I SPY

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SECTION 6

Monitoring, Record Keeping, Sampling Techniques and Economic Thresholds

Introduction

Monitoring pest and beneficial species is one of the most important tools for making informed decisions around pest management.

Frequent, accurate and timely crop monitoring will allow you to:

- be aware of pest and beneficial abundance, and their development and impact on crops and pastures;
- maximise the chance of effective and timely pest control;
- have the confidence that chemical control is either needed or unwarranted.

When inspecting crops, developing a monitoring kit can be useful (see checklist opposite).

There are a range of monitoring methods available, depending on the type of invertebrates you are looking for. Knowledge of the pest's lifecycle and habits, as well as the crop growth stages that are most vulnerable to damage, will allow you to choose the most appropriate technique.

Record keeping is useful for decision-making. Monitoring results should be recorded for each visual observation and sampling technique. Use the supplied monitoring record sheet in this manual or draw up a similar form that suits your specific needs.

Factors to consider for effective monitoring

- What pest is causing the damage?
- Is there more than one pest involved?
- Where are they hiding?
- How many are there?
- Are there any beneficial invertebrates?

Invertebrate numbers should be recorded so they can be compared with known economic threshold levels.

Monitoring kit - checklist

- recording sheet (**Table 6.2** p. 13) and pencil
- hand lens
- ruler to measure invertebrates and row widths
- shovel
- sweep net
- pitfall trap (and liquid solution)
- white plastic containers or trays (e.g. ice cream containers)
- sample jars (non-crushable and some with small vent holes for live specimens)
- plastic bags
- camera
- torch - for night inspections
- sieve

Frequency and timing

In many cases, it doesn't take too much longer to check crops and pastures systematically and to record observations, than some informal monitoring approaches. In cases where pests species are in low numbers and/or are hiding during the day, allow sufficient time to complete thorough checks.

It is essential to monitor crops during critical crop stages such as:

- pre-sowing;
- first few weeks of emergence;
- prior to and during pod/grain formation.

Management and control decisions should be based on timely monitoring throughout the season to detect early damage and assess the impact of beneficial invertebrates.

Insect activity, and hence monitoring, will be influenced by the time of day and weather conditions. Late morning (warmth increases movement) or late afternoon (nocturnal insects become active) are often good times to look. Invertebrates will often move up or down the plant canopy and on or near the soil surface with changes in daily temperature, rainfall and wind events.

Unbiased and random sampling procedures

Invertebrate pests can be unevenly distributed (patchy) across a paddock and go unnoticed when monitoring, especially when plant damage symptoms are relatively minor. Representative parts of a paddock should be checked to account for this.

Inspect in an unbiased random pattern covering representative parts of the crop.

The pattern used for inspecting a paddock will depend on what crops are growing and what stage they are at.

In small paddocks, walking a W-pattern over the whole area, selecting random plants along the way and looking for symptoms and damage is recommended.

In large paddocks at crop seedling stage, driving or using a motor bike to cover the whole paddock using a 'zig-zag' pattern is more practical.

- Randomly pick five sampling stops (positions) along the zig-zag line.
- Check plants within an appropriate radius distance (e.g. five metres) around each sampling stop.
- Avoid focusing on small unrepresentative areas as they can give biased results (e.g. most damage may be on one crop edge or near a grassy shelterbelt).

In advanced crops in large paddocks, driving across is impractical and walking takes too long. It is often best to drive along firebreaks, vehicle tracks or adjoining paddocks, stopping at representative spots around the paddock. Walk into the crop at least 20 m and sample there, to be sure you are not just looking at an edge effect.

Plant damage symptoms

Close inspection on or near damaged plants found within a crop is a good starting point. Thoroughly investigate any obvious bare patches, damage symptoms or thinning of a crop/pasture and determine the cause, extent and distribution of the damage.

Pest damage keys (section 3, p. 18) are a good aid to identify which invertebrates could be present using descriptions of their typical feeding patterns and their natural behaviour (e.g. ground dwelling, found on upper leaves or hiding during the day).

If no pests are immediately obvious after close inspection, then the following techniques in this section could be used, depending on the time of year and crop type.

Determine if the pest damage is:

- only along the crop edges or on one side where it adjoins paddocks that may be the source of migrating pests;
- in patches that are scattered throughout the crop;
- in rows that follow previous cultivation or header trails;
- from a pest that may be hiding during the day. Turning over wood, stubble, rocks or using a tile trap may catch the culprit.

Sample size and number

In general, taking more smaller samples across a wide area is better than taking just a few large samples. For example, inspecting many individual plants for aphids or budworm in spring over a wide area is far more accurate than inspecting one square metre at random.

The numbers of samples required and the level of confidence obtained is linked to population levels. If populations are well above the economic thresholds (ET) or well below ET, then fewer samples need to be taken. When populations are near threshold levels, a larger number of samples will be required to have confidence in the results.

Defined sampling area

Using a defined sampling area often helps to focus attention and provide a measure for calculations of abundance. For example:

- Numbers of insects per leaf/growing point (e.g. mites per seedling, aphids per flowering spike in canola or cereal aphids per tiller in cereals. For assessments of cereal aphids, it is easier to select random tillers and cut them off near ground level with a sharp knife or cutters, then raise them up to eye level for inspection. The single tillers can then be inspected and turned over in good light to view insects hidden under leaf blades).
- A wire frame that is a defined area (e.g. 1/10 m) provides a measure for calculations of abundance. This can be used in established pasture paddocks that have relatively uniform coverage. The sample area provides a manageable way of counting plants, assessing damage or taking cuts for biomass measure.
- Monitoring stations marked by a peg or flagging tape can be placed in designated spots for fixed referral points to look at plant numbers, insect numbers and plant damage changes over time.
- Using a defined-length pole is useful to assess plant numbers and damage along row crops (e.g. number of plants per unit area). The size of the sampling area is best modified to suit the width of the crop rows examined. **Table 6.1** (page 4) provides row length estimates for different crop row spacings. The 1/10 m^2 area is based on distance along a row and the inter-row gap.

Table 6.1 Row length estimates for different crop row spacings

Relationship of crop row width for a sampling area 1/10 m^2	
Crop row spacing (cm)	Row length (cm) (Row length x inter-row gap = 1/10 m^2)
100	10
35.5	28.2
30	33.3
25	40.0
20	50.0
17.5	57.1
15	66.7
10	100
5	200

Confidence in monitoring crops

This is influenced by:

- **Sampling technique.** This will vary depending on the time of year and crop type;
- **Allowing sufficient time** to accurately assess (and identify) pest levels. It may take more than one hour to accurately assess a large paddock for pest populations that are close to ET levels. It will take less time if levels are well above or well below ET;
- **Frequency of monitoring.** Infrequent checks or missing the critical periods can be costly and give the false impression that pests have appeared suddenly, when in reality, they may have been building up over several weeks. For example, a native budworm moth flight may have gone unnoticed and the resultant small larvae may have been present in a pea crop weeks before flowering. Extensive damage to newly formed field pea pods by large larvae would have easily been identified if earlier pre-flowering sweep net sampling was performed;
- **Proportioning damage** where there are a number of issues. Crops can show signs of invertebrate feeding damage together with one or more other stresses such as nutrient deficiency, disease, frost damage and moisture stress.

Confidence in monitoring will result in improved IPM decision making.

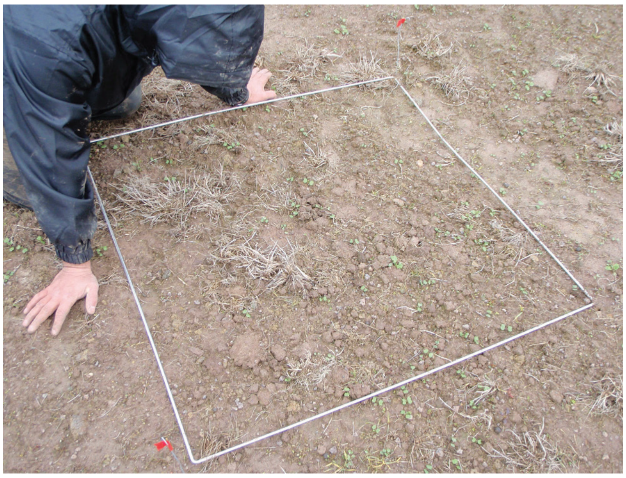
Sampling techniques

Visual observations

Finding pests can sometimes be difficult for the inexperienced observer because of their small size, inconspicuous colours and/or because they hide by day.

Some tips are provided below to assist with monitoring.

- **Digging** over the upper soil surface to uncover hidden pests (e.g. cutworm larvae, false wireworms and cockchafers). A suitable-sized soil sieve can be useful to separate insects from dry soil. **Inspect underground** root systems and soil beneath plants showing poor growth symptoms and yellowing for underground species (e.g. *Desiantha* larvae or adult African black beetles).
- **Tiller and flower inspections.** While walking through a crop, inspect random cereal tillers, or canola or lupin flowering and podding spikes. Record each observation point to work out an average number per tiller or flower spike. Use especially for monitoring aphid populations. Length of stem covered in aphids can also be recorded (see p. 7).
- Physically **uncover** by sifting through plant material such as stubble and leaf litter for ground-dwelling insects (e.g. wireworms, weevils, earwigs and slugs) and also in the inter-row spaces (e.g. armyworms). **Turn over** bits of wood, stones and soil clods to find sheltering pests (e.g. weevils and slugs).
- Spraying small patches of crop (e.g. few square metres) with an insecticide can **kill off** whatever pests are in the sample area. Inspection of this sprayed area early on the following day may expose hidden pests (e.g. weevils, false wireworms and cutworm). Laying trails of poison baits overnight and checking early on the following morning will reveal areas of a paddock where snails and slugs are most prevalent.



Suction sampling

Suction sampling is a sampling method that uses a vacuum machine (sometimes called D-vac). Suction sampling is most effective in dry, upright vegetation <15 cm tall. This method is not effective for larger pests (e.g. some beetles) or those species that live near the soil surface.

A standard petrol-powered garden blower/vacuum machine may be used for suction sampling. A gauze bag or mesh container should be fitted into the suction tube to collect invertebrates while the motor is running at full speed. The suction tube opening should be placed directly over plants and bare soil areas should be avoided. The suction machine should be inverted while on full revs before stopping to withdraw the sample bag or mesh container. Samples should be transferred into a tray where the species collected can be identified and counted.

Main species targeted: *earth mites, lucerne flea, weevils and predatory mites. Most effective in autumn-winter months.*

Sweep net

A sweep net is useful to cover a large sample area quickly. It is particularly useful for invertebrates that are difficult to see. Sweep nets can be obtained from most entomological suppliers. Ensure that a full 180° arc is used and that the lower leading edge of the net is angled and 'sweeps' the crop canopy so the insects fall into the net. Make sure you use the same netting or ring diameter every time. It is recommended that sweep net samples are used in conjunction with some visual observations, particularly on the underside of leaves and lower down in the crop canopy.

Main species targeted: *caterpillars, aphids and many beneficial species including hoverfly adults and larvae, lacewings and ladybirds. Most effective during spring.*

Cut and bash

Select individual plants picked at random. Cut plants near ground level with secateurs. Bash plants over a large plastic rubbish bin (or similar) to dislodge grubs. Record individual results to get average numbers per plant. This can also be used to calculate the number of grubs per square metre if the plant numbers per known area or row-length are also counted.

Main species targeted: *caterpillars. Most effective during spring.*

Brushing or beat sheet

Brushing foliage over white paper or white ice-cream containers can be useful to detect and count small insects. Alternatively, place a yellow or white piece of canvas/tarpaulin material along the furrow and extend up and over the adjacent row of plants. Use a stick to beat the plants multiple times against the beat sheet, moving from the base to the tops of plants. This will dislodge the invertebrates from the sample row onto the beat sheet, where they can be recorded.

Main species targeted: *bugs, caterpillars, aphids and mites. Brushing is effective in autumn through spring. Beat sheet is most effective during spring.*

Sampling with traps

Some invertebrate species can be easily attracted and/or captured through the use of traps and chemical or visual lures. The results of monitoring in this way can provide general evidence of pest presence and activity.

Pitfall traps are containers that are dug into the soil, their open-mouthed tops flush with the ground surface. They are used to capture invertebrates that crawl over the soil surface and fall into the opening. Various containers (e.g. plastic cups) can be used for pitfall traps, which usually have fluid (detergent/water mix or glycol) in the bottom. Ensure that there is no 'edge effect' and that the trap is placed flush with the soil surface, otherwise smaller species may walk around the trap.

Main species targeted: *most ground-dwelling invertebrates, especially beetles, mites, spiders and ants. Effective in autumn through spring.*

Pheromone traps use highly specific odours (pheromones) that have the same function of chemical signals emitted by the targeted female species to attract a mate. As they use female-emitted compounds, they only catch males. They are best suited to signalling the arrival of significant peaks or influxes in moths over broad areas. They are usually unreliable indicators of pest abundance and sampling of crops using other methods (e.g. a sweep net) is advised in conjunction with pheromone trapping.

Main species targeted: *moths. Pheromone lures are available for a number of moth species (e.g. Helicoverpa* spp*). Most effective in spring or before anticipated moth flights.*

Sticky traps are usually made from a yellow cardboard material in varying shapes and sizes and have one or more surfaces coated with a non-drying sticky substance. They can be attached to a post and placed in a paddock (usually just above the crop canopy) to catch flying insects.

Main species targeted: *aphids and wasps. Effective in autumn through spring. They can be useful for early detection of winged aphid arrival into crops.*

Light traps catch many species, but generally not in high enough numbers to have an impact on pest populations. As samples are so diverse (i.e. large numbers of pest, beneficial and non–target species), they are often impractical for estimating numbers. Farmers will often notice large numbers of insects attracted to house or shed lights on warm evenings. Inspecting some of the dead insects that drop beneath the light can give an indication of the movement of pest and/or beneficial species.

Main species targeted: *moths, beetles and bugs. Effective in spring and summer.*

Baiting and shelter/refuge traps

Baits can be placed under refuges or shelters, such as large ceramic tiles, where crawling invertebrates may hide. After a few days, count the number of pests under and around each square, preferably before midday and after moist conditions. Be aware that baits which actively attract slugs and snails can result in numbers which are artificially high. It is important to sample representative parts of each paddock because the distribution of pests can be patchy. Alternatively, shelters can be used without baits to provide a more accurate indication of the numbers present in a paddock. Wet carpet squares and hessian sacks can also be used, but provide a less suitable refuge because they heat up during the day and retain less moisture. Materials used as refuge traps should at least be 30 cm x 30 cm. Place traps when the soil surface is visibly wet, allowing a small space for invertebrates to squeeze underneath.

Seed-germinating baits are swollen germinating seeds that are buried in the soil. The chemicals released from the seed during the germination process can attract pests. This is a quick and effective method to assess potential soil-inhabiting pests that attack seeds and seedlings. Remember to mark where you buried the seeds so you can find them again.

Main species targeted: *nocturnal and ground-dwelling species such as slugs, snails, cutworms, weevils and earwigs.*

Effective monitoring and record-keeping

Monitoring of pest abundance and damage should be recorded together with their distribution within crops. This should be achieved through frequent and unbiased (random) monitoring across representative parts of each paddock. Records should also be kept of beneficial species (diversity and relative abundance), as well as other general field information such as crop health/stage, paddock history, weather patterns and the presence of weeds.

Use the monitoring record sheet supplied in this section (page 13).

Alternatively you can draw up a similar recording sheet that suits your needs. Monitoring sheets should at least indicate the numbers of insects found (including details on numbers of adults and immature stages), date, time, weather conditions and crop observations. This is especially critical if an insecticide treatment is required, so an accurate assessment can be made post-chemical application.

Details of spray operations should include date, time of day, conditions (wind speed, temperature and humidity), product used, product rate and water rate, method of application and other relevant details. Nil or low invertebrate numbers are also important to record.

Accurate records are useful for future reference to review the success of control measures, help refine thresholds and management guidelines applicable to localised situations and practices. They also provide traceability and auditability for compliance obligations, industry quality assurance systems, risk mitigation and surveillance purposes, and 'proof of absence' of pests for continued market access.

Spring monitoring for aphids causing feeding damage

Aphids can have a patchy distribution within crops. Their habit of forming dense colonies in clusters often results in high numbers on a single plant whilst the neighbouring plants have few or no aphids. Several separate sites within a paddock should be checked to account for potential patchy distributions and to avoid under- or over-estimating aphid populations.

Canola crops – check at least five separate representative locations within a paddock and look for aphids on a minimum of 20 random flowering spikes at each point. If more than 20% of these are infested with aphids, control should be considered.

Cereal crops – check at least five separate representative locations within a paddock and look for aphids on randomly picked tillers. If 50% or more of these tillers are infested with 15 or more aphids and crops have a yield expectation of at least 3 t/ha then control should be considered.

Remember that other factors can contribute to an increased risk of economic yield loss including poor finishing rains and crops already under some degree of stress.

Sending samples for identification

Where there is uncertainty around identification of a particular pest or beneficial invertebrate, seek assistance from your local consultant, a departmental entomologist or through your regional PestFax/PestFacts services (see section 4 for more information).

Specimens should be undamaged and in an appropriate developmental stage for reliable identification. Some species show considerable variation in size, colour, shape and appearance between males and females so, where possible, 10-15 fresh specimens should be collected.

Data collection

Adequate information is essential to aid in successful identification and is important in cases where the specimen may become part of an insect collection. Collection data labels should be written with pencil as ink may run or ruin the sample. The minimum information provided should be date, locality, collector name(s), host plant and description of damage (type and extent).

Specimen preparation

Fresh healthy specimens should be placed in a non-crushable plastic container with small pinholes in the lid for ventilation. A small quantity of food on which the insects were feeding should be placed in the container with a piece of tissue to absorb any excess moisture. If strong-jawed predatory insects such as ground beetles or scarab larvae are collected, it is best to place them in separate jars as they may damage each other. Live samples are easier to identify and this is the preferred method of receiving specimens.

Where delays for correct identification are expected, the following preserving methods can be used:

- Hard-bodied insects can be killed and preserved in 70% alcohol or methylated spirits. Never use water.
- Butterflies and moths should be killed by freezing for 24 hours or by placing them in an airtight glass container with a ball of cottonwool or tissue, soaked in nail polish remover or acetone. After killing, place them gently in another container between layers of tissues.
- Larvae should be killed with water at just below boiling point to ensure that they do not turn black and become difficult to identify. The specimens should then be transferred into 70% alcohol for preservation.
- Soil-dwelling animals can be placed in moist soil with the container topped up with a little bit of padding (e.g. tissue) to minimise damage by shaking.

Sending samples

Where possible, samples should be sent via express post. Where it is suspected that samples may be delayed over a weekend before being sent or arriving at their destination, it is better to store them in a fridge, between 2-5 °C, to send the following monday.

Photos

It is possible to identify species from photos, providing a good macro lens is attached to your camera. It is recommended that multiple invertebrate photos are taken, together with photos of the damage they are causing. Good quality digital photos can be e-mailed to a departmental entomologist or consultant for identification.

Economic thresholds

Economic thresholds are one of the cornerstones of IPM. They help to rationalise the use of pesticides and are one of the keys to profitable pest management.

The development of economic thresholds requires knowledge of pests, their damage, and the crop's response to damage.

Yield-based thresholds

Yield-based economic thresholds are based on measured losses from invertebrate feeding damage that has a direct impact on yield.

Quantitative measures of insect density are used to assess the pest status of different pests within a given crop type. The **economic injury level (EIL)** is defined as the pest density at which the loss caused by the pest equals in value the cost of the available control measures. This can also be expressed as the lowest population density that can cause economic damage.

The **economic threshold level (ET)** or action threshold is a density level at which control measures are instigated to prevent the pest population from attaining the EIL.

The formula for calculating the EIL includes the cost of control (chemical plus application costs), market value of the crop, yield loss attributed to a unit number of pest invertebrates and effectiveness of control measures.

EIL = C/VLR

Where

C = cost of control (e.g. $/ha)

V = value per unit of product (e.g. $/kg)

L = yield loss per unit number of insects (e.g. kg of crop eaten by n insects)

R = proportionate reduction of insect populations from control measure

Example: *A farmer estimates his cost of control (C) is $14 per hectare, and the on-farm value (V) of his canola is $390 per tonne ($0.39/kg). If the given loss (L) of each caterpillar found in every 10 sweeps is 6 kg/ha, then:*

EIL = 14 ÷ (0.39 x 6) = 5.98 grubs/10 sweeps

The lack of entomological broadacre research in the southern grain belt has seen many ETs become outdated and somewhat irrelevant to current economic costs and management practices. They will be updated in future.

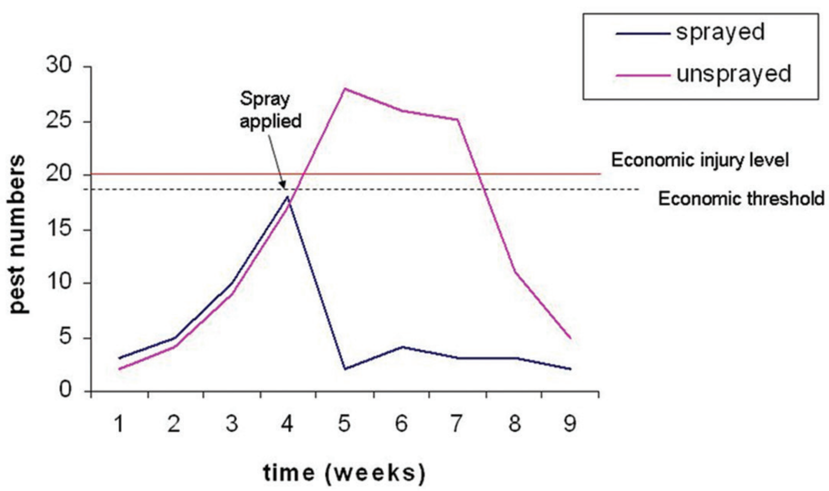
Quality-based or preventative thresholds

A preventative pest threshold is a pest population that is lower than the pest population inflicting critical damage in a crop. In this context, critical damage occurs when a certain quality standard (such as percentage damaged seeds) is breached, resulting in a significant crop value discount. The threshold is set lower than the critical pest population because of the need to avoid this quality reduction - almost at all costs.

When seed quality is the critical pricing factor, preventative thresholds, rather than a yield-based threshold, should be considered.

This type of threshold is quite different from a yield-based threshold where there is no hefty monetary penalty if the threshold is slightly exceeded. Because quality thresholds are usually very low, thorough monitoring for pests is essential. Inadequate sampling will very likely underestimate invertebrate numbers.

Figure 6.1 Economic pest thresholds guiding control decisions



Example: *In an average sized (1500 seeds/m²) crop of edible soybeans, more than 2% of seeds are damaged when green vegetable bug populations exceed 0.5 adult bugs/m². If bug populations exceed this critical level of 2% damaged seeds, the bonus for edible quality is lost and crop value can be downgraded by up to $400/ha (i.e. by many times the cost of control). Thus 0.5 green vegetable bugs/m² is a critical pest population in edible soybeans. The preventative or action threshold in soybeans is set at 0.3 bugs/m² to ensure the critical damage level is not reached or exceeded.*

Crop size/yield is important to consider when using quality thresholds expressed as the maximum level of tolerable damage. This is because a given pest population inflicts more damage in percentage terms in a low yielding crop (i.e. one with fewer seeds per unit area) than the same population in a larger yielding crop with many more seeds per unit area. Therefore, small crops are at an inherently greater risk of being downgraded by pest damage. Consequently, it is desirable to have an estimate of the number of seeds per unit area (usually per square metre) when determining risk and thresholds for your crop.

Defoliation thresholds

Defoliation thresholds are a type of yield-based threshold, but are based on studies linking percent defoliation with yield loss. Studies have shown that vegetative crops are remarkably tolerant of attack and can tolerate up to 33% defoliation with no subsequent loss of yield. However, tolerable defoliation falls to 15-20% during flowering/podding for most crops.

Crop stage and health will ultimately have a large bearing on any decisions taken in these situations. The larger the crop, the less percentage defoliation occurs for a given number of leaf feeding pests. As such, rapidly growing, healthy crops are at lesser risk. Smaller, drought stressed crops not only face the risk of terminal damage, but are much more affected by sap-sucking pests, such as aphids and mites. Varying levels of defoliation are shown in **Figure 6.2.**

Nominal thresholds

Where the damage factor is unknown, pests are often assigned nominal or fixed thresholds, based on the 'gut feelings' of experienced consultants and researchers. While many nominal thresholds have been proved to be reasonably close to the mark, they fall down in situations where crop values and spray costs vary widely. These types of thresholds should be used with caution.

More factors to consider

The presence of a pest does not imply it is causing economic damage to the crop. Monitoring over successive periods will provide a good indication of whether the pest population is increasing or deceasing over time.

Other critical factors to be considered include insect and plant growth stages and the abundance of beneficial invertebrates. Late in the season, the loss of yield caused by driving a spray vehicle and wheel tracks through the crop to apply a treatment must also be considered.

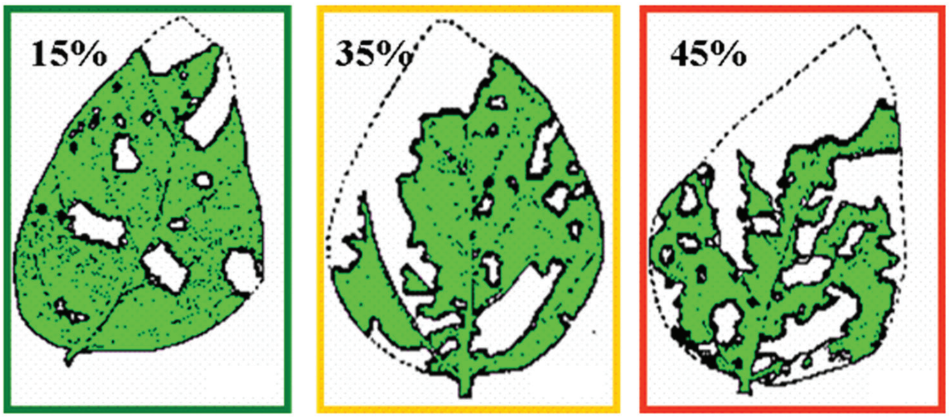
Multi-pest situations

Where a number of pests causing similar damage are present, it is easier to express their combined damage potential in 'standard pest equivalents'. This is much easier than having a separate threshold for each species and is the only workable solution where more than one species is present. Further consideration is needed if pest target species are of varying ages/developmental stages.

Resources

The "Economic threshold ready reckoners" resource contains quick reference tables for key insect pests. These tables include calculations of potential yield loss and economic thresholds for a range of pest densities, costs of control and grain prices. They are avalable at: **http://ipmguidelinesforgrains.com.au/workshops/resources/#bestbet**

Figure 6.2 Percent defoliation of soybean leaflets attacked by *Helicoverpa* larvae.
Note how the measured defoliation seems to be less than suggested by the observer's eye.



Source: Brier et al 2009 (DEEDI)

Thresholds for immature caterpillars

Since crop damage is often caused by the larval stages of a pest, the question is often asked about how to factor young larvae into thresholds and damage estimates. Where older larvae are detected at sub thresholds, the number of smaller larvae will have to be taken into account when assessing potential economic damage.

Thresholds often assume that they will complete their development if not controlled, thus wreaking the maximum possible amount of damage. However, in practice many larvae are attacked by predators, killed by disease or even just forced off the crop (e.g. by rainfall or strong winds) before they reach a damaging size. For this reason, a decision can be made to hold off if the majority of caterpillars present are only small, particularly if large numbers of predators are present. In other situations, pests populations alone (irrespective of size) will be above threshold and determining the damage potential will be unnecessary.

Control decision processes

The ability to assess pest status and make valid control decisions or recommendations depends on the following factors:

- the ability to identify invertebrate pests. Misidentification can lead to incorrect insecticide usage and continuing pest damage (e.g. mistakenly identifying *Bryobia* mites for redlegged earth mites);
- confidence and the ability to find, and then accurately assess, pest population levels;
- availability of an economic threshold and consideration of contributing factors (e.g. crop health and abundance of beneficial species);
- understanding of pest behaviour and risk predictability. This is often shaped by an individual's previous history and experiences of invertebrate pest problems. Fear of potential loss (especially at crop establishment), low confidence in the ability to detect pests and the inconvenience or time involved in monitoring are important practical considerations.

The main impacts of pests in broadacre agriculture are through feeding damage to plants, transmission of diseases (particularly in high rainfall areas), reduced grain quality or appearance, and grain contamination.

Changing market demands will alter the pest status of an insect. For example, acceptable levels of chewed seed damage in field peas will be much higher for feed-grade markets than those destined for human consumption.

Market demands also determine the level of insect contamination that is acceptable in harvested grain samples before price penalties are applied.

Putting it all together

Important factors to consider before deciding to control pests

- **Accurate assessment of pest populations and their distribution within crops.** For example, biased monitoring along a crop edge for weevils and armyworms may give a misleading result. Unbiased random observations across the whole paddock may indicate an average population that is below the EIL. Spot spraying could be an option in this case.
- **Physiological state of the crop.** Is the crop healthy and growing well? Poor crop-growth from moisture stress, poor finishing rains, disease pressure, lack of nutrients, waterlogging or wind/sandblasting will restrict the crop's ability to cope with invertebrate pest pressures.
- **Prevalence of natural control agents** such as parasitic wasps, ladybirds and insect diseases. Little information is currently available regarding the impact of beneficial invertebrates in suppressing pest populations in broadacre grains. However, it is known that large numbers of parasitoids and predators do reduce potential increases in pest populations and their presence should be taken into consideration, especially if pest numbers are approaching spray threshold levels.

Feeding damage: no economic loss

Feeding damage to the host plant can result in no economic loss to the final crop yield. This is because plants can recover from or out-compete the effects of the feeding injury. Economic feeding damage is the measurable loss to the crop yield or quality.

For example, redlegged earth mites and lucerne flea are frequent seedling establishment pests that cause visually obvious injury to plants but may not result in measurable yield loss unless seedlings are severely stunted or actually killed. Even when a percentage of seedlings are killed, some plants such as canola can survive without a measurable yield loss if the remaining plants are able to express compensatory growth.

Native budworm larvae can cause significant injury to the foliage of pre-flowering pulse crops without any measurable economic loss. However, a lesser number of larvae attacking the crop once the pods are formed will often result in measurable damage in the form of harvested grain weight losses.

- **The dynamics of the pest population in relation to crop growth stage.** The amount of crop damage which has already occurred must be considered against any additional damage which will occur if the crops are not sprayed. For example, earth mite numbers may have peaked and caused most of their damage during the cotyledon stage of a canola crop. If inspection occurs when the true leaves have formed, the most critical damaging stage will have passed and plants are likely to outgrow any further damage.
- **Growth stages of the invertebrate population.** For many species, early lifestages consume very little or may even feed on other non-crop sources such as microflora. For example, caterpillar pests such as armyworms, cutworms and *Helicoverpa* species have multiple instars (life-stages), consuming only about 14% of their total food requirement during the first four stages. Thus, the early stages cause relatively little feeding damage. Comparatively, the last two instars consume 86% of the total food requirement.

Outcomes of pest control decisions

No control – Insects below ET - or didn't check.

Apply insecticides when pest levels are below the EIL ('insurance sprays'). This approach is common and somewhat understandable while insecticide prices are low, but it **is ecologically unsustainable**. This practice will increase the risk of insecticide resistance developing, reduce beneficial parasitoids and predator populations and thus increase the reliance on chemicals to control future pest incursions, resulting in higher chemical residues in crops, soils and waterways.

Apply insecticides at the correct time. Well done!

Insecticides applied too late. Plant damage is noticed too late due to a lack of appropriate monitoring. Significant yield losses can be expected despite insecticide application.

Table 6.2 Crop monitoring record sheet **Sample Only**

Observer/recorder:	Paddock number/name:
Crop and variety:	Paddock history (e.g. previous rotations, tillage):
Sowing date:	Chemical history (e.g. seed treatments, foliar insecticides, herbicides) Date:…………………Treatment:…………………………………. Date:…………………Treatment:…………………………………. Date:…………………Treatment:………………………………….

	Observation 1						Observation 2					
	Date:………………..Time:………..am/pm						Date:…………...….Time:…………..am/pm					
Crop growth stage												
Crop growing conditions (e.g. moisture stress)												
Weather conditions at time of sampling												
Sample number	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.
Pest	Record no. per sampling unit (leaf/flowering spike/10 sweeps nets/other)											
Insect												
Life stage												
Damage (% of leaf area)												
Beneficials												
Insect												
Life stage												
Biosecurity Pests	Record absence. If detect anything unusual call the exotic pest hotline 1800 084 881											
Insect												
Paddock Map N X high insect 'A' pressure X X X X	Paddock Map N						Paddock Map N					
Other comments (e.g. weather history, soil moisture, herbicide)												
Decisions/action taken												

Observer/recorder:	Paddock number/name:
Crop and variety:	Paddock history (e.g. previous rotations, tillage):
Sowing date:	Chemical history (e.g. seed treatments, foliar insecticides, herbicides) Date:…………………Treatment:…………………………………… Date:…………………Treatment:…………………………………… Date:…………………Treatment:……………………………………

	Observation 3						Observation 4					
	Date:……………….Time:………..am/pm						Date:………….…..Time:…………..am/pm					
Crop growth stage												
Crop growing conditions (e.g. moisture stress)												
Weather conditions at time of sampling												
Sample number	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.
Pest	Record no. per sampling unit (leaf/flowering spike/10 sweeps nets/other)											
Insect												
Life stage												
Damage (% of leaf area)												
Beneficials												
Insect												
Life stage												
Biosecurity Pests	Record absence. If detect anything unusual call the exotic pest hotline 1800 084 881											
Insect												
Paddock Map N X high insect 'A' pressure X X X X	Paddock Map N						Paddock Map N					
Other comments (e.g. weather history, soil moisture, herbicide)												
Decisions/action taken												

Table 6.3 Check-list of common broadacre pests in southern Australia

Blue = Pests Green = Beneficials Red = Biosecurity threat

A = adult L = larva

		Cereals	Pulse	Canola	Pastures & Lucerne	Southern Ute Guide pp.	Western Ute Guide pp.
Pre and/ or post emergence (winter)	**Mites** RLEM, *Bryobia*, *Balaustium*, BOM	✓	✓	✓	✓	97-101	75-78
	Snails & slugs Numerous spp.	✓	✓	✓	✓	90-94	71-74
	Lucerne flea *Sminthurus viridis*	✓	✓	✓	✓	89	70
	True wireworm larvae (L) Numerous spp.	✓				60	Not in WA
	Cockchafers (L) Blackheaded pasture cockchafer *Accrossidius tasmaniae* Redheaded pasture cockchafer *Adoryphous coulonii* Yellowheaded cockchafer *Sericesthis* spp.	✓			✓	61-63	Not in WA
	WA Cockchafer	✓	✓	✓	✓	Not in SE Australia	46-47
	African black beetle *Heteronychus arator*		✓		✓	64	78
	Grey false wireworm (L) *Isopteron* spp.			✓		57	Not in WA
	Spinedtail weevil *Steriphus caudatus*	✓				49	Not in WA
	Predatory mites Numerous spp.	✓	✓	✓	✓	135-136	111-112
	Carabid beetle (A,L) Numerous spp.	✓	✓	✓	✓	139	115
	Spiders Numerous spp.	✓	✓	✓	✓	134	108-110
	Aphids – bluegreen, pea, cow pea *Acyrthosiphon* spp., *Aphis craccivora*		✓		✓	76-78	57-59
	Canola aphids – green peach, turnip, cabbage *Myzus* sp., *Lipaphis* sp., *Brevicoryne* sp.			✓		73-75	54-56
	Cereal aphids - corn, oat, russian wheat *Rhopalosiphum* spp., *Diuraphis noxia*	✓				70-71, 171	52-53, 138
	Cutworms (L) *Agrotis* spp.	✓	✓	✓		23-24	22-23
	Armyworms (some seasons) (L) *Persectania* spp., *Leucania* sp.	✓			✓	21-22	20-21
	Brown pasture looper (L) *Ciampa arietaria*		✓	✓	✓	36	28
	Pasture day moth (L) *Apina calisto*	✓			✓	34	33
	Grass anthelid (L) *Pterolocera* sp.	✓			✓	45	Not in WA
	Pasture tunnel moth (L) *Philobota productella*	✓			✓	35	Not in WA

Table 6.3 Check-list of common broadacre pests in southern Australia *(continued)*

Blue = Pests **Green = Beneficials** **Red = Biosecurity threat**

A = adult L = larva

		Cereals	Pulse	Canola	Pastures & Lucerne	Southern Ute Guide pp.	Western Ute Guide pp.
Pre and/ or post emergence (winter) *continued*	**Pasture webworm (L)** *Hednota* sp..	✓			✓	32-33	24-25
	***Mandalotus* weevils (A)** *Mandalotus* spp.	✓	✓	✓	✓	52	Not in WA
	Vegetable weevil *Listroderes difficilis*	✓		✓	✓	47	37
	Spotted vegetable weevil *Steriphus diversipes*	✓		✓	✓	48	38
	Bronzed field beetle (L) *Adelium brevicorne*			✓		56	43
	Vegetable beetle *Gonocephalum* spp.	✓ (L)		✓ (A)		59	45
	True wireworm larvae (L) Numerous spp.	✓				60	Not in WA
	Small lucerne weevil (A) *Atrichonotus* sp.			✓	✓	NSW, WA only	39
	White fringed weevil (L) *Naupactus leucoloma*				✓	51	41
	Sitona weevil *Sitona discoideus*				✓	50	40
	Locust *Chortoicetes* sp.	✓	✓	✓	✓	83-84	64-65
	Sandgroper *Clindraustralia* sp.	✓		✓		Not in SE Australia	68
	European earwig *Forficulina auricularia*	✓	✓	✓	✓	88	69
	Rutherglen bug *Nysius vinitor*	✓	✓	✓	✓	65	49
	Predatory mites Numerous spp.	✓	✓	✓	✓	135-136	111-112
	Carabid beetle (A,L) Numerous spp.	✓	✓	✓	✓	139	115
	Spiders Numerous spp.	✓	✓	✓	✓	134	108-110
	Predators ladybirds, hover flies, lace wings, nabids	✓	✓	✓	✓	132-133, 137-141	106-107, 113-114, 116, 119-120
	Parasites aphid parasites, moth parasites	✓	✓	✓	✓	119-131	95-105
	Turnip moth (L) *Agrotis segetum*	✓	✓	✓	✓		

Table 6.3 Check-list of common broadacre pests in southern Australia *(continued)*

Blue = Pests **Green = Beneficials** **Red = Biosecurity threat**

A = adult L = larva

		Cereals	Pulse	Canola	Pastures & Lucerne	Southern Ute Guide pp.	Western Ute Guide pp.
Spring	**Mites** RLEM, *Bryobia*, *Balaustium*, BOM	✓	✓	✓	✓	97-101	75-78
	Aphids – bluegreen, pea, cow pea *Acyrthosiphon* spp. *Aphis craccivora*		✓		✓	76-78	57-59
	Canola aphids – green peach, turnip, cabbage *Myzus* sp., *Lipaphis* sp., *Brevicoryne* sp.			✓		73-75	54-56
	Cereal aphids – corn, oat *Rhopalosiphum* spp.	✓				70-71	52-53
	Armyworms (L) *Persectania* spp., *Leucania* sp.	✓			✓	21-22	20-21
	Native budworm (L) *Helicoverpa* spp.	✓	✓	✓	✓	18-20	17-19
	Diamondback moth (L) *Plutella xylostella*			✓		25-26	26-27
	Lucerne leafroller (L) *Merophyas divulsana*				✓	29	31
	Lucerne seed web moth (L) *Etiella behrii*		✓		✓	27-28	30
	Pea weevil (A) *Bruchus pisorum*		✓			55	44
	White fringed weevil (A) *Naupactus leucoloma*				✓	51	41
	Locust *Chortoicetes* sp.	✓	✓	✓	✓	83-84	64-65
	Rutherglen bug *Nysius vinitor*	✓	✓	✓	✓	65	49
	Predatory mites Numerous spp.	✓	✓	✓	✓	135-136	111-112
	Carabid beetle (A,L) Numerous spp.	✓	✓	✓	✓	139	115
	Spiders Numerous spp.	✓	✓	✓	✓	134	108-110
	Predators ladybirds, hover flies, lace wings, nabids	✓	✓	✓	✓	132-133, 137-141	106-107, 113-114, 116, 119-120
	Parasites aphid parasites, moth parasites	✓	✓	✓	✓	119-131	95-105
	Sunn Pest *Eurygaster integriceps*	✓				181-182	148-149
	Hessian fly *Mayetiola destructor*	✓				169-170	136-137
	Leaf miners Agromyzidae: Diptera	✓	✓	✓	✓	180	146
	Barley stem gall midge *Mayetiola nordei*	✓				175	142

Table 6.4 Check-list of common pests in southern Australia by crop type*

Barley	Main Risk Period			
African black beetle	■	■	■	
Armyworms		■	■	
Australian plague locust	■		■	■
Balaustium mite	■	■		
Blackheaded pasture cockchafer (SE Australia only)	■	■		
Blue oat mite	■	■		
Bryobia mite	■			
Corn aphid			■	
Corn earworm			■	
Cutworms	■	■	■	
Earwigs	■			■
Grasshoppers	■		■	■
Grass anthelid (SE Australia only)		■		
Leafhoppers		■		
Lucerne flea	■	■		
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Oat aphid			■	
Pasture tunnel moth (SE Australia only)		■		
Pasture webworm		■		
Polyphrades weevil (SE Australia only)	■			
Redlegged earth mite	■	■		
Russian wheat aphid	■	■	■	
Sandgropers (WA only)	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Spinetailed weevil (SE Australia only)	■			
Spotted vegetable weevil	■			
True wireworms (SE Australia only)	■			
Vegetable beetle (larvae)	■			
Yellowheaded cockchafer	■	■		

Wheat	Main Risk Period			
African black beetle	■	■	■	
Armyworms		■	■	
Australian plague locust	■		■	■
Balaustium mite	■	■		
Blackheaded pasture cockchafer (SE Australia only)	■	■		
Blue oat mite	■	■		
Bryobia mite	■		■	
Corn aphid			■	
Corn earworm			■	
Cutworms	■	■	■	
Earwigs	■			■
Grasshoppers	■		■	■
Grass anthelid (SE Australia only)		■		
Leafhoppers		■		
Lucerne flea	■	■		
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Oat aphid			■	
Pasture tunnel moth (SE Australia only)		■		
Pasture webworm		■		
Polyphrades weevil (SE Australia only)	■			
Redlegged earth mite	■	■		
Russian wheat aphid	■	■	■	
Sandgropers (WA only)	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Spinetailed weevil (SE Australia only)	■			
Spotted vegetable weevil	■			
True wireworms (SE Australia only)	■			
Vegetable beetle (larvae)	■			
Yellowheaded cockchafer	■	■		

Legend

- ■ Emergence (autumn – early winter)
- ■ Vegetative (winter)
- ■ Flowering (spring)
- ■ Harvest (contaminant)

* *This check-list is a guide only. Pest occurrence and timing may vary between crops, regions, and seasons, influenced by seasonal climatic conditions, soil type and land management programs.*

Table 6.4 Check-list of common pests in southern Australia by crop type* *(continued)*

Oats	Main Risk Period			
African black beetle	■	■	■	
Armyworms		■	■	■
Australian plague locust	■		■	
Balaustium mite	■	■		
Blackheaded pasture cockchafer (SE Australia only)	■	■		
Blue oat mite	■	■		
Bryobia mite	■			
Corn aphid			■	
Corn earworm			■	
Cutworms	■	■	■	
Earwigs	■			
Grasshoppers	■		■	■
Grass anthelid (SE Australia only)		■		
Leafhoppers		■		
Lucerne flea	■	■		
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Oat aphid			■	
Russian wheat aphid	■	■	■	
Polyphrades weevil (SE Australia only)	■			
Redlegged earth mite	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Spinetailed weevil (SE Australia only)	■			
Spotted vegetable weevil	■			
True wireworms (SE Australia only)	■			
Vegetable beetle (larvae)	■			

Lentils	Main Risk Period			
Australian plague locust	■		■	
Balaustium mite	■	■		
Bllue green aphid			■	
Blue oat mite	■	■		
Brown pasture looper	■			
Bryobia mite	■			
Corn earworm			■	
Cowpea aphid			■	
Cutworms	■	■	■	
Earwigs	■			
Grasshoppers	■		■	
Green peach aphid			■	
Lucerne flea	■	■		
Lucerne seed web moth			■	
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Onion maggot	■			
Redlegged earth mite	■	■		
Sandgropers (WA only)	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Thrips	■		■	
True wireworms (SE Australia only)	■			
Vegetable weevil	■	■		

Legend

- ■ Emergence (autumn – early winter)
- ■ Vegetative (winter)
- ■ Flowering (spring)
- ■ Harvest (contaminant)

* *This check-list is a guide only. Pest occurrence and timing may vary between crops, regions, and seasons, influenced by seasonal climatic conditions, soil type and land management programs.*

Table 6.4 Check-list of common pests in southern Australia by crop type* *(continued)*

Lupins	**Main Risk Period**			
Australian plague locust	■		■	
Balaustium mite	■	■	■	
Blue green aphid			■	
Blue oat mite	■	■		
Brown pasture looper	■			
Bryobia mite	■			
Corn earworm			■	
Cowpea aphid			■	
Cutworms	■	■	■	
Earwigs	■			
Grasshoppers	■		■	
Green peach aphid			■	
Lucerne flea	■	■		
Lucerne seed web moth			■	
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Onion maggot	■			
Redlegged earth mite	■	■		
Sandgropers (WA only)	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Thrips	■		■	
Vegetable weevil	■	■		
Weed web moth	■			

Peas	**Main Risk Period**			
Australian plague locust	■		■	
Balaustium mite	■	■		
Blue green aphid			■	
Blue oat mite	■	■		
Brown pasture looper	■	■		
Bryobia mite	■			
Corn earworm			■	
Cowpea aphid			■	
Cutworms	■	■	■	
Earwigs	■			■
Grasshoppers	■		■	
Lucerne flea	■			
Lucerne seed web moth			■	
Mandalotus weevil (SE Australia only)	■			
Native budworm			■	
Onion maggot	■			
Pea aphid			■	
Pea weevil			■	
Redlegged earth mite	■	■		
Slugs	■	■		
Snails (pointed or conical)	■	■		■
Vegetable weevil	■	■		

Legend

- ■ Emergence (autumn – early winter)
- ■ Vegetative (winter)
- ■ Flowering (spring)
- ■ Harvest (contaminant)

* *This check-list is a guide only. Pest occurrence and timing may vary between crops, regions, and seasons, influenced by seasonal climatic conditions, soil type and land management programs.*

Table 6.4 Check-list of common pests in southern Australia by crop type* *(continued)*

Canola	Main Risk Period			
	Emergence	Vegetative	Flowering	Harvest
Australian plague locust	■		■	
Balaustium mite	■	■		
Blue oat mite	■	■		
Bronzed field beetle	■			■
Brown pasture looper	■			
Bryobia mite	■			
Cabbage aphid			■	
Cabbage centre grub			■	
Cabbage white butterfly	■		■	
Cockchafers (WA species only)	■	■		
Corn earworm			■	
Cutworms	■	■	■	
Diamondback moth			■	
Earwigs	■			■
Green peach aphid			■	
Grey false wireworm (SA only)	■			
Lucerne flea	■	■		
Mandalotus weevil (SE Australia only)	■			
Millipedes	■			■
Native budworm			■	
Pasture day moth	■			
Redlegged earth mite	■	■		
Rutherglen bug			■	
Slugs	■	■		
Small lucerne weevil (WA and NSW only)	■			
Snails (pointed or conical)	■	■		■
Spotted vegetable weevil	■			
Thrips	■		■	
Turnip aphid			■	
Vegetable beetle (adults)	■			■
Vegetable weevil	■	■		
Weed web moth			■	

Pastures and Lucerne	Main Risk Period		
	Emergence	Vegetative	Flowering
African black beetle	■	■	■
Australian plague locust	■		■
Balaustium mite	■	■	■
Blackheaded pasture cockchafer (SE Australia only)	■	■	
Blue oat mite	■	■	
Brown pasture looper	■		
Bryobia mite	■		■
Cowpea aphid			■
Cutworms	■	■	■
Earwigs	■	■	■
Grass anthelid		■	■
Grasshoppers	■		■
Leafhoppers		■	■
Lucerne flea	■	■	■
Lucerne leafroller	■	■	■
Lucerne seed web moth			■
Native budworm			■
Pasture day moth		■	■
Pasture tunnel moth (SE Australia only)	■	■	
Pasture webworm	■	■	
Pea aphid	■		■
Redheaded pasture cockchafer	■	■	
Redlegged earth mite	■	■	■
Rutherglen bug			■
Sitona weevil	■		
Slugs	■	■	
Small lucerne weevil (WA and NSW only)	■		■
Snails (pointed or conical)	■	■	■
Spotted alfalfa aphid	■		■
Thrips	■	■	
Weed web moth			■
White-fringed weevil	■	■	■
Yellowheaded cockchafer	■	■	

Legend

- Emergence (autumn – early winter)
- Vegetative (winter)
- Flowering (spring)
- Harvest (contaminant)

* *This check-list is a guide only. Pest occurrence and timing may vary between crops, regions, and seasons, influenced by seasonal climatic conditions, soil type and land management programs.*