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GRDC GROWNOTES™

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 7

INSECT CONTROL

SECTION 7

Insect control

More information

http://thebeatsheet.com.au/wp-content/uploads/2012/04/GoodBadBug-FINALscreen22Feb3.pdf

http://thebeatsheet.com.au/about/

http://thebeatsheet.com.au/helicoverpa/an-economic-threshold-calculator-for-helicoverpa-chickpeas/

http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

7.1 Insect pest management

Insect pest management in pulses is more than just chemical control. Correct identification of the pest or beneficial insects is critical.

Farming practices have a major impact on insect pest incidence and control needs. For example, aphids are worse in bare-ground situations or in early sowing when summer weeds are present. [1]

7.2 Insect control thresholds

Insect control thresholds provide guidelines to allow timely decisions for crop spraying. This can reduce unnecessary spraying and keep populations from reaching a level where damage is high.

The most common threshold used is an economic threshold, which involves control at a density that will prevent pest numbers from reaching an economically damaging population.

The aim of pest management is to keep pest populations below this economic threshold.

Guideline thresholds based on research exist for some pests but most thresholds fluctuate depending on a number of factors. Monitoring and sampling of crops are essential to determine these factors and their influence on where the threshold lies. Farmers who maintain a close watch on pest activity through regular crop inspections and thorough sampling are in a better position to decide if, and when, treatment is needed.

The following factors should be monitored and considered when using thresholds and making spray decisions:

- environmental conditions and the health of the crop
- extent and severity of the infestation and how quickly the population increases
- prevalence of natural control agents such as parasitic wasps, predatory shield bugs, ladybirds and diseases
- type and location of pest damage and whether it affects yield indirectly or directly
- stage in the life cycle of the pest and the potential for damage
- crop stage and ability of the crop to compensate for damage
- amount of damage that has already occurred and the additional damage if the crop is not sprayed
- value of the crop (high value crops cannot sustain too much damage as a small loss in yield or quality could mean a large financial loss), the cost of the spray and its application, and the likely yield or quality benefit gained from control [2]

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

2 Pulse Australia (20130 Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

7.2.1 Beneficial insects

Chickpeas are unique in that they do not host significant numbers of beneficial insects. Small numbers of parasitic flies (tachinids) have been recorded on chickpea, but little else. Therefore, in relation to IPM, there are no in-crop management opportunities via beneficial insects.

If chickpeas are poorly managed, they can contribute large numbers of *Helicoverpa* to the local populations, posing a threat to susceptible summer crops (sorghum, pulses, cotton) grown in the district. To manage *Helicoverpa* well, it is important to sample and identify the different larval instars (very small, small, medium–large, large). Familiarity with these different life stages is critical to determining the likelihood of damage and optimising the timing of control.

Two species of *Helicoverpa*, *H. armigera* (the corn earworm or cotton bollworm) and *H. punctigera* (the native budworm), may occur in chickpea in the northern region. *Helicoverpa armigera* is resistant to some insecticide groups (particularly the synthetic pyrethroids), whereas *H. punctigera* is susceptible to all products. Although it is not always possible to do so, identifying which species is present, or knowing which predominates in the local area, may help growers avoid products that give insufficient control. Some tools can help growers to make this determination. [3]

More information

http://thebeatsheet.com.au/helicoverpa/an-economic-threshold-calculator-for-helicoverpa-chickpeas/

http://ipmworkshops.com.au/wp-content/uploads/Chickpea_IPM-Workshops_north-March2013.pdf

7.3 Pest-management process

Figure 1 outlines the steps in the pest-management process.

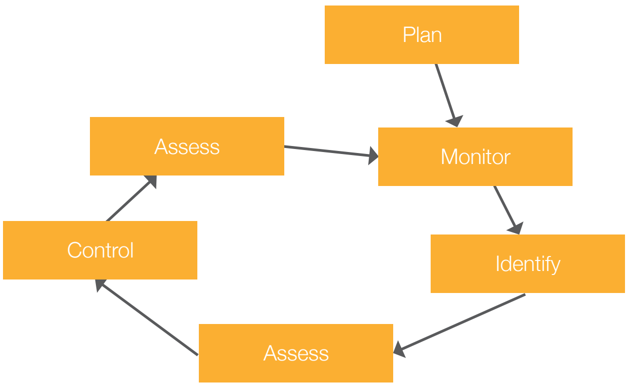


Figure 1: The pest management process.

1. Planning

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

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

2. Monitoring

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

3. Correct identification of insect species

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

4. Assessing options

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

5. Control

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

6. Re-assess and document results

- Assess crops after spraying and record data for future reference.
- Post-spray inspections are important in assessing whether the spray has been effective (i.e. if pest levels have been reduced below the economic threshold). [4]

7.4 Legal considerations of pesticide use

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

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

7.4.1 Registration

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

- against specific pests

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

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

7.4.2 Labels

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

MSDS

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

Permits

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

More information

Details of product registrations and permits are available via the APVMA's website: www.apvma.gov.au.

APVMA

The national body in charge of administering these processes is APVMA and is based in Canberra.

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeded MRLs and litigation.

Pesticide-use guidelines are on the label to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides:

- are applied at rates higher than the maximum specified;
- are applied more frequently than the maximum number of times specified per crop;
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied); or
- are not registered for the crop in question. [5]

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

7.5 Native budworm (*Heliothis*) (*Helicoverpa* spp.)

Helicoverpa spp. are the major insect pests of chickpeas. Other less frequent pests include locusts, aphids, cutworms, false wireworms and blue oat mites.

The larvae of *Helicoverpa* are the main insect pest of chickpeas. It is important to be able to identify the different larval instars (very small, small, medium, large) of *Helicoverpa*. If possible, identifying which of the two species (*H. armigera* or *H. punctigera*) is present, or knowing which is predominate in your area, may help to avoid products that may not provide adequate control.

Description

Figure 2: Native budworm (Helicoverpa, previously Heliothis) moths, showing male (right) and female (left). Note the buff colouring. (Photo: SARDI)

Adult moths are nocturnal, so are rarely seen during the day. They vary in colour from grey-green to pale cream and have a wingspan of 3–4.5 cm. The hind wings have a dark, broad band on the outer margin (Figure 2).

Adult moths lay round eggs (0.5 mm in diameter) singly on the host plant. The eggs are white but turn brown just before hatching. The larvae grow to 5 cm long and vary in colour from green, yellow pink and reddish brown to almost black (Figures 3 and 4).

Figure 3: Left to right: fresh white, brown ring and black larval head in nearly hatching eggs.

Figure 4: *Helicoverpa larvae occur in a range of colours.*

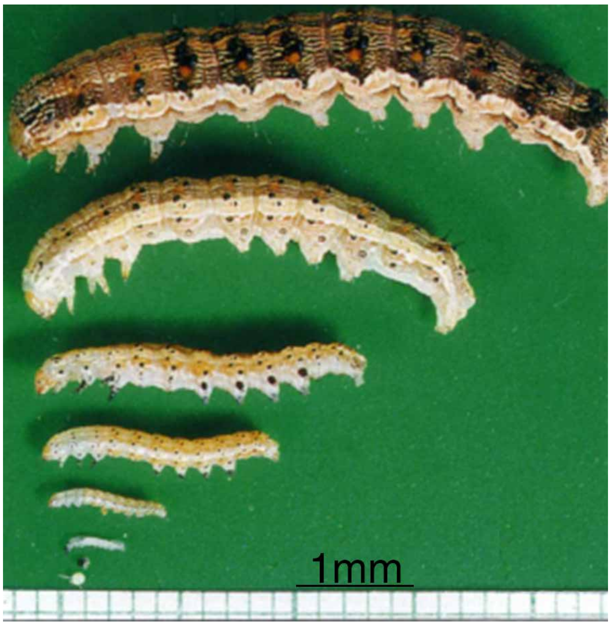


Figure 5: In spring, eggs hatch in 1–2 weeks and larvae feed for 4–6 weeks. This shows all stages from egg to fully grown larvae. Insecticides are more effective on smaller larvae. (Photo: SARDI)

Larvae can be easily identified, despite the colour variation, by a broad yellow stripe along the body (Figure 5). The young larvae (<10 mm) prefer to feed on foliage. Older larvae prefer to feed on pods.

Other larvae, which look like native budworm (*H. punctigera*), may be found in a pulse crop (e.g. southern armyworm and pink cutworm). These are primarily grass feeders and rarely do any damage to pulses.

Two species of Helicoverpa

Both *H. armigera* and *H. punctigera* are found in chickpea in Australia and attack a wide variety of crops, including chickpea.

Visual identification of the different species is sometimes possible from examination of larvae. Small *H. armigera* larvae (3rd instar) have a saddle on the fourth segment and *H. punctigera* do not. This is often difficult to see in the field and the method is not 100% reliable, but may be used as a guide.

In larger (5th and 6th instar) larvae, hair colour on the segment immediately behind the head is a good indicator of species. These hairs are white in *H. armigera* and black in *H. punctigera* (Figure 6). Moths can be differentiated by hindwing colour pattern (Figure 7).

Figure 6: Head of 5th instar H. armigera larva showing the white hairs on the segment immediately behind the head. Larvae of H. punctigera have black hairs. (Photo: R. Lloyd, DPI&F)

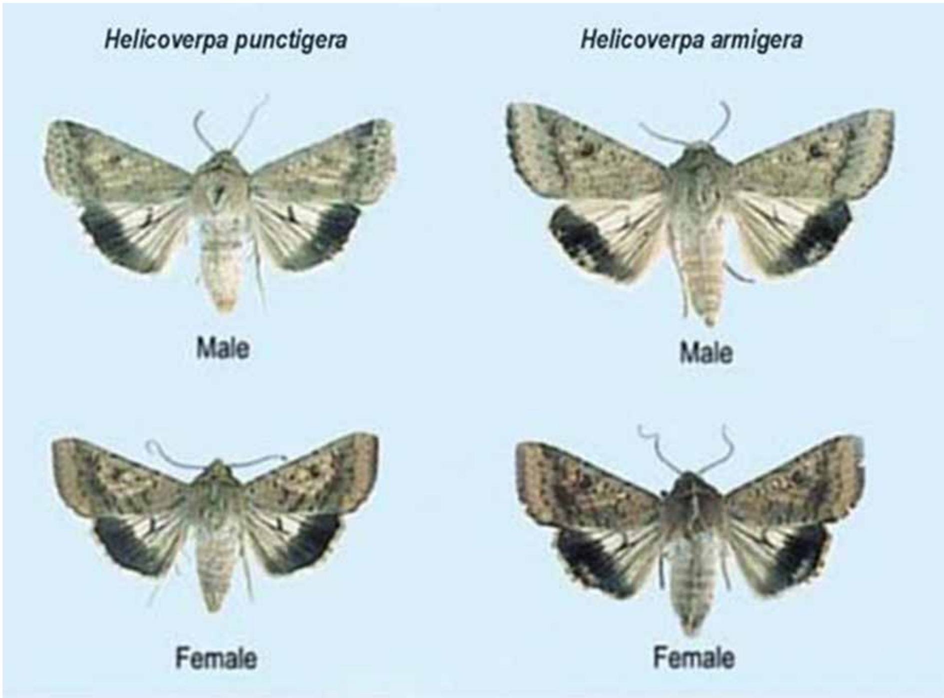


Figure 7: Helicoverpa punctigera and H. armigera moths are distinguished by the presence of a pale patch in the hindwing of H. armigera.

Species composition can vary and will affect control decisions

Species composition in the crop will be influenced by the time of year. In temperate regions (southern Queensland and further south), the majority of *H. armigera* individuals over-winter from mid-March onwards and emerge during September–October. *Helicoverpa punctigera* is usually the dominant species through September, but seasonal variation can lead to *H. armigera*-dominant early infestations in some years, particularly in more northern districts. Pheromone trap catches can be used as an indication of the species present in a region, although they are not a reliable predictor of egg lay within a crop.

If the level of *H. punctigera* infestation is high, any registered product will control the larvae. If *H. armigera* is the dominant species, spray failures with carbamates or pyrethroids may occur because of resistance. The biopesticides *Helicoverpa* nucleopolyhedrovirus (NPV) and *Bacillus thuringiensis* (Bt) currently have no known resistance problems. [6]

7.6 Why distinguish the two species of *Helicoverpa*?

Determining which *Helicoverpa* species is present in the crop is essential, principally because of the differing susceptibility of the two species to synthetic pyrethroids and carbamates.

Visual identification of the different species is sometimes possible from examination of larvae; however, this can be difficult and unreliable with small larvae about the size when control decisions have to be made. A hand lens, microscope or USB microscope is essential for examining small larvae.

Small *H. armigera* larvae (3rd instar) have a saddle on the fourth segment, whereas *H. punctigera* do not (Figure 8). In larger (5th and 6th instar) larvae, look at the hair colour on the segment immediately behind the head—white for *H. armigera* and black for *H. punctigera* (Figure 9).

Figure 8: Medium Helicoverpa armigera (12 mm) showing the distinctive 'saddle' on 4th and 5th body segments (top), and H. punctigera without saddle (bottom).

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

Figure 9: Large Helicoverpa punctigera (left) and H. armigera (right) larvae showing the distinguishing dark and pale hairs, respectively, behind their heads.

7.6.1 Species composition can vary between seasons and regions

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

- Winter rainfall in inland Australia, which drives populations of *H. punctigera*, and the occurrence and timing of wind systems that carry *H. punctigera* from inland Australia to eastern cropping regions.
- Winter rainfall in eastern cropping regions, which drives the abundance of local populations of *H. armigera* through the generation of spring hosts. In regions where chickpeas are grown, they may serve as a significant spring host for *H. armigera* emerging from diapause if these populations are not controlled (e.g. sub-threshold populations across large areas of chickpea, or poorly managed crops).
- Relative timing of flowering–podding (attractive and susceptible) stages and the immigration of *H. punctigera* and emergence of *H. armigera* from overwintering diapause. Note that in Central Queensland, *H. armigera* does not enter winter diapause and will be the predominant species in chickpeas.
- Geographic location. In temperate regions (southern Queensland and further south), most of the *H. armigera* population overwinters from mid-March onwards and emerges during September–October. *Helicoverpa punctigera* is usually the dominant species through September when moths are migrating into eastern cropping regions. Seasonal variation can lead to *H. armigera*-dominant early infestations in some years, particularly in more northern districts. Pheromone trap catches can be used as an indication of the species present in a region. Note that pheromone traps cannot be used to predict the size of an egg-lay within a crop. [7]

7.7 Monitoring chickpeas for insect pests

Chickpeas are susceptible to significant yield loss caused by *Helicoverpa* from podset through to harvest. Although *Helicoverpa* can cause reductions in both yield and quality,

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

the economic threshold for minimising yield loss is much lower than that which would result in a reduction in grain quality.

Seedling insect pests such as cutworm can attack chickpeas, but are rarely an economic problem. Other infrequent pests include blue oat mites, false wireworms, and aphids.

Sampling with a beat sheet is best practice for monitoring *Helicoverpa* in chickpeas. Establishment pests will be detected by visual inspection of seedlings.

Regular monitoring during the susceptible crop stages is critical, particularly for *Helicoverpa*, where you may be dealing with insecticide-resistant larvae, and good control depends on targeting of small larvae.

7.7.1 Sampling strategy and technique

The beat sheet and sweep net are accepted techniques for monitoring *Helicoverpa* larvae in chickpeas. The beat sheet is the recommended technique for crops grown on wider row spacings (>50 cm rows) (Figure 10).

Economic thresholds are developed using a specific sampling technique, an important consideration when making management decisions.

Figure 10: The beat sheet is the recommended technique for sampling crops grown on wider spacings.

Beat sheet v. sweep net

The sweep net and beat sheet have not been calibrated in chickpea, so it is not yet possible to use the one threshold with an adjustment for relative sampling efficiency of the sweep net.

Using a beat sheet

Check crops regularly (at least once a week) from flowering through to harvest, using a beat sheet. In addition to larval counts, visual observation of the crop growth stage, progress of flowering and podding, and the presence of eggs, diseased larvae (NPV) and moths all provide useful information for decision-making.

Each time you inspect, check at least five 1-metre sections of row at a number of sites in the field. Start sampling at least 50 m into the field, and include samples from well into the field to enable a representative average field population to be calculated.

How to use a beat sheet

Place the beat sheet with one edge at the base of a row. On 1-m row spacing, spread the sheet out across the inter-row space and up against the base of the next row. Draping over the adjacent row may be useful for row spacing <1 m, or where there is canopy closure. It also minimises the chance of larvae being thrown off the far side of

Video

Watch a video of sampling chickpeas with a beat sheet at http://www.youtube.com/user/TheBeatsheet the sheet. With a 1-m-long stick (dowel, heavy conduit), shake the row vigorously 10 times to dislodge larvae from the plants. Measure and count larvae on the sheet.

A standard beat sheet is made from plastic or tarpaulin material with heavy dowel on each end to weigh down the sheet. The beat sheet is typically 1.3 m wide by 1.5 m long. The extra 0.15 m on each side catches insects thrown out sideways.

Video

Watch a video of a sweep net being used to sample barley for armyworm at http://www.youtube.com/user/TheBeatsheet

Using a sweep net to monitor Helicoverpa

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

Where crops are sown on narrow row spacings and it is not possible to get a beat sheet between the rows, a sweep net can be used to sample *Helicoverpa*.

Hold the sweep net handle in both hands and sweep it across in front of your body in a 180° arc. Take a step with each sweep. Keep the head of the net upright so the bottom of the hoop travels through the canopy. Use sufficient force in the sweep to pass the hoop through the canopy and dislodge larvae.

Take 10 sweeps and then stop and check the net for larvae. Record the number and size of larvae in each set of 10 sweeps. Repeat at additional sites across the field.

Recording of monitoring data for decision-making

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

Records of insect checking should include as a minimum:

- date and time of day
- crop growth stage
- average number of pests detected, and their stage of development
- checking method used and number of samples taken
- management recommendation (economic threshold calculation)
- post spray counts

The *Helicoverpa* size chart (Figure 11) is an essential reference for decision-making, particularly in chickpea where larval size is taken into account in the economic threshold (beat sheet threshold), and is important in ensuring that any control action is well targeted against susceptible larvae.

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

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

Figure 11: Helicoverpa larval size categories and actual sizes.

Eggs

There are no egg thresholds in chickpeas. Relying solely on egg counts for control decisions in chickpea is unreliable. This is largely due to the difficultly in accurately detecting eggs on the chickpea plant. Egg survival through to larvae can also be highly

More information

See picture on page 14 of 'Insect Ute Guide (Northern Grain Belt)': http://www.grdc.com.au/Resources/Ute-Guides

https://itunes.apple.com/au/app/insect-id-ute-guide-tablet/id667854493?mt=8

variable; therefore, decisions based on egg numbers are less accurate than those based on larval density.

Instead, use egg counts as an indication of an egg-lay event and determine the potential development rate of the *Helicoverpa*. Continue sampling to target small larvae for control.

Eggs take 2–5 days to hatch (generally slower in winter than summer due to temperature differences). Newly laid eggs are white. They turn a brown or off-white colour after a day or two. Eggs very close to hatching are in the 'black head' stage, where the egg is darker in colour and it is possible to see the black head capsule of the developing larva inside.

Very small larvae

The numbers of very small larvae, those that have hatched from the egg in the previous 24 hours, are difficult to estimate in the field. Often they are low in the canopy and remain on leaflets when they fall onto the beat sheet, making them very difficult to see and count. Very small larvae do no economic damage to the crop, their feeding confined to leaves. Early research on *Helicoverpa* showed that the mortality of very small larvae is very high and their value in chickpea monitoring is most likely as indicators of an egg-lay and of potential activity of larger larvae in a week or two. A more detailed discussion follows of why counting and recording very small larvae does not contribute greatly to decision making. [8]

7.8 Economic thresholds for *Helicoverpa*—the cornerstone of decision-making

The economic threshold is classically defined as the pest population likely to cause a loss of yield and/or quality equal in value to the cost of control (chemical plus application). At threshold, the impact of the pest is equivalent to the cost of control, so there will be an economic benefit from controlling the population only if it exceeds the economic threshold.

Calculation of an economic threshold is based on four factors: (*i*) the cost of control, (*ii*) crop value, (*iii*) the average number of insect pests per sampling unit, and (*iv*) the potential loss per pest insect.

7.8.1 Economic thresholds for *Helicoverpa*

This economic threshold is based on beat-sheet sampling (DAFF Queensland 2007).

Vegetative to early flowering: High populations have no impact on yield or quality. In rare situations, control may be warranted during the vegetative and flowering stages, when pest pressure is extreme and plants are defoliated.

Mid-flowering to early podding: Value of crop loss is calculated by the following equation (or refer to the ready-reckoner, Table 1):

Yield loss (\$/ha) = {no. of *Helicoverpa* larvae per m^2 x 2.0 x chickpea price (\$/t)}/100

where 2.0 represents 2 g grain consumed per larva.

This equation has been used to produce the ready-reckoner table (Table 1) for a range of larval densities, and crop prices. Putting a dollar value on the predicted yield loss if nothing is done to control the *Helicoverpa* infestation is a useful way to assess the economic benefit (or otherwise) of spraying.

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

Table 1: The value of yield loss ($/ha) caused by Helicoverpa larvae in chickpea for a range of larval densities (determined by beat sheet sampling) and grain prices

Control is warranted if the cost of control is less than the value of the yield loss predicted [9]

Chickpea price ($/t)	1 larva/m²	2 larva/m²	3 larva/m²	4 larva/m²	5 larva/m²
200	4	8	12	16	20
300	6	12	18	24	30
400	8	16	24	32	40
500	10	20	30	40	50
600	12	24	36	48	60

To calculate a ready-reckoner for economic thresholds (larval density) (Table 2), rather than the value of yield loss, use the following formula:

Economic threshold (no. of larvae/sampling unit) = C ÷ (D x V)

where C is cost of control ($/ha), D is yield loss per larva per sampling unit (kg/ha), and V is chickpea price ($/t).

Table 2: Economic threshold (no. of larvae per sampling unit) ready-reckoner

Assume D = 20 kg/ha (0.02 t/ha)

Cost of control ($/ha)	Crop value ($/t)							
	200	250	300	350	400	450	500	550
10	2.5	2.0	1.7	1.4	1.3	1.1	1.0	0.9
15	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4
20	5.0	4.0	3.3	2.9	2.5	2.2	2.0	1.8
25	6.3	5.0	4.2	3.6	3.1	2.8	2.5	2.3
30	7.5	6.0	5.0	4.3	3.8	3.3	3.0	2.7
35	8.8	7.0	5.8	5.0	4.4	3.9	3.5	3.2
40	10.0	8.0	6.7	5.7	5.0	4.4	4.0	3.6

7.8.2 Dynamic economic thresholds for the northern region

Recently, there have been changes to the way we discuss economic thresholds for *Helicoverpa* (beat sheet based threshold). The most obvious change is that it is no longer a set number of larvae per m². Rather, it is dynamic, and is responsive to the value of the crop ($/t) and the cost of control ($/ha).

Research by Department of Agriculture, Fisheries, and Forestry (DAFF), Queensland, entomologists has examined the impact of *Helicoverpa* on chickpea yield and quality. As a result of this work, the potential yield and quality loss that larvae will cause under average field conditions has been quantified.

The research in Queensland determined the consumption rate of the larvae from hatchling to pupation to be 20 kg of grain per ha per larva per m² (the outcome of the relationship between larval feeding and the compensation by the chickpea plant). Loss attributed to a particular larval density is calculated on the basis that they are large larvae doing maximum damage. The larval density in the relationship was determined using a beat sheet, and the thresholds are accurate only for larval density estimates made using a beat sheet.

Making a decision about whether it is economic to spray, based on specific parameters for each management unit (field), is now possible. Following on from this, a benefit/cost ratio can be applied to the crop. This allows the farmer to determine the risk level. For example, if potential damage to crop is $30/ha, and control cost is $20/ha, there is a

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

ratio of 1.5. Depending upon the individual farmer, they may believe this ratio warrants action, or they may prefer to wait until a ratio of 2 occurs to justify action.

7.8.3 Additional information on using the threshold to make a decision

Helicoverpa activity during flowering does not result in yield loss

Data from six trials in 2006 (DAFF, Queensland) clearly show that controlling *Helicoverpa* at flowering does not result in a significant increase in yield or quality over delaying control until podset (expanded pods) (Figure 12).

In rare situations, control may be warranted during the vegetative and flowering stages, when pest pressure is extreme. If using products that are effective only against small larvae, it may be necessary to apply a spray during flowering to control a population of small larvae to prevent them from causing damage as large larvae during podset and pod-fill.

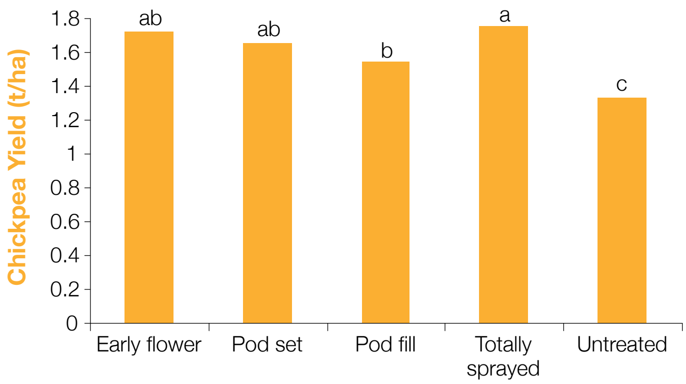


Figure 12: The impact of Helicoverpa on chickpea yield when controlled at different stages of crop maturity. Bars with the same letter are not significantly different from each other.

Larval feeding behaviour—how this influences crop damage

Extensive observational studies of small and large larvae on chickpeas demonstrate that small larvae are primarily foliage feeders, whereas large larvae feed on pods and foliage (see Figure 13). Neither small nor large larvae were observed to have any preference for flowers, which supports the data showing no yield loss when *Helicoverpa* larvae are tolerated during flowering.

If using a product that is effective only against early-instar larvae (e.g. NPV), then the application of control may be necessary during flowering to prevent damage by large larvae at podset.

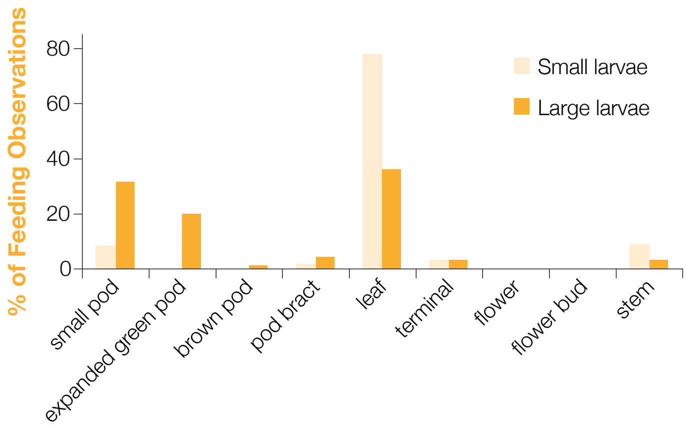


Figure 13: Feeding preferences of small and large Helicoverpa larvae on chickpea when allowed to select feeding sites over a 4–6-h period. Small larvae were 3rd instar, large larvae were 4th–5th instar.

Grain quality

Grain quality is not affected in the range of larval densities for which it is currently economic to spray to prevent yield loss. Recent trials have shown that in the range of 1–4 larvae/m^2, defective grain is well below the level at which discounts or penalties apply (6% by weight; National Agricultural Commodities Marketing Association (NACMA) 2006). Similarly, in the time-of-spraying trials, there was no significant decline in grain quality other than in the untreated plots (Figure 14). Given this result, we can be confident that within the range of larval densities for which it is economic to control, and with the recommendation to withhold treatment until late flowering or podset, quality loss does not need to be factored into the economic threshold.

There is anecdotal information suggesting that larvae will cause significantly more pod damage in exceptional circumstances (e.g. extremely high temperatures, extreme crop moisture stress); however, no trial work had been done to determine to verify or quantify this.

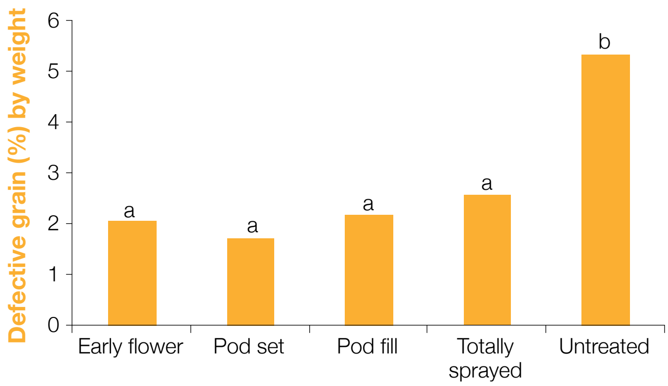


Figure 14: Proportion of defective grain (% by weight) did not increase when Helicoverpa larvae were tolerated during flowering. Bars followed by the same letter are not significantly different from each other.

Natural mortality of larvae is high

The number of large larvae recorded in unsprayed situations is always considerably lower than the number of small larvae recorded in earlier checks. This indicates significant mortality of small larvae. Recent trial work at 19 sites from central Queensland to the Darling Downs has shown an average loss of 70% of larvae from small to large in untreated plots (Figure 15). That is, only one-third of the small larvae recorded survived to become large. In previous studies of *Helicoverpa* larval feeding behaviour, large larvae were found to cause most of the damage, about 80%, with medium larvae contributing about 15% and other instars the remainder (Figure 16). A similar result is expected for chickpea.

This natural mortality (most likely a result of dislodgement from the plant, disease, cannibalism) is important because it means that a proportion of the population will not survive to cause damage to the crop, even if there is no control. Conservatively, it is estimated that the number of small larvae (<7 mm) found in a field sample can be adjusted for natural mortality by assuming that 30% will not survive to cause significant damage as medium and large larvae. Estimating the number of very small larvae is difficult and unreliable in the field, and the inclusion of these larvae in estimates of the population is potentially misleading. Although the data show overall an average 70% mortality across a large number of fields, the average is calculated from a range of mortality from 1% through to 99%; therefore, mortality will vary considerably from field to field. Hence, the conservative suggestion of 30% mortality adjustment rather than 70% adjustment.

In practice, this means that when calculating the number of larvae per m^2 in a field, the following equation is used:

Number per m^2 = {(S x 0.7) + M + L}/row spacing (m)

where S is small, M is medium and L is large larvae; number of larvae is based on the number per metre of row, assessed with a beat sheet; and the multiplier 0.7 is 70% surviving population. Dividing by the row spacing (in metres) adjusts the density for different row spacing.

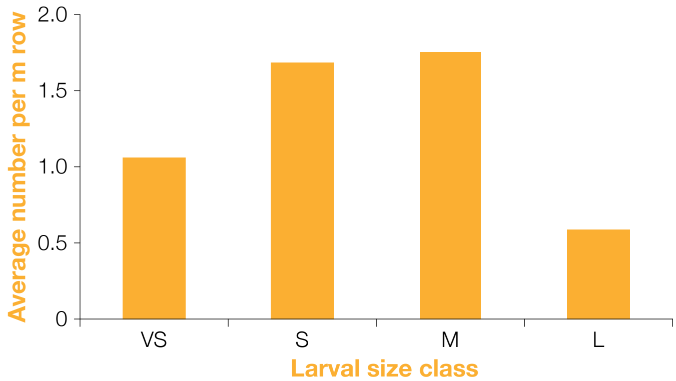


Figure 15: Average numbers of Helicoverpa larvae in the different age classes in untreated chickpea. Data are averaged across 19 sites across central Queensland and the Darling Downs.

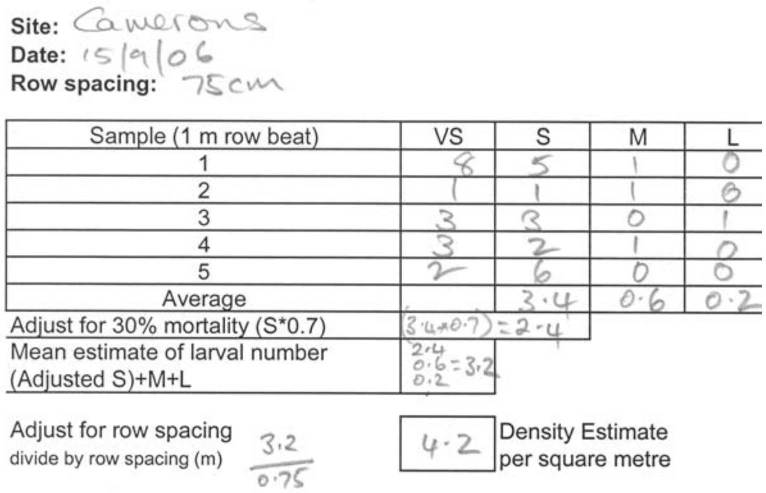
Figure 16: Large Helicoverpa larva feeding on a chickpea pod.

Knowledge gaps

There are no data on the behaviour of larvae in extremely moisture-stressed crops *v.* crops with adequate soil moisture. This means that we cannot say whether there is more, or earlier, flower and pod feeding when foliage appears to be less attractive.

Likewise, there are no data comparing the feeding behaviour of *H. armigera* and *H. punctigera*. The question remains as to whether the different species have differing preferences for leaves, flowers and pods. [10]

7.9 Use of *Helicoverpa* economic thresholds—an example


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

In Figure 17, the field has an average of 4.2 larvae per m^2 (adjusted for mortality of small larvae). Assuming a chickpea price of $400/t, the table of potential yield loss (refer to Table 1) shows the cost of not controlling to be $32/ha. In this example, if the cost of control is less than $32/ha then it is economic to spray. [11]

7.10 Making a decision to control

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

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

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

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

7.10.1 Selecting control options

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

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

'Spray small or spray fail'

Spraying should be carried out promptly once the threshold has been exceeded. Insects grow rapidly under warm spring conditions, and a few days delay in spraying can result in major crop damage and increased difficulty in control (Figure 18). This is particularly so for *H. armigera*.

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

Figure 18: Helicoverpa larva inside a chickpea pod. Larvae that are not controlled when they are small can cause major crop damage.

7.10.2 Key considerations

Chickpeas provide the first host for H. armigera each season

Traditionally, control options have been carbamates and pyrethroids. Resistance to pyrethroids is generally high and spray failures may occur if the population is predominantly *H. armigera*. Recent seasons have seen carbamates perform more reliably as their use in other crops (e.g. cotton) has declined. *Helicoverpa punctigera* is currently susceptible to all chemical groups. Both species are currently susceptible to indoxacarb and the biopesticides, NPV and Bt.

Beneficial insects make little contribution to Helicoverpa control in chickpeas

Malic acid on the chickpea leaves has a repellent effect on many species, especially wasps such as *Trichogramma* and *Microplitis*. The group of parasitic flies called tachinids has been recorded parasitising *Helicoverpa* in chickpeas. The tachinid fly lays its eggs on the larva, usually near the head capsule (see pages 124–125 in the Northern region Ute Guide, and DPI&F brochure 2005: Parasitoids: Natural enemies of helicoverpa). The tachinid larva then feeds and develops inside the *Helicoverpa* larva, and the adult fly emerges from a cocoon in the mature larva or pupae. Tachinid flies usually kill late-instar larvae; therefore, larvae will cause crop damage before they die. For this reason, tachinids have no effect on the damage that larvae can do to a crop, and their presence does not influence the estimate of larval numbers in the crop.

More information

http://www.croplifeaustralia.org.au/default.asp?V_DOC_ID=1952

Resistance management underpins product efficacy

The threat of resistance development to new products will influence their future use patterns. It is likely that chemical companies will avoid season-long use of a single product in a sequence of crops to minimise the likelihood of resistance developing.

The Australian cotton industry has a voluntary Insecticide Resistance Management Strategy (IRMS) that incorporates all insecticides registered for use in cotton. The grains industry does not have an IRMS, although CropLife has strategies for insecticide resistance management for a number of crops

7.10.3 Steward™ (indoxacarb) and the IRMS

Until 2012, indoxacarb use in chickpeas was restricted to avoid lengthy exposure of *Helicoverpa* in the farming system—cutoff 15 October for warm areas, September 15 for hot areas, and October 30 for cool areas.

This restriction has now been lifted, as use patterns in chickpea are, in most seasons, consistent with the recommended window for each region. [12]

7.11 Broader management considerations

- Close monitoring can pay off. In many cases, the larval infestation may not progress past the 'small' stage, and therefore, control is unwarranted. Regular close checking, and reference to records from successive checks, will enable you to determine larval survival.
- Aim for one well-timed spray. Chickpea can tolerate moderate to high numbers of *Helicoverpa* larvae (10–20 larvae/m^2) through late-vegetative and early-flowering growth stages. However, agronomists may suggest that numbers this high during flowering would warrant immediate spraying. Even with mortality, an economic threshold may be exceeded as soon as podset begins. This situation potentially leads to high numbers of advanced stage larvae, resulting in more costly and less reliable control.
- Most yield loss will be sustained from damage caused during pod-fill, and this is the most critical stage for crop protection. Larval infestations are likely to be of mixed ages by the time the crop is well into podding. Products such as Steward™ and Larvin® will adequately control a wide range of larval sizes, and offer around 10–14 days of residual protection if applied to plants that are not actively growing.

The presence of *H. armigera* will influence management decisions. The *Helicoverpa* emergence model is available through the COTTASSIST website: https://www.cottassist.com.au/DIET/about.aspx.

The use of pheromone traps in spring and close visual inspection of larvae provide information on the likely presence of *H. armigera* in chickpeas as the season progresses.

Biopesticides (NPV and Bt) must target smaller larvae (preferably <7 mm in length). Therefore, in situations with high larval densities or across a range of size classes, biopesticides are not the preferred choice. For more information, see the DAFF Queensland brochure 'Using NPV in field crops': http://thebeatsheet.com.au/resources/.

- Keep pod damage in perspective. While larvae and their damage may be evident in a crop, counts of damaged and undamaged pods will give an estimate of actual yield loss accumulating (1 damaged pod per m^2 = 1.7 kg/ha of yield loss). In most

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

cases relative pod damage is far less than initial visual inspections suggest, so careful monitoring of damage in relation to total pod load is recommended. Once pods are damaged, the yield is already lost; pod damage is not useful in making control decisions to prevent yield loss.

- Be aware of withholding periods. Both Steward™ and Larvin® have long withholding periods (21 days), as do some other products. Be aware that late sprays of these products could delay the harvest date.
- Resistance management is vital. The grains industry relies heavily on a limited number of effective insecticides for *Helicoverpa*, particularly for *H. armigera*. Abiding by key insecticide resistance management strategies is good practice:
- Target small larvae to maximise efficacy (Figure 19).
- Be aware of the probability that the population will contain *H. armigera* and select insecticides accordingly.
- If more than one application is made in a crop, rotate insecticide groups.
- Where spray failures are suspected, do not re-treat with the same product.
- Check compatibility of insecticides with fungicides if planning to use together. Mixing fungicides with insecticides is becoming more common because of the fungicide spray programs recommended for control of Ascochyta blight. Some product formulations are not compatible with available fungicides. [13]

Figure 19: Small Helicoverpa larva feeding on exposed sites and vegetative growth as pictured are easily targeted with sprays. (Photo: R. Lloyd, DPI&F)

7.12 Area-wide management strategies for *Helicoverpa*—the role of chickpeas

When assessing whether to control *Helicoverpa* in a chickpea crop, the decision is usually based only on potential yield loss in that crop.

Reduction of the overall size of the *Helicoverpa* population on a regional basis is the aim of an area-wide management (AWM) strategy. It is a move from the paddock-by-paddock control of *Helicoverpa* to an approach where neighbours and their agronomists communicate and cooperate to reduce numbers wherever they can.

Tactics that may be considered in the context of an AWM approach and relate to *Helicoverpa* management in chickpea include:

- reducing the spring *H. armigera* generation in commercial chickpea crops, and minimising the carryover of moths from chickpeas to susceptible summer crops

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

- insecticide resistance management

Chickpeas can host the first generation of Helicoverpa armigera

It is well recognised that chickpeas provide a host for the first generation of *Helicoverpa* in spring. *Helicoverpa armigera* emerge from diapause from late September to October. Temperature variations in temperate regions will mean a variation in emergence from year to year, and region to region; the warmer the temperatures, the earlier *Helicoverpa* moths will emerge. Commercial chickpea crops that are still at flowering and pod-fill stages will be attractive to *Helicoverpa*.

Most larvae developing during normal pod-fill will emerge as moths before harvest, so pupae-busting of these crops is of little benefit. Where there are late larval infestations, cultivation soon after harvest will kill many pupae. Using larvae-checking records and the estimates of *Helicoverpa* development (see Appendix 1), it is possible to estimate the time-frame for effective pupae-busting. Left too long, the pupae will emerge as moths and move into other crops.

These strategies will help to reduce the buildup of the first generation of *Helicoverpa* within a farming region. [14]

7.13 Control options

Choosing the most appropriate chemical for pest control will depend on which pests are present (Table 3), in what numbers, their stage of development (whether eggs, larvae/nymphs or both), resistance levels, and location in the crop (i.e. in flowers or leaf feeding).

Effective insecticides need to be used in a way that will not increase the risk of developing resistance or increasing resistance to these products in the target species or other pests.

Key points:

- Use economic thresholds to make spray decisions.
- Be aware of, and use, the voluntary farming systems IRMS.
- Avoid prolonged use and over-reliance on any one chemical group for *Helicoverpa* control.
- Rotate the main chemical groups where possible.
- Avoid use of pyrethroids on *H. armigera* populations where possible.
- Check compatibility of potential mixing partners before recommending and applying.
- Always read the label supplied with each product before use.
- Abide by withholding periods and factor this into your decision-making about harvest date and/or insecticide use.
- Target small insects.

7.13.1 Resistance management and product selection

It is unlikely that season-long use of a single product will be allowed. For some products, registration on grain crops may not be considered, because of selection pressure, resistance threat, residues and cost.

An IRMS that incorporates all insecticides and all crops in the farming system is required. It allows the best placement for these new products that satisfies sustainable management approaches, and viable commercial returns to agrochemical companies.

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

7.13.2 Other management considerations

Some products (including Steward™ and Larvin®) have long withholding periods. Late sprays of these products could delay the harvest date.

Determine the *Helicoverpa* species present. Consider consulting with entomologists and other agronomists on which products are working in each region. Where spray failures are reported, consider the range of possible causes, including resistance. For example, poor application (coverage, timing) can be mistaken for resistance. [15]

7.14 Checking compatibility of products used in mixtures

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

Check compatibility of potential mixing partners before recommending and applying.

Always read the label supplied with each product before use.

7.14.1 Compatibility of insecticides with mancozeb formulations

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

Table 3 lists several commonly used insecticides and highlights some known incompatibilities with mancozeb. Table 4 outlines some considerations when using chlorothalonil within 10 days of an insecticide application. These lists are by no means exhaustive and have been compiled using current, available data from the chemical.

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

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

Always read the label supplied with the product before each use. [16]

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

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

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

Table 3: Compatibilities of various insecticides with mancozeb

Product	Mancozeb compatibility	Considerations
Larvin 80 WG	Yes	
Larvin 375	Dithane DF, no	
	Dithane M45, yes	Use within 6 h of mixing
Gemstar	Dithane DF, yes	Check pH is within the range 7–8.5
	Dithane M45, yes	Check pH is within range 7–8.5
Lannate EC	Yes	Mix mancozeb first, Lannate second. Use as soon as possible after mixing
DiPel SC	Yes	Mix fungicide first and check pH. A pH >8.5 will require the addition of a buffer to reduce the pH
Karate EC	Yes	Mix mancozeb first, Karate second. Use as soon as possible after mixing
Karate ULV	No	

Table 4: Compatibilities of various insecticides with chlorothalonil

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

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

7.15 Post-spray assessments

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

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

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

With products such as Steward™, the phenomenon of growth dilution is often evident in chickpeas. That is, the growth that was present at the time of application may still have residual activity from the insecticide but new growth will not. It has been observed

More information

https://grdc.com.au/Resources/Bookshop/2015/02/Crop-Aphids-Back-Pocket-Guide

that small larvae can feed on this new growth but incur no crop damage. Rechecking fields sprayed with Steward™ or Larvin® can be complicated and will require regular assessment.

Record spray decision and re-check to confirm control success or failure.

Record details of application equipment (nozzle size, etc.) as well as time of day and weather conditions. This may help interpret what might have gone wrong where poor control is achieved. [17]

7.16 Blue-green aphid *(Acyrthosiphon kondoi)*

The malic acid in chickpeas means that there is little colonisation of chickpea plants by blue-green aphids (Figures 20 and 21). However, blue-green aphids transmit Cucumber mosaic virus (CMV), a non-persistent virus, when visiting chickpea crops. Therefore, management of chickpea crops for protection against blue-green aphid invasion from surrounding areas is important.

Figure 20: Close up of blue-green aphid. (Photo: Grain Legume Handbook)

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

Figure 21: Blue-green aphids. Note the young and older aphids. The brown aphids are dead blue-green aphids that have been parasitised by wasps. (Photo: Grain Legume Handbook)

Lifecycle

Blue-green aphids prefer cooler weather (10–18°C) for breeding. Females produce up to 100 young at a rate of about 7 per day. Winged aphids develop when infestations become crowded. Winged aphids fly or are blown by the wind to start new infestations elsewhere.

Monitoring

Monitor in chickpea and surrounding crops at all crop stages. Colonisation of chickpeas does not occur as it does in other pulses (e.g. lentil or lupin), so invasion comes from adjacent crops and pastures.

Frequent monitoring of seedlings and establishing plants is necessary to detect rapid increases of aphid populations. Stem samples give useful estimates of aphid density. When damage is apparent, intervention may be necessary. Moderating factors include the degree of aphid tolerance of the crop (chickpea suffers little mechanical damage), availability of moisture and the incidence of predators and parasitoids.

Control

In other pulses, a neonicotinoid (Gaucho® 350SD) insecticide seed dressing could be used on susceptible crops to prevent aphids from attacking emerging plants and spreading the persistently transmitted viruses *Bean leaf roll virus* (BLRV) and *Beet western yellows virus* (BWYV) early in the season. Note, though, that Gaucho® (imidacloprid) is not registered in chickpea.

The best protection against aphid infestation and virus spread in chickpea is to control the aphid population and its hosts beforehand. A prophylactic insecticide spray in chickpea to prevent aphid incursion is not desirable.

Spray with insecticide only where damage to growing points is obvious. Broad-spectrum insecticides should be avoided, for conservation of natural enemies.

More information

For additional aphid and virus control details see Pulse Australia Bulletin 'Virus management': www.pulseaus.com.au

If blue-green aphid is the predominant pest, use insecticides that do not kill aphid parasites and predators; for mixed infestations, systemic chemicals that control aphids and mites should be used.

Natural enemies are: hoverfly larvae, aphid parasites, green lacewing larvae, brown lacewing and ladybirds. [18]

7.17 Cowpea aphid *(Aphis cracciuora)*

The malic acid means that there is little colonisation of chickpea plants by cowpea aphids (Figure 22). However, cowpea aphids transmit the non-persistent virus CMV and the persistent virus BWYV when visiting chickpea crops. Management of chickpea crops for protection against cowpea aphid invasion from surrounding areas is therefore important.

Figure 22: Cowpea aphids. Note the different aphid ages, young to old. The older aphids are shiny black. The white cast is a skin, shed as the aphid grows. (Photo: Grain Legume Handbook)

Lifecycle

An infestation of cowpea aphids is generally patchy at first but they will spread through the crop if the weather is fine and warm. Infestations start when winged females colonise a few plants in a crop and give birth to wingless nymphs that live in colonies. This may occur from early winter onwards. As the plant deteriorates the aphids move to neighbouring plants, and the area of infested patches within the crop increases.

Monitoring

Monitor for cowpea aphids in chickpea and surrounding crops and pastures at all crop stages. Colonisation of chickpeas does not occur as it does in other pulses, so invasion comes from adjacent crops and pastures.

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

Control

The best protection against aphid infestation and virus spread in chickpea is to prevent aphids from landing in the crop. This means controlling other sources, but also crop management and sowing into plant or stubble cover to reduce bare ground. Control the aphid population and its hosts beforehand. A prophylactic insecticide spray to prevent aphid incursion is not desirable.

Monitor chickpea and surrounding crops and pastures from early winter, and spray if plants with cowpea aphid can be found easily. Several insecticides for aphid control are highly toxic to bees and should not be applied while bees are foraging. [19]

7.18 Aphids and virus incidence

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

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

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

Aphids can spread viruses persistently or non-persistently. Once an aphid has picked up a persistently transmitted virus (e.g. BWYV) it carries the virus for life, infecting every plant where it feeds on the phloem. Aphids carrying non-persistently transmitted viruses (e.g. CMV) carry the virus temporarily and only infect new plants in the first one or two probes.

Important vectors for non-persistent viruses in pulse crops include green peach aphid, pea aphid, cowpea aphid and blue-green aphid, which will colonise pulse crops (Table 5). Turnip aphid, maize aphid and oat aphid, which are non-colonising species in pulses, may also move through pulse crops, probing as they go, and potentially spreading pulse viruses.

Green peach aphid and pea aphid are also important in spreading persistently transmitted viruses, depending on the virus involved.

Table 5: Differences in transmission of one persistent and two non-persistent viruses by four aphid species

CMV and BWYV are significant virus diseases in chickpea

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

Source: GRDC Fact sheet 2010.

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

7.18.1 Integrated pest management and viruses

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

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

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

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

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

Seed dressings are probably the best aphid protection strategy compatible with an IPM approach, for example, Gaucho® 350SD insecticide seed dressing on other pulses to prevent aphids attacking emerging seedlings and spreading viruses (e.g. CMV, BLRV and BWYV). However, Gaucho® 350SD is not registered for use in chickpea.

Alternatively, a foliar insecticide can be applied early based on forecast reports of the degree of risk. Preferably use a 'soft' insecticide that targets the aphids and leaves beneficial insects unharmed. There is debate over the use of synthetic pyrethroids as a foliar application; they are recommended to prevent BLRV transmission because of so-called 'anti-feed' properties that prevent early colonising of crops by pea aphids. However, discouraging colonisation may increase the spread of aphids and, potentially, virus through a crop.

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

Control the aphids if virus spread and direct feeding damage is of concern.

More information

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/05/Principles-and-Implementation-of-IPM-in-Broadacre-Field-Crops-Risks-and-Benefits

https://grdc.com.au/Resources/Bookshop/2009/12/Integrated-Pest-Management-Fact-Sheet-National

7.18.2 Controlling direct feeding damage

Monitoring crops for direct feeding damage can be worthwhile in most pulse crops, but less so in chickpea. Limited threshold information on aphid numbers is available for determining whether it is economically worthwhile to apply insecticides to prevent damage caused by feeding. Research in Western Australia suggests spraying if >30% of lupin growing tips are colonised by aphids from the flower bud stage through to podding, especially in aphid-susceptible varieties. Thresholds should be considered as a guide only, as many factors influence the economics of spraying.

Routine spraying of synthetic pyrethroid insecticides should be avoided because repeated applications of these insecticides can result in resistance developing in other non-target species (e.g. other aphids, mites) and will kill many natural insect predators.

A 'soft' insecticide is an option for controlling direct feeding damage when aphid populations are increasing.

It is not always possible to maintain a crop relatively clean of aphids. Allowing insects to build up to a sufficient threshold in an IPM approach may be acceptable for physical

More information

www.pulseaus.com.au

crop damage to foliage or even for grain quality. However, it may allow too great a spread of viruses in that crop, particularly early in the season. Most aphid build-up occurs in spring, which can also cause a problem with virus spread.

Some insects (e.g. cowpea aphid) are vectors for crop viruses (e.g. CMV). It takes only a few insect vectors, often undetectable, to cause a major virus problem in pulses, in particular BWYV in chickpea. Aphids do not colonise chickpea, but may spread viruses widely without being detected. The impact is seen well after any aphids have gone.

Insect vector control is only a component of a virus management strategy in pulses. Virus management aims at prevention that involves controlling the virus source, aphid populations and virus transmission into pulse crops. Elimination of summer weeds and self-sown pulses that act as a green bridge is important, as these host viruses and provide a refuge for aphid multiplication (Figure 23). Elimination of virus sources is critical (seed infection or other host species). Crop management is also important. Time of sowing, stubble cover, row spacing, density and crop health all play a role.

A prophylactic approach of spraying insecticides as a regular protectant is not necessarily the answer.[20]

Figure 23: Aphids colonised on a milk thistle plant in the middle of chickpea. This acts as a reservoir for aphid movement onto surrounding chickpea plants and virus infection. (Photo: G. Cumming, Pulse Australia)

More information

https://grdc.com.au/uploads/documents/Plague_Locusts_Factsheets.pdf

7.19 Australian plague locust *(Chortoicetes terminifera)*

Locusts and grasshoppers will cause damage to chickpeas in the same way that they will cause damage to any green material when in plague numbers. Chickpeas may be less vulnerable in the seedling stages than lupins and lentils. However, sheer weight of numbers can lead to significant damage. Crops such as lupin that have epigeal emergence cannot recover if their cotyledons are eaten.

Most locust plagues originate in south-west Queensland and adjacent areas of South Australia, New South Wales and the Northern Territory. Locust populations develop following rainfall in this area.

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

More information

Victorian Department of Environment and Primary Industries: http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/pest-insects-and-mites/plague-locusts

NSW Department of Primary Industries: http://www.dpi.nsw.gov.au/agriculture/pests-weeds/insects/locusts

Department of Agriculture and Food Western Australia: https://www.agric.wa.gov.au/invasive-species/australian-plague-locust-overview

Australian Plague Locust Commission

With suitable conditions, autumn swarms may migrate 200–500 km into pastoral and adjacent agricultural areas. On arrival, they lay eggs, which produce the spring outbreak. [21]

Description

Adults of the Australian plague locust can be identified by their characteristic black spot on the tip of the hind wing (Figure 24). Nymphs or hoppers are more difficult to identify.

If they are in a large band, then it is likely to be the plague locust.

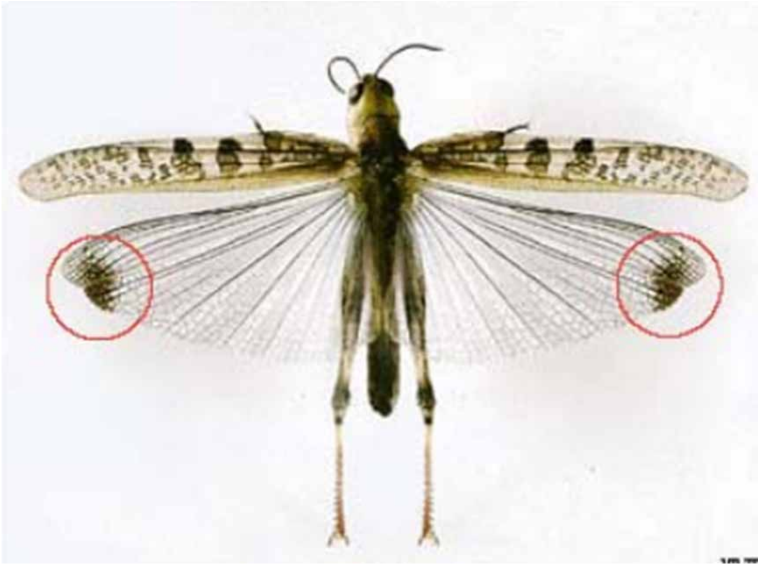


Figure 24: Australian plague locust. Note the black spot at the tip of the hind wing. (Photo: APLC via PIRSA)

Lifecycle

Adults are sexually mature within 2 weeks of developing wings. Females select suitable laying sites in the barest ground available e.g. roadsides, tracks.

Eggs are laid in pods at a depth of 20–50 mm. Each pod contains 30–50 pale-yellow eggs shaped like a banana, 5–6 mm long. Females lay up to four pods each before dying.

Eggs develop according to temperature and moisture. Eggs laid in autumn are usually dormant over winter and hatch in spring with soil temperature increases. Eggs laid in summer under ideal conditions may hatch within 14–16 days.

After hatching, nymphs or hoppers grow through five growth stages (Figures 25 and 26). Wing buds become progressively more notable through each stage.

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

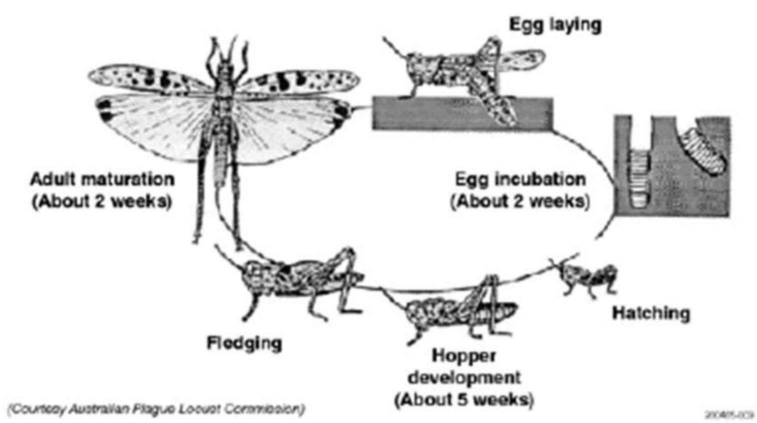


Figure 25: Life cycle of the Australian plague locust.

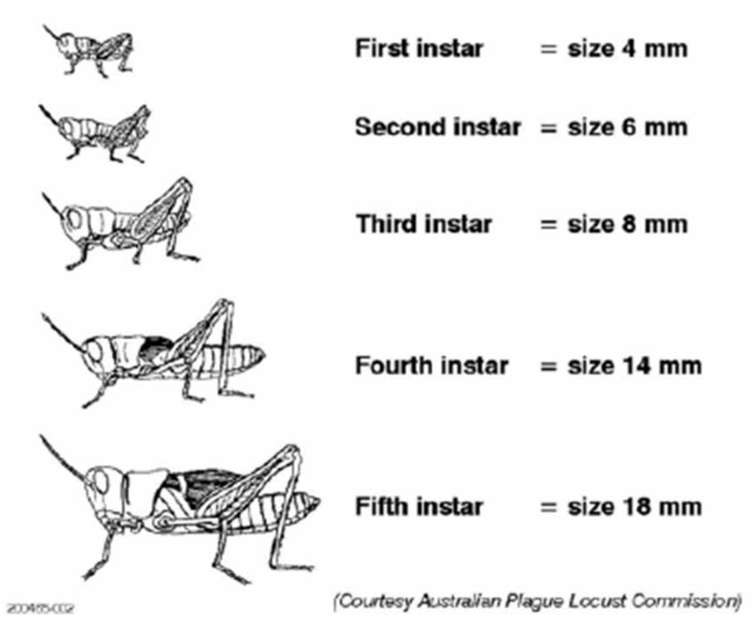


Figure 26: The five growth stages of plague locust nymphs.

Nymphs move away from egg beds and tend to concentrate into dense marching bands of size from a few square metres to several hectares. Bands may merge to increase to several kilometres with a distinct front. Older hoppers can travel up to 500 m in a single day. Hoppers complete their development in 4–6 weeks.

After their final moult, young adults emerge with fully developed wings. Milling flights increase over the band until the majority of hoppers have fledged. Adults concentrate into groups called swarms, which make low drifting flights up to 50 m high, and they can cover 10–20 km per day. Flight behaviour depends on the age of the adult, wind speed and temperature. Long-distance migration will occur at night if green feed has been available to enable fat accumulation.

Damage

Crops can be physically damaged, particularly seedlings. Rejection at grain delivery can occur if adult locusts, or parts of them, are present in the sample, or if objectionable stains and odour exist.

Control

The Australian Plague Locust Commission (APLC) undertakes surveillance threat assessments, forecasting and control measures when locust populations in outbreak areas have the potential to cross into agricultural areas.

In the event of a plague, local government may undertake some spraying operations (e.g. roadsides) within their own area. Where significant problems are expected government agencies may undertake large-scale control in pastoral and adjacent agricultural areas.

Effective suppression of locusts can only be achieved by cooperation between landowners, local governments and government agencies, combined with ongoing APLC activities.

More information

www.apvma.gov.au

Cultivation of egg beds will destroy the eggs. Use approved insecticides to target the bands of nymphs before they take flight. Advice on timings and chemicals can be obtained from state government departments or local chemical resellers. Often APVMA permits are required for chemical use. [22]

7.20 Spur-throated locust *(Austracris guttulosa)*

More information

Comprehensive details of life cycle and controls are found at: http://www.dpi.nsw.gov.au/agriculture/pests-weeds/insects/locusts

https://www.agric.wa.gov.au/pest-insects/spur-throated-locust

QDAF (2015). Spur-throated locust

Spur-throated locust (Figures 27 and 28) is a pest of pastures, crops and some tree species. It is a tropical species of northern Australia, but extends its habitat into areas experiencing wet summer seasons.

It is often noticed in northern New South Wales, and in northern grain areas in Western Australia, but it rarely reaches damaging numbers. It is a declared pest insect in New South Wales.

Figure 27: Adult-spur throated locust. (Photo: Australian Plague Locust Commission)

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

Figure 28: Adult spur-throated locust in a near mature lupin crop—note the pods. (Photo: K. Roberts NSW DPI)

Damage

Spur-throated locusts can cause damage to crops when they migrate in from neighbouring pastures and vegetation.

Life cycle

After hatching, nymphs or hoppers grow through six growth stages. Nymphs take 10 weeks to reach maturity. Nymphs do not form into large bands, so cannot be identified in the air, unlike the Australian plague locust.

Control

Control measures may be economic only in high-value crops or with high densities. Nymphs do not band and are generally quite scattered. Effective control will only be achieved if nymphs are also controlled adjoining pastures and vegetation to prevent re-invasion.

Ensure that product registration or a current APVMA permit exists before using any insecticide. [23]

More information

www.apvma.gov.au

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

7.21 Exotic chickpea insects

7.21.1 Exotic leaf miners (Diptera: Agromyzidae)

The Agromyzidae are a well-known group of small, similar flies whose larvae feed internally on living plant tissue, often as leaf and stem miners. Nearly all agromyzids are host-specific, but a few highly polyphagous species have become important pests of agriculture and horticulture in many parts of the world.

Key exotic agromyzid species for chickpeas include: chickpea leaf miner (*Liriomyza cicerina*) (Figure 29); American serpentine leaf miner (*Liriomyza trifolii*); and pea leaf miner (*Chromatomyia horticola*). The host range of these exotic species extends beyond chickpeas.

Description

Diagnostic characters are dealt with at the family level due to the extreme difficulty in differentiating species.

Adults are up to 2 mm in length, black/grey and yellow in colour with a conspicuous, bright yellow marking on the base of the thorax (scutellum) in most species. They are not very active flyers and tend to remain close to their target hosts. Adults lay eggs below the leaf surface.

Larvae are legless maggots up to 3 mm in length. They can be cream to yellowish in colour and are typically cylindrical in shape, tapering at the head region. There are three larval stages, which feed internally on plant tissue creating a tunnel or 'mine'. They can occasionally feed on the outside of pods.

Pupae look like tiny brown rice grains. *Liriomyza* species leave the plant to pupate in crop debris, soil or sometimes on the leaf surface, whereas *C. horticola* pupates inside the leaf at the end of the larval tunnel.

Damage

Larvae feed beneath the leaf surfaces, creating a winding tunnel or mine (Figures 30 and 31). Most leaf mines are greenish in colour at first, turning whitish over time. Some can also have distinct frass (waste) trails deposited in dark stripes on the sides of the mine (e.g. *L. trifolii*). Leaf mines wind irregularly through the leaf, increasing in width as larvae mature. Mine shapes in leaf tissue vary depending on species.

Leaf-miner damage is usually more severe in spring, with two to three generations occurring during the growing season.

Leaf-miner damage includes leaf destruction and retarded plant growth, and in severe infestations, total crop losses can occur, both from larval-mining and from leaf-puncturing caused by females ovipositing and sap-feeding. Infested plants are also susceptible to secondary attack by pathogenic fungi entering leaf punctures and mechanical transmission of plant viruses.

Surveillance

Leaf-mining is usually the first and most obvious symptom of the presence of leaf miners that can be seen in the field. Leaf-mining damage can also be caused by moth larvae, and exotic Agromyzidae species can be confused with native leaf miners. Any suspect mining should be sent for identification.

Entry Potential: Medium. Entry as eggs or larvae via imported plant material.

Establishment and Spread Potential: High.

Economic Impact: Medium.

Overall risk: Medium.

Initial incursions are likely to arise from horticultural areas and grains industry will face secondary attack. *Liriomyza* readily establish after introduction and rapidly spread.

Control is difficult. Economic impacts could be highly significant in most crops and across most cropping regions if eradication is not achieved. [24]

Figure 29: Chickpea leaf miner (Liriomyza cicerina). (Photo: A. Ames DPI Victoria, www.PaDIL.gov.au)

Figure 30: Larval-mining damage. (Photo: ' I Spy' Resource Manual (PaDIL))

24 P Ridland, M Malipatil (2008) Industry Biosecurity Plan for the Grains Industry Threat Specific Contingency Plan. American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia September 2008.

Figure 31: Larval-mining damage on daisy leaf caused by American serpentine leaf miner (L. trifolii). (Photo: Central Science Laboratory, Harpenden Archive, UK, bugwood.org)

7.22 Beneficial organisms

Beneficial organisms are important in overall pest management. Their impact in chickpea may be less than in other pulses because the malic acid in chickpea plants acts as a deterrent to many pest and beneficial insect species.

All pest populations are regulated to some degree by the direct effects of other living organisms. Beneficial organisms include a range of wasps, flies, bugs, mites, lacewings, beetles and spiders that can reduce insect pest populations through predation and parasitisation. Virus and fungal diseases also provide control.

A wide range of beneficial organisms can be grouped into three categories:

1. *Parasites*—organisms that feed on or in the body of another host. Most eventually kill their host and are free-living as an adult (parasitoids) (e.g. aphid wasp parasites).
2. *Predators*—mainly free-living insects that consume a large number of prey during their lifetime (e.g. shield bugs, lacewings, hover flies, spiders, predatory mites and predatory beetles).
3. *Insect diseases*—include bacterial, fungal and viral infections of insects.

Inappropriate use of an insecticide that reduces the number of beneficials can result in a more rapid build-up of insect populations and reliance on further use of insecticide. IPM in its simplest form is a management strategy in which a variety of biological, chemical and cultural control practices are combined to provide stable, long-term pest control.

A key aim of any IPM program is to maximise the number of beneficial invertebrates and incorporate management strategies other than pesticides that will help to keep pest insect numbers below an economic threshold.

Correct identification and regular monitoring are the cornerstone of IPM. When monitoring crops for insects, it is important to also check for the presence of, and record the build-up or decline in, the numbers of these beneficials, to make the best insect control decisions.

Integrate other pest management practices, together with the use of insecticides only where necessary, to maximise the number of beneficial organisms. This will result in better control of insect pest populations and a reduced reliance on the use of insecticide. [25]

A list of some beneficial organisms is provided below. For more details and photographs of beneficial organisms in insect management see:

CESAR web site: www.cesaraustralia.com/sustainable-agriculture/identify-an-insect/insect-gallery/

The GRDC 'Ute Guides' for specific pulse crops (lentil, field pea, faba bean and vetch) or insects

'I SPY: Insects of southern Australian broadacre farming systems identification manual and information resource' (Bellati *et al.* 2012)

Beetles
Carabid beetle (*Notonomus gravis*)
Transverse ladybird
Common ladybird

Bugs
Damsel bug (Nabidae)
Assassin bug
Glossy shield bug
Spined predatory shield bug (*Oechalia schellenbergii*)

Flies
Hoverfly (Syrphidae)
Tachinid fly

Lacewings
Green lacewing (Chrysopidae)
Brown lacewing (Hemerobiidae)

Mites
Pasture snout mite (*Bdellodes lapidaria*)
French anystis mite

Caterpillar wasps
Orange caterpillar parasite wasp
Two toned caterpillar wasp
Banded caterpillar wasp
Telenomus wasp
Orchid dupe
Trichogramma wasp
Braconid wasp (*Microplitis demolitor*)

Aphid wasps
Aphidius ervi
Trioxys complanatus wasp

Spiders
Wolf spider (Lycosidae)
Jumping spider (Salticidae)

Insect diseases—viral and fungal
Bacillus thuringiensis (BT)
Nuclear polyhedrosis virus (NPV)

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

Appendix 1: Predicted Helicoverpa development times in temperate regions

APPENDIX 1. Predicted heliothis development times based on HEAPS model simulations using long term average daily temperatures. Note that insects are presumed to begin at half-way through the initial stage on the starting date. Also note that in any given period temperatures may vary substantially from the long term averages, and therefore this table should be used as a guide only.

Starting date and stage		Central NSW Predicted days until...			North West NSW Predicted days until...			South West Qld Predicted days until...			Darling Downs Qld Predicted days until...			Central Highland Qld Predicted days until...		
		Large	Pupa	Moth	Large	Pupa	Moth	Large	Pupa	Moth	Large	Pupa	Moth	Large	Pupa	Moth
9 Sept	W. egg	34	53	78	34	52	74	29	45	64	32	50	70	22	35	51
	Small	13	38	64	12	35	62	12	30	52	12	34	59	9	24	42
	Medium	5	28	56	5	27	55	5	24	48	5	26	54	4	19	38
	Large	-	14	46	-	13	41	-	13	40	-	13	41	-	10	30
16 Sept	W. egg	32	50	75	32	49	69	27	42	60	30	47	66	20	31	47
	Small	12	34	61	12	34	59	10	28	48	12	32	56	9	22	39
	Medium	5	27	54	5	25	53	5	21	44	5	25	51	4	17	35
	Large	-	13	43	-	13	41	-	11	37	-	11	39	-	9	28
23 Sept	W. egg	30	47	70	30	47	66	24	38	56	27	44	63	19	31	46
	Small	12	33	59	11	32	56	9	26	46	11	29	51	7	20	36
	Medium	5	25	52	5	25	51	4	20	41	5	23	47	3	15	32
	Large	-	13	41	-	11	39	-	10	34	-	11	39	-	8	26
30 Sept	W. egg	29	47	64	28	43	62	22	35	52	27	42	61	18	29	43
	Small	10	30	55	12	31	53	9	25	43	9	27	47	7	18	34
	Medium	5	24	51	5	24	48	4	19	39	5	21	44	3	15	31
	Large	-	10	38	-	10	38	-	9	31	-	10	36	-	7	24
7 Oct	W. egg	27	44	63	26	42	60	21	33	49	25	39	58	16	27	41
	Small	11	29	54	10	27	48	9	23	41	9	26	45	6	18	33
	Medium	5	23	48	4	22	44	4	18	36	4	20	40	3	14	29
	Large	-	11	38	-	10	36	-	9	29	-	10	34	-	7	23
14 Oct	W. egg	26	41	59	24	39	57	19	31	46	23	37	56	16	26	40
	Small	9	26	49	10	27	46	8	21	38	9	25	44	6	17	31
	Medium	4	20	44	4	20	41	3	16	34	4	19	38	3	14	28
	Large	-	10	37	-	10	34	-	8	27	-	9	31	-	7	22
21 Oct	W. egg	24	39	55	23	36	53	19	30	44	20	33	52	15	25	39
	Small	9	27	46	9	25	43	7	19	35	9	23	42	6	16	30
	Medium	4	19	42	4	19	38	3	15	32	4	18	37	3	13	27
	Large	-	9	34	-	9	31	-	8	26	-	9	28	-	6	21
28 Oct	W. egg	23	37	54	20	33	49	17	28	42	19	32	49	15	25	38
	Small	9	25	44	8	23	41	6	18	33	7	21	40	6	16	30
	Medium	4	20	39	3	18	36	3	14	30	4	16	35	3	12	26
	Large	-	9	34	-	7	28	-	7	24	-	8	27	-	6	20
4 Nov	W. egg	22	35	50	19	31	46	17	27	41	19	31	47	15	25	37
	Small	9	25	41	8	21	38	7	18	32	7	20	39	6	16	29
	Medium	3	18	37	3	17	35	3	14	28	3	16	35	2	12	26
	Large	-	10	30	-	8	27	-	7	23	-	8	27	-	6	20
11 Nov	W. egg	21	33	49	18	30	44	15	25	38	19	31	45	15	24	36
	Small	9	23	40	7	20	36	6	17	31	7	20	37	6	16	28
	Medium	3	18	34	3	15	32	3	13	27	3	15	33	2	12	25
	Large	-	9	28	-	8	26	-	7	21	-	8	27	-	6	20

7.23 References and further reading

P. Bailey (Ed.) (2007) 'Pests of field crops and pastures: identification and control.' CSIRO Publishing, Melbourne.

J Bellati, P Mangano, P Umina, K Henry K (2012) 'I SPY: Insects of southern Australian broadacre farming systems identification manual and information resource.' Department of Primary Industries and Regions South Australia. ISBN: 978-0-646-53795-5.

L Breen (2003) Budworm Watch Program—more than monitoring. Australasia Pacific Extension Network, http://www.regional.org.au/au/apen/2003/abstracts/p-37.htm

GRDC (2011) 'Snail identification and control. The Back Pocket Guide.' GRDC GroundCover Direct, http://www.grdc.com.au/Resources/Publications/2011/03/Snail-Identification-and-Control-The-Back-Pocket-Guide

GRDC. Faba bean: The Ute Guide, Southern region. GRDC Resources, https://www.grdc.com.au/Resources/Ute-Guides

GRDC Field pea: The Ute Guide, Southern region. GRDC Resources, https://www.grdc.com.au/Resources/Ute-Guides

GRDC. Insects: The Ute Guide, Southern region. GRDC Resources, https://www.grdc.com.au/Resources/Ute-Guides

GRDC, Lentil: The Ute Guide, Southern region. GRDC Resources, https://www.grdc.com.au/Resources/Ute-Guides

GDRC. Vetch: The Ute Guide, Southern region. GRDC Resources, https://www.grdc.com.au/Resources/Ute-Guides

Grain Legume Handbook Committee (2008) 'Grain legume handbook for the pulse industry.' Supported by the Grains Research and Development Corporation.

Loss SP, Brandon N & Siddique KHM (1998) 'The chickpea book: A technical guide to chickpea production.' Agriculture Western Australia, South Perth Bulletin 1326.

P Mangano, P Michael, D Hardie (2006) Management of native budworm in pulse and canola crops in the south-west of Western Australia. Department of Agriculture and Food Western Australia Farmnote 184.

S Micic, K Henry, P Horne (2007) Identification and control of pest slugs and snails for broadacre crops in Western Australia. Department of Agriculture and Food Western Australia Bulletin 4713, http://www.agric.wa.gov.au/objtwr/imported_assets/content/pw/ins/pp/gc/slugsnailbulletin.pdf

S Oliver (2011) Spur throated locust. NSW Department of Primary Industries Fact sheet 11/13, http://www.dpi.nsw.gov.au/content/agriculture/pests-weeds/insects/locusts/spur-throated-locust

K Perry, P Mangano, P Umina, A Freeman, R Jones, W Hawthorne, J Davidson (2010) Aphids and viruses in pulse crops—Western and Southern regions. GRDC Fact Sheet July 2010, http://www.grdc.com.au/Resources/Links-Pages/PestLinks/Invertebrate-Pests/~/media/BBCFB13BF5FD4F41A5B3519898D7A1AD.pdf

Pest and Disease Information Service (2009) Sending specimens for identification. Department of Agriculture and Food Western Australia Garden note 360.

BA Pyke, EH Brown (1996) 'The cotton pest and beneficial guide.' GOPRINT, Brisbane.

SARDI (2003) 'Bash'Em, Burn'Em, Bait'Em: Integrated snail management in crops and pastures.' South Australian Research and Development Institute. Available at: http://www.grdc.com.au/GRDC-Snails-BashBurnBait

TopCrop (2001) Crop Insects: The Ute Guide. Northern Grain Belt edition.

P Umina (2007) Redlegged earth mite. Department of Environment and Primary Industries Victoria Agriculture Notes AG0414, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/pest-insects-and-mites/redlegged-earth-mite

P Umina (2007) Blue oat mite. Department of Environment and Primary Industries Victoria Agriculture Notes AG1300, http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/pest-insects-and-mites/blue-oat-mite

P White *et al.* (Eds) (2005) Producing pulses in the northern agricultural region. Department of Agriculture and Food Western Australia Bulletin 4656, ,http://www.agric.wa.gov.au/objtwr/imported_assets/content/fcp/lp/bn4656_northern_pulse_manual.pdf

P White *et al.* (Eds) (2005) Producing pulses in the southern agricultural region. Department of Agriculture and Food Western Australia Bulletin 4656, ,http://www.agric.wa.gov.au/objtwr/imported_assets/content/fcp/lp/southern_pulse_manual.pdf

Brochures

J Boddington, D Murray (1998) Chemical-free heliothis pupae control. DPI Qld Farming Systems Institute, CropLink QI98036.

J Boddington, D Murray (1998) Spring trap crops snare damaging heliothis. DPI Qld Farming Systems Institute, CropLink QI98035.

H Brier, M Lucy (1999) Controlling green vegetable bug (GVB) and other pod sucking bugs in mungbeans. DPI Qld Farming Systems Institute, CropLink QI990003.

H Brier, M Lucy (1999) Identifying insect pests in soybeans. DPI Qld Farming Systems Institute, CropLink QI99036.

DPI&F (2005) Understanding *Helicoverpa* ecology and biology in southern Queensland: Know the enemy to manage it better. DPI&F Qld Information Series QI070878, http://www.daf.qld.gov.au/__data/assets/pdf_file/0005/72689/Insects-Helicoverpa-ecology-biology.pdf

DPI&F (2005) Using NPV to manage helicoverpa in field crops. DPI&F Qld Information Series QI04080, http://www.daf.qld.gov.au/__data/assets/pdf_file/0007/76876/Insects-NPV-to-mange-helicoverpa.pdf

DPI&F (2005) Parasitoids: Natural enemies of helicoverpa. DPI&F Qld Information Series QI04081, http://www.daf.qld.gov.au/__data/assets/pdf_file/0003/64677/Insect-Parasitoids-Natural-enemies-helicoverpa.pdf

J Ferguson, M Miles, D Murray, M Dillon, G Kauter, R Lloyd, R Sequeira (2000) Spring trap crop management guidelines. Cotton CRC QI00049.

M Miles, J Ferguson (2003) Trap-cropping: A fad or a useful Helicoverpa management tool, DPI Qld Farming Systems Institute, DPI Notes.