SOUTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 7

INSECT CONTROL

PEST MANAGEMENT PROCESS | LEGAL CONSIDERATIONS OF PESTICIDE USE | APHIDS | BLUE OAT MITE | REDLEGGED EARTH MITE (RLEM) | LUCERNE FLEA | CUTWORMS | LOCUSTS | NATIVE BUDWORM

Insect control

Key messages

- Chickpea is more tolerant of most insects than other pulses because of the malic acid they produce. The crop is less susceptible to redlegged earth mite, lucerne flea and aphids than other pulses, though these pests should be monitored and controlled.
- Native budworm (*Helicoverpa punctigera*) is a major pest of pulse crops across southern Australia.
- Chickpea is highly susceptible to native budworm. Crops need to be monitored from flowering through to pod-fill. Small grubs less than 1 cm are damaging. Economic threshold for control can be as low as 1 grub per 10 sweeps of a sweep net.
- When thresholds are exceeded, native budworms can be controlled with insecticides although timing and coverage are both critical to achieving good control.
- The crop will need to be sprayed with an appropriate insecticide if caterpillars are present and pods have started to form.
- Regular monitoring will help determine whether the crop needs to be sprayed. An insecticide application will be necessary if one caterpillar is found in 10 sweeps of the crop. Sweeps should be made while walking through the paddock and consist of a standard sweep of around two metres, sampling the top 15 cm of the crop canopy.
- Synthetic pyrethroids are most effective for native budworm control and will prevent reinfestation for up to six weeks after application. [1]

Chickpea has only one major pest, the native budworm caterpillar, *Helicoverpa punctigera*. Caterpillars do most damage at pod-set through to maturity, and can reduce both grain yield and quality (Table 1).

Insects other than native budworm are rarely a problem in chickpeas post establishment. Chickpeas secrete an organic acid (malic acid) from hairs on their leaves, stems and pods, making the crop unattractive to insects.

Seedlings are most vulnerable to damage:

- before they develop three to four 'true' leaves
- during periods of moisture stress
- when other factors such as low soil temperature or soil compaction limit plant growth. [2]

1 K Regan (2016) Production packages for kabuli chickpea in Western Australia—post planting guide. GRDC, https://www.agric.wa.gov.au/chickpeas/production-packages-kabuli-chickpea-western-australia-post-planting-guide

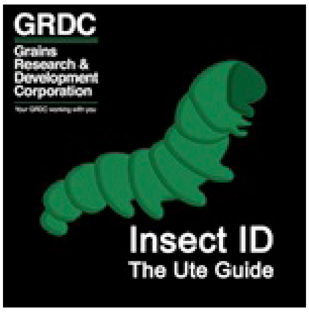
2 IPM Guidelines (2016) Chickpea—southern region, GRDC, http://ipmguidelinesforgrains.com.au/crops/winter-pulses/chickpea-southern-region/

Table 1: *Chickpea crop stage vulnerability to insect pests. Present: Insect pest present in crop but generally not damaging. Damaging: Crop susceptible to damage and loss caused by insect pest.*

Pest	Crop stage				
	Emergence/ Seedling	Vegetative	Flowering	Podding	Grainfill
RLEM	Damaging	Present	Present		
Lucerne flea	Damaging				
Cutworms	Damaging				
Aphids	Damaging	Present	Present		
Thrips	Present	Present	Present		
Native budworm		Present	Present	Damaging	Damaging

(Source: IPM Guidelines)

Insect ID: The Ute Guide



The Insect ID Ute Guide is a comprehensive reference guide for insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control them. Photos have been provided for multiple lifecycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be confused with. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. [3]

App features:

- Region selection.
- Predictive search by common and scientific names.
- Compare photos of insects side by side with insects in the app.
- Identify beneficial predators and parasites of insect pests.
- Opt to download content updates in-app to ensure you are aware of the latest pests affecting crops for each region.
- Ensure awareness of international bio-security pests.

Insect ID: The Ute Guide is available on Android and iPhone.

The changing status of pests and the future of pest management in the Australian grains industry

The Australian grains industry is dealing with a shifting complex of invertebrate pests due to evolving management practices and climate change as indicated by an assessment of pest reports over the last 20–30 years. A comparison of pest outbreak reports from the early 1980s to 2006–07 from south-eastern Australia highlights a decrease in the importance of pea weevils and armyworms, while the lucerne flea,

3 GRDC, https://grdc.com.au/Resources/Apps

Balaustium mites, blue oat mites and Bryobia mites have increased in prominence. These changes are the result of several possible drivers. Patterns of pesticide use, farm management responses and changing cropping patterns are likely to have contributed to these shifts. Drier conditions, exacerbated by climate change, have potentially reduced the build-up of migratory species from inland Australia and increased the adoption rate of minimum and no-tillage systems in order to retain soil moisture. The latter has been accompanied by increased pesticide use, accelerating selection pressures for resistance. Other control options will become available once there is an understanding of interactions between pests and beneficial species within a landscape context and a wider choice of 'softer' chemicals. Future climate change will directly and indirectly influence pest distributions and outbreaks as well as the potential effectiveness of endemic natural enemies. Genetically modified crops provide new options for control but also present challenges as new pest species are likely to emerge. [4]

7.1.1 Key Integrated Pest Management (IPM) strategies for chickpeas:

- Tolerate early damage. Chickpeas can compensate for early damage by setting new buds and pods to replace those damaged by pests. Excessive early damage can reduce yields and delay harvest.
- Damage to pods is of more concern than damage to the plant. The grubs chew holes into the soft pod and feed on the developing and filling seed. Yield loss will occur at larval densities lower than those causing a reduction in grain quality (% defective seed). This is because *Helicoverpa* consumes most of a chickpea seed; the remaining damaged seed is generally lost during harvest.
- Monitor larval infestations as mortality of small larvae can be high. Refer to records from successive checks to help interpret check data and make decisions about the need for, and timing of, control.
- Aim for one well-timed spray: Chickpea can tolerate moderate to high numbers of native budworm larvae (10–20 larvae/m^2) through late-vegetative and early-flowering stages. Yield loss is sustained from damage at pod-fill—the most critical stage for protecting the crop.
- Post treatment checks are critical to determine efficacy and possible reinfestation prior to harvest. [5]
- Chickpeas are unique in that they do not host significant numbers of beneficial insects. Small numbers of parasitic flies (tachinids) have been recorded on chickpea, but little else. Therefore, in relation to IPM, there are no in-crop management opportunities via beneficial insects.

7.1 Pest management process

Figure 1 outlines the steps in the pest management process.

4 AA Hoffmann, AR Weeks, MA Nash, GP Mangano, PA Umina. (2008) The changing status of invertebrate pests and the future of pest management in the Australian grains industry. Animal Production Science, 48(12), 1481-1493.

5 IPM Guidelines (2016) Chickpea—southern region, GRDC, http://ipmguidelinesforgrains.com.au/crops/winter-pulses/chickpea-southern-region/

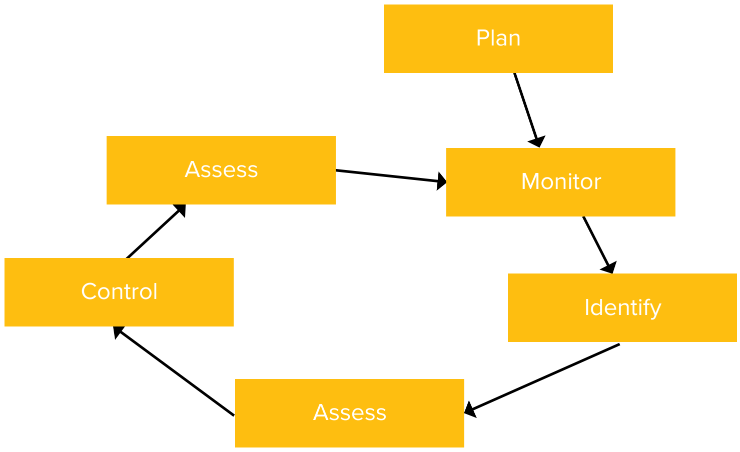


Figure 1: *Pest management process.*

1. Planning
- Be aware of which pests are likely to attack the crop in your region and become familiar with when to monitor for particular pests, what the pests look like, and damage symptoms.
- Assess sampling protocols and plan how you will cope with the logistics of sampling.
- Be aware of the latest management options, pesticide permits and registrations in chickpeas, and any use and withholding-period restrictions.

2. Monitoring
- Scout crops thoroughly and regularly during 'at-risk' periods, using the most appropriate sampling method.
- Record insect counts and other relevant information with a consistent method to allow comparisons over time.

3. Correct identification of insect species
- Identify the various insects present in your crop, whether they are pests or beneficial species, and their growth stages.
- Identify the different larval instars of *Helicoverpa* (very small, small, medium, large).
- Other minor pests of chickpeas should be recorded. These might include locusts, aphids, cutworms, false wireworms, thrips and loopers.

4. Assessing options
- Use the information gathered from monitoring to decide on the control action (if any) required.
- Make spray decisions based on economic threshold information and your experience. Other factors, such as insecticide resistance and area-wide management strategies, may affect spray recommendations.

5. Control
- Ensure that your aerial operators and ground-rig spray equipment are calibrated and set up for best practice guidelines.
- If a control operation is required, ensure that application occurs at the appropriate time of day.
- Record all spray details, including rates, spray volume, pressure, nozzles, meteorological data (relative humidity, temperature, wind speed and direction, inversions and thermals) and time of day.

6. Re-assess and document results

- Assess crops after spraying and record data for future reference.
- Post-spray inspections are important in assessing whether the spray has been effective, i.e. if pest levels have been reduced below the economic threshold. [6]

7.1.1 PestNotes

PestNotes are designed specifically for growers, agronomists and farm advisers. They bring together the best available information and images on more than 50 invertebrate pests of the southern cropping region. These information sheets have been developed through a collaboration between **cesar** and the South Australian Research and Development Institute. [7]

7.2 Legal considerations of pesticide use

Information on the registration status, rates of application and warnings related to withholding periods, occupational health and safety (OH&S), residues and off-target effects should be obtained before making decisions about which pesticide to use. This information is available from the state department chemical standards branches, chemical resellers, the Australian Pesticide and Veterinary Medicine Authority (APVMA) and the pesticide manufacturer.

This section provides background to some of the legal issues surrounding insecticide usage, but it is not exhaustive. Specific questions should be followed up with the appropriate staff from your local state department.

7.2.1 Registration

All pesticides go through a process called registration, where they are formally authorised (registered) by APVMA for use:

- against specific pests
- at specific rates of product
- in prescribed crops and situations
- where risk assessments have evaluated that these uses are:
- effective (against the pest, at that rate, in that crop or situation)
- safe, in terms of residues not exceeding the prescribed maximum residue level (MRL)
- not a trade risk.

For more information see www.apvma.gov.au.

MORE INFORMATION

www.apvma.gov.au

7.2.2 Labels

A major outcome of the registration process is the approved product label, a legal document that prescribes the pest and crop situation in which a product can be legally used, and how.

MSDS

Material Safety Data Sheets (MSDS) are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable handling and storage safety protocols.

Permits

In some cases a product may not be fully registered but is available under a permit with conditions attached, which often requires the generation of further data for eventual registration.

6 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

7 PestNotes, http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeded MRLs and litigation. Pesticide-use guidelines are on the label to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides:

- are applied at rates higher than the maximum specified;
- are applied more frequently than the maximum number of times specified per crop;
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied); or
- are not registered for the crop in question. [8]

7.3 Aphids

Aphids are small insect pests with oval-shaped green, brown or black bodies. Often occurring in colonies, aphids suck on sap, causing loss of vigour, and in some cases yellowing, stunting or distortion of plant parts (Table 2). Honeydew (unused sap) secreted by the insects can cause sooty mould to develop on leaves. When aphids transmit viruses, the impact on crop growth and yield can be significant. The earlier the transmission of virus, the greater the potential impact.

Direct aphid feeding rarely causes major damage to broadacre crops, and control measures are generally unnecessary, as parasitoids and predators keep populations in check. Exceptions occur when aphid populations are extreme (particularly early) or the compensatory ability of the crop is compromised by stress (particularly moisture stress), and aphid impact on flowering or pod-set/fill may be significant.

Pulse aphids:

- Cowpea aphid *Aphis craccivora*
- Blue green aphid *Acyrthosiphon kondoi*
- Green peach aphid *Myzus persica*
- Pea aphid *Acyrthosiphon pisum*

Table 2: *Susceptibility of pulse crops to aphids according to growth stage.*

Pre-Plant/ Plant	Seedling	Vegetative	Budding/ Flowering
Aphids can transmit viruses.	Cowpea aphid: Colonies start in growing points. Blue green aphid: infest growing tips first then move down stems to the crown as numbers build up. Risk of large infestations is higher if weather conditions are mild and hosts abundant.	In lupins direct feeding during flowering can cause flower abortion and poor pod-set. Heavily infested crops may show signs of wilting—more severe in water-stressed crops. Early colonisation by virus-infected aphids may result in yield losses from virus infections; bean yellow mosaic virus infection (BYMV) or cucumber mosaic virus (CMV). Look for aphids on stems and lower leaves.	Most sensitive crop stage to damage: reduce flowering reduce or prevent pod-set and pod-fill Look for aphids on stems, lower leaves, buds and flowering heads.

(Source: IPM Guidelines)

8 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Cowpea aphids are black, or dark grey-green, sometimes with a white 'dust' over them (Figure 2). Dense colonies can develop on individual plants, or in well-defined patches. Infestations start in the growing tip, and spread down the stem, causing leaf bunching and stem twisting. Cowpea aphids tolerate warm dry weather, and can be severe on water-stressed plants. Water stress and warm weather before flowering can result in heavy, extensive infestations.

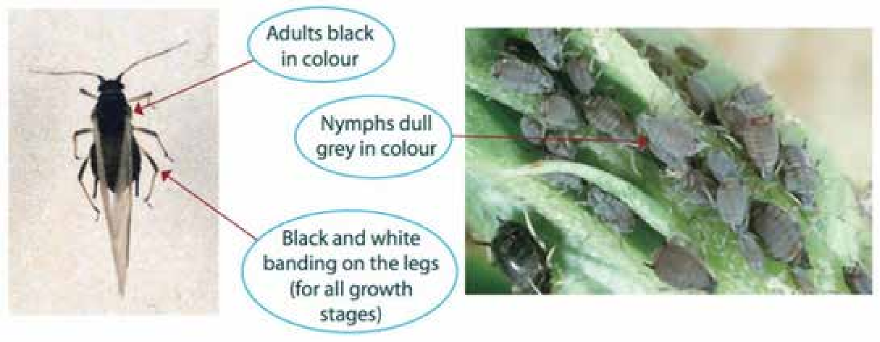


Figure 2: *Distinguishing characteristics/description of cowpea aphids*

Source: Bellati *et al.* 2012 in cesar

Green peach aphid (GPA), *Myzus persicae,* is a widely recognised pest of grains and horticultural crops. It came into particular prominence ss the vector of Beet western yellows virus, which severely impacted many canola crops across south-eastern Australia.

GPAs are waxy green (except the winged adults, which are almost black) (Figure 3). Occasionally, colours of individual wingless GPAs can range from a pale yellow-green to an orange-red. They usually feed in buds and flowers, and do not often form large dense colonies. Generally they are widespread, in low numbers, rather than well-defined patches. They tolerate cool/moist and warm/dry conditions.

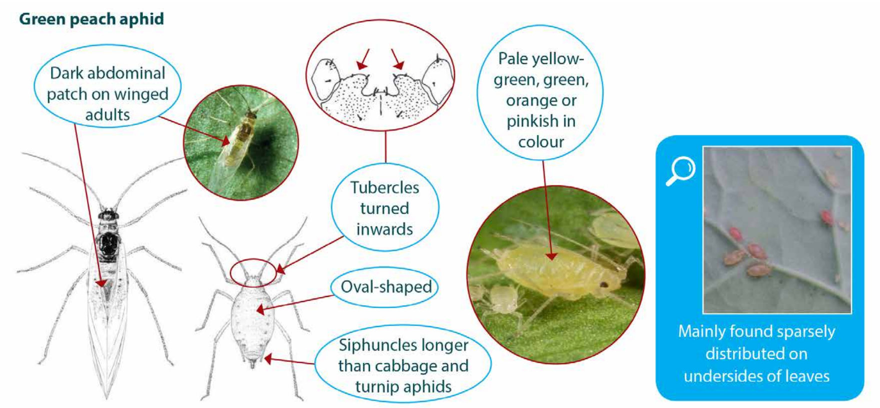


Figure 3: *Distinguishing characteristics/description of GPA*

Source: Bellati *et al.* 2012 in cesar

GPA is resistant to many groups of pesticides. DNA resistance testing is ongoing; to date we have tested 45 populations. Results continue to indicate resistance to the three chemical groups tested: synthetic pyrethroids (e.g. alpha-cypermethrin), organophosphates (e.g. dimethoate) and carbamates (e.g. pirimicarb and imidacloprid). You can view updated resistance maps for SA, Victoria and NSW by clicking here. Despite the high resistance levels to organophosphates across all regions, in some cases, growers have successfully used high levels of dimethoate (i.e. 800 ml/ha) to control GPA populations. Conversely, a similar rate of dimethoate has been reported to offer little control against a GPA population, again in an area where organophosphate resistance was identified. This further serves to illustrate the complexity of this resistance mechanism, and that test strip spraying and working on a case-by case scenario is currently the most effective way to manage resistance in this chemical group. [9]

Life cycle

Winged aphids fly into crops from surrounding vegetation and pastures. Spring population size depends on autumn and winter conditions. Long autumn growing periods allow early build-up and spread of aphids. Mild (not cold) winters allow further development and spread of winged aphids, which can establish many small colonies of wingless aphids throughout a crop. Reproduction is rapid if plant growth and spring weather is favourable, until the colonies are large, and winged aphids redevelop. All aphids are female and give birth to live young, without mating. Viruses carried by flying aphids are transmitted to plants as they feed and establish colonies. Wingless aphids feeding on infected plants can also crawl to healthy plants (through the canopy or after falling to the ground) and spread disease. Viruses can be brought into crops from outside paddocks, or spread within a crop from infected plants.

Damage

Aphids feeding on crops can cause yield loss before plant symptoms become obvious. Large colonies, with more than 40 aphids per stem, cause distortion of leaves, stems and flowers. By the time such symptoms are evident, there will have been yield loss that cannot be recovered by spraying to control the aphids. The crop should be treated before aphid numbers increase markedly. The economic loss over a paddock depends on the area infested, and on the numbers of aphids in each growing tip or bud. Yield losses are greater if virus transmission also occurs. Virus infection causes additional plant symptoms. Aphid feeding slows growth, distorts flowers, and reduces pod-set and fill. Viruses transmitted by the aphids cause a range of symptoms, including 'shepherds crook', stunting, and leaf yellowing. Low numbers of aphids can spread viruses, whereas larger widespread populations are needed to cause direct feeding loss. Virus diseases can cause significant yield loss in pulses. Aphids can carry and spread these diseases, at population levels that cause little damage from direct feeding.

Widespread infestations of GPA during autumn and winter of 2014 contributed to an outbreak of Beet western yellows virus (BWYV, syn. Turnip yellows virus) in southern Australia. Canola crops across the lower and mid-north regions of South Australia, the Eyre Peninsula, western Victoria and some parts of NSW have been severely affected by the virus.

The severity of the current BWYV outbreak is possibly due to a combination of the following factors:

- summer rainfall which resulted in a 'green bridge' of weed hosts of BWYV and aphids;
- the early start to the season and early sowing;
- very mild autumn conditions which contributed to early (and extended) levels of aphid activity through till late June;
- crop management practices;
- the prevalence of insecticide resistance in GPA (particularly to pyrethroids, organophosphates, carbamates); and
- the low proportion of canola seed treated with imidacloprid (Gaucho®) in some areas.

In South Australia, canola crops in the lower and mid-north were the most severely impacted, followed by the South Australian/Victorian Mallee, and some yield loss from BWYV infection has also occurred in canola crops on Eyre Peninsula.

BWYV is an aphid-borne virus that causes yield and quality losses in canola crops. It also infects other crop and pasture species including mustard, chickpea, faba bean,

9 cesar (2014) Green peach aphid. PestFacts south-eastern. Issue 11 08 October 2014, http://cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2014/pestfacts-issue-no-11-8th-october-2014/green-peach-aphid/

VIDEOS

1. Green peach aphids and beet western yellows virus.

field pea, lentil, lupin, lucerne, medic and subterranean clover. BWYV is found widespread throughout southern and eastern Australia.

BWYV infection causes reddening, purpling or yellowing of lower leaves of canola plants. Plants infected early (well before flowering) are often pale and stunted and these plants produce few flowers or seeds. Symptoms are milder and stunting is lacking with late infection. In late infections there is minimum effect on yield. Leaf symptom type and severity differ depending on plant age at infection, environmental conditions and the canola variety involved. Symptoms of BWYV in canola can be confused with those caused by nutrient deficiencies, waterlogging or other plant stresses that cause yellowing, reddening or purpling of lower leaves.

BWYV is not seed-borne and survives from one growing season to the next in over-summering canola, broad-leafed weed species, and perennial legume pastures. BWYV is spread by several aphid species that colonise canola including GPA which is the principle vector. The virus infects the phloem cells in a plants' vascular system but not its other tissues. BWYV is transmitted persistently, i.e. once an aphid feeds on the phloem cells of an infected plant, it acquires the virus. When the infective aphid probes the phloem of a healthy plant, it infects the plant and continues transmitting BWYV for the rest of its life. [10]

Control

Aphid numbers can rise and fall rapidly, mainly in response to weather conditions, so they are virtually impossible to predict beyond a few days. The potential for grain yield loss is high if five or more aphids are found in 30% of buds on the main stem or first branches of a plant, and 15% or more of the crop is affected at this level. Waiting until colonies are large, and plant damage symptoms are obvious, is too late; yield loss has occurred and cannot be recovered. The type of aphid does not matter. GPA is more difficult to kill than the other aphids, and higher rates of aphicide should be used. An aphicide that does not kill beneficial insects (wasps, ladybeetles, lacewings, hoverflies) is preferred. It may be necessary to apply aphicide twice in a season, as each set of buds and flowers develops. Spot spraying may be effective. CMV is carried over in seed from infected plants, and can also be transmitted by aphids. Within a crop, aphids spread CMV from plants growing from infected seed. Usually the disease is localised and patchy, but yield losses due to the virus can exceed 50% if the infection spreads throughout a paddock early on. Recommended management strategies include early seeding, high seeding rates to generate dense stands, use of uninfected seed, and strategic application of aphicides to kill aphids in late winter/early spring. BYMV spreads into paddocks from neighbouring pastures. It is usually restricted to paddock edges, but occasionally widespread infections occur, resulting in severe yield loss. Sparse crops (low seeding rate, seedling loss) are especially vulnerable. Management strategies include high seeding rates to generate dense stands, cereal barriers around the crop, heavy grazing of adjoining pasture paddocks to reduce aphid numbers, and strategic aphicide sprays. [11]

7.3.1 Bluegreen aphid

Bluegreen aphids (BGA) are relatively large (up to 3 mm), matt blue-green, with a pair of slender tubes like exhaust pipes (cornicles) projecting from the back to beyond the tip of the abdomen (Figure 4). Winged aphids fly into pastures or crops and start colonies of wingless aphids, which cause damage. Overcrowding or plant deterioration triggers the development of new winged aphids which migrate to establish new colonies. Winged aphids can spread viruses.

10 B Coutts, R Jones, P Umina, J Davidson, G Baker, M Aftab (2015) Beet western yellows virus (synonym: Turnip yellows virus) and green peach aphid in canola. GRDC Update Papers 10 February 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Beet-western-yellows-virus-synonym-Turnip-yellows-virus-and-green-peach-aphid-in-canola

11 PestWeb Lupin aphids. DAFWA, http://agspsrv34.agric.wa.gov.au/ento/pestweb/Query1_1.idc?ID=1923328529

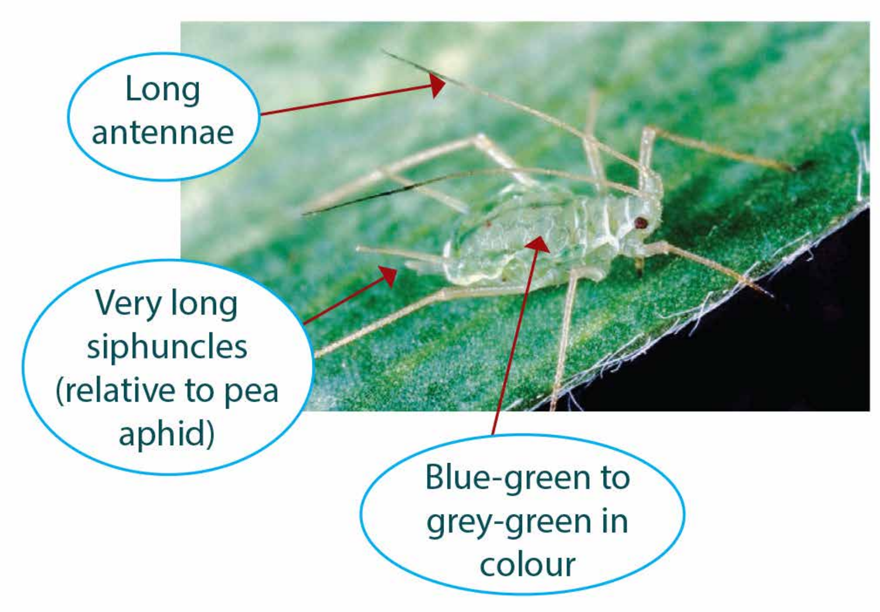


Figure 4: *Distinguishing characteristics/description of bluegreen aphid*

Source: Bellati *et al.* 2012 in cesar.

Life cycle

Like other aphids, all BGA are females and give birth to live young, without having to mate. Reproduction rates are very high so numbers increase rapidly when conditions are favourable. BGA survive hot dry summers in low numbers on sheltered host plants, usually as winged aphids. Migration into germinating annual legumes or lucerne occurs in autumn, and large colonies can develop if it is warm and mild. Winter cold slows reproduction until spring, when populations grow rapidly on favourable plants. During heavy infestations, plants can be covered with white speckles, which are cast-off aphid skins. The number of winged aphids flying between paddocks also increases throughout spring; these can be caught with 'sticky' traps.

Damage

Annual medics, lucerne, subterranean clover and lupins are susceptible to BGA. In lucerne and medics, heavy infestations cause stunted growth, leaf curling and leaf drop. Dry matter production can be reduced. In subterranean clover, leaves wilt before turning grey-brown and dying, becoming dry and 'crisp'. Pastures take on a patchy burnt appearance. Seed yield of annual species can be reduced by 20–80%. The higher the legume content and the lighter the grazing pressure from flowering onwards, the greater the risk of aphid damage. Ungrazed swards with more than 50% legume dominance are at greatest risk in spring. BGA favour growing tips of medic or lucerne, while in subterranean clover they are widely dispersed under the canopy, particularly on flower/burr peduncles.

Control

For lucerne, sow resistant or tolerant cultivars. Parasitic wasps (Photo 1), ladybeetles, lacewings, hoverflies and fungus diseases exert useful biological control. Aphid resistant annual medics and subterranean clover are not common, so insecticides may be needed in lightly or ungrazed spring pastures, if maximum seedset and spring dry matter production is wanted. Redlegged earth mite can cause similar spring losses, and may also be present. If BGA is the predominant pest, use insecticides that do not kill aphid parasites and predators; for mixed infestations, systemic chemicals that control aphids and mites should be used.

Photo 1: *Bluegreen aphid and parasitoid wasp*

Source: cesar

7.3.2 Management

Monitoring

Monitor terminals/growing tips.

- Check at least 5 points in the field and sample 20 plants at each point.
- Check regularly at different locations across a field as populations are often patchy.
- Aphids are often first observed along the edges of crops. Inspect crops from crop edge to centre of paddock. Infestations may be patchy or in 'hot spots'.
- Infestations can be reduced by heavy rain. If rain occurs when spray decision is made but not carried out monitor again to determine is spray still required.
- Record the number of large and small aphids (adults and juveniles), the number of beneficials as well as parasitised aphids (mummies), and the impact of infestation on crop.

Repeat sampling provides information on whether the population is increasing (lots of juveniles), stable or declining (lots of adults and winged adults). [12]

Table 3 summarises control strategies against aphids.

12 IPM Guidelines (2016) Aphids in pulses. GRDC, http://ipmguidelinesforgrains.com.au/pests/aphids/aphids-in-pulses/

Table 3: *Best Bet IPM strategies for controlling aphids in winter pulses in the southern growing region.*

	Post Harvest, pre-sowing	Establishment – vegetative	Flowering - maturity
Aphid vectors and virus source	Control green bridge (in fallows) Sow virus – free seed Sowing into standing stubble may reduce aphid landing	Asses risk of aphid outbreak High risk when: Warm, mild conditions Abundant weed hosts Nearby food sources eg. Clover/medic Aim to close canopy and minimise gaps to outcompete infected plants	Conserve and monitor beneficials that suppress aphids. Use of broad spectrum pesticides may flare aphids. Check post-application for signs of flaring
Aphids – direct damage (not virus) Cowpea Green peach Blue-green Pea aphid	Remove green bridge (aphid hosts) to minimise build up during autumn and spring. Sowing into standing stubble may reduce aphid landing and delay aphid build up in crops.	Control in-crop weeds to minimse sources of aphids Beneficials suppress low population and reduce the chance of outbreaks. High nitrogen may make the crop more attractive to aphids	Monitoring: Conserve and monitor beneficials that suppress aphids. If not control is required, use soft options (eg. Pirimicarb). Use of broad spectrum pesticides may flare aphids. Check post-application for signs of flaring. Note: knowledge of damaging levels is limited.

Source: IPM Guidelines

Chemical control:

- Systemic insecticides are the preferred chemical control (aphids often shelter in spray-inaccessible areas of the plant). However in very dry conditions translocation of chemicals may be impaired and insecticide will be less effective.
- If chemical control is required, consider aphid specific products (e.g. pirimicarb) to preserve beneficials. Refer to the beneficial impact table.
- If heavy rain and cool temperature are forecast consider delaying spray decisions until after rain and monitor again.
- Seed treatments and border spraying (autumn/early winter) when aphids begin to colonise crop edges may provide sufficient control.
- Controlling aphids to prevent virus is not an economic proposition as a small number of aphids can transmit virus and these populations could establish without being detected.
- Rotate chemicals to prevent resistance. GPA potentially has resistance to SPs and OPs. [13]

13 IPM Guidelines (2016) Aphids in pulses. GRDC, http://ipmguidelinesforgrains.com.au/pests/aphids/aphids-in-pulses/

Cultural control:

- Control alternative hosts (wet autumn and spring promotes the growth of weed hosts—when weed hosts dry off aphids move into crops). Legume pasture species are also hosts.
- Sow crops early where possible to enable plants to flower before aphid numbers peak.
- Sow clean seed tested for CMV in lupins or Pea seed-borne mosaic virus (PSbMV) in field peas.
- Cover of bare ground through rapid canopy development assists in deterring aphids, e.g. narrow rows with high seeding rates.
- High intensity rain during crop growth can suppress aphids.
- Research shows that high levels of reflective stubble may deter aphids especially in crops with wide row spacing. [14]

7.3.3 Aphids and virus incidence

Aphids can damage crops by spreading viruses or they can cause direct damage when feeding on plants. Feeding damage generally requires large populations, but virus transmission can occur before aphids are noticed. Pre-emptive management is required to minimise the risk of aphids and their transmission of viruses. Aphids are the principal, but not sole, vectors of viruses in pulses; some viruses are also transmitted in seed.

An integrated approach to aphid and virus management is needed to reduce the risk of yield or quality loss.

Different aphid species transmit different viruses to particular crop types. Viruses are already transmitted before detection, but aphid species identification is important because management strategies can vary. Pulses are annual crops, whereas aphids and the viruses they spread have alternative hosts between seasons. Aphid population development is strongly influenced by local conditions. Early breaks and summer rainfall favour early increases in aphids and volunteers that host viruses, resulting in a higher level of virus risk.

Integrated management practices that aim to control aphid populations early in the season are important in minimising virus spread. Aphids can spread viruses persistently or non-persistently. Once an aphid has picked up a persistently transmitted virus, e.g. BWYV, it carries the virus for life, infecting every plant where it feeds on the phloem. Aphids carrying non-persistently transmitted viruses, e.g. CMV, carry the virus temporarily and only infect new plants in the first one or two probes.

Important vectors for non-persistent viruses in pulse crops include GPA, pea aphid, cowpea aphid and blue green aphid, which will colonise pulse crops (Table 4). Turnip aphid, maize aphid and oat aphid, which are non-colonising species in pulses, may also move through pulse crops, probing as they go, and potentially spreading pulse viruses. GPA and pea aphid are also important in spreading persistently transmitted viruses, depending on the virus involved. [15]

14 IPM Guidelines (2016) Aphids in pulses. GRDC, http://ipmguidelinesforgrains.com.au/pests/aphids/aphids-in-pulses/

15 GRDC (2010) Aphids and viruses in pulse crops fact sheet. Western and Southern region. GRDC 12 July 2010, https://grdc.com.au/Resources/Factsheets/2010/07/Aphids-and-Viruses-in-Pulse-Crops-Factsheets

Table 4: *Differences in transmission of one persistent and two non-persistent viruses by four aphid species.*

Aphid species	Cucumber mosaic virus (non-persistent)	Pea seed-borne mosaic virus (non-persistent)	Beet western yellows virus (persistent)
Green peach aphid	Yes	Yes	Yes
Pea aphid	Yes	Yes	-
Cowpea aphid	Yes	Yes	Yes
Bluegreen aphid	Yes	-	-

Source: GRDC

7.3.4 Integrated pest management and viruses

An integrated approach with crop, virus and insect management is required to control aphids and viruses in pulse crops.

Minimise the pool of potentially virus-infected plant material near crops by controlling the 'green bridge' of weeds, pastures and volunteer pulses that can harbour viruses and aphids over summer or between crops. This includes weeds around dams, tracks and the margins of crops.

Source clean seed and test retained seed for viruses including CMV, BYMV, Alfalfa mosaic virus (AMV) and PSbMV. Sow tested seed with <0.1% virus infection to reduce the pool of virus-infected material. Field pea seed should have <0.5% PSbMV. Where possible, choose a pulse variety that has virus resistance.

Resistance to CMV seed transmission has been bred into many new lupin varieties, including JENABILLUP⚜. YARRUM⚜ field pea has resistance to BLRV and PSbMV. Pulse Breeding Australia is increasing its emphasis on developing pulse crop lines with increased virus resistance. Faba bean lines with resistance to BLRV and field pea with resistance to BLRV and PSbMV have been identified and should be commercially available in the future.

Some species of aphids are attracted to areas of bare earth. Use minimal tillage and sow into retained stubble, ideally inter-row to discourage aphid landings. This applies especially to minimising CMV spread in chickpea and lupins.

Seed dressings are probably the best aphid protection strategy compatible with an IPM approach, for example, Gaucho® 350SD insecticide seed dressing on other pulses to prevent aphids attacking emerging seedlings and spreading viruses (e.g. CMV, BLRV and BWYV). However, Gaucho® 350SD is not registered for use in chickpea. Alternatively, a foliar insecticide can be applied early based on forecast reports of the degree of risk. Preferably use a 'soft' insecticide that targets the aphids and leaves beneficial insects unharmed. There is debate over the use of synthetic pyrethroids as a foliar application; they are recommended to prevent BLRV transmission because of so called 'anti-feed' properties that prevent early colonising of crops by pea aphids. However, discouraging colonisation may increase the spread of aphids and, potentially, virus through a crop.

Synthetic pyrethroid insecticides should not be used to control GPA, an important vector of BWYV, as most populations of GPA are resistant. Monitor crops and neighbouring areas regularly. Identify the species of aphid present and their numbers. [16]

16 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

7.4 Blue oat mite

Blue oat mites (BOM) (*Penthaleus* spp.) are species of earth mites, which are major agricultural pests of southern Australia and other parts of the world, attacking various pasture, vegetable and crop plants. BOM were introduced from Europe and first recorded in NSW in 1921. Management of these mites in Australia has been complicated by the recent discovery of three distinct species of BOM, whereas prior research had assumed just a single species.

Blue oat mites are important crop and pasture pests in southern Australia. They are commonly found in Mediterranean climates of Victoria, NSW, SA, WA and eastern Tasmania (Figure 5). There are three main species of BOM: *Penthaleus major*, *Penthaleus falcatus* and *Penthaleus tectus*. These species differ in their distributions.

Figure 5: *The known distribution of blue oat mites in Australia.*

Source: cesar)

Adult BOM are 1 mm in length and approximately 0.7–0.8 mm wide, with 8 red-orange legs. They have a blue-black coloured body with a characteristic red mark on their back (Figure 6). Larvae are approximately 0.3 mm long, are oval in shape and have three pairs of legs. On hatching, BOM are pink-orange in colour, soon becoming brownish and then green.

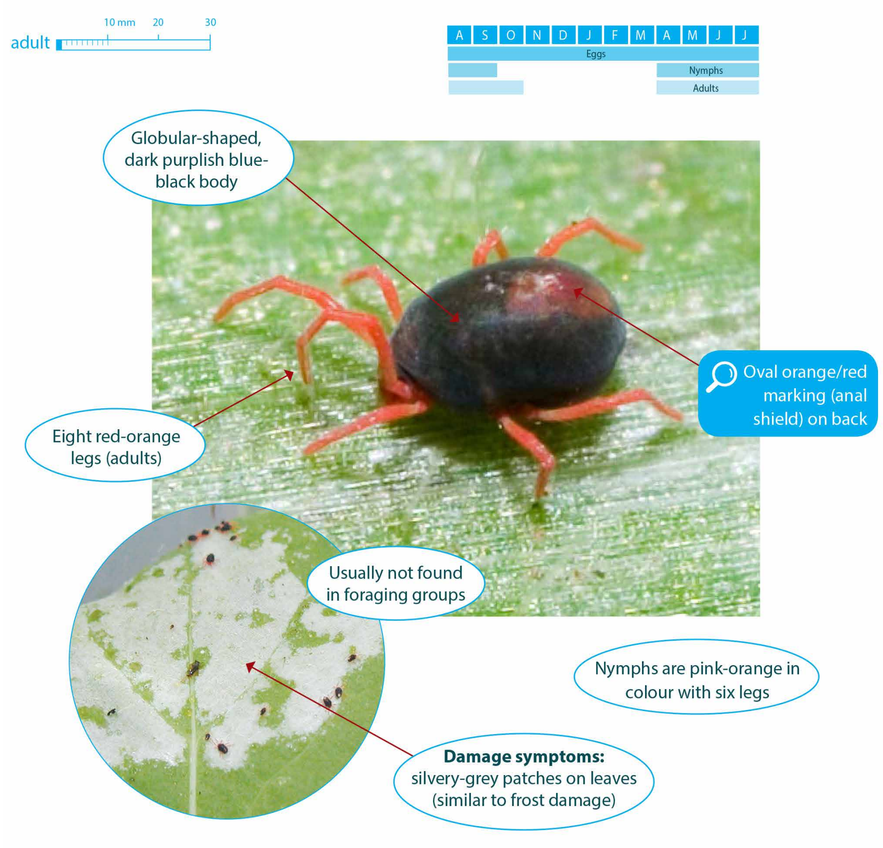


Figure 6: *Distinguishing characteristics of Blue oat mite.*

Source: Bellati *et al.* (2012in cesar

BOM are often misidentified as redlegged earth mites (RLEM) in the field, which has meant that the damage caused by BOM has been under-represented. Despite having a similar appearance, RLEM and BOM can be readily distinguished from each other. RLEM have a completely black coloured body and tend to feed in larger groups of up to 30 individuals. BOM have the red mark on their back and are usually found singularly or in very small groups.

7.4.1 Damage caused by BOM

Feeding causes silvering or white discoloration of leaves and distortion, or shrivelling in severe infestations. Affected seedlings can die at emergence with high mite populations. Unlike redlegged earth mites, blue oat mites typically feed singularly or in very small groups.

Mites use adapted mouthparts to lacerate the leaf tissue of plants and suck up the discharged sap. Resulting cell and cuticle destruction promotes desiccation, retards photosynthesis and produces the characteristic silvering that is often mistaken as frost damage (Photo 2). BOM are most damaging to newly establishing pastures and emerging crops, greatly reducing seedling survival and retarding development.

Photo 2: *Typical Blue oat mite damage to leaf.*

Source: AgVic

Young mites prefer to feed on the sheath leaves or tender shoots near the soil surface, while adults feed on more mature plant tissues. BOM feeding reduces the productivity of established plants and is directly responsible for reductions in pasture palatability to livestock. Even in established pastures, damage from large infestations may significantly affect productivity.

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal growing conditions for seedlings enable plants to tolerate higher numbers of mites.

7.4.2 Managing BOM

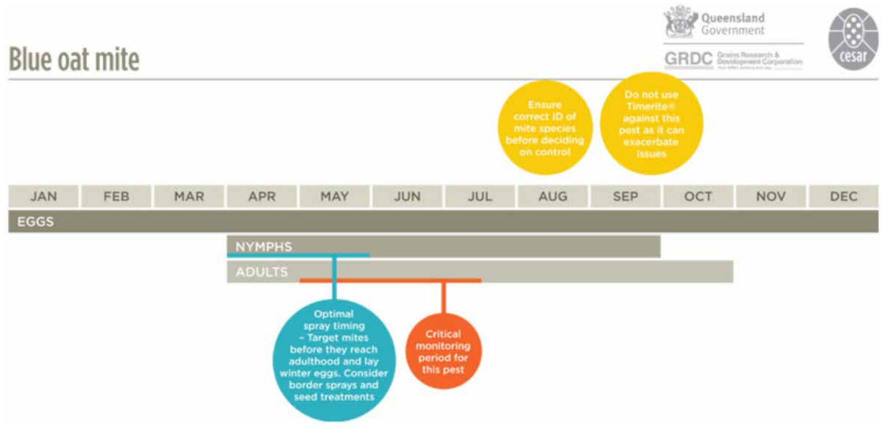


Figure 7: *Critical time periods for managing BOM.*

Source: cesar

Chemical control

Chemicals are the most common method of control against earth mites. Unfortunately, all currently registered pesticides are only effective against the active stages of mites; they do not kill mite eggs.

While a number of chemicals are registered in pastures and crops, differences in tolerance levels between species complicates management of BOM. *P. falcatus* has a high natural tolerance to a range of pesticides registered against earth mites in Australia and is responsible for many control failures involving earth mites. The other BOM species have a lower level of tolerance to pesticides and are generally easier to control with chemicals in the field.

Chemical sprays are commonly applied at the time of infestation, when mites are at high levels and crops already show signs of damage. Control of first generation mites before they can lay eggs is an effective way to avoid a second spray. Hence, pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, as adults will then begin laying eggs. While spraying pesticides in spring can greatly reduce the size of RLEM populations the following autumn, this strategy will generally not be as effective for the control of BOM.

Pesticides with persistent residual effects can be used as bare-earth treatments. These treatments can be applied prior to, or at sowing to kill emerging mites and protect the plants throughout their seedling stage.

Systemic pesticides are often applied as seed dressings to maintain the pesticide at toxic levels within the plants as they grow. This can help minimise damage to plants during the sensitive establishment phase, however, if mite numbers are high, significant damage may still occur before the pesticide has much effect.

To prevent the buildup of resistant populations, spray pesticides only when necessary and rotate pesticides from chemical classes with different modes of action. To avoid developing multiple pesticide resistance, rotate chemical classes across generations rather than within a generation.

Information on the registration status, rates of application and warnings related to withholding periods, OH&S, residues and off-target effects should be obtained before making decisions on which pesticide to use. This information is available from the DEPI Chemical Standards Branch, chemical resellers, APVMA and the pesticide manufacturer. Always consult the label and MSDS before using any pesticide.

Biological & cultural control

Integrated pest management programs can complement current chemical control methods by introducing non-chemical options, such as cultural and biological control.

Although no systematic survey has been conducted, a number of predator species are known to attack earth mites in Australia. The most important predators of BOM appear to be other mites, although small beetles, spiders and ants may also play a role. The French anystis mite is an effective predator but is limited in distribution. Snout mites will also prey upon BOM, particularly in pastures. The fungal pathogen, Neozygites acaracida, is prevalent in BOM populations during wet winters and could be responsible for observed “population crashes”.

Preserving natural enemies when using chemicals is often difficult because the pesticides generally used are broad-spectrum and kill beneficial species as well as the pests. Impact on natural enemies can be reduced by using a pesticide that has the least impact and by minimising the number of applications. Although there are few registered alternatives for BOM control, there are groups such as the chloronicotinyls, which are used in some seed treatments that have low–moderate impacts on many natural enemies.

Cultural controls such as rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival, decreasing the need for chemical control. When *P. major* is the predominant species, canola and lentils are potentially useful rotation crops, while pastures containing predominantly thick-bladed grasses should be carefully monitored and rotated with other crops. In situations where P. falcatus is the most abundant mite species, farmers can consider rotating crops with lentils, while rotations that involve canola may be the most effective means of reducing the impact of *P. tectus*.

Many cultural control methods for BOM can also suppress other mite pests, such as RLEM. Cultivation will significantly decrease the number of over-summering eggs, while hot stubble burns can provide a similar effect. Many broad-leaved weeds provide an alternative food source, particularly for juvenile stages. As such, clean fallowing and the control of weeds within crops and around pasture perimeters, especially of bristly ox tongue and cats ear, can help reduce BOM numbers.

Appropriate grazing management can also reduce mite populations to below damaging thresholds. This may be because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources. Grazing pastures

VIDEOS

2. GCTV9: Redlegged earth mites.

in spring to less than 2 t/ha Feed On Offer (dry weight), can reduce mite numbers to low levels and provide some level of control the following year. [17]

7.5 Redlegged earth mite (RLEM)

The redlegged earth mite (RLEM), *Halotydeus destructor*, is a major pest of pastures, crops and vegetables in regions of Australia with cool wet winters and hot dry summers. The RLEM was accidentally introduced into Australia from the Cape region of South Africa in the early 1900s. These mites are commonly controlled using pesticides; however, non-chemical options are becoming increasingly important due to evidence of resistance and concern about long-term sustainability. RLEM is a sap-sucking pest of crops and pastures. They often co-exist with blue oat mites. The mites are often gregarious and are found clumped together in large numbers. They disperse quickly when disturbed. [18]

7.5.1 Symptoms

What to look for

Insect adult:

- Adults are 1 mm long with a black body and eight red-orange legs (Photo 3).
- Newly hatched mites are 0.2 mm long with a pinkish-orange body and 6 legs and are not generally visible to the untrained eye.

Photo 3: *Leathery cotyledons with adult RLEM.*

Source: DAFWA 2013

Plant:

- Feeding causes a silver or white discolouration of leaves and distortion. If damage is severe plants shrivel and die (Photo 4).
- Damage is more severe when seedlings are stressed (e.g. cold waterlogged or very dry conditions).

17 Agriculture Victoria (2007) Blue oat mite, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite

18 P Umina (2007) Redlegged earth mite. Agriculture Victoria, Ag Note AG0414 January 2007, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

Photo 4: *Silver leaf discolouration.*

Source: DAFWA 2013

7.5.2 Damage caused by RLEM

The RLEM is called an earth mite because it spends 90% of its time on the soil surface, rather than on the foliage of plants. The mites feed on the foliage for short periods and then move around before settling at another feeding site. Other mites are attracted to volatile compounds released from the damaged leaves, which results in feeding aggregations. RLEM feeding reduces the productivity of established plants and has been found to be directly responsible for reduction in pasture palatability to livestock. [19]

Large numbers of redlegged earth mite are commonly found in annual pastures at the break of the season and may cause heavy loss of subterranean clover and annual medic seedlings. These species are susceptible throughout the growing season, and can suffer losses in dry matter (10–80%) and seed yield (20–80%) in spring. The greater the legume content of pastures and the lighter the grazing pressure, the higher the risk of loss from mites. They also attack lupins, rape, field peas, serradella (cotyledons only) and vegetables, but normally do not affect grasses or cereals severely. Mites rupture cells on the surface of leaves and feed on exuding sap; affected leaves look silvered, but do not have holes as with lucerne flea attack. Mite damage to seedlings is more severe if plant growth is slowed. This could be caused by cold and/or waterlogging, low seedling density after a false break, low seed banks after a crop, or if pastures or stubble are being reseeded. Capeweed increases their reproductive potential, and legumes in paddocks with a lot of capeweed may be severely damaged, especially where mites can attack smaller clover and medic seedlings from the shelter of large capeweed plants. [20]

In Southern crops RLEM:

- Will damage all field crops and pastures.
- Reduces production and quality of older plants during the growing season.
- Reduces seed yield of legumes in spring.
- Silvering of leaves, distortion of leaf shape in broadleaf crops.
- Affected seedlings can die.

19 P Umina (2007) Redlegged earth mite. Agriculture Victoria, Ag Note AG0414 January 2007, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

20 PestWeb Redlegged earth mite. DAFWA, http://agspsrv34.agric.wa.gov.au/Ento/pestweb/Query1_1.idc?ID=247419235

- Seedlings can be killed below ground before they emerge.

7.5.3 Conditions favouring development

Earth mites are active in the cool, wet part of the year, usually between April and November. During this winter-spring period, RLEM may pass through three (sometimes only two) generations, with each generation surviving six to eight weeks (Figure 8).

RLEM eggs hatch in autumn following exposure to cooler temperatures and adequate rainfall. It takes approximately two weeks of exposure to favourable conditions for over-summering eggs to hatch. This releases swarms of mites, which attack delicate crop seedlings and emerging pasture plants.

RLEM eggs laid during the winter-spring period are orange in colour and about 0.1 mm in length. They are laid singly on the underside of leaves, the bases of host plants (particularly stems) and on nearby debris. They are often found in large numbers clustered together. Female RLEM can produce up to 100 winter eggs, which usually hatch in eight to ten days, depending on conditions.

Towards the end of spring, physiological changes in the plant, the hot dry weather and changes in light conditions combine to induce the production of over-summering or 'diapause eggs'. These are stress resistant eggs that are retained in the dead female bodies. Diapause eggs can successfully withstand the heat and desiccation of summer and give rise to the autumn generation the following year. Autumn conditions trigger egg hatching. [21]

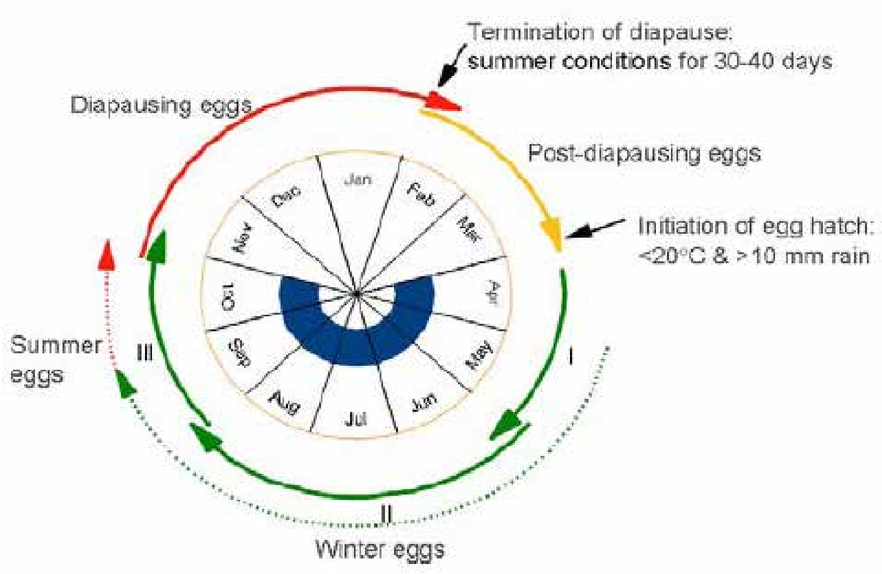


Figure 8: *The life cycle of the redlegged earth mite.*

Source: AgVic

7.5.4 Management of RLEM

Key points:

- Spray only if you need to. RLEM have been detected that have resistance to synthetic pyrethroids. Rotate chemical groups in and between seasons, as this will help to reduce resistance occurring.
- Use insecticide seed treatments for crops and new pastures with moderate pest pressure rather than spraying whole paddocks. This allows for smaller quantities of pesticide to be used that will directly target plant feeding pests.

21 P Umina (2007) Redlegged earth mite. Agriculture Victoria, Ag Note AG0414 January 2007, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

- Control weeds before seeding, particularly in late autumn or winter sown crops where RLEM are likely to hatch before seeding. At least one week of bare soil can 'starve out' most of the mite population before crops are sown.
- Control weeds in the crop and along fence lines that provide habitat for mites. A weed free crop will have few mites and over-summering eggs to carry through to the following season.
- Controlled grazing of pasture paddocks that will be cropped next year will reduce mite numbers to levels that are almost as effective as chemical sprays. Sustained grazing of pastures throughout spring to maintain them at levels below 2 tonnes per hectare. Feed on offer (FOO) (dry weight) will restrict mite numbers to low levels.
- Apply insecticides to paddocks that are to be cropped during spring to prevent RLEM populations producing over-summering eggs. This will minimise the pest population for the following autumn. TIMERITE® is a free package that provides a date in spring for a spray application to stop female RLEM from producing over-summering eggs.
- Look at your cropping rotations to decrease reliance on pesticides. The risk is generally highest if paddocks have been in long-term pasture (with high levels of broad-leafed plants) where mite populations have been uncontrolled. Lower risk paddocks that generally do not require mite control are often those which follow a weed free cereal or chickpea crop. [22]

Monitoring

Carefully inspect susceptible pastures and crops from autumn to spring for the presence of mites and evidence of damage. It is especially important to inspect crops regularly in the first three to five weeks after sowing. Mites are best detected feeding on the leaves in the morning or on overcast days. In the warmer part of the day RLEM tend to gather at the base of plants, sheltering in leaf sheaths and under debris. They will crawl into cracks in the ground to avoid heat and cold. When disturbed during feeding they will drop to the ground and seek shelter.

RLEM compete with other pasture pests, such as blue oat mites, for food and resources. Competition within and between mite species has been demonstrated in pastures and on a variety of crop types. This means control strategies that only target RLEM may not entirely remove pest pressure because other pests can fill the gap. This can be particularly evident after chemical applications, which are generally more effective against RLEM than other mite pests.

Chemical control

Chemicals are the most commonly used control option against earth mites. While a number of chemicals are registered for control of active RLEM in pastures and crops, there are no currently registered pesticides that are effective against RLEM eggs.

Autumn sprays:

Controlling first generation mites before they have a chance to lay eggs is the only effective way to avoid the need for a second spray. Hence, pesticides used at or after sowing should be applied within three weeks of the first appearance of mites, before adults begin to lay eggs. Timing of chemical application is critical.

1. Pesticides with persistent residual activity can be used as bare earth treatments, either pre-sowing or at sowing to kill emerging mites. This will protect seedlings which are most vulnerable to damage.
2. Foliage sprays are applied once the crop has emerged and are generally an effective method of control.
3. Systemic pesticides are often applied as seed dressings. Seed dressings act by maintaining the pesticide at toxic levels within the growing plant, which then affects mites as they feed. This strategy aims to minimise damage to plants

22 DAFWA (2015) Diagnosing redlegged earth mite. https://www.agric.wa.gov.au/mycrop/diagnosing-redlegged-earth-mite

during the sensitive establishment phase. However, if mite numbers are high, plants may suffer significant damage before the pesticide has much effect.

Spring sprays:

Research has shown that one accurately timed spring spray of an appropriate chemical can significantly reduce populations of RLEM the following autumn. This approach works by killing mites before they start producing diapause eggs in mid-late spring. The optimum date can be predicted using climatic variables, and tools such as TIMERITE® can help farmers identify the optimum date for spraying. Spring RLEM sprays will generally not be effective against other pest mites.

Repeated successive use of the 'spring spray' technique is not recommended as this could lead to populations evolving resistance to the strategy. To prevent the development of resistance, the selective rotation of products with different Modes of Action is advised.

Biological control

There is evidence of natural RLEM populations showing resistance to some chemicals; therefore, alternative management strategies are needed to complement current control methods.

At least 19 predators and one pathogen are known to attack earth mites in Australia. The most important predators of RLEM appear to be other mites, although small beetles, spiders and ants also play a role in reducing populations. A predatory mite (Anystis wallacei) has been introduced as a means of biological control; however, it has slow dispersal and establishment rates. Although locally successful, the benefits of this mite are yet to be demonstrated.

Preserving natural enemies may prevent RLEM population explosions in established pastures but this is often difficult to achieve. This is mainly because the pesticides generally used to control RLEM are broad-spectrum and kill beneficial species as well as the pests. The chemical impact on predator species can be minimised by choosing a spray that has least impact and by reducing the number of chemical applications. Although there are few registered alternatives for RLEM, there are groups that have low-moderate impacts on many natural enemies such as cyclodienes.

Natural enemies residing in windbreaks and roadside vegetation have been demonstrated to suppress RLEM in adjacent pasture paddocks. When pesticides with residual activity are applied as border sprays to prevent mites moving into a crop or pasture, beneficial insect numbers may be inadvertently reduced, thereby protecting RLEM populations.

Cultural control

Using cultural control methods can decrease the need for chemical control. Rotating crops or pastures with non-host crops can reduce pest colonisation, reproduction and survival. For example, prior to planting a susceptible crop like canola, a paddock may be sown to cereals or lentils to help reduce the risk of RLEM population build-up. Cultivation can also help reduce RLEM populations by significantly decreasing the number of over-summering eggs. Hot stubble burns can provide a similar effect.

Clean fallowing and controlling weeds around crop and pasture perimeters can also act to reduce mite numbers. Control of weeds, especially thistles and capeweed, is important, as they provide breeding sites for RLEM. Where paddocks have a history of damaging, high-density RLEM populations, it is recommended that sowing pastures with a high-clover content be avoided.

Appropriate grazing management can reduce RLEM populations to below damaging thresholds, possibly because shorter pasture results in lower relative humidity, which increases mite mortality and limits food resources.

Other cultural techniques including modification of tillage practices, trap or border crops, and mixed cropping can reduce overall infestation levels to below the economic control threshold, particularly when employed in conjunction with other measures. [23]

Managing resistance

Though RLEM have only been found to show resistance to insecticides in WA, it is important to uphold best practice measure to prevent resistance from emerging closer to home.

Identify your mites

RLEM are often found with other mites, such as blue oat mite (BOM), Bryobia (clover) mite or Balaustium mite, but resistance has only been found in RLEM. In situations where spray failures have occurred, it is important to correctly identify the mite.

Plan ahead to reduce mite numbers

If you prepare paddocks in the preceding season, there will be lower numbers of pests on your crops. Consider the following to reduce pest numbers:

- Control weeds in the crop and along fence lines. Weeds provide habitat for mites. Controlling weeds with herbicides, cultivation or heavy grazing will decrease mite numbers. A weed free crop will have few mites and over-summering eggs to carry through to the following season.
- Controlled grazing of pasture paddocks in the year prior to a cropping year will reduce RLEM numbers to levels similar to chemical sprays. Sustained grazing of pastures throughout spring to maintain Feed on offer levels below two tonnes per hectare (t/ha) (dry weight) will restrict mite numbers to low levels. Control RLEM in spring.
- Applying insecticides to some paddocks during spring to prevent RLEM populations producing over-summering eggs will decrease the pest population in the following autumn. Only specific paddocks should be selected for spring spraying based on FOO levels, future grazing management options, seed production requirements and intended paddock use next season. The routine spraying of all pasture paddocks in spring using TIMERITE® dates to prevent a build-up of mites is unlikely to be sustainable. TIMERITE® is a free package that provides a date in spring for a spraying to stop RLEM from producing over-summering eggs.
- Use cropping rotations to decrease reliance on pesticides. Some paddocks will have a higher or lower risk of RLEM damage depending on previous crop rotations. The risk is generally highest if paddocks have been in long-term pasture (with high levels of broad-leafed plants) where mite populations have been uncontrolled. Lower risk paddocks that generally do not require mite control are often those which follow a cereal or canola weed free crop where conditions are less favourable for mite increase.

What you can do this season

Spray only if you need to

Farmers that currently have populations of resistant RLEM have mostly used repeated applications of SP chemicals as 'insurance' sprays to minimise anticipated pest risks. To decrease the likelihood of resistance developing on your property apply insecticides only on paddocks that have damaging numbers of pests.

Where spraying is needed, rotate chemical groups

For example, rotate between Synthetic Pyrethoids (SP, Group 3A) and Organophosphate (OP, group (Group 1B), e.g. dimethoate or omethoate), in and between seasons, as this will help to reduce resistance build-up. If spraying other pests, such as aphids, try not to use SPs. Consider other chemical options such as pirimicarb.

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23 P Umina (2007) Redlegged earth mite. Agriculture Victoria, Ag Note AG0414 January 2007, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

Predict hatchings of RLEM on your property to target your control strategy

Knowing approximately when the first autumn hatchings of RLEM is occurring on your property will help to determine if they will coincide with seedling crops. RLEM hatch in autumn from their over-summering egg stage, after adequate rainfall and at least seven days of average temperatures below 20°C. Crops sown in seasons with 'early breaks' with maximum temperatures well above 20°C (for example, canola sown in April) will not be damaged by RLEM.

Use insecticide seed treatments

Use insecticide seed treatments for crops and sown pastures with moderate pest pressure rather than spraying whole paddocks. Seed treatments allow smaller quantities of pesticide to be used that directly target plant feeding pests, allowing any predatory insects to continue their important beneficial role. [24]

7.6 Lucerne flea

The lucerne flea, *Sminthurus viridis* (Collembola: Sminthuridae), is a springtail that is found in both the northern and southern hemispheres but is restricted to areas that have a Mediterranean-type climate. It is thought to have been introduced to Australia from Europe and has since become a significant agricultural pest of crops and pastures across the southern states. It is commonly observed on loam-clay soils, and it is not related to the fleas which attack animals and humans.

The adult lucerne flea is approximately 3 mm long with light green-yellow colouring and an irregular pattern of darker patches over the body (Photo 5). Lucerne fleas are wingless, have globular abdomens and can jump large distances relative to their size. Their mottled colouration, small size and elusive habits can often make detection difficult.

Photo 5: *Yellow-green wingless and globular adults sometimes with dark markings.*

Source: DAFWA 2013

Eggs, which are laid in batches, are covered in a soil layer making them almost impossible to detect in the field. The eggs are yellow-cream and about 0.3 mm in diameter. The newly hatched nymphs are approximately 0.75 mm long and are pale

24 S Micic (2016) Prevent redlegged earth mite resistance. DAFWA, https://www.agric.wa.gov.au/mites-spiders/prevent-redlegged-earth-mite-resistance?page=0%2C2

yellow in colour. Young nymphs resemble adults except they are much smaller in size and will moult several times before reaching maturity.

Lucerne fleas have a characteristic ability to 'spring' off vegetation when disturbed. This is due to a stiff appendage folded under their abdomen called a furcula, which is unfolded with such speed and force that it launches the lucerne flea into the air.

While regional movement of lucerne flea is limited, anecdotal evidence suggests that the incidence of lucerne flea is increasing, even in areas of continuous cropping. The increased adoption of minimum and no-tillage may be contributing to the pest's increased survival and range expansion. [25]

7.6.1 Symptoms

What to look for

Paddock:

- Small jumping bugs that appear early in the season and chew young leaves on heavier textured soils.

Plant:

- Cereals, canola and pasture legumes have chewed leaves with transparent 'windows' (Photo 6).
- Green material completely removed in severe infestations.

Photo 6: *Chewed leaves have transparent 'windows' on a wheat (left) and clover (right) leaf.*

Source: AgVic

Insect adult:

- Adults (3 millimetres) yellow-green, wingless and globular in shape sometimes with dark markings.
  Insects 'spring' off foliage when disturbed. [26]

7.6.2 Damage caused by lucerne flea

Lucerne fleas move up plants from ground level, eating tissue from the underside of foliage. They consume the succulent green cells of leaves through a rasping process, avoiding the more fibrous veins and leaving behind a layer of leaf membrane. This makes the characteristic small, clean holes in leaves which can appear as numerous small 'windows'. In severe infestations this damage can stunt or kill plant seedlings. [27]

- Lucerne flea can kill seedling crops and pastures and re-growth of lucerne.
- Yield loss varies with the growth stage of the plant.

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25 G McDonald (1995) Lucerne flea. Agriculture Victoria, Ag Note AG0415 June 1995 Updated June 2008, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/lucerne-flea

26 DAFWA (21015) Diagnosing lucerne flea. https://www.agric.wa.gov.au/mycrop/diagnosing-lucerne-flea

27 G McDonald (1995) Lucerne flea. Agriculture Victoria, Ag Note AG0415 June 1995 Updated June 2008, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/lucerne-flea

- Broadleaf seedlings are most susceptible.
- Young nymphs feed on the soft tissue on the underside of leaves leaving transparent 'windows'.
- Adults and older nymphs chew irregular holes in leaves and can completely defoliate plants. [28]

7.6.3 Thresholds for control

Speculative thresholds: the key is early control because of the impact of seedling vigour on crop performance.

- Establishing pasture: 15 per 100 cm^2 (sampling method not established, but could use that proposed by Taverner *et al.* 1996).
- A suggested threshold for other crops—treat if 50% of leaf area is likely to be damaged. [29]

7.6.4 Conditions favouring development

The lucerne flea has a similar seasonal biology to other important pests of establishing crops, such as the redlegged earth mite. Lucerne fleas generally hatch from over-summering eggs in March–April following soaking autumn rains. They reproduce sexually and, depending on favourable temperatures and moisture availability, may go through as many as three to five generations between autumn and spring. Each generation takes three to five weeks, with each female capable of laying up to three batches of eggs during this time.

Winter eggs are laid in moist crevices on the soil surface in batches of about 20–60, usually under vegetation and debris. Females then excrete a fluid substance containing ingested soil and glandular secretions over the eggs. This acts to both camouflage and protect the eggs.

At the onset of warmer and drier conditions, over-summering eggs are produced which are protected from desiccation by a clay cement layer excreted by females. Consequently, lucerne fleas are more common on heavier loam/clay soils and are rarely found on sandy soils. The protective coating also prevents eggs from hatching when rain is insufficient for lucerne flea development or for the establishment of host plants.

7.6.5 Management of lucerne flea

Monitoring

Monitoring is the key to reducing the impact of lucerne flea. Crops and pastures grown in areas where lucerne flea has previously been a problem should be regularly monitored for damage from autumn through to spring. Susceptible crops and pastures should also be carefully inspected for the presence of lucerne fleas and evidence of damage.

It is important to frequently inspect winter crops, particularly canola and pulses, in the first three to five weeks after sowing. Crops are most susceptible to damage immediately following seedling emergence. Pastures should be monitored at least fortnightly from autumn to spring, with weekly monitoring preferred where there have been problems in previous years.

Lucerne fleas are often concentrated in localised patches or 'hot spots' so it is important to have a good spread of monitoring sites within each paddock. Examine foliage for characteristic lucerne flea damage and check the soil surface where insects may be sheltering.

Some sprays require application at a particular growth stage, so it is also important to note the growth stage of the population. Spraying immature lucerne fleas before

28 IPM Guidelines (2016) Lucerne flea. GRDC, http://ipmguidelinesforgrains.com.au/pests/lucerne-flea-in-winter-seedling-crops/

29 IPM Guidelines (2016) Lucerne flea. GRDC, http://ipmguidelinesforgrains.com.au/pests/lucerne-flea-in-winter-seedling-crops/

they have a chance to reproduce can effectively reduce the size of subsequent generations.

Lucerne fleas compete for food and resources with other agricultural pests such as redlegged earth mites and blue oat mites. This means control strategies that only target one species may not reduce the overall pest pressure because other pests can fill the gap. It is therefore important to assess the complex of pests before deciding on the most appropriate control strategy.

Chemical control

Lucerne fleas are commonly controlled post-emergence, usually after damage is first detected. Control is generally achieved with an organophosphate insecticide (e.g. omethoate). In areas where damage is likely, a border spray may be sufficient to stop invasion from neighbouring pastures or crops. In many cases, spot spraying, rather than blanket spraying, may be all that is required.

If the damage warrants control, treat the infested area with a registered chemical approximately three weeks after lucerne fleas have been observed on a newly emerged crop. This will allow for the further hatch of over-summering eggs but will be before the lucerne fleas reach maturity and begin to lay winter eggs.

In pastures, a follow-up spray may be needed roughly four weeks after the first spray to control subsequent hatches, and to kill new insects before they lay more eggs. Grazing the pasture before spraying will help open up the canopy to ensure adequate spray coverage. The second spray is unlikely to be needed if few lucerne fleas are observed at that time.

Crops are most likely to suffer damage where they follow a weedy crop or a pasture in which lucerne flea has not been controlled. As such, lucerne flea control in the season prior to the sowing of susceptible crops is recommended.

Caution is advised when selecting an insecticide. Several chemicals registered for redlegged earth mites (i.e. synthetic pyrethroids such as cypermethrin) are known to be ineffective against lucerne flea. When both lucerne fleas and redlegged earth mites are present, it is recommended that control strategies consider both pests, and a product registered for both is used at the highest directed rate between the two to ensure effective control.

Information on the registration status, rates of application and warnings related to WHP, OH&S, residues and off-target effects should be obtained before making decisions on which insecticide to use. This information is available from the DPI Chemical Standards Branch, chemical resellers, APVMA and the pesticide manufacturer. Always consult the label and MSDS before using any insecticide.

Biological control

Several predatory mites, various ground beetles and spiders prey upon lucerne fleas. Snout mites (which have orange bodies and legs) are particularly effective predators of this pest (Photo 7). The pasture snout mite (*Bdellodes lapidaria*) and the spiny snout mite (*Neomulgus capillatus*) have been the main focus of biological control efforts against lucerne flea.

Photo 7: *Predatory adult snout mite.*

Photo: A Weeks (cesar), AgVic

There are some examples of this mite successfully reducing lucerne flea numbers. Although rarer, the spiny snout mite can also drastically reduce lucerne flea populations, particularly in autumn.

Three species of predatory mites feed on lucerne flea. They include:

- pasture snout mite (*Bdellodes lapidaria*);
- spiny snout mite (*Neomulgus capillatus*); and
- French anystis mite (*Anystis wallacei*) can provide effective suppression of lucerne flea.

Some field experiments indicate a 70–90% control of lucerne fleas by predatory mites. Other reports suggest that predatory mite activity is rarely effective to reduce lucerne flea impact on seedling crops. Predatory mites are slow to spread and can only do so by crawling. Redistribution of predatory mites is possible using suction machines to collect and transfer mites from established to new sites.

Other beneficials include: ground beetles and spiders. [30]

7.7 Cutworms

Cutworms are plump, smooth caterpillars, of several moth species. They feed on all crop and pasture plants, damaging them near the ground. When mature, they pupate in the soil. Cutworm caterpillars grow to about 40 mm long, but they usually cannot be seen as they hide under the soil or litter by day. Often they can be located by scratching the surface near damaged plants where they can be seen curled up in a defensive position.

Caterpillars with a pink tinge belong to the pink cutworm, Agrotis munda, which has caused widespread damage in agricultural areas north of Perth. The dark grey caterpillars of the Bogong moth, *Agrotis infusa*, have been extremely damaging in most parts of the agricultural areas from time to time. Large numbers of patterned caterpillars belonging to different genera, *Rictonis* and *Omphaletis*, have also been found attacking cereals in agricultural areas.

Adult cutworms are stout-bodied moths with patterned wings. They fly very well and may be seen on window panes at night as they are attracted to lights. [31]

Where have they been reported?

In Victoria in 2015, large numbers of cutworms caused extensive damage to a large barley crop north of St. Arnaud in the Wimmera district. The caterpillars chewed seedlings back to ground level, affectively wiping out almost 90% of the paddock. Cutworms were reported attacking a vetch crop near Donald, in the Wimmera. The larvae have completely severed plant stems just above the soil surface, causing significant damage across about 40% of the paddock. Cutworms may also have been responsible for extensive damage to a canola crop near Murtoa, also in the Wimmera district. The crop, which was at the cotyledon stage, experienced significant feeding damage typical of cutworms, with large areas of the paddock requiring re-sowing. Cutworms were also responsible for crop damage around Elmore, in the Northern Country district of Victoria. Several canola paddocks were affected. [32]

7.7.1 Symptoms

What to look for

Insect adult:

- Adult cutworms are stout-bodied moths with patterned wings (Photo 8).

30 IPM Guidelines (2016) Lucerne flea. GRDC, http://ipmguidelinesforgrains.com.au/pests/lucerne-flea-in-winter-seedling-crops/

31 S Micic (2016) Cutworm: pests of crops and pastures. DAFWA, https://www.agric.wa.gov.au/pest-insects/cutworm-pests-crops-and-pastures

32 cesar (2014) Cutworms. PestFacts south-eastern. Issue 3 22 May 2014, http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2014/pestfacts-issue-no-3-22nd-may-2014/cutworms/

Photo 8: *Cutworm moths.*

Source: DAFWA 2013

Insect larvae:

- Caterpillars are up to 50 mm long, hairless with a dark head.
- They vary in colour and can be:
- dark grey to green body often with lines and/or dark spots running along length
- pale grey-green body with a pinkish tinge, often with lines and/or dark spots running along length
- orange-brown body with diagonal markings (Photo 9).

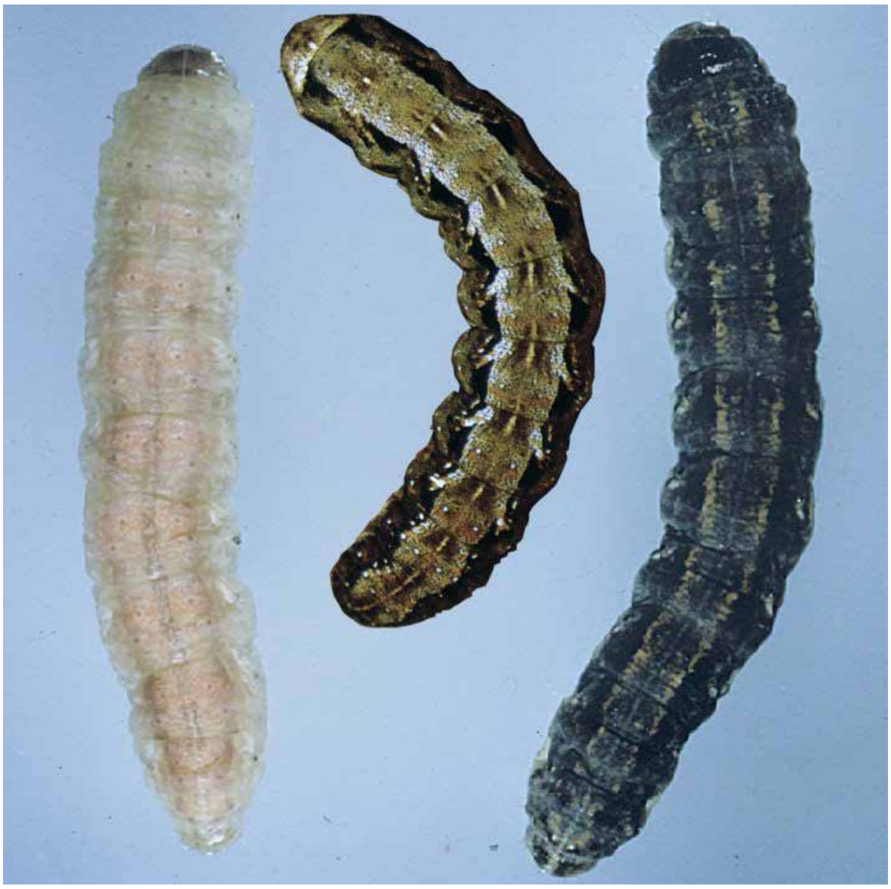


Photo 9: *Larvae of the three main species of cutworm.*

Source: DAFWA 2013

Paddock:

- Commonly patches with plants that have leaves lopped or are cut off at the base (Photo 10).

Photo 10: *Damage often occurs in patches.*

Source: DAFWA 2013

Plant:

- Damage is worst at the seedling stage but can persist for several weeks.
- Larvae hide in the soil during the day, often at the base of lopped plants (Photo 11). [33]

33 DAFWA (2015) Diagnosing cutworm in canola and pulses. https://www.agric.wa.gov.au/mycrop/diagnosing-cutworm-canola-and-pulses

Photo 11: *Lopped lupin and wheat (insert) plants.*

Source: DAFWA 2013

7.7.2 Damaged caused by cutworms:

- Small larvae cause skeletonised or scalloped leaves (damage may be confused with that of lucerne flea or pasture web worm).
- Large larvae sever seedling stems near ground level.
- Large larvae (40–50 mm) are the damaging stage. These larvae may remain below the soil surface feeding on the stem at or below ground level.
- While generally a pest of seedlings (1 to 5 leaf stage), cutworms can occasionally cause damage at tillering and early stem elongation in winter cereals. [34]

Economic and financial considerations

To assist in assessing the economic risk and financial costs associated with various treatment strategies go to MyEconomicTool.

There may be other economic and financial implications that need to be considered when choosing a management option. These may include:

Pre-crop:

- Understand the potential yield losses associated with cutworm feeding damage.
- Assess the costs and benefits of taking preventative action.
- Assess the cost and benefits of controlling summer weeds (green bridge) to reduce potential feed source.

34 IPM Guidelines (2016) Cutworms. GRDC, http://ipmguidelinesforgrains.com.au/pests/soil-insects/cutworms/

In-crop:

- Compare the costs, benefits and risk of each management option against doing nothing or delaying treatment.
- Ignore all previous treatment costs in assessing current management options.
- Undertake a 'what if' scenario analysis to see what impact changing variables, such as grain price and season, have on the net income.

Post-crop:

- Consider using IPM system and include a resistance management strategy into your spray program to reduce the chance of cutworm and other non-target insects becoming resistant. [35]

View these economic considerations in more detail.

7.7.3 Conditions favouring development

Cutworm moths can fly large distances and favour bare or lightly vegetated areas for egg-laying. Moths emerge in late spring or early summer and are often observed entering houses and buildings for shelter over summer. They have one generation per year.

They are most damaging in autumn when large caterpillars (>20 mm) transfer from summer and autumn weeds onto newly emerged crop seedlings.

7.7.4 Thresholds for control

Control is warranted when two larvae per 0.5 metre of crop row are present under visual inspection.

7.7.5 Control

Cutworms are easily controlled by insecticides. They are most damaging in autumn when large caterpillars (>20 mm) transfer from summer and autumn weeds onto newly emerged seedlings.

Monitoring:

- Inspect crops regularly from emergence to establishment. Larvae are active from late afternoon through the night.
- Look for signs of feeding on leaves—if detected, search the soil and stubble in the areas that are damaged, or where the plant stand is thinned.
- Larvae may move into a crop from a neighbouring weedy fallow, particularly as the weeds start to dry off, or are sprayed. Be alert to sources of larvae from outside the field.

Chemical control:

- Treat the crop when seedling loss is nearing minimal plant density crop requirements.
- Treat older plants if more than 50% of plants have 75% or more leaf tissue loss.
- Chemical control is most effective when applied late in the day to maximise likelihood of larvae contacting/ingesting insecticide when they emerge at night to feed.
- Ground-rig applications may provide flexibility to treat just affected areas, or to apply a border spray where larvae are moving into the crop from neighbouring weeds.

Cultural control:

- Control weeds in and around fields prior to planting to reduce potential cutworm infestations.

35 DAFWA (2015) Diagnosing cutworm in canola and pulses. https://www.agric.wa.gov.au/mycrop/diagnosing-cutworm-canola-and-pulses

- Be aware of cutworm movement from sprayed weedy fallow into neighbouring crops.
- Prolonged green feed in autumn allows larvae to develop to a large size by the time crops emerge.
- Aim to control potential hosts at least two weeks prior to planting to ensure larvae do not survive to infest crops.

Biological control

Biological control agents, or beneficials, include fly and wasp parasites, predatory beetles and diseases, continually reduce cutworm numbers but cannot be relied on to give adequate control. Orange and two-toned caterpillar parasites and orchid dupe are key parasitoids. These beneficials may suppress cutworm populations, but are unlikely to prevent crop loss in the event of an outbreak. [36]

7.8 Locusts

Locusts and grasshoppers will cause damage to chickpeas in the same way that they will cause damage to any green material when in plague numbers. Chickpeas may be less vulnerable in the seedling stages than lupins and lentils. However, sheer weight of numbers can lead to significant damage (Photo 12).

Photo 12: *Locust swarms can travel long distances on the wind. Landholders are required to report locust activity.*

Source: Pulse Australia

36 IPM Guidelines (2016) Cutworms. GRDC, http://ipmguidelinesforgrains.com.au/pests/soil-insects/cutworms/

Though locust plagues are infrequent, they can be unpredictable and cause serious damage if not managed.

In spring 2010, Victoria experienced high densities of the pest species Australian plague locust (APL). Swarms across northern Victoria intensified, with swarms reported in the Bordertown-Ouyen, Cullulleraine-Mildura, Sea Lake-Swan Hill and Kerang-Echuca areas (see Figure 9). [37]

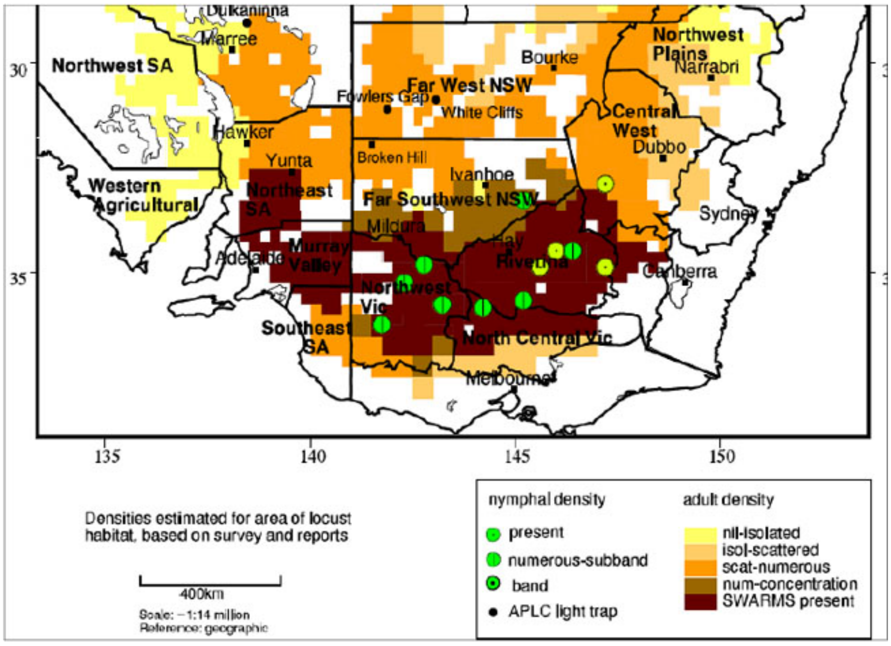


Figure 9: *Locust activity in south-eastern Australia in December 2010. Modified from DAFF (January 2011).*

Source: AgVic

Chortoicetes terminifera is a serious agricultural pest in Australia. An individual locust can consume 30–50% of its body weight daily, and swarms are very dense and highly mobile, migrating up to 700 km in a day. Swarms can be in excess of 50 individuals per square metre, consuming up to 10 tonnes of vegetation per day.

7.8.1 Effect on growing crops

While it is well known that cereals are particularly vulnerable to locusts, the susceptibility of the various pulses is uncertain, but we must assume that they could be attacked while they remain green. It is important to note that:

- Established green crops are susceptible to damage by adult locusts but tend to be avoided by hoppers (immature locusts), although crop edges can be damaged and may warrant a perimeter spray.
- Locusts cause little damage to crops that have dried off, but crops that are beginning to dry down when locusts begin to fly are still susceptible to attack.
- Even slight damage to pulse crops that have a high grain value or are destined for specific export markets could justify the cost of control (Photo 13).
- As a general rule, hopper and adult numbers should be closely monitored, and if any damage is seen, then spraying should be commenced immediately.
- Comply with label directions for the chosen insecticide and pay particular attention to WHP for harvest/windrowing or swathing, and for grazing/fodder. [38]

37 B Gagliardi, S Long, G Rose, L Golding, J Lieschke, T Daw Quadros, L Metzeling, V Pettigrove (2011) Australian plague locust response—Assessment of effects, Agriculture Victoria, Centre for Aquatic Pollution Identification and Management Technical Report #9 December 2011, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/plague-locusts/australian-plague-locust-reponse-assessment-of-effects

38 Pulse Australia (2015) Australian pulse bulletin: Impact of locusts on pulse crops and grain quality. http://pulseaus.com.au/growing-pulses/publications/locust-control

Photo 13: *Locust hatchlings cause the most damage when they form feeding bands that move across the land eating anything that is green.*

Source: Pulse Australia

7.8.2 Locusts can impact pulse deliveries

Key points:

- Locusts pose more than just a physical threat to pulse crop yields and quality.
- Controlling locusts before harvest is imperative to ensure marketable quality grain and to ensure successful delivery.
- Pulse growers need to make contact with their receival agent well in advance of harvest to discuss probable industry attitudes to high locust inclusion in the grain sample.
- Both receival agents and marketers may reject grain with high locust inclusion despite the sample technically meeting the receival standard for field insects.
- Grain staining, slimes and objectionable odours may arise from squashing live locusts during harvest. This material is difficult, if not impossible to remove.
- Objectionable material and odours in the sample will result in the product being rejected at the receival point.
- Only permitted chemicals are to be used for control of locusts.
- Maximum residue limits apply and grain samples may be collected and analysed for compliance with regulatory and market requirements. [39]

MORE INFORMATION

Pulse Australia: Locust can impact on pulse deliveries.

7.8.3 Management of locusts

The decision on how locusts in crops are best managed is affected by a range of factors including:

- Growth stage of the crop, i.e. is there any green plant material or has the crop completely dried off?
- Ability to harvest early—desiccation may be an option to advance harvest.
- Delivery standards required for the specific pulse—discuss requirements with potential buyers.
- Risk to market from pesticide residues—WHP for windrowing/swathing is the same as harvest.
- Ability to clean physical locust contamination from harvested grain.

Control

The most effective and easiest way for landholders to control locusts is by ground spraying the hoppers when they have formed into dense aggregations called bands (Table 5). This normally occurs from 1–2 weeks after hatching. The time available for

39 Pulse Australia (2010) Locusts can impact on pulse deliveries. Australian Pulse Bulletin PA 2010 #12, http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-locust-harvest.pdf

controlling an outbreak is short with hoppers taking about five weeks to develop into swarming adults. Hoppers are most likely to hatch in pasture paddocks and along roadsides, fence lines and non-cultivated ground around the crop perimeter, but some hoppers may hatch from egg beds laid within crops particularly bare areas such as wheel tracks where tram lining is practiced.

Table 5: *Summary of locust insecticide applications in Victoria on public land 2010–2011. 1 SC = suspensible concentrate, 2 ULV = ultra-low volume concentrate.*

Chemicals sprayed	# cases	Area treated (Ha)
Fipronil	30	488
Fenitrothion 1000	55	4,537
Green Guard SC 1	119	1,617
Green Guard ULV 2	5	3,370
Other	1	5
TOTAL	210	10,017

Source: AgVic

It is critical in these situations that the correct insecticide is used to avoid residue issues. Australian grain produce must meet minimum residue levels (MRLs). Individual deliveries of grain will be tested for chemical residues, to detect the use of unapproved pesticides and to ensure that WHPs have been followed.

- Only use an insecticide that is registered or has a permit for locust control in the specific pulse crop.
- Users must obtain, read and adhere to the conditions of APVMA permits prior to use.
- Follow label directions and pay attention to the WHP. Following pesticide application, the relevant withholding period MUST expire BEFORE cutting for hay, windrowing, harvest or undertaking of any similar operation.
- Plan well ahead in choosing the most appropriate product(s) to suit your situation as availability may become an issue as the season progresses.
- Be aware of the receival standards that apply to insect contamination (alive or dead) and grain damage from locust feeding.
- Be aware of nil tolerance for odour and taints that could arise from crushing locusts during harvest, handling or while in storage.
- Avoid inadvertent contamination of grain with other chemicals not used in pulses. [40]

In Victoria, growers are encouraged to report immature or adult locusts to the Victorian DEPI through the Customer Service Centre (136 186) or email plant.protection@depi.vic.gov.au. DEPI is particularly interested to receive any reports of egg-laying. In NSW, reports of egg-laying should be directed to the APLC**.**

MORE INFORMATION

Impact of locusts on pulse crops and grain quality.

Australia Plague Locust Response—Assessment of Effects.

7.9 Native budworm

The native budworm (*Helicoverpa punctigera* or, as it was known, *Heliothis punctigera*) is native to Australia and is distributed, particularly during spring, throughout much of the central and southern regions of the country. Native budworm is a major pest of pulse and canola crops in southern Australia and can develop large populations over extensive areas on native plants. Native budworm breeds over winter in the arid inland regions of South Australia, New South Wales, Queensland and Western Australia on desert plants before migrating into southern agricultural areas in late winter or spring causing damage to crops. They can migrate as far south as Tasmania. Migratory flights are unpredictable, as moths may be carried hundreds of kilometres from breeding areas by high altitude air currents.

40 Pulse Australia (2015) Australian pulse bulletin: Impact of locusts on pulse crops and grain quality. http://pulseaus.com.au/growing-pulses/publications/locust-control

Effective control requires understanding when the crop is at risk and the economic threshold for when to spray. In terms of production losses chickpeas, faba beans, tomatoes, field peas, lentils, lupins, canola and lucerne are important hosts. [41]

Unlike other parts of Australia or overseas where *Helicoverpa armigera* is abundant (the cotton bollworm or corn earworm), the control of native budworm poses no great problem in southern winter-growing areas of Australia. There is no known resistance to chemicals, and temperatures during the growing season do not allow a high level of activity until the crop is podding.

Lifecycles of *Helicoverpa* spp takes 4–6 weeks from egg to adult in summer and 8–12 weeks in spring or autumn. The lifecycle stages are egg, larvae, pupa and adult (moth) (Figure 10).

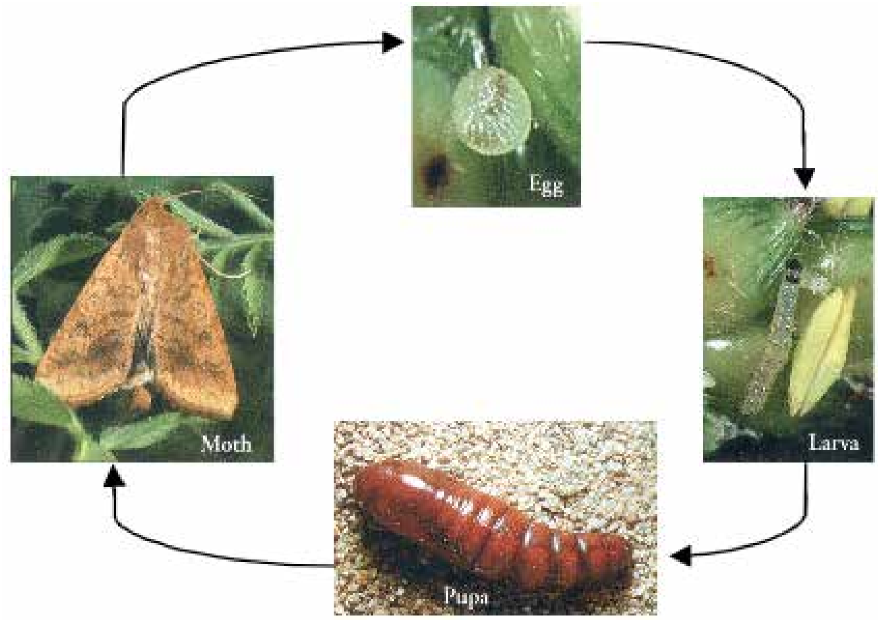


Figure 10: *Lifecycle of Helicoverpa.*

Source: Pulse Australia

Eggs

Budworm eggs can be found singly on the growing tips and buds of plants. They are small (about 0.5 mm in diameter) but quite visible to the naked eye after close inspection of the plant. Moths can lay up to 1,000 white spherical eggs mostly found near the top of the plant. They are white when first laid but they change colour to yellow and brown as they get closer to hatching, with larvae emerging in 7–14 days (Photo 14).

41 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

Photo 14: *Left to right: fresh white, brown ring and black larval head in nearly hatching eggs.*

Source: DAFF.

Larvae/caterpillars

The newly hatched caterpillars (larvae) are very small and are often easily missed when inspecting a crop. When first hatched, they are about 1.5 mm long with dark brown heads and white bodies. The young caterpillars feed on leaf or pod material for about two weeks before they become large enough (5 mm long) to be noticed in the crop.

It takes a further four weeks until they are fully grown (40 mm long), which is about seven weeks from the time of egg-laying.

These development times are based on average spring temperatures when caterpillars are active in central cropping areas of Western Australia. Later in the season, or in more northerly areas, developmental rates for caterpillars will be faster.

The caterpillars vary greatly in colour from green through orange to dark brown and are often seen with their heads inside pods. They usually have dark stripes along the body and are sparsely covered with fine bristles. [42]

During full development they will pass through six or seven growth stages or instars, until they are 35–40 mm long (Figure 11). When fully grown, their colour ranges from green, yellow, buff, red or brown to almost black, with a broad yellow-white stripe down each side of the body and a dark stripe down the centre of the back. The skin of the caterpillars appears rough to touch, due to long, dark hairs on prominent bumps on the body surface (Figures 12 and 13). New moth flights and egg-laying will result in caterpillars of varying sizes in a crop. Caterpillars eat increasing quantities of seed and plant material as they grow with the last two growths stages (fifth and sixth instar) responsible for eating over 90% of their total grain consumption.

42 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

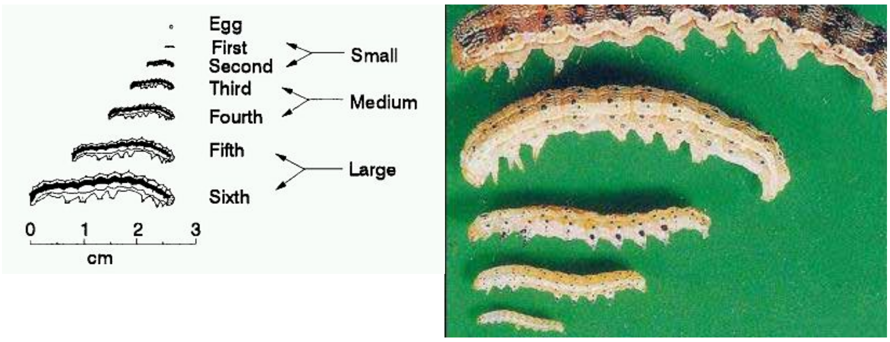


Figure 11: *Approximate instar sizes of the budworm.*

Source: Agriculture Victoria, DAFWA

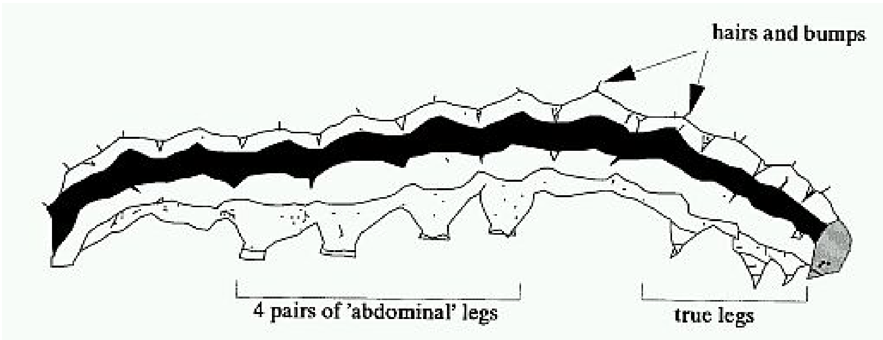


Figure 12: *Distinguishable features of native budworm larva.*

Source: Agriculture Victoria

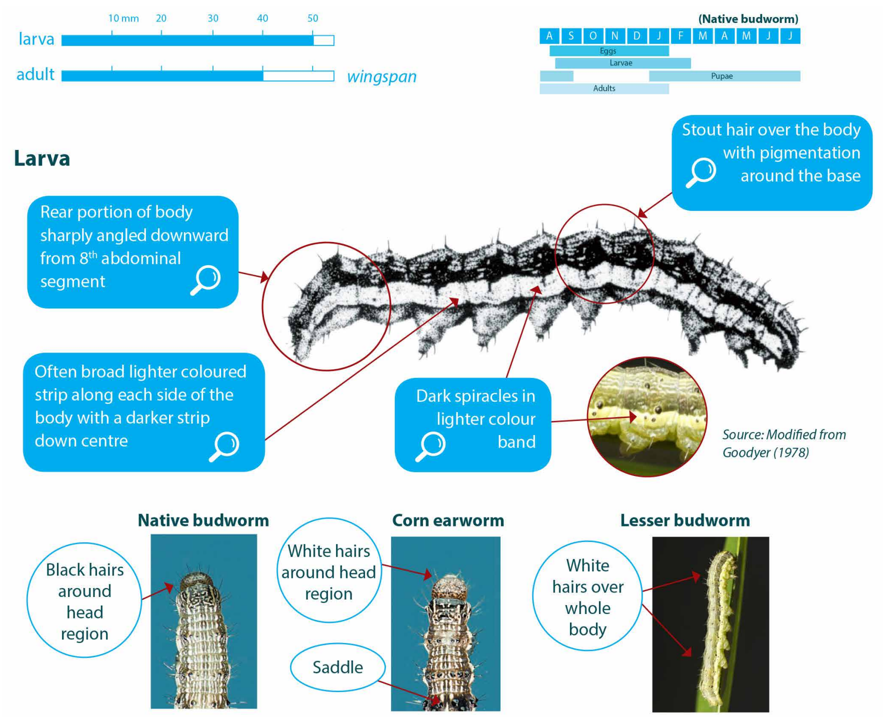


Figure 13: *Distinguishing characteristics/description of native budworm.*

Source: Bellati *et al.* 2012 in cesar

Pupa

When fully mature, the caterpillars crawl to the ground, burrow from 20–150 mm in depth into the soil and pupate. Pupae are cigar-shaped, 12–22 mm long, and during development change in colour from a yellow-orange to a shiny dark brown. The length of the pupal stage depends on several environmental factors and varies from two weeks to several months.

Adult

Adult moths are medium sized (wingspan 30–40 mm) and stout bodied (Photos 15 and 16). The forewings are buff-olive to red-brown with numerous dark spots and blotches. The hind wings are pale grey with dark veins and a dark band along the lower edge. Moths are usually active during the evening and night. Moths can be seen in crops by their rapid, low-level flight that takes a zigzag path then diving into a crop to lay eggs.

Photo 15: *Native budworm larvae showing prominent hairs (left) and buff coloured adult (right).*

Source: cesar

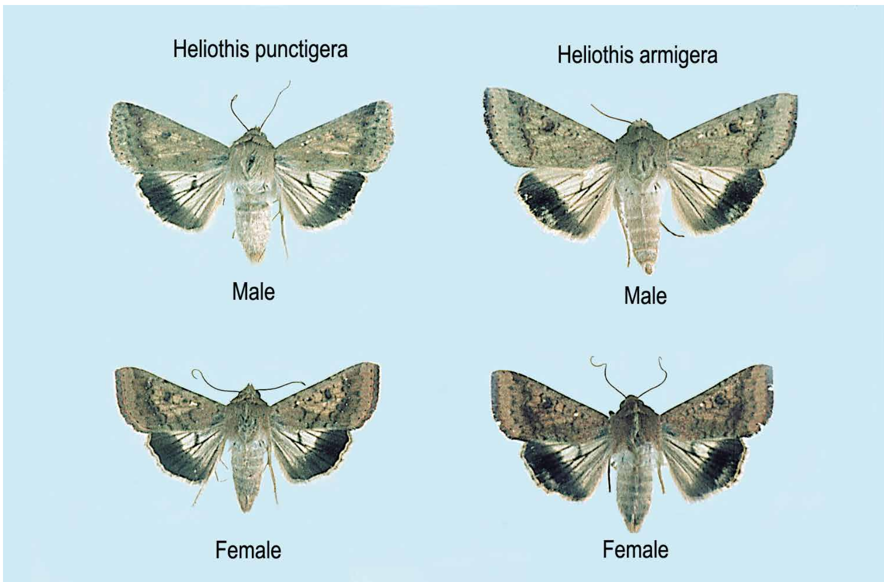


Photo 16: *Helicoverpa punctigera male (top left) and female (bottom left) compared to Helicoverpa armigera male (top right) and female (bottom right). Both male and female Helicoverpa armigera have a white patch on their hindwings.*

Source: GRDC

Mortality of eggs and caterpillars

Only a small proportion of eggs laid by moths survive to the damaging large caterpillar stage. There is a high death rate in the egg and small caterpillar stages. Eggs may be dislodged and small caterpillars may become stuck or drown due to wet weather.

Predators and parasitoids also affect population numbers and can suppress them below economic damage thresholds. If numbers of native budworm are high, populations can crash due to viruses and disease. [43]

7.9.1 Varietal resistance or tolerance

Crops vary in their attractiveness to moths as sites for egg-laying. Crop density and crop growth stage (flowering and podding) will affect the number of eggs laid by the native budworm moths. The feeding behaviour of caterpillars also changes according to the type of crop the caterpillars are feeding upon.

Chickpea, field pea, lentil and faba bean crops:

- These crops are very susceptible to all sizes of caterpillars during the formation and development of pods.
- Tiny caterpillars can enter emerging pods and damage developing seed or devour the entire contents of the pod.

7.9.2 Damage caused by pest

Native budworm caterpillars most frequently attack the fruiting parts of plants (Photo 17) but also feed on the terminal growth, flowers and leaves. All pulse crops grown in southern Australia are susceptible to attack, especially when pods are present. This includes chickpea, field pea, faba bean, lentil, lupin and canola. Direct losses are usually associated with yield through grain being wholly or partially consumed by the caterpillar. However indirect losses from quality issues can result in downgrading or even rejection from high levels of damaged grain, weathering or fungal infections from holes in pods, discolouration or odour. [44] A single caterpillar can attack four to five pods before reaching maturity and will feed in crops for four to six weeks.

Photo 17: *Large Helicoverpa larva feeding on a chickpea pod.*

43 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

44 T Bray (2010) Managing native budworm in pulse crops. Pulse Australia, Southern Pulse Bulletin PA 2010 #18, http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Pulses-native-budworm.pdf

Cost of native budworm

Losses attributed to native budworm come from direct weight loss through seeds being wholly or partly eaten. Grain quality may also be downgraded through unacceptable levels of chewed grain or fungal infections introduced via caterpillar entry into pods. The percentage of broken, chewed and defective seed found in grain samples affects the final price of pulse crops marketed for human consumption. This applies particularly to the large-seeded crops such as kabuli chickpea, faba bean, lentil and field pea. [45]

7.9.3 Conditions favouring development

Native budworm is the major pest of grain legumes in spring (Table 6). At this time of year, the adult moths fly from inland breeding areas, on weather systems, and lay eggs in pulse and canola crops. Early spring is the time when grain growers should be checking all pulse and canola crops for native budworm eggs and larvae as crops reach the susceptible flowering and podding stages.

Table 6: *Conditions leading to risk of damage and loss from native budworm in chickpeas.*

High risk	Moderate risk	Low risk
Wet winters in breeding areas of central Australia + suitable weather conditions that bring moths from the north on northerly winds, resulting in spring migrations. Repeated influxes of moths over long periods, resulting in need for continuous monitoring and potentially repeat infestations.	Broadleaf weeds hosting cutworm and Helicoverpa that move into the crop as large, damaging larvae. Hot weather in spring can cause small larvae to burrow into pods. Wet harvest weather resulting in pods that are 'softer' for longer and susceptible to damage right up to harvest.	Dry winters in breeding areas. Low source population. Absence of frontal wind systems that provide opportunities for migration.

Source: IPM Guidelines

Species composition in the crop will be influenced by a number of factors, such as:

- Winter rainfall in inland Australia, which drives populations of *H. punctigera*, and the occurrence and timing of wind systems that carry *H. punctigera*.
- Relative timing of flowering–podding (attractive and susceptible) stages and the immigration of *H. punctigera* and emergence of *H. armigera* from overwintering diapause.
- Geographic location. In temperate regions, most of the *H. armigera* population overwinters from mid-March onwards and emerges during September–October. *Helicoverpa punctigera* is usually the dominant species through September when moths are migrating into eastern cropping regions. Seasonal variation can lead to *H. armigera*-dominant early infestations in some years. [46]

Native budworm breeds during winter in the semi-arid regions of Australia and moths can often migrate long distances in early spring into the southern agricultural districts. Adults are nocturnal and often seen around lights at night which can be an indicator of their arrival.

Crop types can vary in attractiveness to moths for egg-laying and as a general rule lentils are the most attractive followed by field pea, vetch, faba bean, chickpea, and lupin. Crop health, density and growth stages (flowering and podding) will generally affect the number of eggs laid with moths mostly preferring the more advanced

45 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

46 M Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

dense and succulent areas. Feeding behaviour of caterpillars also changes according to the pulse type with field pea, chickpea, lentil and faba bean crops being more susceptible to all sizes of caterpillars during pod formation and development. [47]

7.9.4 Thresholds for control

Thresholds depend on crop value, cost of control and tolerance of feeding damage. Suggested thresholds (check 5–10 sites) are:

- chickpeas (kabuli): 2–3 larvae in 10 sweeps
- chickpea (Desi type): 5 larvae in 10 sweeps

Threshold tables

The losses given (Table 6) are for the number of caterpillars netted in crops during early pod formation for all crops except lupins and canola. For these canola and lupins numbers are during pod maturation.

To use the table you need to substitute:

- control costs with your own actual costs
- expected grain price per hectare based

This will calculate the economic threshold or the number of caterpillars that will cause more financial loss than the cost of spraying (e.g. Table 7).

Table 7: *Example to calculate the economic threshold or the number of caterpillars that will cause more financial loss than the cost of spraying.*

The on-farm value of field peas is $185 per tonne (t)
The cost of control is $12 per hectare (ha)

ET = C ÷ (K x P)
Where:
ET = Economic threshold (numbers of grubs in 10 sweeps)
C = Control cost (includes price of chemical + application) ($ per ha)
K = Kilogram per hectare (ha) eaten for every one caterpillar netted in 10 sweeps or per square metre (see Table 2)
P = Price of grain per kg (price per tonne ÷ 1000)

Therefore economic threshold for field pea = 12 ÷ (50 x (185 ÷ 1000)) = 1.3 grubs per 10 sweeps

Source: DAFWA

Table 8: *Economic thresholds (ET) for native budworm on chickpeas.*

P Grain price per tonne	C Control costs including chemical + application	K Loss for each grub in 10 sweeps (kg/ha/grub)	ET Grubs in 10 sweeps	ET Grubs in 5 lots of 10 sweeps	ET Grubs (>15 mm) per m^2
420	10	30	0.8	4	-

Note: Growers using this table to calculate spray thresholds should substitute their own control costs and the current on-farm grain price expected.

Source: DAFWA

Where:

ET = Economic threshold (numbers of grubs in 10 sweeps)
C = Control cost (includes price of chemical + application) ($ per ha)
K = Kilogram per hectare (ha) eaten for every one caterpillar netted in 10 sweeps or

47 T Bray (2010) Managing native budworm in pulse crops. Pulse Australia, Southern Pulse Bulletin PA 2010 #18, http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Pulses-native-budworm.pdf

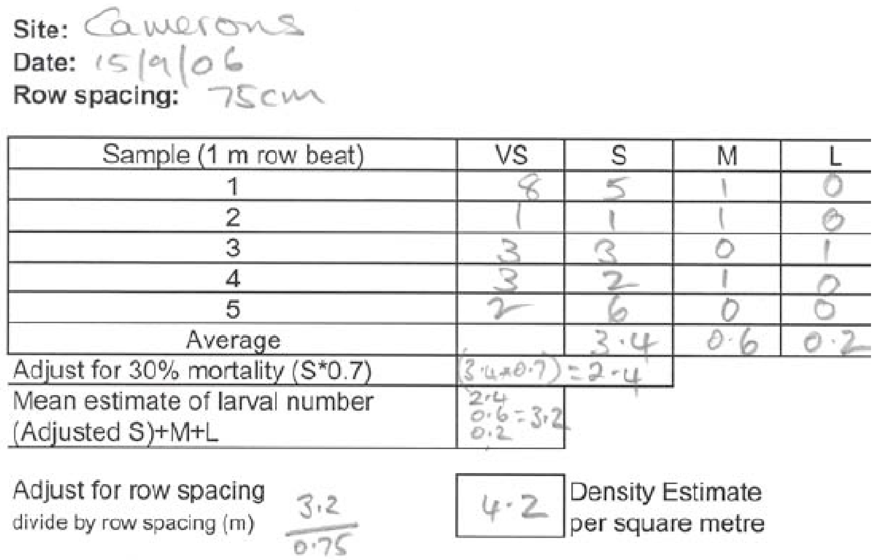
per square metre
P = Price of grain per kg (price per tonne ÷ 1000).

The ready-reckoner table (Table 9) shows data for a range of larval densities, and crop prices. Putting a dollar value on the predicted yield loss if nothing is done to control the *Helicoverpa* infestation is a useful way to assess the economic benefit (or otherwise) of spraying.

Table 9: *The value of yield loss ($/ha) caused by Helicoverpa larvae in chickpea for a range of larval densities (determined by beat sheet sampling) and grain prices. NOTE: Control is warranted if the cost of control is less than the value of the yield loss predicted.* [48]

Chickpea price ($/t)	Value of yield loss ($/ha)				
	1 larva/m^2	2 larva/m^2	3 larva/m^2	4 larva/m^2	5 larva/m^2
200	4	8	12	16	20
300	6	12	18	24	30
400	8	16	24	32	40
500	10	20	30	40	50
600	12	24	36	48	60

In Figure 14, the field has an average of 4.2 larvae per m^2 (adjusted for mortality of small larvae). Assuming a chickpea price of $400/t, the table of potential yield loss (refer to Table 5) shows the cost of not controlling to be $32/ha. In this example, if the cost of control is less than $32/ha then it is economic to spray.


Site: Camerons
Date: 15/9/06
Row spacing: 75cm

Sample (1 m row beat)	VS	S	M	L
1	8	5	1	0
2	1	1	1	0
3	3	3	0	1
4	3	2	1	0
5	2	6	0	0
Average		3.4	0.6	0.2
Adjust for 30% mortality (S*0.7)	(3.4×0.7)=2.4			
Mean estimate of larval number (Adjusted S)+M+L	2.4 0.6 0.2 = 3.2			

Adjust for row spacing divide by row spacing (m): 3.2 / 0.75
4.2 Density Estimate per square metre

Figure 14: *Example of a field check sheet with sampling data recorded for Helicoverpa larvae in chickpea.*

Source: DAFF

Adjusting thresholds

Use of the table and calculations will provide a personalised and more precise measure of potential loss from native budworm damage. Sometimes the loss would turn out to be less than predicted, if, for example, the season is shortened by a lack of moisture.

48 M Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

Premiums paid for exceeding quality standards for high value and large-seeded pulses (like kabuli chickpea) may necessitate even lower thresholds than those provided in the table. [49]

7.9.5 Making a decision to control

Several factors (in addition to number of larvae) will influence a decision on whether to spray, timing and product choice:

- Age structure of the larval population may need to be considered in relation to time to desiccation or harvest. For example, a late egg-lay is unlikely to result in economic damage if the crop is 7–10 days away from harvest.
- Proportions of *H. punctigera* making up the total population are important and can be determined by visual identification, time of year, pheromone trap catches and local experience.
- Spray conditions and drift risk must be considered.
- Information on insecticide options, resistance levels for *Helicoverpa* and recent spray results in the local area should be sought.
- Residual of the products may have implications.

Selecting control options

We depend on insecticides for the management of *Helicoverpa* in chickpeas, and the high usage of a limited group of compounds against successive pest generations imposes severe selection pressure. Invariably, selection is for individuals in a population that are not killed by normal application rates of insecticides. With continued insecticide application, the frequency of resistant individuals in the population increases, leading to field-control failures.

The potential for natural enemies of *Helicoverpa* (predators, pathogens and parasitoids) to limit the development of damaging populations of larvae, while typically low in chickpeas, may also influence product selection.

'Spray small or spray fail'

Spraying should be carried out promptly once the threshold has been exceeded. Insects grow rapidly under warm spring conditions, and a few days' delay in spraying can result in major crop damage and increased difficulty in control..

If a spray application is delayed for more than 2 days, for any reason, the crop should be rechecked and reassessed before any control action is implemented. [50]

7.9.6 Management of Helicoverpa

Monitoring

All crops should be scouted weekly during flowering for moth activity and eggs, then at least two times per week during pod-fill for eggs and larvae. The main egg-laying period is often around the flowering period when moths can be quite abundant. Eggs can often be found on the vegetative or floral growing points, new leaves, stems, flowers, flower buds and young pods. They may not be obvious to the untrained eye unless there is a heavy egg-lay or until small larvae can be found. [51]

Light traps and pheromone traps can indicate presence of adults in spring. Monitor crops 1–2 weekly until pod-set, then increase frequency when moths and/or larvae are detected.

49 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

50 M Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

51 Bray T (2010) Managing native budworm in pulse crops. Pulse Australia, Southern Pulse Bulletin PA 2010 #18, http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Pulses-native-budworm.pdf

- Use beat sheet (wide rows), sweep net (narrow rows) and/or visual sampling (Photo 18). Where border sprays were used to control pea weevil, start sampling well into the crop.
- Look for eggs—on leaves, buds and flowers. Start looking for eggs mid-August or when the crops start flowering and moths are detected.
- Repeat sampling at 5–10 sites across the field—more sites give greater level of confidence.
- Assess pod burrowing by looking for holes and splitting open 20–40 pods and look for larval damage.
- Record number, sizes, and crop development stage. Record /m^2 to compare numbers with appropriate thresholds. In southern grain regions, average number of caterpillars per 10 sweeps of an insect sweep net is the standard for comparison and thresholds.

The quickest and easiest method to sample most crops is to sweep with an insect net, taking 2 m long sweeping arcs, using the standard net size (380 mm diameter).

Multiples of 10 sweeps should be taken in several parts of the crop. If more than 10 consecutive sweeps are made, there are likely to be too many dead flowers and leaves in the sample to locate the small caterpillars easily.

Netting is most efficient in short and thin crops and less efficient in tall dense crops. It is very important to keep the lower leading edge of the sweep net slightly forward of the net opening so that dislodged grubs are picked up and carried into the net.

Photo 18: *Sweep-netting a chickpea crop (left) and use of a beat sheet (right).*

Source: DAFWA and The Beatsheet

In years of large moth influxes or wet springs where crops continue to flower/pod, monitoring should continue until pods are dry and no longer able to be penetrated by larvae.

How to use a beat sheet

Place the beat sheet with one edge at the base of a row. On 1-m row spacing, spread the sheet out across the inter-row space and up against the base of the next row. Draping over the adjacent row may be useful for row spacing <1 m, or where there is canopy closure. It also minimises the chance of larvae being thrown off the far side of the sheet. With a 1-m-long stick (dowel, heavy conduit), shake the row vigorously 10 times to dislodge larvae from the plants. Measure and count larvae on the sheet. A standard beat sheet is made from plastic or tarpaulin material with heavy dowel on each end to weigh down the sheet. The beat sheet is typically 1.3 m wide by 1.5 m long. The extra 0.15 m on each side catches insects thrown out sideways.

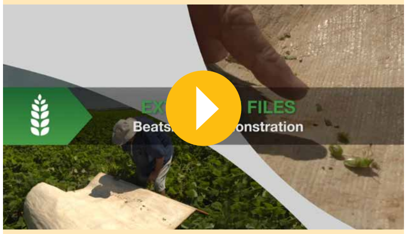
Using a sweep net to monitor Helicoverpa

A standard sweep net has a cloth bag and an aluminium handle. With heavy use, the aluminium handle can shear off; more robust, wooden handles are often fitted by agronomists.

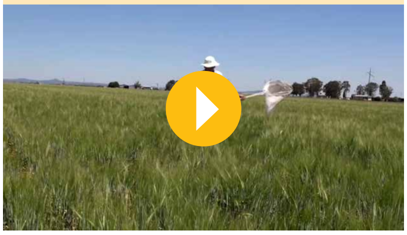
Where crops are sown on narrow row spacings and it is not possible to get a beat sheet between the rows, a sweep net can be used to sample *Helicoverpa*. Hold the sweep net handle in both hands and sweep it across in front of your body in a 180° arc. Take a step with each sweep. Keep the head of the net upright so the bottom

VIDEOS

3. GCTV16: Extension files – IPM Beatsheet Demo.



4. How to use a sweep net to sample for insect pests.



of the hoop travels through the canopy. Use sufficient force in the sweep to pass the hoop through the canopy and dislodge larvae. Take 10 sweeps and then stop and check the net for larvae. Record the number and size of larvae in each set of 10 sweeps. Repeat at additional sites across the field. [52]

Monitoring for adult moths

Male moths are easily captured in pheromone (female sex scent) traps. Pheromone traps can provide an indication of the species presence in a region but are not a reliable predictor of actual egg-lay or grub numbers within a crop (Photo 19).

Photo 19: *Pheromone trap used for detecting moths.*

Source: Pulse Australia

Pheromone trap catches—data updates

Stay up to date with native budworm numbers in your local areas. Weekly trap catch data for *H. punctigera* and *H. armigera* from locations across all states can now be viewed online. The adjustable bar below the map allows selection of a time period (1 wk, 2 wks, 1 mth etc.). [53]

Recording of monitoring data for decision-making

Keeping records should be a routine part of insect checking. Successive records of crop inspections will show whether pest numbers are increasing or decreasing, and will help in deciding whether a control is necessary.

Records of insect checking should include as a minimum:

- date and time of day
- crop growth stage
- average number of pests detected, and their stage of development
- checking method used and number of samples taken

52 M Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

53 The Beatsheet. https://jamesmaino.shinyapps.io/MothTrapVis/

- management recommendation (economic threshold calculation)
- post-spray counts

The *Helicoverpa* size chart (Table 10) is an essential reference for decision-making, particularly in chickpea where larval size is taken into account in the economic threshold (beat sheet threshold), and is important in ensuring that any control action is well targeted against susceptible larvae.

Eggs and very small larvae are not included in the economic threshold for *Helicoverpa* (beat sheet threshold) due to high natural mortality.

Table 10: *Helicoverpa larval size categories and actual sizes.*

Helicoverpa larval size categories and actual sizes		
Actual larval size	**Larval length (mm)**	**Size category**
	1-2 mm	very small
	4-7	small
	8-23	medium
	24-30+	large

Source: IPM Guidelines for Chickpeas

Chemical control

Key points:

- Aim to control larvae before they enter the protection of pods (Photo 20)—target small larvae <7 mm.
- Synthetic pyrethroids are very effective but their broad-spectrum activity has a negative impact on any beneficial insects present.
- Commercially available NPV gives up to 80% control in chickpeas.
- Bt is effective against *Helicoverpa*.
- There is usually a range of rates on the insecticide label to allow for varying conditions such as the size of the caterpillars. The choice of rate should not be solely driven by the lowest price. Also consider impact of chemical use on other pests and beneficial species.
- Inspect crops after spraying to ensure chemical applications have been effective and to detect further infestations until the crop is no longer susceptible. [54]

54 IPM Guidelines (2016) Native budworm in winter pulses. GRDC, http://ipmguidelinesforgrains.com.au/pests/helicoverpa/native-budworm-in-winter-pulses/

Photo 20: *Helicoverpa entering a chickpea pod.*

Source: Pulse Australia

The decision to spray for chickpea needs to be considered from the time of first podding.

If caterpillar numbers are below the threshold levels provided, the decision to spray should be delayed and periodic sampling continued. One well-timed spray to control native budworm caterpillars should be sufficient in most situations.

Sweep netting of the crop should be carried out after spraying to confirm that the required level of control has been obtained. Effectively applied synthetic pyrethroids will prevent reinfestation for up to six weeks after spraying. Subsequent caterpillar hatchings will usually be too late to cause any damage. [55]

One well-timed spray with a synthetic pyrethroid should provide good control of larvae and prevent reinfestation for up to six weeks. Synthetic pyrethroid insecticides are very effective but their broad-spectrum activity impacts negatively on beneficial insects.

Refer to the beneficial impact table for more information.

Most insecticides used for budworm control are contact chemicals and therefore it is important to have complete coverage of the target. A medium spray quality is necessary as they are light and will flow around with the airstream, particularly at low airflow rates and increase the chance of striking the target inside the canopy.

They are however more subject to off-target drift when conditions are not ideal and air induction/inclusion or venturi nozzles are becoming more popular to achieve more uniform droplet size at low pressures. Most insecticide spraying should be at less than 210 µm (microns) VMD (volume mean diameter, i.e. 50% of droplets >2 10µm, and 50% of droplets <210 µm). This is generally finer than for most herbicides and labels will sometimes specify a droplet range along with water volumes. [56]

There are several insecticides registered for the control of native budworm. Timing and coverage are both critical to achieving good control. Try to target small larvae up to 7 mm in length and apply insecticides before larvae move into flowering pods.

55 P Mangano, S Micic (2016) Management and economic thresholds for native budworm. DAFWA, https://www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

56 Bray T (2010) Managing native budworm in pulse crops. Pulse Australia, Southern Pulse Bulletin PA 2010 #18, http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Pulses-native-budworm.pdf

IPM options include the use of Bt (*Bacillus thuringiensis*) and Nuclear polyhedrosis virus (NPV) based biological insecticides. Small larvae are generally easier to control because they are more susceptible to insecticides, and leaf feeding makes them susceptible to ingestion of active residues on the plant surface. Larvae entrenched in buds and pods will be more difficult to control and chemical residual will be important in contacting them.

The crop should be re-inspected 2–4 days after spraying to ensure enough caterpillars have been killed to prevent future damage and economic loss. In years of very high moth activity and extended egg lays, a second spray may be required. [57] Remember that larger larvae will often burrow into pods and control becomes more difficult being shielded from the spray and more likely to survive.

Be aware of insecticide withholding periods (WHP) close to harvest and remember that windrowing is classified as harvest.

Many traditional pyrethroid insecticides (e.g. alpha-cypermethrin) have a 21-day WHP in canola; however there are newer generation pyrethroids available (e.g. Trojan® or Karate®) with a shorter 7-day WHP. [58]

Biological control

A key component to any IPM is to maximise the number of beneficial organisms and incorporate management strategies that reduce the need for pesticides. Correct identification and monitoring is the key when checking for build-up or decline in beneficials. There are many natural enemies that attack native budworm. The egg stage is susceptible to the parasite Trichogramma ivalae, a minute wasp that has been recorded in up to 60% of eggs along with egg predators such as ladybird beetles, lacewings and spiders. Beneficials attacking larvae include shield bugs, damsel bugs, assassin bugs, tachinid flies (their larvae prey on caterpillars), orange caterpillar parasite, two-toned caterpillar parasite, orchid dupe, lacewings and spiders. Naturally occurring fungal diseases and viruses also play an important role in some seasons.

Beneficials:

- Be aware of key beneficials before larvae infest the crop.
- *Trichogramma* wasps parasitise *Helicoverpa* eggs and *Microplitis*, *Heteropelma*, *Netelia* sp. and other wasps parasitise *Helicoverpa* larvae.
- Predatory bugs such as *Geocorris* and *Nabis* prey on eggs and small larvae while *Cermatulus* and *Oechalia* also attack larger larvae.
- Ants and spiders also eat *Helicoverpa* eggs and larvae.
- NPV is a virus which only infects *Helicoverpa* species. This occurs naturally but can also be applied—see chemical control. [59]

7.9.7 Management nearing desiccation and harvest

Hot, dry weather will rapidly advance a chickpea crop (Photo 21) which means that very small and small larvae are unlikely to survive on leaves of rapidly deteriorating quality. As the pods dry they also become more resistant to damage by small to medium larvae. In summary, this means that the major source of damage in a senescing crop is late and by medium and large larvae.

57 G McDonald (2015) Native budworm. cesar February 2015, http://www.cesaraustralia.com/sustainable-agriculture/pestnotes/insect/Native-budworm

58 GRDC (2014) Budworm in Western Australia. https://grdc.com.au/Media-Centre/Hot-Topics/Budworm-in-Western-Australia

59 IPM Guidelines (2016) Native budworm in winter pulses. GRDC, http://ipmguidelinesforgrains.com.au/pests/helicoverpa/native-budworm-in-winter-pulses/

Photo 21: *Chickpea crop nearing desiccation and harvest.*

Source: The Beatsheet

Therefore, the recommended approach to managing *Helicoverpa* populations in the later stages of a chickpea crop is to continue to monitor both number and size of larvae. If the population of medium and large larvae exceeds the economic threshold, AND the crop is still susceptible then treatment may be warranted.

At this stage of the crop, a wait and see approach (continue checking the crop 1–2 times a week) to is recommended principally because it is difficult to predict a week or two ahead how fast a crop will dry down, and what the *Helicoverpa* population will be while the crop is still susceptible. The alternative approach is to treat above threshold populations of small larvae when they are detected. This approach is likely to result in treatment of fields that subsequently would not have been at risk of damage, particularly if the crop dries faster, or larval mortality is higher than expected.

The options available for the treatment of *Helicoverpa* infestations late are limited because of WHP. Methomyl has a 1 day WHP while thiodicarb has a 21 day WHP. Indoxacarb (Steward™) has a 21 day WHP, but no more than one application is permitted per crop growth cycle. Check with others in your local area on their experience with the efficacy of options when making a choice. [60]

7.9.8 Broader management considerations

Close monitoring can pay off. In many cases, the larval infestation may not progress past the 'small' stage, and therefore, control is unwarranted. Regular close checking, and reference to records from successive checks, will enable you to determine larval survival.

Aim for one well-timed spray. Chickpea can tolerate moderate to high numbers of *Helicoverpa* larvae (10–20 larvae/m^2) through late-vegetative and early-flowering growth stages. However, agronomists may suggest that numbers this high during flowering would warrant immediate spraying. Even with mortality, an economic threshold may be exceeded as soon as pod-set begins. This situation potentially leads to high numbers of advanced stage larvae, resulting in more costly and less reliable control.

60 The Beatsheet (2008) Managing Helicoverpa larvae in chickpea crops close to desiccation and harvest. The Beatsheet 05 November 2008, http://thebeatsheet.com.au/managing-helicoverpa-larvae-in-chickpea-crops-close-to-dessication-and-harvest/

Most yield loss will be sustained from damage caused during pod-fill, and this is the most critical stage for crop protection. Larval infestations are likely to be of mixed ages by the time the crop is well into podding. Products such as Steward™ and Larvin® will adequately control a wide range of larval sizes, and offer around 10–14 days of residual protection if applied to plants that are not actively growing. [61]

7.9.9 Native budworm in failed chickpea crop—subsequent threats

Helicoverpa larvae surviving in failed chickpea crops may be a threat to the following crop. With some chickpea crops being sprayed out, rather than harvested, there are reports of *Helicoverpa* larvae surviving on crop residues. The survival of larvae, particularly large late instar larvae, poses a threat to subsequent crops.

Larvae will persist in what may appear to be dead chickpea plants, surviving by feeding on the stems, or any other green bits that may take longer to dry down. Clearly, cool wet weather will slow the rate of crop dry down, and may allow the larvae to survive longer. Emerging seedlings are very susceptible to *Helicoverpa* feeding.

While the use of herbicides is not recommended for the control of insect pests, herbicides may have some impact on *Helicoverpa* larvae. In the late 1990s, it was observed that Sprayseed® applied to finish off chickpea trap crops also killed *Helicoverpa* larvae, but such observations need to be confirmed with further data. There are no observations on the impact of other herbicides on *Helicoverpa*, so it remains important to check the crop residues. Please report any suspected larval deaths (due to herbicides) to the Beatsheet.

If the chickpea field is going into fallow, or not being planted immediately, the larvae will likely starve to death, or complete their development and pupate. [62]

7.9.10 Checking compatibility of products used in mixtures

With the fungicide spray programs recommended for Ascochyta blight control, mixing of fungicides with insecticides is becoming more common. However, some product formulations are NOT compatible with available fungicides.

Check compatibility of potential mixing partners before recommending and applying.

Always read the label supplied with each product before use.

Compatibility of insecticides with mancozeb formulations

It is the responsibility of the agronomist ultimately to ensure that any recommendation is safe for the crop.

Table 11 outlines some considerations when using chlorothalonil within 10 days of an insecticide application. These lists are by no means exhaustive and have been compiled using current, available data from the chemical.

Always check with individual companies and read product labels for specific information.

Note that formulations can vary between companies or they may be changed without notice. Compatibilities provided are a guide only and should be followed up with companies if problems occur.

Always read the label supplied with the product before each use.

61 M Miles (2013) Chickpea insect pest management. Department of Agriculture, Fisheries and Forestry, Queensland, http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

62 The Beatsheet (2010) Helicoverpa larvae surviving in failed chickpea crops may be a threat to the following crop. The Beatsheet 08 November 2010, http://thebeatsheet.com.au/helicoverpa-larvae-surviving-in-failed-chickpea-crops-may-be-a-threat-to-the-following-crop/

Always ensure that a product (or mixture) is safe for the crop before recommending and applying. [63]

Table 11: *Compatibilities of various insecticides with chlorothalonil.*

Product	Chlorothalonil compatibility	Considerations
Steward™ (indoxacarb)	Yes. Widely used with chlorothalonil and no know compatibility issues	
Oil-based emulsifiable or flowable pesticides	Some incompatibilities. The excerpt (right) is from the Crop Care Barrack 720 label. Also see labels of other chlorothalonil products available under permit.	DO NOT tank mix Crop Care Barrack 720 with EC formulations when spraying after shuck fall. COMPATIBILITY: This product is compatible with wettable powderformulations of the most commonly used fungicides, insectcdes and miticides. Do not combine with oil-based emulsifiable or flowable pesticides, unless prior experience has shown the combination to be physically compatible and non-injurous to your crop. This product should not be mixed with spraying oils or sprayed on to crops that have been sprayed with oil for at least 10 days after the oil spray. Oils should not be sprayed on crops treated with this product for at least 10 days after the last spray. Wetting agents have not improved performance. Under some conditions, certain surfactants may cause injury.

Source: compiled with the assistance of Bayer CropScience, Sumitomo Chemical Australia, DuPont, Crop Care Australasia and Infopest

7.9.11 Post-spray assessments

After applying a spray to control a pest infestation, a post-spray assessment or follow-up check is essential to ensure that pest numbers were successfully reduced to below the threshold.

Sometimes sprays fail to work as effectively as required or expected. This can occur for a variety of reasons, such as inadequate application (coverage, timing), insecticide resistance, or too-high expectations of the product selected. Poor application is sometimes mistaken as resistance.

Where a spray failure is suspected, detailed records can assist in determining the cause of the apparent failure.

With products such as Steward™, the phenomenon of growth dilution is often evident in chickpeas. That is, the growth that was present at the time of application may still have residual activity from the insecticide but new growth will not. It has been observed that small larvae can feed on this new growth but incur no crop damage. Rechecking fields sprayed with Steward™ or Larvin® can be complicated and will require regular assessment.

Record spray decision and re-check to confirm control success or failure. Record details of application equipment (nozzle size etc.) as well as time of day and weather conditions. This may help interpret what might have gone wrong where poor control is achieved. [64]

63 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

64 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.