manual: A World Compendium (Thirteenth Edition),. Where LD50 data is not available impacts are based on comments and descriptions. Where LD50 data is available impacts are based on the following scale: very low = LD50 (48h) > 100 ug/bee, low = LD50 (48h) < 100 ug/bee, moderate = LD50 (48h) < 10 ug/bee, high = LD50 (48h) < 1 ug/bee, very high = LD50 (48h) < 0.1 ug/bee.

⁶ Wet residue of these products is toxic to bees, however, applying the products in the early evening when bees are not foraging will allow spray to dry, reducing risk to bees the following day.

⁷ Very high impact on minute two-spotted ladybeetle and other ladybeetles for wet spray, moderate impact for dried spray.

⁸ May be detrimental to eggs and early stages of many insects, generally low toxicity to adults and later stages.

IMPORTANT NOTICE: Although the authors have taken reasonable care in the advice, neither the agencies involved nor their officers accept any liability resulting from the interpretation or use of the information set in this document. Information provided is based on the current best information available from research data. Users of insecticides should check the label for registration in their particular crop & state, and for rates, pest spectrum, safe handling and application details. Further information on products can be obtained from the manufacturer.

Data sources (Table 5.2):

Cotton Pest Management Guide 2015-2016. Cotton Info Team (2015)

Toxicity of Tomato & Bell Pepper Insecticides/Miticides to Beneficial Insects. Mark A. Mossler, University of Florida AFAS Extension (2008).

Koppert Biological Systems (<http://side-effects.koppert.nl/>).

HAL project VG04004 "National diamondback moth project: integrating biological chemical and area-wide management of brassica pests".

BioBest Beneficials Data (<http://www.biobestgroup.com/en/side-effect-manual>)

Llewellyn R (Ed.). 2002. The Good Bug Book, 2nd edition. Integrated Pest Management Pty Ltd.

Conserving the benefits of insecticides using an IPM approach

The routine use of low cost non-selective pesticides can be very effective, but indiscriminate use of chemicals can also lead to changes in the populations of non-target pests and increase potential chemical resistance. Over-use of insecticides will also affect the pest/beneficial balance and secondary pests may flare up, which can be more problematic than the initial pest problem.

Pest populations are often affected by competition from other pests within farming systems. For example, applying chemicals with specific activity against redlegged earth mite (e.g. bifenthrin) will frequently lead to a substantial increase in lucerne flea numbers through the removal of competition. In other cases, farmers have commented that by increasing their pesticide usage they have not solved their pest problems, but have selected for pests that are more difficult to kill, such as *Balaustium* mites.

Non-selective insurance (prophylactic) sprays to protect crops 'just in case' is not a sustainable practice.

The application of broad-spectrum insecticides in a strategic and targeted manner (e.g. seed treatments, baits and spot or border spraying rather than wide-spread and insurance applications), will help to avoid the detrimental effects on natural enemies and increase their benefits.

Rotation of insecticide groups

Effective and sustainable insecticide management seeks to minimize the selection pressure on invertebrates to develop insecticide resistance. Alternations or rotations of chemicals from groups with different modes of action will ensure that successive generations of the pest are not repeatedly treated with the same chemical compound. This particularly applies to pests with multiple generations in the one season that may require several spray applications.

Rotating use of the commonly used synthetic pyrethroid (group 3A) and organophosphate groups (1B) in broadacre farming, with other groups (where possible), will help to minimise resistance development of target and non target pests.

Other important considerations when chemical control is required include:

- chemical rotation of insecticide groups to reduce the pressure of resistance onset;
- increasing or decreasing the rates of insecticides may speed up the development of resistance and in the case of increasing rates, could lead to unacceptable levels of residues;
- target the spray application to the most vulnerable pest life-stage;
- spray application techniques (e.g. time of day, nozzle selection to avoid drift, good coverage);
- withholding periods for stock, harvest or fodder crops - check label;
- delay the spraying of a non-selective insecticide for as long as possible.



Area-wide management (AWM)

What is AWM?

Area-wide management (AWM) aims to solve pest management problems by coordinating the efforts of growers in an area. AWM can take many forms, from neighbours discussing how to tackle common pest problems through to centrally organized groups that implement a coordinated control tactic. AWM may be particularly useful for mobile (or transient) pests where management at a larger-scale may be more effective than a paddock-by-paddock approach (**Figure 5.3**).

AWM can also improve our ability to achieve IPM goals. IPM principles can be applied at the paddock-scale, but some activities may provide better results if used across larger areas (**Figure 5.4**). This is where AWM comes in. For example the Australian Plague Locust Commission implements an AWM plan to control locust populations. These pests are highly mobile, migratory species that have the ability to inflict damage across a range of agricultural industries in multiple states. A coordinated area-specific and time-dependent response to threats posed by this pest is required. Another example comes from AWM groups that were developed in response to cotton bollworm, *Helicoverpa armigera*, problems in cotton on the Darling Downs in Queensland. AWM groups had regular meetings before, during and after the season to share information. Their objective was to reduce the survival of overwintering insecticide-resistant pupae and reduce damage to susceptible crops across a region.

The benefits of AWM

AWM can be used to address a number of objectives relating to pest problems at a regional or district scale. For certain species, a sustained reduction in pest populations across time is more likely to be achieved if other susceptible crops and pastures surrounding the paddock are taken into consideration (**Figure 5.3**). The same is true for increasing the abundance and activity of beneficial species. Actions aimed at minimising the spread and/or development of insecticide resistance, and the spread of diseases vectored by insect pests are more likely to provide better long-term results if efforts are coordinated across neighbouring growers.

For which broadacre pests is AWM applicable?

AWM works best for species that are mobile, migratory, or capable of being transported large distances. For these species the home-range of an individual may be much larger than a single paddock. Control tactics applied at the paddock-scale may only help for short periods of time because the species can recolonise quickly.

There are species that have lower mobilities, but are still potential candidates for AWM. Coordinating the timing of control tactics may have the biggest impact on these species (e.g. species that may have developed resistance to insecticides). **Table 5.3** is a rough guide that indicates which pest species are likely candidates for AWM. If you are experiencing problems with these species you should consider an AWM approach.

First steps towards AWM

Here is a general guide to the steps involved in developing an AWM approach.

Step 1. Define the problem

What is the pest problem? Is it high abundance of a pest causing direct damage and yield loss, or perhaps a pest causing damage at critical times of crop growth or establishment? Is there control failure that may be linked to pest resistance to an insecticide?

Step 2. Identify the objective

Minimising crop damage and increasing profit may be the ultimate objective of AWM, but what are the specific goals of an AWM approach? They may include reducing pest densities over the long-term, slowing new pest arrivals into the crop, slowing the spread of insecticide resistance, stopping disease transmission, or making sure pests are at low levels during a critical crop growth stage.

Step 3. Where, when, and how big is the problem?

Identify what crops this pest attacks. Determine how many growers in the area are experiencing a similar problem. Examine maps and assess the location of susceptible crop-types now or in future plantings, the location of large areas of other host plants such as pasture or weeds, and any likely sources of beneficial species.

Step 4. What are the management options?

Consider a range of management options that include pre-season actions such as destroying weeds that host pests between seasons, sometimes known as the 'green bridge' (see p 10 this section). Make sure you can identify the pest and the relevant beneficial species in the field. Know what insecticides work best, their availability, and the economic threshold (see p 9, section 6) for spraying. Think about cultural control options including grazing pastures and the timing of crop harvest (see p 11 this section).

Step 5. Gain commitment from participants

Make sure all growers are committed to the plan and feel confident in the actions they need to take. It may help to ask your local district agronomist (DA) or trusted consultant to coordinate the group's activities. Plan a monitoring strategy that is simple to use and discuss how results will be communicated to the group.

Step 6. Monitoring, recording and communicating throughout the season

As the season progresses catch up regularly to let each other know how it's going. At the end of the season get together and reflect on the season and discuss what worked and what could be improved.

AWM examples

1. **Green peach aphid** (see p 42, section 4) is a highly mobile species that can move rapidly into a region and has shown resistance to insecticides. The objective of an AWM plan in your region may be to reduce the populations of over-summering aphids on weeds and slow the spread of resistance. Before the season starts get together as a group and map out the likely locations of crops at risk (canola and pulse crops). Determine if resistance is present in your region and to what chemicals (you may need to send samples to your Department of Agriculture or Primary Industries).

Clarify the identification of this species as it can easily be confused with other aphid species. Assess the over-summering weather conditions and, if and where, a 'green bridge' is present. Before planting discuss how the group will communicate during the season and plan some management options (see p 44, section 4). During the season monitor and record as planned, and compare pest levels to thresholds of economic injury. Keep regular contact with the group and share information on where you do and don't see aphids and if beneficial species are present and active.

If pest levels reach threshold, hence a spray is required, use a selective insecticide that doesn't disrupt beneficial species. Before spraying, check the mode of action, and develop a plan for rotating different chemical groups throughout the season. After applying an insecticide, monitor to assess if the spray(s) worked, and watch for 'flaring' of secondary pests.

2. **Native budworm** (see p 11, section 4) is a pest that migrates from inland Australia into agricultural regions and its life-cycle is well known. The larvae cause damage to pulses and canola but will also damage other crops and pastures as it feeds on a wide variety of host plants. When developing an AWM plan for this species, (in addition to the steps detailed in example 1) you could use pheromone traps (see p 6, section 6) to monitor for influxes. Traps are placed across a wide area and checked weekly. The information is communicated to the AWM group (or to a pest alert service such the PestFax/ PestFacts services) where all trap information is collated and disseminated to subscribers. This is a great early-warning system, and can signal the need for more frequent monitoring for the larval stages that are most damaging. Crop monitoring to determine whether the pest has reached threshold can be conducted using a sweep net (see p 5, section 6).



Figure 5.3. Diagram illustrating the concept of AWM.

A. indicates a hypothetical pest outbreak.

B. indicates a situation where a pest is controlled on a paddock-by-paddock basis.

C. indicates AWM where all habitat-patches are controlled in a co-ordinated fashion.

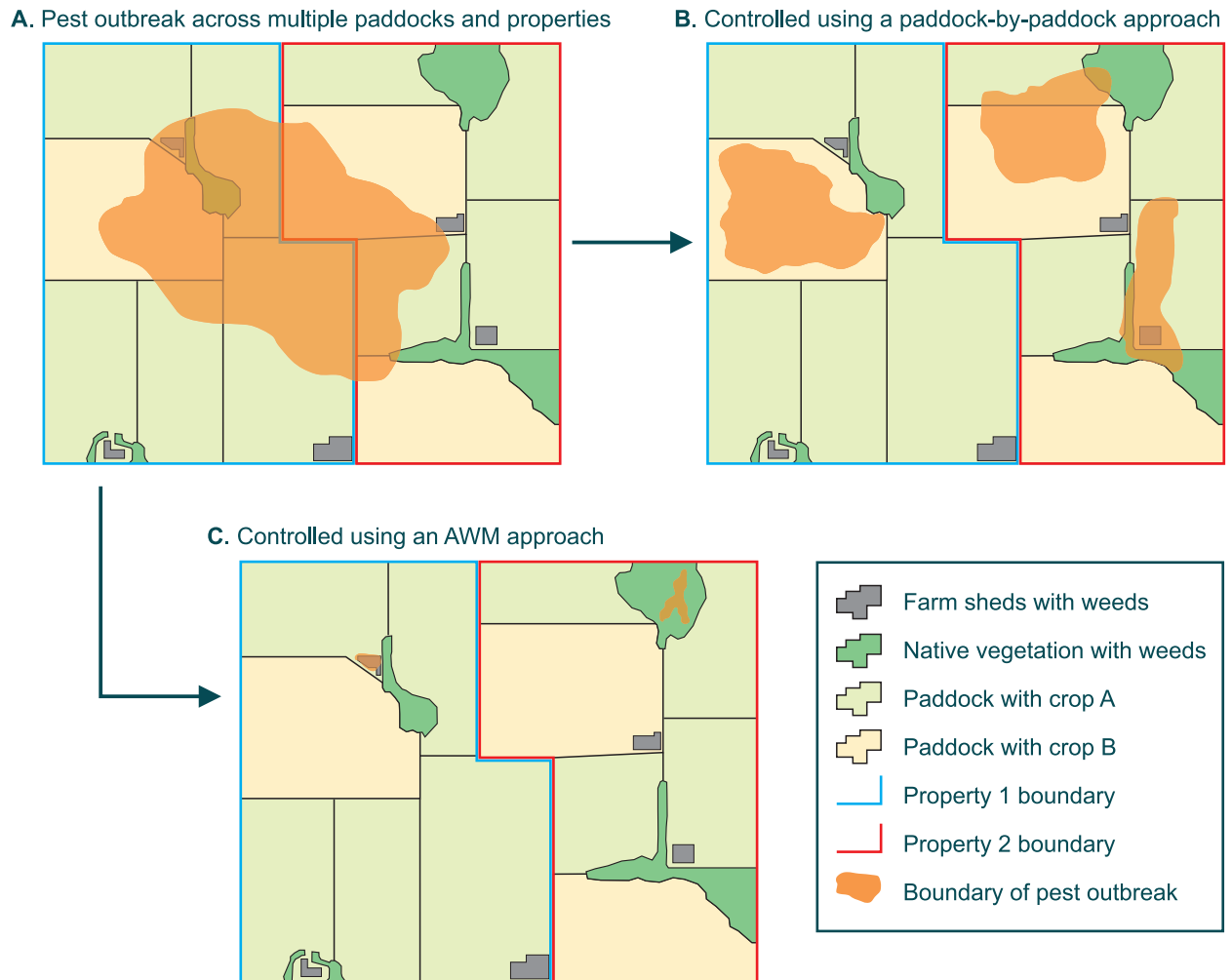


Figure 5.4 How IPM and AWM work together to achieve pest management at larger scales

(Source: L. Wilson, pers. comm.).

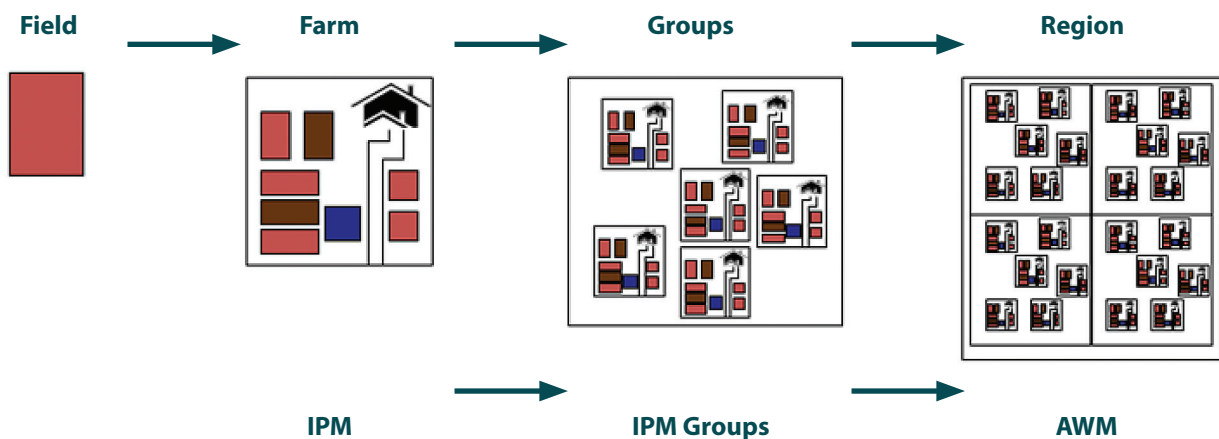


Table 5.3 Pest species for which an AWM approach may prove more useful than a paddock-by-paddock approach.

Mobility and outbreak frequency across large areas:

*** high; **intermediate; * low; ? too little information for confirmation.

Insecticide Resistance:

✓ recorded in Australian grain crops; x not recorded

AWM:

✓ AWM may bring benefits over a paddock-by-paddock approach;

~ AWM provide some benefit but other species are high priority for developing AWM;

x little added benefit from AWM.

PESTS	MOBILITY	OUTBREAK FREQUENCY	INSECTICIDE RESISTANCE	AWM
green peach aphid	***	***	✓	✓
oat aphid	***	***	x	✓
rutherglen bug	***	**	x	✓
diamond back moth	***	***	✓	✓
budworm (<i>Helicoverpa</i> spp.)	***	***	✓	✓
Australian plague locust	***	*	x	✓
redlegged earth mite	**	***	✓	✓
Other aphids (corn, spotted alfalfa, blue green, pea)	***	**	x	~
green mirid	***	*	x	~
cockchafer	**	**	x	~
wheat curl mite	**	*** ¹	x	~ ²
<i>Bryobia</i> mite or clover mite	**	**	x	~
two-spotted mite	*	*	x	~
<i>Balaustium</i> mite	**	***	x	~
blue oat mite	**	***	x	~
cutworms	***	**	x	~
armyworms	***	**	x	~
lucerne seed web moth	***	**	x	~
snails	**	**	x	~
thrips (western flower, onion, plague thrips)	**	*	✓	~
lesser budworm (<i>Heliothis punctifera</i>)	**	*	x	x
leafhoppers	?	*	x	x
true and false wireworms	**	**	x	x
weevils	?	*	x	x
European earwig	**	**	x	x
lucerne flea	*	***	x	x
brown wheat mite	**	*	x	x
slugs	*	***	x	x
black Portugese millipede	?	*	x	x

¹ Can reach high abundance in local outbreaks

² Controlling the 'green bridge' may be important for reducing disease transmission by this pest

(Source: S. Macfadyen, N. Schellhorn, J. Holloway, P. Umina and G. Fitt, pers. comm.)



IPM in Practice: Case Studies

Case study 1

Shelterbelts in agricultural landscapes suppress invertebrate pests

Location: Western district and Northern Country, Victoria

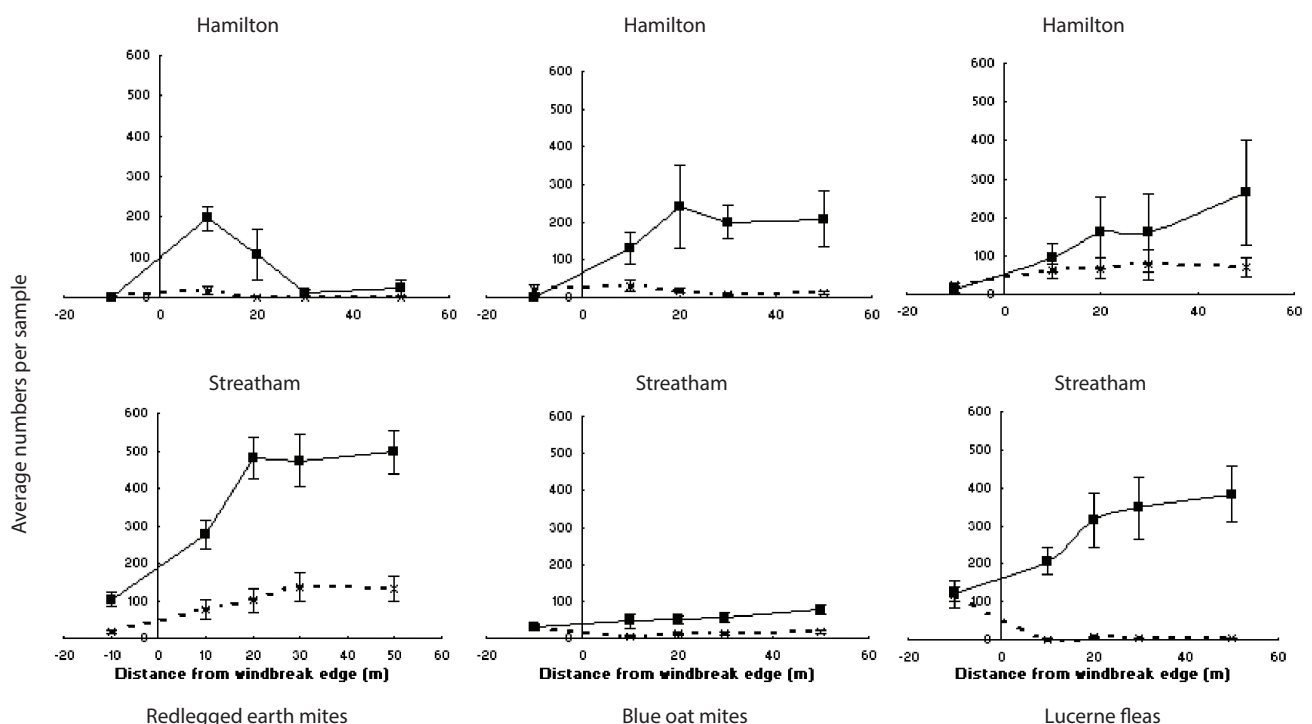
Date: 2003-2004

Lead Researcher: Angelos Tsitsilas (CESAR)

Summary: Landscape ecology can be manipulated in such a way that promotes natural enemies and aids IPM strategies. The use of windbreaks in providing a reservoir for key functional invertebrates and their impact on pest species was investigated. Invertebrates along transects running from replicated shelterbelts into pastures were sampled. Numbers of redlegged earth mites, blue oat mites and lucerne fleas were low within shelterbelts. Numbers were typically lower adjacent to shelterbelts compared with 50 m into the pasture, an effect that was much more apparent when shelterbelts carried a groundcover of high grass (>30 cm).

The windbreak composition/ecology is important, with long grasses and shrubs offering complexity, which in turn provides more niches for important beneficial invertebrates such as spiders, predatory mites, parasitoids and pollinators. Thus, relatively simple measures, such as the management of a windbreak understorey can be used to maximise the use of naturally occurring biological control and have a direct negative impact on pest invertebrates.

(Adapted from Tsitsilas et al., 2006. *Australian Journal of Experimental Agriculture* 46: 1379-1388).



Number of pest species in windbreaks and in adjoining pasture. Transect points are marked as negative when extending into the windbreak and positive into the adjacent pasture. Closed squares and solid lines = simple shelterbelts. Crosses and dashed lines = complex shelterbelts. Error bars = standard errors for transect points. (Data from Tsitsilas et al., 2006 AJEA 46: 1379-1388).

Case study 2

Selective chemicals and their role in broadacre cropping

Location: Northern Country, Victoria

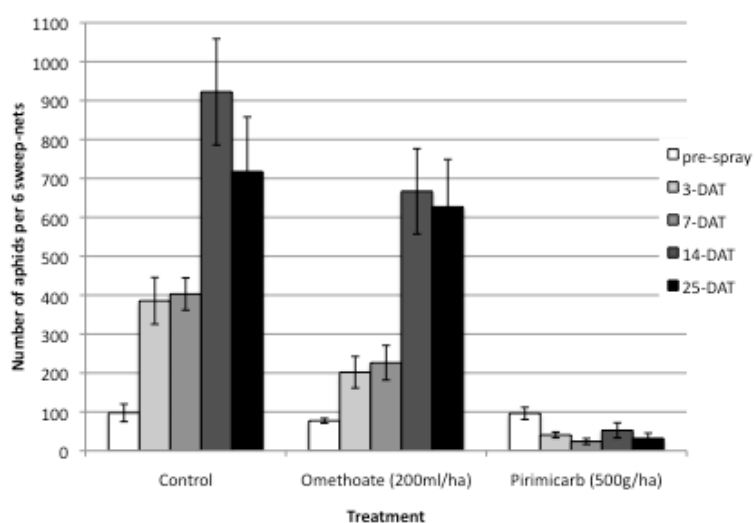
Date: 2008

Lead Researcher: Stuart McColl (CESAR)

Summary: Although chemical control is still an important part of an IPM strategy, there needs to be a shift from using broad-spectrum pesticides to more selective alternatives if they are available. Broad-spectrum chemicals invariably kill non-target organisms, whereas the use of more selective or 'soft' pesticides is an effective management tool that facilitates – rather than disrupts – the natural biological control that already exists. By specifically targeting plant-feeding invertebrates, they allow beneficial species to remain in the system to help suppress pest numbers.

A trial was performed in a canola crop in late spring to examine the efficacy of the selective aphicide (pirimicarb) against the cabbage aphid, *Brevicoryne brassicae*. This was compared with a conventional broad-spectrum insecticide. Pirimicarb provided very good control of cabbage aphids up to 25 days after application. Pirimicarb also showed little negative effect on a number of important beneficial predatory invertebrates, including lady beetles, lacewings and hoverflies.

(Unpublished findings from S. McColl and P. Umina).



Preliminary field trials assessing the 'soft' chemical pirimicarb, for the control of cabbage aphids in a late-spring canola crop at Elmore, Victoria, in 2008. Control = unsprayed canola. DAT = days after treatment application. Error bars = standard error of the mean. (McColl & Umina, unpublished).



Case study 3

IPM in Australian Grains: the costs and benefits of insecticides

Location: Charlton Victoria, Cootamundra NSW, Churramulka SA, Beverly and Wickepin in WA

Date: two cropping seasons (canola in 2010, wheat in 2011)

Lead Researcher: Dr Darryl Hardie

Summary: In theory an application of an insecticide should lead to fewer pests, therefore less feeding damage to crop plants, and ultimately higher yields at the end of the season. However, the use of some insecticides can lead to other problems such as pest resurgence, secondary pest outbreaks and the development of pesticide resistance. This project developed on-farm demonstration trials, established with regional grower groups across southern Australia, to understand the costs and benefits of different levels of insecticide-use.

Each trial consisted of three pest management strategies; a conventional approach, based on the spray pattern used to manage pests in each local area; an alternative approach using monitoring of pest and beneficials, and plant damage to decide when (and if) to intervene with sprays, and a control with little to no insecticide

applications. We found that greater insecticide use reduced insect pests and associated feeding damage. However this was not coupled with higher yields. For canola, insecticide seed treatments were most likely to deliver a yield benefit. Other insecticide inputs were unnecessary and economically costly in low-pest pressure years. For wheat, none of the insecticide inputs provided an economically justifiable yield gain.

These results indicate that there are opportunities for growers to reduce insecticide inputs without risking yield loss in low-pest pressure years. Identifying low pest pressure years in advance may allow growers to use strategic monitoring to assess risk of pest outbreaks. Repeating this study at times of high pest pressure will give us a better indication of the benefits of certain insecticide groups.

(Adapted from final report for GRDC project #UWA00134)

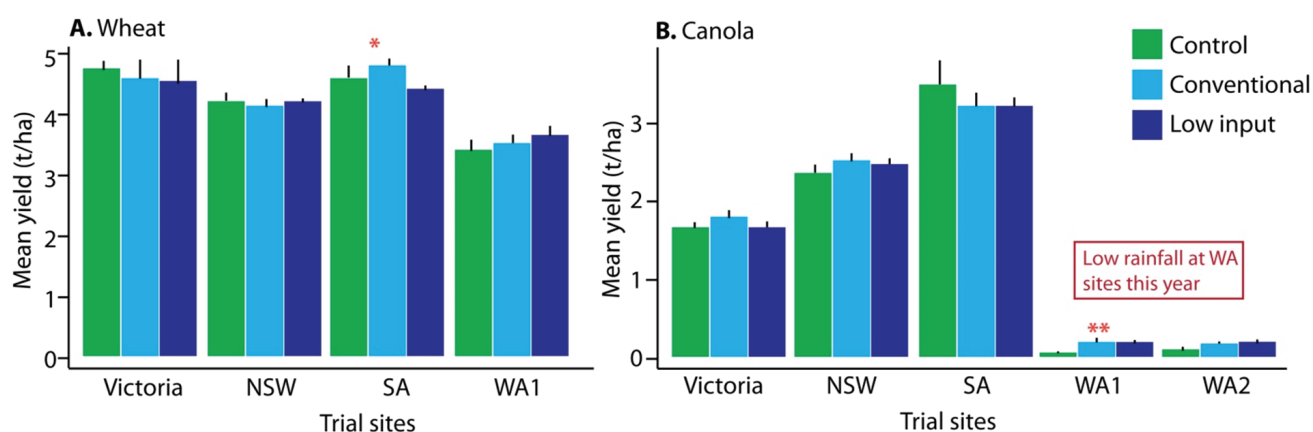


Figure 1: Impact of pest management approach on crop yield in field trials of wheat (A) and canola (B) at five sites across southern Australia. Overall we found no significant effect of pest management approach on crop yield (** exception WA1 canola). In SA wheat * we found a significant effect but this was sensitive to the presence or absence of one sample point.

Case Study 4

The effects of grazing on redlegged earth mite populations

Location - South Stirlings, Mt. Barker and North Dandalup, Western Australia

Date: 1992 - 1994*

Lead Researcher : Phil Michael (DAFWA)

*reviewed in 2017

Summary: Redlegged earth mites are a major pest of pastures and seedling crops in southern Australia. Their impact on agricultural productivity is related to their pest abundance which in turn is related to season and paddock habitat. Pasture production with dominance of broad-leaved species such as clover and capeweed is particularly conducive to redlegged earth mite increase. Farming systems in high rainfall areas of Western Australia often have several years of pasture production followed by a cropping phase, such as canola. In this situation there is a high risk of seedling damage and heavy reliance on insecticides to protect seedling canola against RLEM damage.

Research was conducted over a three year period on three separate locations to investigate the effects of intensive grazing levels and pest control on pasture growth and composition, pest populations and animal productivity. Three grazing treatments were set-up to maintain pasture feed on offer (FOO) levels of 1.4 t DM/ha, 2.8 t DM/ha and set stocked (S/S) at the district average stocking rate for each locality, being South Stirlings, Mount Barker and North Dandalup.

Merino wethers were replaced as one year olds, each year and at each site. Additional merino wethers from outside the experimental paddocks were added or removed from trial plots as required to maintain the required treatment feed on offer levels. At each sites, the grazing treatments were randomly allocated within 3 blocks, with and without pest control (total of 18 plots). The fenced plots ranged from 0.5 – 1.2 ha for differentially grazed treatments and 1.0 to 1.6 ha for set stocked treatments.

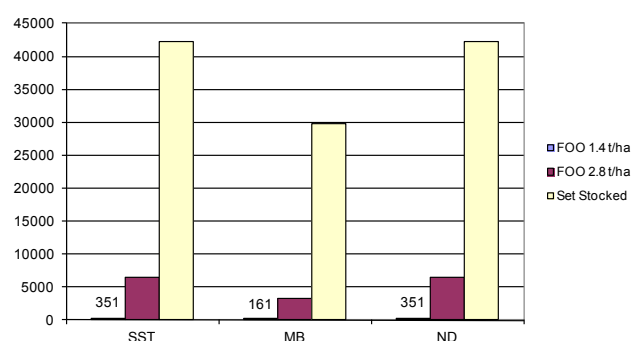


Figure A: The effects of grazing to 1.4, 2.8 t DM/ha or set stocked on spring (year 1) redlegged earth mite numbers per m² at three sites. SST=South Stirling, MB=Mount Barker, ND=North Dandalup

Results showed that grazing was clearly a major factor in affecting RLEM populations over the three seasons and sites.

Reductions in mite numbers with grazing were repeatedly seen with more than ten times the number of RLEM often found in pasture clumps compared with adjacent “patched grazed” areas. A combination of reasons is involved in the reduction including ingestion of eggs and mites by grazing stock, trampling and creating a less favourable / more exposed environment for the mites.

Importantly there was a strong correlation between spring and autumn RLEM populations with carryover populations remaining very low in the 1.4 and 2.8 t DM/ha treatments compared to set stocked plots shown in the graphs below (Figures A and B). The low levels of mites found in the spring and autumn populations of the 1.4t DM/ha treatments were at levels approaching those achieved by repeated spray applications in the treated plots (not shown as they were close to zero).

The research has demonstrated that strategic intensive grazing can be confidently used as an IPM management tool to manage RLEM populations within the pasture phase and between seasons perhaps prior to a cropping season, with minimal use of insecticides.

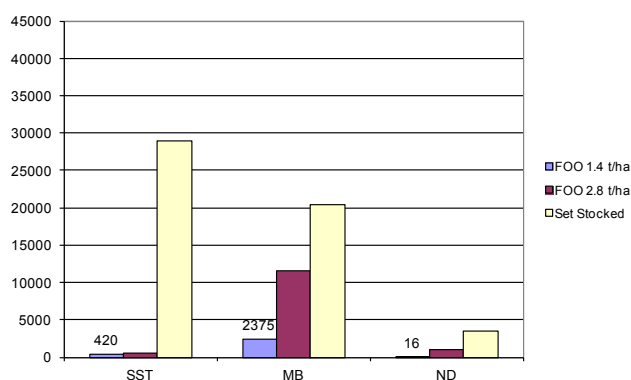


Figure B: The effects of grazing to 1.4, 2.8 t DM/ha or set stocked on the following autumn (year 2) redlegged earth mite numbers per m² at three sites. SST=South Stirling, MB=Mount Barker, ND=North Dandalup

Note - The lower levels of autumn mites at North Dandalup (ND) was because of overgrazing during summer.