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GRAINS RESEARCH
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WHEAT

SECTION 7

INSECT AND OTHER PEST CONTROL

INTEGRATED PEST MANAGEMENT | LUCERNE FLEA (SMINTHURUS VIRIDIS) | EARTH MITES | SLUGS | APHIDS | ARMYWORM | SNAILS | SOIL PESTS | INSECT MONITORING TECHNIQUES FOR FIELD CROPS

February 2016

SECTION 7

Insect and other pest control

Insects are not usually a major problem in winter wheat but sometimes they build up to an extent that control may be warranted. For current chemical control options, refer to the Pest Genie or Australian Pesticides and Veterinary Medical Authority (APVMA) websites. [1]

Where chemical control is warranted, farmers are increasingly being strategic in their management and avoiding broad-spectrum insecticides where possible. Thresholds and potential economic damage are carefully considered.

Agronomist's view

Insect and other arthropod pests that can pose a problem include blue oat mite (*Penthaleus* spp.), redlegged earth mite (*Halotydeus destructor*), *Bryobia* mites (*Bryobia* spp.), cutworms, aphids, slugs, snails, earwigs, millipedes, slaters, army worms, pasture webworm, pasture cockchafers, and grass anthelids, lucerne flea (*Sminthurus viridis*), leaf hoppers, slugs, snails, millipedes, slaters and locusts (Tables 1 and 2). Mice may also cause damage.

Table 1: Pests that pose a risk to cereal crops [2]

High risk	Moderate risk	Low risk
Soil insects, slug and snails		
Some crop rotations increase the likelihood of soil insects: cereal sown into a long-term pasture phase high stubble loads above-average rainfall over summer–autumn History of soil insects, slugs and snails Summer volunteers and *Brassica* weeds will increase slug and snail numbers Cold, wet establishment conditions expose crops to slugs and snails	Information on pest numbers prior to sowing from soil sampling, trapping and/or baiting will inform management Implementation of integrated slug management strategy (burning stubble, cultivation, baiting) where there is a history of slugs Increased sowing rate to compensate for seedling loss caused by establishment pests	Slugs and snails are rare on sandy soils
Earth mites		
Cereals adjacent to long-term pastures may get mite movement into crop edges Dry or cool, wet conditions that slow crop growth increase crop susceptibility to damage History of high mite pressure	Leaf curl mite populations (transmitters of *Wheat streak mosaic virus*) can be increased by grazing and mild wet summers	Seed dressings provide some protection, except under extreme pest pressure

1 DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

2 NIPI. Winter cereals. NIPI IPM guidelines, http://ipmguidelinesforgrains.com.au/crops/winter-cereals/

High risk	Moderate risk	Low risk
Aphids		
Higher rainfall areas where grass weeds are present prior to sowing—higher risk of *Barley yellow dwarf virus* transmission by aphids Wet summer and autumn promoting survival of aphids on weed and volunteer hosts	Wet autumn and spring promote the growth of weed hosts; when weed hosts dry off, aphids move into crops Planting into standing stubble can deter aphids landing Use of seed dressings can reduce levels of virus transmission and delay aphid colonisation Use of SPs and OPs to control establishment pests can kill beneficial insects and increase the likelihood of aphid survival	Low-rainfall areas—lower risk of BYDV infection High beneficial activity (not effective for management of virus transmission)
Armyworm		
Large larvae present when the crop is at late ripening stage	High beneficial insect activity (particularly parasitoids) Rapid crop dry-down	No armyworm present at vegetative and grain-filling stages

More information

cesar: Insect gallery

NIPI: Insect identification aids

GRDC Update Papers: Don't forget the good guys—recognising and identifying beneficial insects in your paddock

cesar PestFacts: Grass anthelids

GRDC Ute Guides: Insects

GRDC Update Papers: Insect pests—resistance, virus vectors and lessons from 2014

Table 2: Incidence of pests of winter cereals [3]

Present, present in crop but generally not damaging; Damaging, crop susceptible to damage and loss; snails are also a grain contaminant at harvest

	Crop stage			
	Emergence	Vegetative	Flowering	Grainfill
Wireworms	Damaging	Present		
Cutworm	Damaging			
Black headed cockchafer	Damaging	Present		
Earth mites	Damaging	Present		
Slugs, snails	Damaging			
Brown wheat mite		Damaging		
Aphids	Present	Damaging	Present	Present
Armyworm		Present	Present	Damaging
Helicoverpa armigera				Damaging

Stay informed about invertebrate pest threats throughout the winter growing season by subscribing to SARDI's PestFacts South Australia and cesar's PestFacts south eastern.

Subscribers to PestFacts also benefit from special access to **cesar**'s extensive Insect Gallery, which can be used to improve skills in identifying pest and beneficial insects.

Use Tables 3 and 4 below to identify damage caused by key pests, and to assess risk and determine control measures for establishment pests.

[3] NIPI (2014) Winter cereals. NIPI IPM guidelines, http://ipmguidelinesforgrains.com.au/crops/winter-cereals/

Table 3: Crop damage pest identification key for the Southern Region—cereals [4]

Leaves or plants cut off and lying on the ground or protruding from small holes next to plants; brown caterpillars (up to 15 mm long) with black heads, present in web- lined tunnels; wheat or barley seeded into grassy pasture paddocks.	Webworm
Leaves or plants cut off and lying on the ground or protruding from small holes next to plants. Slender larvae, up to 35 mm long, construct silk-lined tunnels that protrude above ground to form chimneys.	Pasture tunnel moth*
Leaves or plants cut off and lying on the ground or protruding from small holes next to plants. Larvae are brown with black and yellow marking, covered in tufts of stout hairs and can grow up to 50 mm in length.	Grass anthelid*
Leaves of young seedlings fed upon or damaged; in severe cases seedlings are ring-barked at ground level causing them to drop. Adults are 3-5 mm long, round and dull brown resembling small clods of dirt.	Mandalotus weevil*
Plants eaten close to or below ground level causing plant death and bare patches within the crop.	Polyphrades weevil*
Larvae emerge from tunnels with rain events to feed on foliage. Can cause bare patches in crops during late autumn and early winter. 'C' shaped larvae with six legs and a black to brown head capsule.	Blackheaded pasture cockchafers*
Large portions of plants eaten and some leaves or plants cut off. Smooth, fat caterpillars up to 40 mm long usually found just under the soil surface and may curl up when disturbed.	Cutworms
Green material removed in irregular patches from one surface of the leaf leaving white window-like areas; paddocks may appear white; presence of dumpy, wingless, greenish yellow insects, which spring off plants when disturbed.	Lucerne flea
Leaves shredded or chewed, slimy trails.	Slugs and snails
Smooth, shiny brown animals with curved pincers at the end of the body. Damage irregular, often similar to slug damage, mostly in patches, when sown in heavy stubble.	Earwigs
Grasshoppers and locusts.	Grasshoppers and locusts
Minor leaf chewing; presence of dark brown to black caterpillars up to 60 mm long with two yellow spots near posterior end.	Pasture day moth
Presence of tiny 8-legged (nymphs have 6 legs) velvety black or brown crawling creatures with orange-red legs, found on plants or on soil surface at the base of plants.	Redlegged earth Mite Blue oat mite Balaustium mite
Plants stunted and dying at emergence and up to tillering; chewing of seed and stem below ground; white legless larvae up to 7 mm long present near point of attack.	Spotted vegetable weevil or Desiantha weevil
Plants stunted or dying; roots eaten; slow-moving, soft bodied insects usually in a 'C' shape, cream-coloured apart from head and visible gut contents; found near roots.	Cockchafers African black beetle
Plants yellowing and withering; on light soils mostly on coastal plain; stems underground shredded; presence of elongated, cylindrical insects up to 75 mm long, first pair of legs adapted for digging.	Sandgropers**
Green and straw-coloured insect droppings like miniature square hay bales on ground; cereal heads on ground; some chewing of leaves and seed heads of weeds such as ryegrass. Smooth, fat caterpillars up to 40 mm long, with three stripes on collar behind head; found at base of plants or climbing plants.	Armyworm
Seeds chewed but heads not severed; caterpillars up to 40 mm long, sparsely covered with small bumps and bristles, may be various shades of green, yellow, orange or brown; found on seed heads.	Native budworm and related species
Presence of many grey- green insects approx. 2 mm long, with or without wings, on upper portions of stem. If heavy infestations, plants stunted; sticky with secretions, possibly black mould growing on secretions;	Aphids
Damage in fine pale dots in wriggly or zigzag lines. Yellow to green, 3 mm long wedge-shaped sucking insects that jump sideways when disturbed.	Leafhoppers

* Relevant in S.E. Australia only

[4] GRDC (2012) I spy. Insects of Southern Australian Broadacre Farming Systems Identification Manual and Education Resource. GRDC, http://grdc.com.au/Resources/Bookshop/2012/11/I-SPY

Table 4: Establishment pests of the Southern Region—risk assessment and management [5]

Pre-season	Pre-sowing	Emergence	Crop establishment
Earth mites and lucerne flea			
Assess risk. High risk when: • history of high mite pressure • pasture rotating into crop • susceptible crop being planted (e.g. canola, pasture, lucerne) • seasonal forecast for dry or cool, wet conditions that slow crop growth If risk is high: • ensure accurate identification • use TIMERITE® (redlegged earth mites only) • heavily graze pastures in early–mid spring	If high risk: • use an insecticide seed dressing on susceptible crops • plan to monitor more frequently until crop establishment • use higher sowing rate to compensate for seedling loss • consider scheduling a post-emergent insecticide treatment If low risk: • avoid insecticide seed dressings (esp. cereal and pulse crops) and plan to monitor until crop establishment	Monitor susceptible crops through to establishment using direct visual searches. Be aware of edge effects; mites move in from weeds. around paddock edges If spraying: • ensure accurate identification of species before deciding on chemical • consider border sprays (mites) and 'spot' sprays (lucerne flea) • spray prior to winter egg production to suppress populations and reduce risk in the following season	As the crop grows, it becomes less susceptible unless growth is slowed by dry or cool, wet conditions
Slugs			
Assess risk. High risk when: • high stubble load • annual average rainfall >450 mm history of slug infestations • canola being planted • summer rainfall • heavy clay soils	If high risk: • burn stubbles • cultivate worst areas • remove weeds in paddocks/ along fencelines at least 8 weeks before sowing • deploy shelter traps before sowing • sow early to get crop established prior to cold conditions • use soil compaction at sowing (e.g.. press-wheels) • bait at/after sowing prior to emergence	Assess risk. High risk under cold conditions and with slow plant growth. Use shelter traps or directly search at night when slugs are active to confirm slugs as the cause of seedling loss. If slug pressure is high, successive baiting may be necessary. Monitoring will guide bait use	As the crop grows, it becomes less susceptible unless growth is slowed by cool conditions Resowing may be required if plant stands are unsatisfactory
False wireworm and true wireworm			
Assess risk. High risk when: • history of wireworm pressure • soils high in organic matter • high stubble and summer–autumn litter cover	Conduct direct visual search for adult beetles over summer and autumn. Search (in soil) for beetle larvae 2 weeks prior to sowing. If high risk: • reassess crop choice or timing of sowing • consider an insecticide seed dressing (particularly fipronil) or in-furrow treatment • use soil compaction at sowing (e.g. press-wheels) • consider higher sowing rate to compensate for seedling loss	Limited options for control once crop is sown. Consider resowing severely affected areas of crop	Damage to established crops is rare

[5] NIPI (2014) Establishment pests—Southern Region. 'Best bet' IPM strategy. NIPI IPM Workshops, http://ipmworkshops.com.au/wp-content/uploads/BestBet_EstablishmentSouth2014.pdf

Pre-season	Pre-sowing	Emergence	Crop establishment
Scarabs			
Assess risk. High risk when: • sowing crop into pasture, esp. with a high clover content • previous history of scarab damage to crop in that field • wetter than average seasons • minimum/no tillage • Under high pressure: • spray African black beetle adults in spring • avoid overgrazing pastures	Dig soil within paddock to determine incidence of scarab larvae. If high risk: • cultivate land • avoid sowing grass pastures • use soil compaction at sowing (e.g. press-wheels) • consider higher sowing rate to compensate for seedling loss	Assess risk. High risk when dry conditions slow plant growth. Limited options for control once crop is sown. Larvae of most species do not emerge from the soil. For black headed pasture cockchafer, spray around heavy dews or light rainfall which will trigger larvae activity	Resowing may be an option, but some species have a 2-year life cycle, so larvae can persist through winter into spring. ID will guide this decision
Others—e.g. earwigs, slater, millipedes, weevils			
Assess risk. High risk when: • history of high pest pressure • minimum/no tillage • high stubble load • heavier soils • Monitor in spring using shelter traps, direct searches and/or pitfall traps	• If high risk: • burn stubbles • cultivate worst areas • use cracked wheat baits • avoid sowing canola	Monitor susceptible crops through to establishment. Directly search at night to confirm pest species as the cause of seedling loss (Note: large numbers of these pests can be found in paddocks without causing crop damage)	Damage to established crops is rare

More information

NIPI IPM Workshops: Establishment pests—Southern Region

NIPI IPM Workshops: Decision making for insect management in grain crops

7.1 Integrated pest management

Pests are best managed by using an integrated pest management (IPM) approach. Careful planning prior to sowing, followed by regular monitoring of crops after sowing, will ensure that potential problems are identified and, if necessary, treated early.

The IPM approach uses a range of management tactics to keep pest numbers below the level where they cause economic damage. It focuses on natural regulation of pests, particularly by encouraging natural enemies, and on using broad-spectrum chemicals only as a last resort. IPM relies on monitoring the crop regularly, having pests and beneficial insects correctly identified, and making strategic control decisions according to established damage thresholds. [6]

Key IPM strategies:

- Where the risk of establishment pest incidence is low (e.g. earth mites), regular monitoring can be substituted for the prophylactic use of seed dressings.
- Where establishment pests and aphid infestations are clearly a result of invasion from weed hosts around the field edges or neighbouring pasture, a border spray of the affected crop may be sufficient to control the infestation and allow the build-up of natural predators.

Insecticide choices:

- Redlegged earth mites, blue oat mites, and other mite species can occur in mixed populations. Determine species composition before making decisions because they have different susceptibilities to chemicals.
- Establishment pests have differing susceptibilities to insecticides (synthetic pyrethroids (SPs), organophosphates (OPs) in particular). Be aware that the use of some pesticides may select for pests that are more tolerant.

Insecticide resistance:

- Redlegged earth mites have been found to have high levels of resistance to SPs such as bifenthrin and alpha-cypermethrin.

[6] K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf

- *Helicoverpa armigera* has historically had high resistance to pyrethroids, and the inclusion of nuclear polyhedrosis virus (NPV) is effective where mixed populations of armyworm and *Helicoverpa* occur in maturing winter cereals. [7]

7.2 Lucerne flea (*Sminthurus viridis*)

Lucerne flea is an important pest of establishing crops. It is identified by its action of jumping between plants rather than flying. Early-sown crops are more at risk of attack. Frequent crop inspection from the time of emergence, and early control measures, are important because of the impact of seedling vigour on crop performance. Ensure that monitoring is sufficient to detect localised patches or 'hot spots'. Seek advice on management and spray strategies. [8]

Figure 1: Adult lucerne flea (Sminthurus viridis). (Photo: cesar)

7.2.1 Description

Adult lucerne fleas are globular, wingless insects, 2–3 mm long with green, brown and yellow markings (Figure 1). They appear yellow-green to the naked eye, although their globular abdomens are often a mottled pattern of darker pigments. They make jumping movements when disturbed. Nymphs resemble the adults except in size. [9]

7.2.2 Seasonal development and symptoms

Lucerne fleas hatch following periods of good, soaking autumn–winter rainfall and can cause significant damage to emerging crops and pastures at this time of year. They can also cause considerable damage to older crops if numbers build up under favourable conditions throughout the season.

Lucerne fleas have a wide host range. They will attack most broadacre crops, including canola, lucerne, pastures, cereals and some pulses. Feeding results in the appearance of distinctive transparent 'windows'. They are generally a problem in regions with loam or clay soils.

Crops should be inspected frequently at, and immediately following, emergence, when most susceptible to damage. Paddocks are most likely to have problems when

[7] NIPI (2014) Winter cereals. NIPI IPM guidelines, http://ipmguidelinesforgrains.com.au/crops/winter-cereals/

[8] P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

[9] CropPro. Lucerne flea. Pests in canola. CropPro, http://www.croppro.com.au/cb_pages/pests_in_canola_-_in_crop.php?category_id=2374

they follow a weed-infested crop or a pasture in which the lucerne flea has not been controlled.

7.2.3 Impact

The cells of the upper surface of leaves and cotyledons are eaten, resulting in small 'windows' in the leaves. Severe infestations cause skeletonised leaves, with only the more fibrous veins remaining. This damage is quite distinctive and can be used to help identify lucerne flea as the key pest.

More information

Agriculture Victoria: Lucerne flea

GRDC Grain Research Advice: Knowledge, timing, key to lucerne flea control

NIPI IPM Guidelines: Lucerne flea in winter seedling crops

GRDC: Canola best practice management guide. Lucerne flea (p. 51)

NIPI: I Spy Manual. Lucerne flea (section 4, pp. 63–64)

7.2.4 Management

Only when infestations are severe should lucerne flea be sprayed. In some instances, spot spraying with registered chemicals may be adequate. Several natural enemies such as mites, beetles and spiders prey upon lucerne fleas, and blanket spraying is harmful to these natural control agents. Seed dressing can also be a useful technique to prevent damage by lucerne flea. [10]

Snout mites (which have orange bodies and legs) are effective predators of lucerne fleas, particularly in pastures, where they can prevent pest outbreaks. The complex of beneficial species (including snout mites) should be assessed before deciding on control options. [11]

Several options are available to growers for controlling the lucerne flea. Foliar insecticides can be applied ~3 weeks after lucerne fleas have been observed in a newly emerged crop. This will allow for further hatching of oversummering eggs but will be before lucerne fleas reach the adult stage and begin to lay winter eggs. If spraying is required, do not use SPs.

In paddocks where damage is likely, a border spray may be sufficient to prevent movement of lucerne fleas into the crop from neighbouring paddocks. Lucerne fleas are often distributed patchily within crops; therefore, spot-spraying is generally all that is required. Do not blanket-spray unless the infestation warrants it.

7.3 Earth mites

A good mite-control program starts with a population-reduction treatment the previous spring (see Table 4 above). Learn to identify these species of mites to ensure that the correct insecticide and rate is applied to the correct pest.

See Australian Pesticides and Veterinary Medicines Authority for up-to-date on-label information.

7.3.1 Blue oat mite (*Penthaleus* spp.)

Blue oat mites (Figure 2) are important pests of seedling winter cereals.

Adults and nymph mites pierce and suck leaves, resulting in silvering of the leaf tips. Feeding causes a fine mottling of the leaves, similar to the effects of drought. Heavily infested crops may have a bronzed appearance, and severe infestations cause leaf tips to wither and can lead to seedling death. Damage is most likely during dry seasons when mites in large numbers heighten moisture stress; control may be warranted in this situation.

Check from planting to early vegetative stage, particularly in dry seasons, monitoring several sites throughout the field (Table 5). Blue oat mites are most easily seen in the cooler part of the day or in cloudy conditions. They shelter on the soil surface when conditions are warm and sunny. If pale-green or greyish irregular patches appear in the crop, check for the presence of blue oat mite at the leaf base.

[10] CropPro. Lucerne flea. Pests in canola. CropPro, http://www.croppro.com.au/cb_pages/pests_in_canola_-_in_crop.php?category_id=2374

[11] cesar (2010) Lucerne flea. PestFacts south-eastern, Issue 3, 21 May 2010. cesar, http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2010/pestfacts-issue-no-3-21st-may-2010/lucerne-flea/

Where warranted, foliar application of registered insecticide may be cost-effective. Check the most recent research to determine the likely susceptibility of blue oat mite to the available registered products. Cultural control methods can contribute to reduction in the size of the autumn mite population (e.g. cultivation, burning, controlling weed hosts in fallow, grazing and maintenance of predator populations).

Eggs laid in the soil hibernate throughout winter; therefore, populations of the mite can build up over a number of years and cause severe damage if crop rotation is not practiced. The use of control tactics solely in spring will not prevent the carry-over of eggs into the following autumn.

Predators of blue oat mites include spiders, ants, predatory beetles and the predatory *Anystis* mite and snout mite. Blue oat mites are also susceptible to infection by a fungal pathogen (*Neozygites acaracida*), particularly in wet seasons. [12]

The blue oat mite is an important pest of seedling winter cereals. When infestations are severe, the leaf tips wither and eventually the seedlings die.

Figure 2: Blue oat mite (Penthaleus sp.). (Photo: A Weeks, cesar)

Table 5: Management summary of blue oat mite [13]

Scientific name	*Penthaleus major, P. falcatus*, *P. tectus*
Description	Adults are 1 mm long and have eight legs. Adults and nymphs have a purplish-blue, rounded body with red legs. They move quickly when disturbed. The presence of a small red area on the back distinguishes it from the redlegged earth mite
Similar species	Brown wheat mite, redlegged earth mite
Crops attacked	Mainly a pest of cereals and grass pastures, but will feed on pasture legumes and many weeds
Damage	Adults and nymphs pierce and suck on leaves resulting in silvering of the leaf tips in cereals. When heavy infestations occur, the leaf tip withers and the seedling can die. In canola, leaves are mottled or whitened in appearance
Monitor	Check from planting to early vegetative stage, particularly in dry seasons. Most easily seen in the late afternoon when they begin feeding on the leaves
Control	Foliar applications of insecticides may be cost-effective if applied within 2–3 weeks of emergence in autumn. The use of control tactics solely in spring will not prevent the carry-over of eggs into the following autumn. For current chemical control options see Pest Genie or APVMA
Natural enemies	Thrips and ladybirds

Blue oat mites are often confused with redlegged earth mites. There are three recognised pest species of blue oat mites in Australia: *Penthaleus major*, *P. falcatus*, and *P. tectus*. Accurate identification of the species requires examination by an

[12] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[13] DAF Qld (2010) Blue oat mite. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/mites-overview/blue-oat-mite

entomologist. The species vary with respect to their geographical distribution in Australia. [14]

7.3.2 Redlegged earth mites (*Halotydeus destructor*)

Characteristics and management of redlegged earth mites (Figure 3) are summarised in Table 6.

Figure 3: Adult redlegged earth mites (Halotydeus destructor). (Photo: cesar)

Table 6: Management summary of redlegged earth mite

Scientific name	*Halotydeus destructor*
Description	Adults are 1 mm long and have eight legs. Adults and nymphs have a black, somewhat flattened body and red legs
Similar species	Similar in appearance to blue oat mite; however, blue oat mite can be distinguished by a small oval red area in the middle of the back
Distribution	Originated in South Africa, now found in New Zealand and Australia. The redlegged earth mite is widely distributed in winter-rainfall-dominant regions of southern Australia
Pest status	Major, widespread, regular, in southern Australia
Crops attacked	Damages all field crops and pastures, especially at seedling stage. A major pest of legume pastures and canola
Damage	Adults and nymphs feeding cause a silver or white discoloration of leaves and distortion of leaf shape. Affected seedlings can die. Seedlings can be killed before emergence. There is also reduced production and quality of older green plants during the growing season and reduced seed yield of legumes in spring
Risk period	Autumn to spring, especially at germination
Life cycle	On winter-rainfall pastures: The redlegged earth mite is active in the cool, wet months from May to November. They hatch in autumn at the break of the season, from oversummering eggs that have been in a state of arrested development (diapause) since the end of the previous spring. Hatching is triggered by a significant rainfall event combined with a period of 7–10 days where the mean daily maximum temperature is <21°C Eggs hatch into six-legged larvae and then develop through three nymphal stages into adults. Nymphs and adults have eight legs. During winter, the redlegged earth mite passes through three generations on average, each lasting about 8 weeks. When conditions are favourable, numbers can increase rapidly, with peaks in autumn and/or spring

[14] K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf

More information

GRDC: Insect ID: the Ute Guide tablet edition

Monitoring	Monitor pastures regularly from the time of first emergence of seedlings. Approach quietly as mites will disperse quickly if disturbed. If mites are not found on the plants, look carefully at the soil surface. A hand lens will be required to detect newly hatched larvae and young nymphs
Action level	Any sign of mite activity or damage at germination warrants control. At other times of the season, feeding damage to >20% of the leaf area may warrant control
Control	Chemical control: Treating seed with systemic insecticide before sowing pastures protects seedlings from attack. Chemical sprays do not kill mite eggs, so it is important to time spraying for when most mites have emerged. Spraying should be timed for autumn or spring. In autumn, chemicals should be applied after the break of season, and after all of the oversummering eggs have hatched but before adult mites start laying eggs. For current chemical control options see APVMA Cultural control: Heavy grazing in winter and spring reduces mite populations. Control of broadleaf weeds in summer can reduce mite populations in autumn. Natural enemies: A predatory mite, *Anystis wallacei*, was imported from France to Australia in 1965 for biological control and has established at some sites, where it has caused significant mortality of redlegged earth mites. Its effectiveness is limited by its slow dispersal

TIMERITE® for management of redlegged earth mite

TIMERITE® is an information package that provides individual farmers with the optimum spray date on their farm to control redlegged earth mites during spring. Developed by CSIRO and Australian Wool Innovation, TIMERITE® predicts the optimum date in spring to control redlegged earth mites, just after they have ceased laying normal winter eggs on pasture and just before diapause. (Diapause is when adult redlegged earth mites produce eggs that are retained in the body of the adult female and are therefore protected from the effects of insecticide applications.) The single, strategic spray has a two-fold effect: controlling redlegged earth mites in spring and decreasing the summer population that emerges in the following autumn. The package may form part of an integrated management strategy to control redlegged earth mites.

Close attention should be paid to individual pesticide labels when controlling earth mites. Application rates vary with situations, such as bare earth or post-emergence of crops or pasture. Correct identification of earth mite species is essential. Registrations sometimes include redlegged earth mites only, not blue oat mites or *Bryobia* mites. Application rates may vary with earth mite species. See APVMA.

This strategic approach has little effect on non-target invertebrates, both pest and beneficial, during the following autumn. Farmers need to identify geographically the location to be sprayed. This can be done by a local feature, such as town or mountain, or the longitude and latitude of the area. This information is used to find the optimum date from the package. The spray date for each farm is the same date each year. For information, phone Australian Wool Innovation toll free on 1800 070 099 or visit the website: AWI: TIMERITE. [15]

7.3.3 *Balaustium* mites *(Balaustium medicagoense)*

Description

Balaustium mites grow to 2 mm in length and have a rounded, red-brown body with eight red-orange legs (Figure 4). Adults are covered with short, stout hairs. They are slow moving and have distinctive, pad-like structures on their forelegs. The *Balaustium* mite is commonly confused with *Bryobia* mite, and sometimes with blue oat mite and redlegged earth mite. However, *Balaustium* mites are generally twice as large as other mites when adults. Newly hatched mites are bright orange with six legs and are only 0.2 mm in length.

[15] K Hertel, K Roberts, P Bowden (2013) Insect and mite control in field crops. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf

Figure 4: Balaustium mites (Balaustium medicagoense). (Photo: cesar)

Seasonal development

Little is known about the biology of *Balaustium* mites. *They* usually have two generations per season and are unlikely to require cold temperatures to stimulate egg hatching like other species.

Impact

Balaustium mites are unusual in that they not only feed on plants but also prey upon other small invertebrates. They have been reported to feed on several different groups, including various Collembola species and other mites. *Balaustium* mites were originally thought to be a beneficial predator with some reports suggesting that they provided localised control of redlegged earth mites. Only recently have *Balaustium* mites been confirmed to feed on plant material.

Canola, lupins and cereals are the most susceptible crops, particularly at the seedling stage. Some broadleaf weeds are alternative hosts. Typical damage to cereals, grasses and pulses is 'silvering' or 'whitening' of the attacked foliage, similar in appearance to damage caused by redlegged earth mites and blue oat mites. However, *Balaustium* mite damage differs in that they tend to attack the leaf edges and tips of plants. Adult mites are likely to be responsible for the majority of feeding damage to plants.

Balaustium mites feed on plants by using their adapted mouthparts to probe leaf tissue and suck up sap. In most situations, they cause little damage; however, when numbers are high and plants are already stressed from other environmental conditions, significant damage to crops can occur.

Management

There are very few effective biological control options. Early control of summer and autumn weeds within and around paddocks, especially cape weed and grasses, will help to control populations. *Balaustium* mites have a high natural tolerance to chemicals and they will typically survive pesticide applications aimed at other mite pests. [16]

Distribution

Balaustium mites are widespread throughout most agricultural regions in southern Australia with a Mediterranean-type climate (Figure 5). They are found in Victoria, New South Wales and South Australia. They are generally restricted to coastal areas and do not occur far inland or in the drier Mallee areas of Victoria and South Australia.

[16] GRDC (2012) Crop mites. Back Pocket Guide. GRDC, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

Balaustium mites have been found in Tasmania; however, no systematic sampling has been conducted and the distribution across the state remains unknown.

Similar to other pest mites, long-range dispersal is thought to occur via the movement of eggs in soil adhering to livestock and farm machinery or through transportation of plant material. Movement may also occur if oversummering eggs are moved by summer winds.

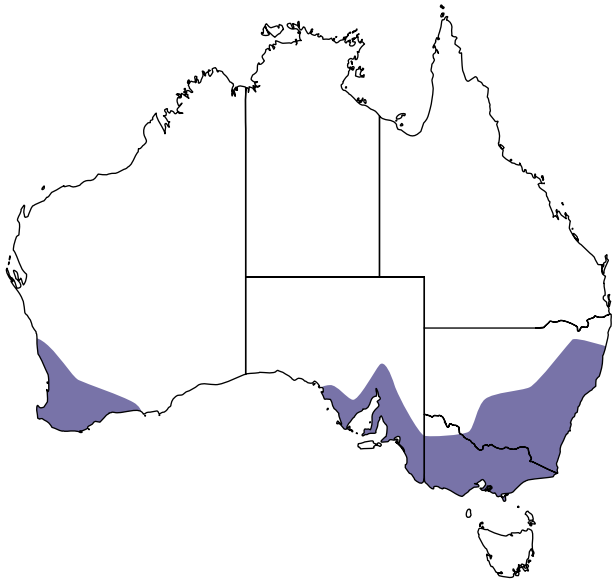


Figure 5: Distribution of Balaustium mite in southern Australia. (Source: Agriculture Victoria)

Monitoring

The impact of mite damage is increased when plants are under stress from adverse conditions such as prolonged dry weather or waterlogged soils. Ideal conditions for seedling growth enable plants to tolerate higher numbers of *Balaustium* mites. 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 3–5 weeks after sowing.

Crops sown into paddocks that were in pasture the previous year should be regularly inspected. Weeds present in paddocks prior to cropping should also be checked for the presence and abundance of *Balaustium* mites. Mites are best detected feeding on the leaves, especially on or near the tips, during the warmest part of the day. They are difficult to find when conditions are cold and/or wet.

One of the most effective methods to sample mites is by using a D-Vac, which is based on the vacuum principle, much like a domestic vacuum cleaner. Typically, a standard, petrol-powered garden blower/vacuum machine is used. A sieve is placed over the end of the suction pipe to trap mites vacuumed from plants and the soil surface. [17]

7.3.4 *Bryobia* mites

Description

Bryobia mites (also referred to as clover mites) are smaller than other commonly occurring pest mites, reaching ~0.75 mm in length as adults. They have an oval, flattened dorsal body that is dark grey, pale orange or olive and have eight pale-orange legs (Figure 6). The front pair of legs is much larger, about 1.5 times their body length. Nymphs are small with bright-red bodies and pale legs. [18]

[17] Agriculture Victoria (2010) *Balaustium* mite. AG1413. DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/balaustium-mite

[18] GRDC (2012) Crop mites. Back Pocket Guide. GRDC, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

The egg of the *Bryobia* mite is minute, globular and red. It can be distinguished from European red mite eggs by its smooth appearance and lack of a spike. The nymph looks like the adult but is smaller. [19]

Many species of *Bryobia* mites are found in grain crops in Australia. They are found in high numbers in the warmer months from spring through to autumn. *Bryobia* mites prefer broadleaf plants such as canola, lupins, vetch, lucerne and clover, but they will also attack cereals. [20]

Figure 6: Adult Bryobia mite. (Photo: cesar)

Management

There are no known biological control options. Crops that follow clover-dominant pastures are most at risk, and should be monitored carefully. Early control of summer and autumn weeds within and around paddocks, especially broadleaf weeds such as cape weed and clovers, will help to control populations.

Several pesticides are registered for use on *Bryobia* mites; higher rates are usually required than for redlegged earth mites and blue oat mites. *Bryobia* mites have a natural tolerance to several chemicals. [21]

7.3.5 Brown wheat mite (*Petrobia latens*)

The mature brown wheat mite is about the size of a pinhead, globe-shaped and brown. It has been a sporadic pest of winter cereals. Populations reach troublesome levels only under very dry conditions.

7.4 Slugs

7.4.1 Description

Typically, the grey field slug *(Deroceras reticulatum)* is 35–50 mm long and light grey to fawn, with dark brown mottling (Figure 7). When disturbed, it will exude a sticky, milky secretion over its body. The black-keeled slug (*Milax gagates*) is 40–60 mm long and

[19] Agriculture Victoria (2000) The *Bryobia* mite and the pear-leaf blister mite. DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/the-bryobia-mite-and-the-pear-leaf-blister-mite

[20] GRDC (2012) Crop mites. Back Pocket Guide. GRDC, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

[21] GRDC (2012) Crop mites. Back Pocket Guide. GRDC, http://www.grdc.com.au/Resources/Publications/2012/06/GRDC-Crop-Mites-Back-Pocket-Guide

uniform black or brown with a ridge (keel) down its back (Figure 8). It can burrow to 20 cm underground. [22]

Figure 7: Grey field or reticulated slug (Deroceras reticulatum). (Photo: M Nash)

Figure 8: Black-keeled slug (Milax gagates). (Photo: M Nash)

7.4.2 Seasonal development and symptoms

Slugs are hermaphrodites; therefore, both individuals of a mating pair lay eggs. They will breed whenever moisture and temperature conditions are suitable—generally from mid-autumn to late spring. Eggs are laid in batches in moist soils and they will hatch within 3–6 weeks, depending on temperature. Juveniles look like smaller versions of the adult.

Slugs feed aboveground on stems and leaves, and belowground on seeds, shoots and roots. Damage is greatest when seedling growth is slow because of cool, wet or dry conditions. Grey field slugs are mainly surface-active, whereas black-keeled slugs burrow and can feed directly on germinating seeds. Slugs can be underestimated as pests because they are nocturnal and shelter during dry conditions, and therefore are not generally visible during daylight hours. [23]

7.4.3 Impact

Slugs damage newly sown crops and pasture, and damage is often difficult to detect or is incorrectly attributed to agronomic factors. If the population is large, damage to seedlings can be extensive. The black-keeled slug is more problematic in drier

[22] GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf

[23] GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf

environments such as South Australia, although it is widespread throughout south-eastern Australia. [24],[25]

7.4.4 Management

Cultivation prior to sowing, delaying sowing after summer cover has been sprayed out, stubble and weed removal, and baiting are all effective methods for reducing slug populations. When slug pressure is high, baiting alone may not provide total crop protection. [26]

7.5 Aphids

7.5.1 Oat or wheat aphid (*Rhopalosiphum padi*)

Oat or wheat aphid (Figure 9, Table 7) is one of the most common aphids infesting winter cereals. Typically, this species colonises the base and lower portions of the plant. [27]

Figure 9: Oat or wheat aphid. (Photo: QDAFF)

Table 7: Oat or wheat aphid management summary [28]

Scientific name	*Rhopalosiphum padi*
Description	Adults are 2 mm long, olive-green to black with a red rust patch at the rear end and may have wings. Antennae extend to half the body length. Nymphs are similar but smaller. Wheat and oat aphids are very similar to corn aphids
Distribution	An introduced species found in all states of Australia
Crops attacked	Barley, wheat and oats
Life cycle	Produces many generations through the growing season. Winged and non-winged forms occur
Damage	Aphids feed directly on stems, leaves and heads, and in high densities cause yield losses and plants may appear generally unthrifty. This type of damage is rare throughout the grainbelt. Aphids can spread *Barley yellow dwarf virus* (BYDV) in wheat and barley
Monitoring and action level	Aphids can affect any crop stage but are unlikely to cause economic damage to cereal crops expected to yield <2 t/ha (for virus damage) and <3 t/ha (for direct feeding). Consider treatment if there are 10–20+ aphids on 50% of the tillers

[24] G Baker (2009) Pests of canola and their management. Ch. 9. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, https://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[25] GRDC (2013) Slug identification and management. GRDC Slug control Fact Sheet, March 2013, http://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf

[26] CropPro. Slugs. Pests in canola. CropPro, http://www.croppro.com.au/cb_pages/pests_in_canola_-_in_crop.php?category_id=2381

[27] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[28] DAF Qld (2011) Oat aphid, wheat aphid. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/oat-aphid,-wheat-aphid

Control	Chemical control: Apply a foliar insecticide in late winter or spring to avoid direct damage to tillers and heads. To prevent losses from BYDV in virus-prone areas, control aphids early in the cropping year. Prevent infestation by applying a seed dressing to early-sown wheat crops and a foliar insecticide in high-pressure years if necessary (predator friendly). For current chemical control options, see Pest Genie or APVMA Cultural control: Controlling the green bridge (i.e. controlling weeds over the summer fallow) is an effective control measure to prevent aphid survival into the next season.
Host-plant resistance	In virus-prone areas, use resistant plant varieties to minimise losses due to BYDV
Natural enemies	Predation by hoverflies, lacewings and ladybeetles and parasitism by wasps can reduce aphid populations, but this does not happen in every season. Heavy rain may reduce aphid populations significantly

7.5.2 Corn aphid (*Rhopalosiphum maidis*)

Corn aphid (Figure 10, Table 8) is also a common species found in winter cereals. It generally colonises the upper parts of the plant, particularly the rolled up terminal leaf. [29]

Figure 10: Corn aphid (Rhopalosiphum maidis). (PHOTO: QDAFF)

Table 8: Corn aphid management summary [30]

Scientific name	*Rhopalosiphum maidis*
Description	Up to 2 mm long, light to dark olive-green with a purple area at the base of small tube-like projections at the rear of the body. Adults are generally wingless. Antennae extend to about one-third of body length. Nymphs are similar, but smaller in size
Similar species	Other species of aphids
Distribution	An introduced species, probably Asiatic in origin, found in all states of Australia
Crops attacked	Sorghum, maize, winter cereals and many grasses. Life cycle on cereals: A parthenogenetic species that undergoes many generations through the growing season. Both winged and non-winged forms occur

[29] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[30] DAF Qld (2010) Corn aphid. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/corn-aphid

Damage	In cereal: Aphids feed on stems, leaves and heads, and in high densities cause yield losses. However, this type of damage is uncommon throughout the cereal belt. Risk period: Most prevalent on cereals in late winter and early spring. High numbers often occur in years when an early break in the season and mild weather in autumn and early winter provide favourable conditions for colonisation and multiplication
Monitoring	Estimate percentage of plants infested and percentage of leaf area covered by aphids
Action level	Aphids are unlikely to cause economic damage to cereal crops expected to yield <3 t/ha. To avoid damage by direct feeding, consider treatment if there are ≥10–20 aphids on 50% of the tillers
Chemical control	Chemical control is cost-effective. See Pest Genie or APVMA for current control options. Conservation of natural enemies: A range of parasitoids and predators will help reduce aphid populations. Predators of aphids include: ladybird larvae, damsel bugs, big-eyed bugs and the larvae of green lacewings and hoverflies. Wasp parasitoids mummify and kill aphids

7.5.3 Rose-grain aphid (*Metopolophium dirhodum*)

Rose-grain aphid (Figure 11, Table 9) generally colonises the undersides of the leaves, high in the canopy. [31]

Figure 11: Rose-grain aphid (Metopolophium dirhodum), adult and nymphs. (Photo: QDAFF)

Table 9: Rose-grain aphid management summary [32]

Scientific name	*Metopolophium dirhodum*
Description	Adults are 3 mm long, green to yellow-green with long and pale siphunculi (tube-like projections on either side at the rear of the body) and may have wings. There is a dark green stripe down the middle of the back. Antennae reach beyond the base of the siphunculi. Nymphs are similar but smaller in size
Similar species	Because of its distinctive colour, it is unlikely to be confused with other aphids
Distribution	An introduced species that has been recorded in New South Wales, Queensland, South Australia, Tasmania and Victoria
Crops attacked	Wheat, barley, triticale, oats
Life cycle	Undergoes many generations during the growing season; winged and non-winged forms occur
Damage	Adults and nymphs are sap-suckers. Under heavy infestations, plant may turn yellow and appear unthrifty. Can spread BYDV in wheat and barley

[31] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[32] DAF Qld (2011) Rose-grain aphid. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/rose-grain-aphid

Monitoring and action level	Can affect any crop stage; assess the potential for direct-feeding damage in late winter. Estimate the number of aphids per tiller. Aphids are unlikely to cause economic damage to cereal crops expected to yield <3 t/ha
Control	Chemical control: Apply a foliar insecticide in late winter or spring to avoid damage to tillers. To prevent losses from BYDV in virus-prone areas, control aphids early in the cropping year. For current chemical control options see Pest Genie or APVMA Cultural control: There are no known effective cultural control methods for this aphid
Natural enemies	Predation by hoverflies , lacewings and ladybird beetles , parasitism by wasps and heavy rainfall can reduce aphid populations

7.5.4 Thresholds for control

Inspect for aphids throughout the growing season by monitoring leaves, stems and heads as well as exposed roots. Choose six, widely spaced positions in the crop, and at each position examine five consecutive plants in a row. Research is under way into damage thresholds and control options for cereal aphids. Some research indicates that aphid infestations can reduce yield by ~10% on average. Current notional thresholds suggest that control is warranted when there are >10–20 aphids on 50% of the tillers.

The decision to control aphids on winter cereals depends on the size of the aphid population and the duration and timing of the infestation. Controlling aphids during early crop development generally results in a recovery of the rate of root and shoot development, but there can be a delay. Aphids are more readily controlled in seedling and pre-tillering crops, which are less bulky than post-tillering crops. Corn aphids in the terminal leaf tend to disappear as crops come into head, and other species usually decline in abundance about this time as natural enemy populations build up.

More information

GRDC Fact Sheets: Cereal aphids. Northern Region

Always determine the level of natural enemy activity when making control decisions about aphids. The thresholds above are for aphid damage—there is not a threshold for BYDV transfer.

7.6 Armyworm

Armyworms (Figure 12) are the caterpillar stage of certain moths, and can occur in large numbers, especially after good rain following a dry period. Larvae shelter in the throats of plants or in the soil and emerge after sunset to feed on the leaves of all winter cereals, particularly barley and oats, generally during September and October. Leafy cereal plants can tolerate considerable feeding, and control in the vegetative stage is seldom warranted unless large numbers of armyworms are distributed throughout the crop or are moving in a 'front', destroying young seedlings or completely stripping older plants of leaves. The most serious damage occurs when larvae feed on the upper flag leaf and stem node as the crop matures.

Figure 12: Common armyworm (Leucania convecta). (Photo: QDAFF)

The most common species are common, inland and southern armyworms (*Leucania convecta*, *Persectania dyscrita* and *Persectania ewingii*). Infestations are evident from scalloping on margins of leaves caused by feeding of the older larvae. Larvae target the stem node as the leaves become dry and unpalatable, and the stem is often the last part of the plant to dry. One larva/m^2 can cause a grain loss of 70 kg/ha.day (Table 10). Larvae take ~8–10 days to develop through the final, most damaging instars, with crops susceptible to maximum damage for this period (Table 11).

Check for larvae on the plant and in the soil litter under the plant. The best time to do this is late in the day when armyworms are most active. Alternatively, look around the base of damaged plants where the larvae may be sheltering in the soil during the day. Using a sweep net (or swing a bucket), check a number of sites throughout the paddock. Sweep sampling is particularly useful early in an infestation when larvae are small and actively feeding in the canopy. One full sweep with a net samples the equivalent of 1 m^2 of crop.

Early recognition of the problem is vital, because cereal crops can be almost destroyed by armyworm in just a few days. Although large larvae do the head lopping, controlling smaller larvae that are still leaf-feeding may be more achievable. Prior to chemical intervention, consider how quickly the larvae will reach damaging size, and the development stage of the crops. Small larvae take 8–10 days to reach a size capable of head-lopping, so if small larvae are found in crops nearing full maturity–harvest, spray may not be needed, whereas small larvae in late crops that are still green and at early seedfill may reach a damaging size in time to reduce crop yield significantly.

Control is warranted if the armyworm population distributed throughout the crop is likely to cause the loss of 7–15 heads/m^2. Many chemicals will control armyworms. However, their effectiveness often depends on good penetration into the crop to achieve contact with the caterpillars. Control may be more difficult in high-yielding, thick-canopied crops, particularly when larvae are resting under soil at the base of plants. Larvae are most active at night; therefore, spraying in the afternoon or evening may produce the best results. If applying sprays close to harvest, be aware of relevant withholding periods.

Biological control agents may be important in some years. These include parasitic flies and wasps, predatory beetles and diseases. Helicoverpa NPV is not effective against armyworm. [33]

Table 10: Value of yield loss incurred by armyworm larvae (1 or 2/m^2) per day, based on various grain values for wheat and an estimated loss, given 1 larva/m^2, of 70 kg/ha

Considering these results, and the relatively low cost of controlling armyworm, populations of >1 large larva/m^2 in ripening crops warrant spraying

Value of grain (AU$/t)	Value of yield loss ($) per ha per day	
	1 larva/m^2	2 larvae/m^2
$140	$9.80	$19.60
$160	$11.20	$22.40
$180	$12.60	$25.20
$200	$14.00	$28.00
$220	$15.40	$30.80
$250	$17.50	$35.00
$300	$21.00	$42.00
$350	$24.50	$49.00
$400	$28.00	$56.00

[33] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

Table 11: Armyworm management summary [34]

Scientific name	*Leucania convecta*—common armyworm
Description	Common armyworm: First-instar larvae are about 1 mm long. From the second instar, stripes develop along the top and sides of the larva and become more distinct as the larva grows. Crowded larvae are usually darker than uncrowded. The mature larva grows up to 40 mm in length and has three characteristic pale stripes on the head, collar (segment behind the head) and tail segment. They are smooth-bodied with no distinct hairs. The body also has lateral stripes. The forewings of the moth have a wingspan of about 40 mm and are fawn or buff coloured
Similar species	Adults of the common and northern armyworms may be confused. Genitalia dissections by a specialist are required to separate the species. The larval stages likely to be encountered in cereals are all similar in appearance
Distribution	Common armyworm is a native Australian species, recorded in New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia
Crops attacked	Common armyworm damages barley, oats, wheat, native pasture grasses and perennial grass seed crops
Life cycle	Common armyworms have three generations per year. The winter and spring generations damage cereals. Moths fly into cereal crops and lay their eggs in the folds of dried or drying leaves on grasses or cereals. Females lay up to 1000 eggs in irregularly shaped masses, cemented in tight folds of foliage. Eggs hatch as little as 3–4 days after laying and young larvae, with the assistance of wind, disperse through the crop on fine silken threads. The larvae feed on leaves and stems. Larvae usually develop through six instars but sometimes seven. Indicative development times at constant temperature are: egg-laying to hatch, 7 days at 20°C and 2.5 days at 30°C; larval stages (including pre-pupal stage) 34.2 days at 20°C and 17.2 days at 30°C. Larvae pupate in the soil. Pupal stage lasts 20.1 days at 20°C and 10.1 days at 30°C. Development time from neonate to adult emergence is 61 days at 20°C and 41 days at 30°C (Smith 1984)
Risk period and damage	Risk period: The greatest risk to cereals is spring. Moth flights occur in September and October, and the later stage larvae damage cereals often in the weeks prior to harvest. The mature larval stages of the winter generation will sometimes march in cereal crops in late winter and cause serious damage to crops, particularly on the edges of paddocks. Crops directly seeded into standing stubbles are susceptible to severe defoliation during the vegetative stage as the winter generation matures. Damage: There are two distinct periods for economic damage. The first, defoliation during early vegetative development, is less common than the second through ripening. In southern Australia, the wheat head stays green later and armyworms feed along the heads and damage grain rather than excising the whole head
Monitoring and action level	Large numbers of armyworm moths are attracted to farm lights on warm nights in September and October. This provides the first warning of potential problems in cereals. Armyworm larvae are difficult to find in cereals crops because they hide at the base of plants or under clods of soil during the day. Search at the base of plants and under clods of soil to estimate the number of larvae per m^2. Presence of green–yellow pellet-shaped droppings of the larvae on the ground is usually a reliable sign of larvae. Monitor for larvae at dusk with a sweep net; sweep netting during the day can be unreliable. Action level is 2 larvae/$m^2$for barley, but other cereals are likely to tolerate slightly higher numbers
Control	Chemical control: A range of insecticides is registered for armyworm control in cereals. Insecticides should target larvae 10–20 mm long. Larvae >20 mm long can be difficult to kill and may require higher rates of insecticide. If possible, spray late in the day as larvae are active at night. See Pest Genie or APVMA for current control options. Cultural control: Windrowed or swathed crops dry out rapidly, rendering them unattractive for the feeding of armyworm larvae. They are also less susceptible to wind damage (head shattering)

[34] DAF Qld (2010) Common, northern and sugarcane armyworms. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/armyworm-overview/common,-northern-and-sugarcane-armyworms

Natural enemies	Armyworm larvae are attacked by a number of parasitoids that may be important in reducing the intensity of outbreaks. However, when armyworms are in numbers likely to cause damage, parasitoids are unlikely to give timely control. Predators include green carab beetles, populations of which increase dramatically in inland Australia in response to abundant noctuid larvae induced by favourable seasons. Other predators include the predatory shield bugs and perhaps common brown earwigs. Fungal diseases are recorded as causing mortality of armyworm

7.7 Snails

Snail numbers can explode in seasons with wet springs, summers.

Snails appear to build up most rapidly in canola, field peas and beans. However, they can feed and multiply in all crops and pastures. Baiting before egg laying is therefore vital. Timing and choice of controls will depend on the season. Baiting should be ceased 8 weeks before harvest to avoid bait contamination in grain.

Understand the factors that determine effectiveness of control. Monitor snails regularly to establish numbers, types, activity and success of controls. To control snails, you will need to apply a combination of treatments throughout the year.

7.7.1 Description

Snails are a mollusc with a rasping tongue and one single muscular 'foot' for movement. Much of their body is encased in a shell, which they secrete as they grow.

7.7.2 Symptoms

Snails consume cotyledons and this may resemble crop failure. Shredded leaves, chewed leaf margins, and irregular holes all occur as a direct result of feeding damage by snails. They generally invade from crop edges.

7.7.3 Control

Free-living nematodes carrying bacteria that cause snail death may help to reduce populations under certain field conditions. Hard grazing of stubbles, cabling and/or rolling of stubbles, stubble burning, cultivation, and removal of summer weeds and volunteers are all effective management options. Molluscicidal baits are effective on mature snails, and IPM-compatible, but can be less effective on juveniles. [35]

7.8 Soil pests

Occurrence of soil-dwelling pests is difficult to predict, so advice on their control should be sought prior to sowing if any problems are foreseen. The most severe damage tends to occur in crops following pasture, or if stubble has been retained. [36]

7.8.1 Cutworm (*Agrotis* spp.)

Several species of cutworms (*Agrotis* spp.) (Figure 13) attack establishing cereal crops. As their name suggests, cutworm larvae sever the stems of young seedlings at or near ground level, causing the collapse of the plant (Table 12). Damage usually shows up as general patchiness or as distinct bare areas in a very short time. Controlling weeds in the fallow prior to planting will assist in reducing cutworm population and reduce crop damage. This should be done at least 3-4 weeks prior to sowing. Chemical control may be warranted if larval numbers exceed 2/0.5-m row in emerging crops. The best time to monitor is late afternoon–evenings when larvae feed. During the day, scratch away soil around damaged plants to find larvae sheltering in the soil. For more information

[35] CropPro. Snails. Pests in canola. CropPro, http://www.croppro.com.au/cb_pages/pests_in_canola_-_in_crop.php?category_id=2382

[36] P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

read, how to recognise and monitor for soil insects in: Insect pest management in winter cereals. [37]

Figure 13: Cutworm (Agrotis sp.) larvae on soil surface. (Photo: J Wessels)

Table 12: Cutworm description and management summary [38]

Scientific name	*Agrotis* spp.
Description	Larvae are up to 50 mm long, hairless with dark heads and usually darkish bodies, often with longitudinal lines and/or dark spots. Larvae curl up and remain still if picked up. Moths are a dull brown-black
Similar species	May be confused with armyworms and Helicoverpa larvae
Crops attacked	All field crops. Crops are at most risk during seedling and early vegetative stages
Damage	Young caterpillars climb plants and skeletonise the leaves or eat small holes. Older larvae may also climb to browse or cut off leaves, but commonly cut through stems at ground level and feed on the top growth of felled plants. Caterpillars that are almost fully grown often remain underground and chew into plants at or below ground level. They usually feed in the late afternoon or at night. By day they, hide under debris or in the soil
Monitoring and action level	Inspect crop twice weekly in seedling and early vegetative stage. Larvae feed late afternoons and evenings. Chemical control is warranted when there is a rapidly increasing area or proportion of crop damage
Life cycle	Usually a single generation during early vegetative stages. Moths prefer to lay their eggs in soil in lightly vegetated (e.g. a weedy fallow) or bare areas. Early autumn egg-laying results in most damage to young cereals. Larvae hatch and feed on host plants right through to maturity. Mature larvae pupate in the soil. Under favourable conditions, the duration from egg-lay to adult emergence is 8–11 weeks, depending on the species

[37] DAF Qld (2012) Insect pest management in winter cereals. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/ipm-information-by-crop/insect-pest-management-in-winter-cereals

[38] DAF Qld (2010) Cutworm. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/cutworm

Control	Chemical control: Insecticide application is cost-effective. The whole crop may not need to be sprayed if distribution is patchy; spot spraying may suffice. See Pest Genie or APVMA for current control options. Cultural control: Control weeds 3–4 weeks prior to sowing. Natural enemies: Cutworms are attacked by a number of predators, parasites and diseases
Pest status	Minor, widespread, irregular

7.8.2 Wireworms and false wireworms

Importance

Wireworms and false wireworms are common, soil-inhabiting pests of newly sown winter and summer crops. Wireworms are the larvae of several species of Australian native beetles, which are commonly called 'click beetles', from the family Elateridae.

False wireworms are also the larval form of adult beetles, some of which are known as 'pie-dish beetles', which belong to another family (Tenebrionidae), and have distinctively different forms and behaviour. Both groups inhabit native grassland and improved pastures, where they cause little damage. However, cultivation and fallow decimates their food supply, and hence, any new seedlings that grow may be attacked and sometimes destroyed. They attack the seedlings at pre- and post-emergence of all oilseeds, grain legumes and cereals, particularly in light, draining soils with a high organic content.

The incidence of damage caused by wireworms and false wireworms appears to be increasing with increasing use of minimum tillage and short fallow periods.

7.8.3 False wireworms

In crops, false wireworms are mostly found in paddocks with high contents of stubble and crop litter. They may affect all winter-sown crops.

Description

There are many and varied species of false wireworm, but they share some general characteristics. Larvae are cylindrical, hard-bodied, fast-moving, golden brown to black-brown or grey with pointed upturned tails or a pair of prominent spines on the last body segment. Several common groups (genera) of false wireworms are found in south-eastern Australia:

- Grey or small false wireworm (*Isopteron* (*Cestrinus*) *punctatissimus*). Larvae grow to ~9 mm in length. They are grey-green, have two distinct protrusions from the last abdominal (tail) segment (Figure 14), and tend to have a glossy or shiny exterior. Hence, they are most easily recognised in the soil on sunny days, when their bodies are reflective. The adults are slender, dark brown and grow to ~8 mm in length. Eggs are <1 mm in diameter. There are several species of this pest genus, but *I. punctatissimus* appears to be the species most associated with damage.
- Large or eastern false wireworm (*Pterohelaeus* spp.). The largest group of false wireworms, they are the most conspicuous in the soil and grow up to 50 mm in length. They are light cream to tan, with tan or brown rings around each body segment, giving the appearance of bands around each segment (Figure 14). The last abdominal segment has no obvious protrusions, although under a microscope, there are a number of distinct hairs. Adults are large, conspicuous and often almost ovoid beetles with black, shiny bodies (Figure 15).
- Southern false wireworm (*Gonocephalum* spp.) grows to ~20 mm in length and has body colour and marking similar to the large false wireworm. Adults are generally dark brown-grey, oval beetles, and sometimes have a coating of soil on the body. Adults have the edges of the body flanged, hence the common name pie-dish beetles.

- Bronzed field beetle (*Adelium brevicorne*) larvae are shiny dark brown, grow to 12 mm long, and are cylindrical with two distinct, upturned spines on the end of the body. Adults are shiny black with a slight bronze appearance, grow to 11 mm long and are present from spring to autumn. There is one generation per year.

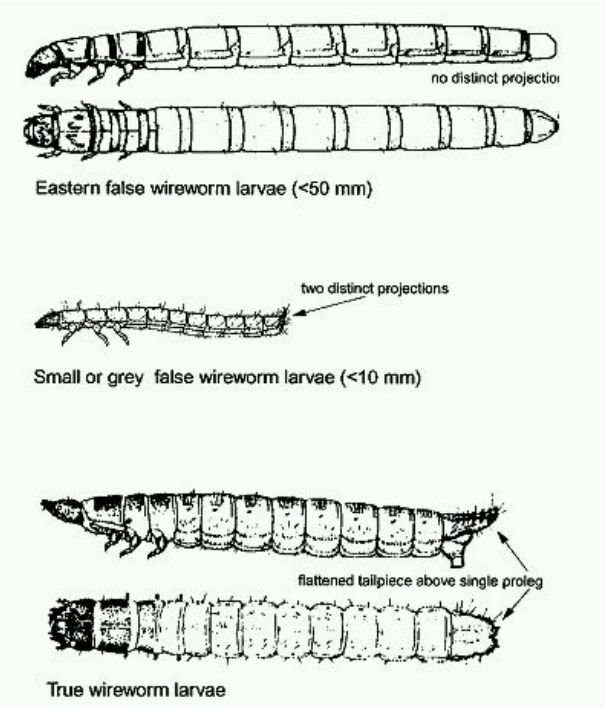


Figure 14: Two common false wireworm larvae and a 'generalised' true wireworm larva.

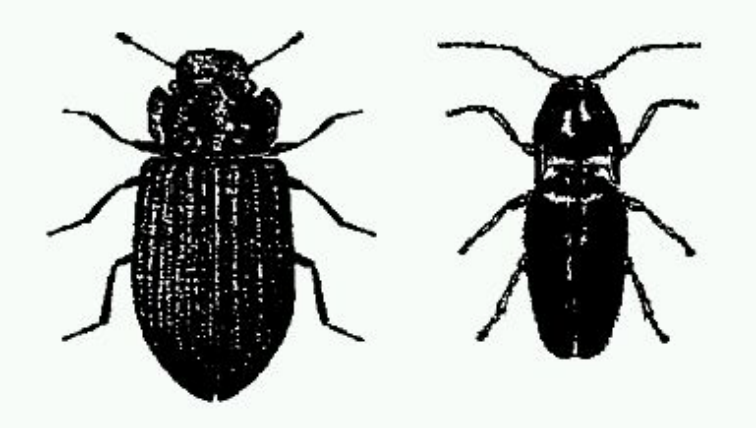


Figure 15: Adult (beetles) of the false wireworm (left) and true wireworm (right). [39]

Seasonal development and symptoms

Larvae of most false wireworm species prefer to feed on decaying stubble and soil organic matter. When the soil is reasonably moist, the larvae are likely to aggregate in the top 10–20 mm where the plant litter is amassed. When the soil dries, the larvae move down through the soil profile, remaining in or close to the subsoil moisture, and occasionally venturing back to the soil surface to feed. Feeding is often at night when the soil surface becomes dampened by dew.

[39] G McDonald (1995) Wireworms and false wireworms. Agriculture Victoria, DEDJTR, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects-and-mites/wireworms-and-false-wireworms

Nothing is known of the conditions that trigger the switch in the feeding of false wireworms from organic matter and litter to plants. Significant damage is, however, likely to be associated with soils that remain dry for extensive periods. Larvae are likely to stop feeding on organic matter when it dries out, and when the crop plants provide the most accessible source of moisture.

Impact

Affected crops may develop bare patches, which can be large enough to require resowing. Damage is usually greatest when crop growth is slow in cold, wet conditions.

The larger false wireworms can cause damage to most field crops. The larvae can hollow out germinating seed, sever the underground parts of young plants, or attack the aboveground hypocotyl or cotyledons. Damage is most severe in crops sown into dry seedbeds, and if germination is slowed by continued dry weather.

Sampling and detection

The principles for detection and control of false and true wireworms are generally similar, although different species may respond slightly differently according to soil conditions.

Crops should be sampled immediately before sowing. Two methods are available, although neither is completely reliable. This is because larvae change their behaviour according to soil conditions, particularly soil moisture and temperature:

1. Soil sampling. Take a minimum of five random samples from the paddock. Each sample should consist of the top 20 mm of an area of soil 0.50 m by 0.50 m. Carefully inspect the soil for larvae. Calculate the average density per m^2 by multiplying the average number of larvae found in the samples by 4. Control should be considered if the average exceeds 10 small false wireworms, or 10 of the larger false wireworms.
2. Seed baits. Seed baits have been used successfully to sample true and false wireworms in Queensland and overseas but they have not been rigorously tested in Victoria. Preliminary work indicates that they can be used to determine the species of larvae present, and give an approximate indication of density. Pre-soak ~200–300 g of a large seed bait, such as that of any grain legume, for 24 h. Select 5–10 sites in the paddock, place a handful of the soaked seed into a shallow hole (50 mm), and then cover with about 10 mm of soil. Mark each hole with a stake, and re-excavate after ~7 days. Inspect the seed and surrounding soil for false wireworm larvae. This technique is most likely to be successful when there is some moisture within the top 100 mm of soil.

Control

Crop residues and weedy summer fallows favour survival of larvae and oversummering adult beetles. Clean cultivation over summer will starve adults and larvae by exposing them to hot dry conditions, thus preventing population increases. Suitable crop rotations may also limit increases in populations.

If damage occurs after sowing, no treatment is available, other than resowing bare patches with an insecticide treatment.

7.8.4 True wireworms

These slow-moving larvae tend to be less common, although always present, in broadacre cropping regions and are generally associated with wetter soils than is the case for false wireworms.

Description

Larvae grow to 15–40 mm, are soft-bodied, flattened and slow moving. This distinguishes them from false wireworms, which are hard bodied, cylindrical and fast moving. Their colour ranges from creamy yellow in the most common species to red

brown; their head is dark brown and wedge-shaped. The tailpiece is characteristically flattened and it has serrated edges (Figure 14). Adults are known as click beetles, because of their habit of springing into the air with a loud click when placed on their backs. They are dark brown, elongated and 9–13 mm long (Figure 15).

Seasonal development and symptoms

There may be one generation or several per year, depending on species. Most damage occurs from April to August and adults emerge in spring. True wireworms prefer low-lying, poorly drained paddocks and are less common in dry soils. Larvae are quite mobile through the soil and they will attack successive seedlings as they emerge. Adults are typically found in summer and autumn in bark, under wood stacks or flying around lights.

Adult click beetles emerge in spring and summer, mate and lay eggs, and then may spend a winter sheltering under the bark of trees. The connection between trees and adult beetles may explain why damage is often, but not always, most pronounced on tree lines. True wireworms have a long life in the soil and are active all year, even in winter.

Impact

The damage caused by true wireworms is similar to that of false wireworms, except that most damage is restricted to below the soil surface. Larvae eat the contents of germinating seed and underground stems of establishing plants, causing wilting and death.

Sampling, detection and control

See above discussion on false wireworm for full details. Wireworms and false wireworms can be controlled only if they are detected in the seedbed before sowing. Insecticide can be applied to the soil with fertiliser, or seed can be treated.

7.8.5 Weevils

Weevils are a diverse group of beetles commonly found in Australian grain crops (Table 13, Figure 16). Adult weevils appear very different from the larvae. Adults have a hardened body, six prominent legs and an elongated, downward-curved head forming a ‘snout’. Larvae are legless, maggot-like in shape and may be confused with fly larvae. Weevil larvae possess a small, hardened head capsule.

Crop weevils feed on vegetative parts of crop plants including the roots, stems, shoots, buds and leaves. Both adults and larvae can be damaging to plants, depending on the species, crop type and time of year. Typical feeding damage observed is scallop-shaped holes along the edges of leaves.

Weevils can be difficult to control with chemicals because of their secretive habits. Several species are also patchy in their distribution within paddocks. For some species, seed treatments and foliar insecticides can provide a level of control.

Weevils are typically favoured by minimum tillage and stubble retention. Cultivation, burning and reducing the amount of stubble will reduce the suitable habitat for weevils and reduce their number. Identification of crop weevils is important when making control decisions. The distinctive appearance of weevils means that they are unlikely to be confused with other beetles. However, distinguishing between the many species of weevil is challenging. Crop weevils: the Back Pocket Guide is designed to assist growers in identifying the most commonly observed weevils found in the southern and western cropping regions.[40]

Weevil damage can occur at any time of the season, but feeding during autumn and early winter is typically the most critical. Inspect paddocks and nearby weeds prior to sowing and monitor crops for signs of seedling damage and bare patches within

[40] GRDC (2013) Crop weevils: the Back Pocket Guide. GRDC, http://www.grdc.com.au/GRDC-BPG-CropWeevils

paddocks. Look for signs of chewing damage on plants, often characterised by scallop-shaped holes along the leaf margins, ring-barking of seedlings, and loss of plant vigour. Searches may need to be undertaken during the night because is when weevils are most active.

Weevils, particularly larvae, can be difficult to control with chemicals because of their subterranean habits, meaning that they remain protected from insecticide exposure. Exceptions are the vegetable and grey-banded leaf weevils, whose larvae also feed on foliage. A few registered products are available for the active stages of several weevil species.[41]

Table 13: Description of common weevil species

Weevil species	Adult length (mm)	Distinctive features of adult weevils	Larval head capsule colour
Fuller's rose	8	Yellow or grey stripe on thorax and abdomen	Light
Grey-banded leaf	8	Pale band on rear of abdomen	Dark
Mandalotus	3–5	Dull brown, paddle-shaped bristles; short snout	Yellow–brown
Sitona	5	Three white strips on thorax; broad snout	Brown
Small lucerne	7	Less distinct lateral stripes than whitefringed	Light
Spinetail	7	Wing covers taper to spine (females); longer snout	Yellow
Spotted vegetable	5-7	Mottled–specked; longer snout	Brown
Whitefringed	10-15	Light lateral stripes	Light
Vegetable	10	Light-coloured 'V' at rear of abdomen	Brown

Figure 16: Small lucerne weevil (left) and Fuller's rose weevil (right). (Source: cesar)

7.8.6 Earwigs

Reports are increasing of European earwigs (*Forficula auricularia*) causing significant damage to emerging crops. Stubble retention in combination with wet springs and summers and an early autumn break appears to favour the build-up of these insects.

[41] **Cesar** (2015) Weevil pests. PestFacts south-eastern, issue 2, May 2015. cesar, http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2015/pestfacts-issue-no-2-22nd-may-2015/weevil-pests/

The damage caused by earwigs can be difficult to identify, and because control can also be difficult, growers should seek advice if they suspect or see earwigs. [42]

Correctly identifying earwig species is important because they have roles as pests or beneficial species. Not all earwigs found in crop paddocks are pests (Figure 17). Although European earwigs are renowned as pests, other earwigs can be benign or beneficial.

Other common earwig species include:

- Common brown earwig, *Labidura truncata*, which is a native and beneficial species. They are mostly red-brown and 10–45 mm in length. This species is most common in sandy habitats but occurs across southern Australia and mainly feeds on soft-bodied insects such as caterpillars, lucerne flea and mites. It can be distinguished by an orange triangle behind its head on the elytra (wing cases). Males have long slender forceps with a distinctive tooth near the middle of the inner edge.
- Black field earwig, *Nala lividipes*, which is a minor pest species of broadacre agriculture, only occasionally attacking crops. They are smaller, at about 15 mm long, shiny black, and can be a pest of seeds and seedlings. Adults have wings and can fly; nymphs resemble adults but are wingless. The black field earwig is omnivorous, meaning they can be a pest and a predator. They can attack wheat, sorghum, maize and sunflowers. They eat newly sown and germinating seeds and the roots of crops, resulting in poor establishment. Black field earwigs prey upon a range of insects, including wireworms and *Helicoverpa* spp.
- *Euborellia* spp. are small, dark-coloured earwigs ranging from 10 to 25 mm in size. There are many subspecies, and they can be difficult to distinguish. They are flightless and appear to form mating pairs that maintain a small territory. Male and females will often be found together and, at times, with a brood of young earwigs. Preliminary research indicates that they may not be plant feeders and are likely to be more predatory.

Figure 17: Top left: European earwig, Forficula auricularia—a pest species. Top right: common brown earwig, Labidura truncata—a native and predatory species. (Photos: DAFWA) Bottom: black field earwig, Nala lividipes—a predatory species and minor pest. (Photos: DAF Qld)

[42] P Matthews, D McCaffery, L Jenkins (2015) Winter crop variety sowing guide 2015. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

Seasonal development

European earwigs complete one generation per year, although females can produce two broods in some years. They can survive in a range of environments and the length of their life cycle depends on temperature. At 25°C, development from egg to adult takes 9–10 weeks but at 15°C it takes up to 5 weeks longer. In winter, adult females lay batches of 20–80 white, oval eggs in burrows in the topsoil, which hatch in 2–3 weeks.

In some years, under favourable environmental conditions, earwigs may lay eggs in late spring to produce a second summer brood. There are several nymphal instars (stages between moults). Female earwigs remain in the burrow, protecting the eggs and nymphs.

Impact

European earwigs mainly attack canola but will also attack cereals, lupins and some legume crops. Damage can be scattered because of their patchy distribution. Earwigs chew the stems and cotyledons of emerging seedlings, killing plants or slowing plant development. As the plant grows, foliar damage includes shredded leaf tips and jagged holes in leaves.

Earwigs can completely defoliate young seedlings, leaving only stems or bare ground in patches. They can also chew through seedpods. Earwigs feed together at night, and in many cases, damage will start along the edges of a paddock. Earwig damage to plant leaves resembles feeding damage caused by slugs. Damage has been reported mainly in the medium- and high-rainfall zones, including South Australia's Mid North and South East regions, Victoria's Western District and the South West Slopes of New South Wales. Nearly all cases of damage have occurred in paddocks where minimum or no-till practices were used with high stubble loads, and often on heavier soils.

Management—windrowing and harvesting

Grain with high numbers of earwigs may require cleaning to meet delivery standards.

Monitoring

It is important to distinguish earwig species in order to make the most appropriate management decision and accurately assess the risk of attack to emerging crop seedlings. Native earwig species can have an important role in IPM and in the control of other insects. Monitoring for earwigs is best conducted at night, using a torch, because they are nocturnal feeders.

Another approach is to set pitfall traps—a small plastic cup buried flush in the soil. A small amount of liquid in the bottom will help to contain the insects that fall into the trap. Traps should be left for at least 24 h and are useful for catching invertebrates.

7.8.7 Black Portuguese millipedes (*Ommatoiulus moreleti*)

In the last 5–10 years, the black Portuguese millipede (*Ommatoiulus moreleti*) (Figure 18) has been emerging as a sporadic but damaging pest of broadacre agriculture, particularly canola.

The increase has been linked to stubble retention, no-till farming practices and improvements in soil organic matter, which have provided a more favourable habitat for millipedes to survive and reproduce. Recent wet summers have contributed to a population build-up in some parts of southern Australia, and planting of more vulnerable crops has led to increased damage.

The black Portuguese millipede is native to Europe and has been accidentally introduced to other countries, including Australia, where it is now common across south-eastern Australia.

Figure 18: Black Portuguese millipede (Ommatoiulus moreleti). (Photo: Western Australian Museum)

Description

The smooth, cylindrical body of the black Portuguese millipede distinguishes it from other native species, which often have rougher and more uneven bodies. They come from the same family as several native Australian millipedes and centipedes, called myriapods, meaning 'many-legged'. Measuring 30–45 mm, adult millipede bodies consist of up to 50 segments with each segment having two pairs of legs. When disturbed, they either curl up in a tight spiral or thrash to escape.

Native millipedes are widespread in low numbers, but black Portuguese millipedes are found in large numbers and are quite mobile for their size, especially after opening autumn rains. They can move several hundred metres in a year.

They are transported between properties and to new regions in plant material, infested soil and farm machinery. [43]

Seasonal development and symptoms

Black Portuguese millipedes start mating in March and April and lay most of their eggs in April and May. Mature females lay ~200 yellowish white eggs the size of a pinhead, in a small hole they make in the soil.

An immobile, legless stage hatches from each egg and develops into the first active stage of the life cycle after ~7 days (Figure 19). This first stage has only three pairs of legs. Millipedes grow through a series of moults. At each moult, the millipede adds more legs and body segments until it is mature.

During the first year of life, millipedes are quite small and easily overlooked. After the first year, juveniles reach the seventh, eighth or ninth stage of development and they will be about 1.5 cm long. After this, they moult only in spring and summer.

During moulting, millipedes are vulnerable because the new cuticle (outside skin layer) is soft and easily damaged. Black Portuguese millipedes usually mature after 2 years when they are in the tenth or eleventh stage of growth.

Millipedes feed on leaf litter, damp and decaying wood, fungus and vegetable matter such as tender roots, mosses, pollen or green leaves on the ground. They can play a role in breaking down organic matter in the soil. As a result, they occur in greater numbers in undisturbed leaf litter and organic mulch and in areas where winter weeds, such as sour sobs and Salvation Jane, form a mostly continuous groundcover. Millipedes are not numerous in cultivated areas or bare ground.

[43] GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters

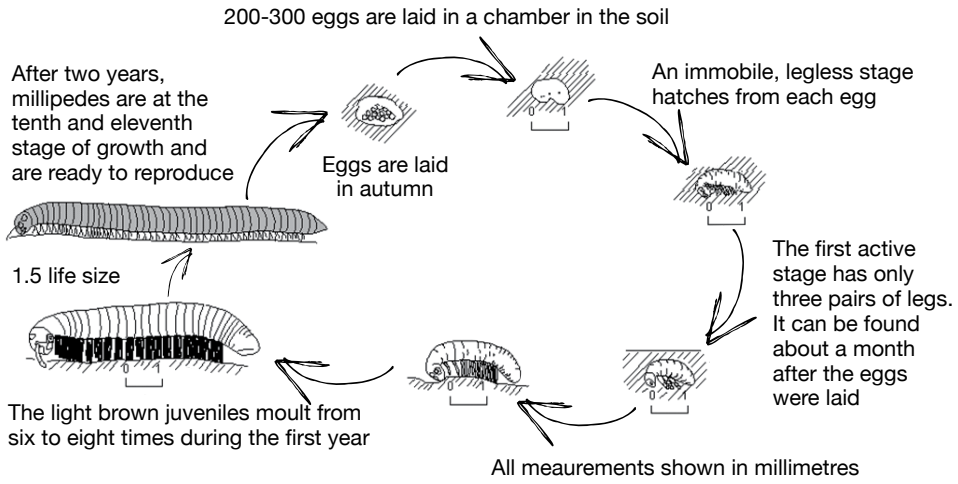


Figure 19: Life cycle of black Portuguese millipede.

Impact

Because black Portuguese millipedes generally feed on organic matter, crop feeding damage is relatively rare. Black Portuguese millipedes occasionally attack living plants by chewing the leaves and stems. They may feed on crop plants when they are seeking moisture, but this has not been confirmed.

Damage to cereals can occur where the stems of young plants are chewed.

In the southern region, damage has been reported in the medium- and high-rainfall zones including near Wagga Wagga and Henty in New South Wales, the Mid North, Yorke Peninsula and Kangaroo Island in South Australia, and the Western District and Wimmera areas of Victoria. In many cases, damage has been worst in areas with high volumes of retained stubble or where plant matter from the previous year was present.

The presence of black Portuguese millipedes does not always mean damage. In many instances, no damage has occurred despite large populations of millipedes. Millipedes are mostly active and feed at night, which is the best time to check whether they are causing damage. [44]

Management

Control options for millipedes are limited but some measures will curb populations. No insecticides are registered to control millipedes in broadacre agriculture.

Cultural

Reducing the amount of trash and stubble over summer and early autumn is likely to be the most effective way to reduce millipede numbers. Other factors to consider in management of crops and rotations include:

- Burning stubbles may reduce millipede populations.
- Early sowing of high-vigour varieties at a higher seeding rate will help to compensate for seedling losses from pest damage.

Biological

Millipedes have very few natural predators. Their bodies contain rows of glands that secrete a pungent yellowish fluid when they are agitated, and this fluid makes millipedes distasteful to predators such as birds.

A parasitic native nematode, *Rhabditis necromena*, attacks and kills millipedes by reproducing in the millipede's gut. However, the use of nematodes is unlikely to be economically viable for broadacre crop release.

[44] GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters

Some spiders and beetles will eat millipedes but these predators will not significantly reduce large populations.

7.8.8 Slaters

Slaters perform an important recycling role in the environment. However, native and introduced slaters have become an increasing pest of broadacre crops and pastures. The move to minimum or no-tillage and stubble retention is likely to have created a more favourable environment in cropping paddocks for slaters. Stubble provides a cool, moist habitat, and crumbly clay soil surfaces and cracking clays aid their survival.

Description and development

Slaters are also known as woodlice, sowbugs and pill bugs. They are crustaceans, related to crabs, lobsters and prawns but are adapted to living on land. They have a hard skeleton on the outside of their bodies, seven pairs of jointed legs, and two pairs of antennae (Figure 20).

Most slaters are detritivores, meaning they feed on decaying vegetation and associated fungi, as well as on dead animal matter such as insects. They can eat living plants, such as seedlings and root vegetables, but only rarely.

Slaters need damp conditions and they will die if exposed to open and dry situations. They tend to be active at night when the risk of dehydration is low.

Female slaters keep their eggs in a pouch until the young hatch. Hatchlings then leave the parent and are completely independent. Slaters grow through a series of moults in which the outer rigid skeleton is shed, allowing growth to the next, larger stage and finally to adult stage. When moulting, slaters shed in two stages: the top half of their body first, followed by the remaining half 2 days later. During moulting, the slater is very vulnerable and must find shelter. [45]

Figure 20: Like black Portuguese millipedes, slaters generally feed on organic matter, and their populations and the incidence of crop attack have increased in recent years. (Photo: © NICK MONAGHAN, LIFEUNSEEN.COM)

[45] GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters

Species

Several slater species are found in Australia including:

- Common slater (*Porcellio scaber*). Originally introduced from Europe, the species is widespread in Australia. The common slater can grow up to 20 mm in length and is usually pale grey; however, brown, yellow or orange hues have been observed.
- Pill bug (*Armadillidium vulgare*). This is also a European species, introduced to Australia, and gets its name from its ability to roll into a ball when disturbed. It can grow up to 18 mm and is dark brown to black.
- Flood bug (*Australiodillo bifrons*). Populations of flood bugs have increased in parts of New South Wales. The flood bug is ~7–8 mm long and 4 mm wide with an oval-shaped and flattened body, light brown, with darker irregular spots and a dark-brown stripe down the middle of the back. It is a lowland, swampy-soil species. Areas worst affected in the past by flood bugs are prone to flooding.

Symptoms

Little is known about the biology of slaters and their potential to become a widespread agricultural pest in Australia.

Slaters can cause significant feeding damage, leading to seedling mortality and stunted plant growth. In some situations, crops or parts of paddocks may need to be re-sown. Often, symptoms resemble feeding damage caused by lucerne flea.

Slater feeding on plants results in an uneven, rasping-type damage that can appear similar to slug and snail damage. They can chew the tops of emerging cotyledons or leaves of crop seedlings, leaving only the seedling stumps.

The flood bug in particular has potential to cause rapid damage to crops because of its ability to swarm. A consistent mass of slaters moves along the soil surface, climbing trees or moving into logs or posts (Figure 21). Swarms can contain >100,000 individuals, sometimes up to 1,000,000, and include all life stages, from juveniles to adults.

The size of swarms varies and is likely to be influenced by the time of day, weather conditions and surrounding vegetation. Thousands of seedlings can be eaten in a very short time when swarms are large enough.

Figure 21: Typical swarming behaviour of flood bug (Australiodillo bifrons) moving across a wheat paddock. (Photo: A Weeks, cesar)

Impact

Slaters rarely attack broadacre crops; however, problems with slaters have increased considerably in the last 5 years. In south-eastern Australia, slaters have caused damage to wheat, oats, canola, lentils and pastures.

The presence of slaters, even in high numbers, in a paddock does not always mean that crop damage will occur, because slaters generally feed on decaying organic matter. Feeding on emerging crop seedlings is relatively rare. It is not known what makes slaters suddenly prefer to eat seedlings rather than organic matter.

In south-eastern Australia, damage has been reported in the medium- and high-rainfall zones including South Australia's Mid North and Yorke Peninsula, Victoria's Wimmera and Western Districts, and central New South Wales. In many cases (but not all), damage has been reported where there was an accumulation of stubble or other plant matter, or cracked soils. [46]

Management

Management options are limited after crop emergence, so prevention is a key part of control. No insecticides are registered to control slaters. Slaters are relatively unaffected by many foliar applications of SPs and OPs to control other crop-establishment pests, even when applied at very high rates.

Managing stubble is likely to be the most effective strategy to reduce slater numbers. Some growers have had success managing slaters by burning crop residues.

7.9 Insect monitoring techniques for field crops

Monitoring for insects is an essential part of successful IPM programs. Correct identification of immature and adult stages of both pests and beneficials, and accurate assessment of their presence in the field at various crop stages, will ensure appropriate and timely management decisions. Good monitoring procedure involves not just knowledge of and the ability to identify the insects present, but also good sampling and recording techniques and common sense.

7.9.1 Factors that contribute to quality monitoring

Knowledge of likely pests or beneficials and their life cycles is essential when planning a monitoring program. As well as visual identification, you need to know where on the plant to look and the best time of day to get a representative sample.

Monitoring frequency and pest focus should be directed at crop stages likely to incur economic damage. Critical stages may include seedling emergence and flowering/grain formation.

Sampling technique is important to ensure that a representative portion of the crop has been monitored, because pest activity is often patchy. Defining sampling parameters (e.g. number of samples per paddock and number of leaves per sample) helps sampling consistency. Actual sampling technique, including sample size and number, will depend on crop type, age and paddock size, and is often a compromise between the ideal number and location of samples, and what is practical considering time constraints and distance covered.

Random sampling should be balanced with areas of obvious damage. Random sampling aims to give an overall picture of what is happening in the field, but any obvious hotspots should also be investigated. The relative proportion of hotspots in a field must be kept in perspective with less heavily infested areas.

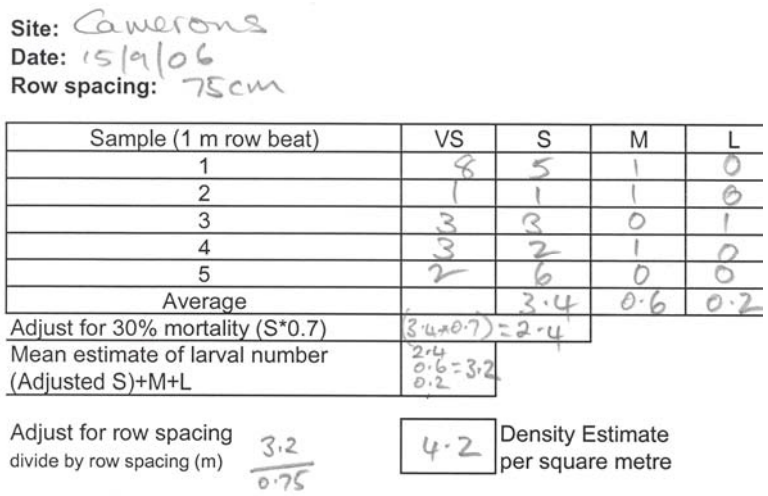
7.9.2 Keeping good records

Accurately recording the results of sampling is critical for good decision making and

[46] GRDC (2013) Millipedes and slaters in no-till systems. GRDC Black Portuguese millipedes and slaters Fact Sheet, October 2013, http://www.grdc.com.au/GRDC-FS-Millipedes-Slaters

being able to review the success of control measures (Figure 22). Monitoring record sheets should show the following:

- numbers and types of insects found (including details of adults and immature stages)
- size of insects (particularly important for larvae)
- date and time
- crop stage and any other relevant information (e.g. row spacings, weather conditions, and general crop observations)



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 22: An example of a field check sheet for chickpeas, showing adjustments for field mortality and row spacings.

Consider putting the data collected into a visual form that enables you to see trends in pest numbers and plant condition over time. Being able to see whether an insect population is increasing, static or decreasing can be useful in deciding whether an insecticide treatment may be required, and if a treatment has been effective. If you have trouble identifying damage or insects present, keep samples or take graphs for later reference.

Records of spray operations should include:

- date and time of day
- conditions (wind speed, wind direction, temperature, presence of dew and humidity)
- product(s) used (including any additives)
- amount of product(s) and volume applied per hectare
- method of application including nozzle types and spray pressure
- any other relevant details

7.9.3 Sampling methods

Beat sheet

A beat sheet is the main tool used to sample row crops for pests and beneficial insects. Beat sheets are particularly effective for sampling caterpillars, bugs, aphids and mites. A standard beat sheet is made from yellow or white tarpaulin material with heavy dowel on each end. Beat sheets are generally 1.3–1.5 m wide and 1.5–2.0 m deep (the larger dimensions are preferred for taller crops). The extra width on each side catches insects thrown out sideways when sampling, and the sheet´s depth allows it to be draped over the adjacent plant row. This prevents insects being flung through or escaping through this row.

To use the beat sheet, place one edge at the base of plants in the row to be sampled.

Drape the other end of the beat sheet over the adjacent row. This may be difficult in crops with wide row spacing (≥1 m); in this case, spread the sheet across the inter-row space and up against the base of the next row.

Using a 1-m stick, shake the plants in the sample row vigorously in the direction of the beat sheet 5–10 times. This will dislodge the insects from the sample row onto the beat sheet.

Reducing the number of beat sheet shakes per site greatly reduces sampling precision. The use of smaller beat sheets, such as small fertiliser bags, reduces sampling efficiency by as much as 50%.

Use the datasheets to record type, number and size of insects found on the beat sheet.

One beat does not equal one sample. The standard sample unit is five non-consecutive 1-m-long sections of row, taken within a 20-m radius, i.e. 5 beats = 1 sample unit. This should be repeated at six locations in the field (i.e. 30 beats per field).

Increasing the number of samples taken increases the accuracy of the assessment of pest activity, particularly for pests that are patchily distributed, such as pod-sucking bug nymphs.

When is the best time to use the beat sheet?

Crops should be checked weekly during the vegetative stage.

Caterpillar pests are not mobile within the canopy, and checking at any time of the day should report similar numbers.

Pod-sucking bugs, particularly green vegetable bugs, often bask on the top of the canopy during the early morning, and they are more easily seen at this time.

Some pod-sucking bugs, such as brown bean bugs, are more flighty in the middle of the day and therefore more difficult to detect when beat-sheet sampling. Other insects (e.g. mirid adults) are flighty no matter what time of day they are sampled, so it is important to count them first.

In very windy weather, bean bugs, mirids and other small insects are likely to be blown off the beat sheet.

Using the beat sheet to determine insect numbers is difficult when the field and plants are wet.

Although the recommended method for sampling most insects is the beat sheet, visual checking in buds and terminal structures may also be needed to supplement beat-sheet counts of larvae and other, minor pests. Visual sampling will also assist in finding eggs of pests and beneficial insects.

Most thresholds are expressed as pests per m^2. Hence, insect counts in crops with row spacing <1 m must be converted to pests/m^2. To do this, divide the 'average insect count per row metre' across all sites by the row spacing (in metres). For example, in a crop with a row spacing of 0.75 m (75 cm), divide the average pest counts by 0.75.

Other sampling methods

Visual checking is not recommended as the sole form of insect checking; however, it has an important support role. Leaflets or flowers should be separated when looking for eggs or small larvae, and leaves checked for the presence of aphids and silverleaf whitefly. If required, dig below the soil surface to assess soil insect activity. Visual checking of plants in a crop is also important for estimating how the crop is progressing in terms of average growth stage and other agronomic factors.

Sweep-net sampling is less efficient than beat-sheet sampling and can underestimate the abundance of pest insects present in the crop. Sweep netting can be used for flighty insects and is the easiest method for sampling mirids in broadacre crops or crops with narrow row spacing. It is also useful if the field is wet. Sweep netting works best for smaller pests found in the tops of smaller crops (e.g. mirids in mungbeans), is less

efficient against larger pests such as pod-sucking bugs, and is not practical in tall crops with a dense canopy such as coastal or irrigated soybeans. At least 20 sweeps must be taken along a single 20-m row.

Suction sampling is a quick and relatively easy way to sample for mirids. Its main drawbacks are unacceptably low sampling efficiency, a propensity to suck up flowers and bees, noisy operation, and high purchase cost of the suction machine.

Monitoring with traps (pheromone, volatile, and light traps) can provide general evidence on pest activity and the timing of peak egg-lay events for some species. However, it is no substitute for in-field monitoring of actual pest and beneficial numbers. [47]

[47] DAF Qld (2012) Insect monitoring techniques for field crops. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/insect-monitoring