NORTHERN
MARCH 2016

GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

SOYBEAN

SECTION 7

INSECT CONTROL

NAME AND DESCRIPTION OF PEST (IDENTIFICATION) | MODERATE, LESS FREQUENT AND MINOR PESTS | THRESHOLDS FOR CONTROL | MANAGEMENT OF INSECT PEST | BENEFICIAL INSECTS | KEY PARASITOIDS AND PREDATORS

SECTION 7

Insect control

Soybeans can be attacked by pests at any stage from seedlings to harvest, but are most attractive to insect pests from flowering onwards. Soybeans are more tolerant of insect damage than most other grain legumes and noticeable damage (particularly leaf damage) does not necessarily result in yield loss. The basic Integrated Pest Management (IPM) strategy for soybeans is to avoid non-selective pesticides for as long as possible to foster a build-up of predators and parasites (i.e. to 'go soft early'). This buffers the crop against pest attack during later crop stages, and greatly reduces the risk of subsequent helicoverpa, silverleaf whitefly and mite attack. However many pests have a major impact on yield and quality, and intervention with pesticides is frequently unavoidable.

Major pests in soybeans are helicoverpa (heliothis), podsucking bugs, and potentially silverleaf whitefly. Other lesser and/or infrequent, but damaging pests, include loopers, grass blue butterfly, cluster caterpillar, soybean moth, soybean aphid, mirids, monolepta beetle and crickets. Note that beanfly and bean podborer, both major pests in other summer pulses, are not a threat to soybeans.

Soybeans are more attractive to a range of foliage-feeding pests (e.g. numerous loopers, grass blue butterfly, and leaf miners) than other summer pulses. During the vegetative stage, 33% leaf defoliation can be tolerated without yield loss, although this falls to 16% during pod set.

Helicoverpa can attack at any stage from seedlings onwards. High helicoverpa populations have a severe impact on vegetative crops because they destroy the plant's axilliary buds, the precursors to the floral buds. Soybeans can compensate for considerable damage during early podding because they set a large number of 'reserve pods' which can replace pods eaten by helicoverpa.

Podsucking bugs (PSB) are major soybean pests. The most damaging species are the green vegetable bug (Nezara viridula), the large and small brown bean bugs (Riptortus and Melanacanthus sp. respectively) and the redbanded shield bug (Piezodorus oceanicus). Soybeans can compensate for potential yield loss due to bug damage, but bug damage reduces seed quality. Only 3% seed damage is tolerated in edible soybeans, and the action threshold for PSB in edibles is based on 2% damage.

Silverleaf whitefly (SLW) are a potential threat to soybeans. However the introduced SLW parasite Eretmocerus hayati, native parasites and predators, have largely stabilised whitefly populations in most regions in most years. Note that beneficials targeting SLW are only effective if they are not disrupted by non-selective pesticides, particularly in vegetative and flowering crops.

Soybean aphids are present in most crops but are mostly kept in check by ladybirds and hoverfly larvae. However above-threshold soybean aphid populations (>250 aphids per plant) can have a devastating impact on yield and harvest maturity.

Mirids have far less impact in soybeans than mungbeans. Up to 5 mirids/m^2 have no impact on yield.

Other pests that spasmodically occur in very damaging numbers include monolepta beetle in coastal sugar-growing regions, and soybean moth larvae (which mine inside the leaves) in all regions.

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

More information

H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

The Beatsheet, Insect pest management for Australia's Northern Region: http://thebeatsheet.com.au/

GRDC (2013) Stem fly outbreak batters soybean crops: http://www.grdc.com.au/Media-Centre/Media-News/North/2013/04/stem-fly-outbreak-batters-soybean-crops

Scout crops regularly with a beat sheet, at least weekly pre flowering, and twice weekly post flowering. In a typical soybean crop, budget for one deltamethrin spray for podsucking bugs, and one helicoverpa spray after flowering, preferably with a moderately selective pesticide such as indoxacarb. Check all registrations regularly on the APVMA/PUBCRIS website and only use products registered in soybeans.[1]

7.1 Name and description of pest (identification)

7.1.1 Helicoverpa (*Helicoverpa armigera*, *H. punctigera*)

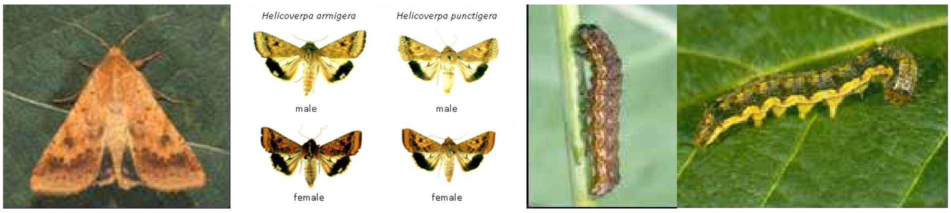

Figure 1: Helicoverpa armigera female moth, Helicoverpa armigera and H. punctigera moths. Also, medium large (18 mm) and large H. armigera larvae (36 mm). Note the pale spot in the dark perimeter band of H. armigera's hind wing, (not present in H. punctigera), the larvae's uniform body thickness, 4 pairs of abdominal prolegs, sparse hairs, and wide pale lateral band. (Photo: Australian Oilseeds Federation)

Pest status: Helicoverpa can severely damage all crop stages and all plant parts of soybeans. Vegetative soybeans are more attractive to helicoverpa than the vegetative stages of other summer pulses and can even be damaged during the seedling stage. However the crop is at greatest risk of attack from flowering to late podfill. In sub-coastal and inland southern Queensland, summer legumes are at greatest risk from *H. armigera* from mid December onwards.

Identification: Helicoverpa larvae can be confused with loopers, armyworms or cluster caterpillars. Their colour is very variable ranging from green to orange to brown to black. Look for a broad pale band along each flank, a lack of large dark spots, four pairs of abdominal prolegs, sparse body hairs and a parallel body. Young *H. armigera* larvae have a dark saddle behind the head while *H. punctigera* larvae don't. Large *H. armigera* larvae have white hairs behind the head. Larvae can reach 35 mm in length.

Helicoverpa moths have a 35 mm wingspan. The forewings of males are straw-colour and those of females are brown. Forewings of both sexes have dark markings. Hindwings are pale cream with a wide, dark outer band. *H. armigera* has a distinctive pale spot in the hindwing's dark outer band. This spot is missing in *H. punctigera*.

Damage: Helicoverpa defoliation is characterised by rounded chew marks and holes (loopers make more angular holes). Helicoverpa also attack auxiliary buds and terminals in vegetative crops. This type of damage can have a severe impact on subsequent podset, particularly if there are high populations in seedling or drought-stressed crops. Early terminal and bud damage can also result in pods being set closer to the ground. Such pods are more difficult to harvest. In drought stressed crops, the last soft green tissue is usually the vegetative terminals, which are thus more likely to be totally consumed than in normally growing crops.

Once crops reach flowering, larvae focus on buds, flowers and pods. Young larvae are more likely to feed on vegetative terminals, young leaves and flowers before attacking pods. Small pods may be totally consumed by helicoverpa, but larvae target seeds in large pods. Crops are better able to compensate for early than late pod damage. However in drought-stressed crops, early damage may delay or stagger podding with subsequent yield and quality losses. Damage to well-developed pods also results in the weather staining of uneaten seeds due to water entering the pods.

[1] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Monitoring: Beat sheet sampling is the preferred sampling method for medium to large helicoverpa larvae. Small larvae should be scouted for by inspecting (opening) vegetative terminals and flowers. Damage to vegetative terminals is often the first visual clue that helicoverpa larvae are present. Soybeans should also be scouted for eggs and moths, to pinpoint the start of infestations and increase the chance of successful control.

Inspect crops weekly twice weekly from early budding until late podding. The sampling frequency during the vegetative stage has been increased to increase the chance of detecting caterpillar pests while they are still small enough to control with biopesticides.

Sample six widely-spaced locations per crop management unit. Take 5 one-metre long samples at each site with a 'standard' beat sheet. Convert larval counts/m to larvae/m^2 by dividing counts by the row spacing in metres.

Beat sheet sampling may only detect 50% of small larvae in vegetative and podding soybeans, and 70% during flowering, as they feed in sheltered sites such as leaf terminals. However many of these small larvae will be lost to natural mortality factors before they reach a damaging size and in most crops, and this mortality will cancel out any sampling inefficiencies. Altacor provides outstanding and extended crop protection with low toxicity to beneficials.

Thresholds: In vegetative crops, thresholds for many leaf feeding pests are expressed as % tolerable defoliation or % tolerable terminal loss. Before flowering, soybeans can tolerate up to 33% leaf loss without loss of yield. However recent data (Rogers 2010) shows that helicoverpa populations infecting less than 33% damage can cause serious yield loss, because the larvae not only feed on leaves, but also attack terminals and auxiliary buds. The data indicates an economic threshold of approximately 7 helicoverpa larvae per square metre (7.5/m^2) in mid to late vegetative soybeans. This threshold should be lowered in early vegetative or stressed crops. Helicoverpa thresholds for podding soybeans currently range from 1-2 larvae/m^2 (depending on crop value and pesticide cost).

Chemical control: Prior to flowering, biopesticides, particularly helicoverpa nuclear polyhedrosis virus (NPV), are recommended in preference to chemical insecticides. This helps conserve beneficial insects to buffer crops against helicoverpa attack during the susceptible reproductive stages, and avoids faring of other pests such as silverleaf whitefly and mites.

Cultural control: Where possible, avoid successive plantings of summer legumes. Good agronomy and soil moisture are crucial as large, vigorously growing plants suffer less defoliation for a given helicoverpa population and have less risk of terminal damage.

In water-stressed crops, terminals are more attractive to larvae than wilted leaves. Vigorously growing plants with adequate available moisture are better able to replace damaged leaves and to compensate for flower and pod damage.

Natural enemies: The number of beneficial insects varies with crop age, from crop to crop, region to region, and from season to season. The combined action of a number of beneficial species is often required to have a significant impact on potentially damaging helicoverpa populations. It is therefore desirable to conserve as many beneficials as possible.

Natural enemies of helicoverpa include predators of eggs, larvae and pupae, parasites of eggs, larvae and pupae, and caterpillar diseases. Predatory bugs and beetles attacking helicoverpa eggs and larvae include: spined predatory bug, glossy shield bug, damsel bug, bigeyed bug, apple dimpling bug, assassin bugs, red and blue beetle, and predatory ladybirds. Other important predators include ants, spiders and lacewings. Egg parasites include the tiny Trichogramma spp. wasps. Caterpillar parasites include Microplitis, Heteropelma and Netelia sp. wasps and several species of tachinid flies including Carcelia sp. The banded caterpillar parasite Ichneumon promissorius is actually a pupal parasite.

With the exception of the egg parasites and Microplitis, most parasites don't kill helicoverpa until they reach the pupal stage. Predatory earwigs and wireworm larvae are significant predators of helicoverpa pupae.

Naturally occurring caterpillar diseases frequently have a marked impact on helicoverpa in summer legumes. Outbreaks of NPV are frequently observed in crops with high helicoverpa populations. [2]

7.1.2 Pod-sucking bugs

Pod-sucking bugs can move in at budding but significant damage is confined to pods early podfill to harvest maturity. While bugs start breeding as soon as they move into flowering crops, nymphs must feed on pods to complete their development. Bugs cause shrivelled and distorted seed, and can severely reduce yield and seed quality. Bugs can even damage seeds in pods that are nearing harvest maturity. Late bug damage reduces seed quality but not yield. As only 3% seed damage is tolerable in culinary soybeans, bug thresholds are based on seed quality, not seed yield.

A number of pod-sucking bug species attack soybeans and include:

- green vegetable bug
- redbanded shield bug
- large brown bean bug
- small brown bean bug
- brown shield bug

The green vegetable bug (GVB) and the brown bean bugs are equally damaging to crops, while the damage potentials of the redbanded and brown shield bugs are 0.75 and 0.2 of that of a GVB respectively. Nymphs of all species are less damaging than adults. While 1st instar nymphs cause no damage, subsequent instars are progressively more damaging with the 5th and final instar being nearly as damaging as adults. To determine the damage potential of mixed bug species populations, convert all species (adults and nymphs) to GVB adult equivalents (GVBAEQ).[3]

Green vegetable bug (GVB), Nezara viridula

Figure 2: Green vegetable bug adult (15 mm), 4th instar nymphs (8 mm) and egg raft (about to hatch). (Photo: Australian Oilseeds Federation)

Distribution: GVB was first recorded in Australia in 1916 (an accidental introduction) and is now found in all Australia states and territories.

Pest status: Major, widespread and regular. GVB is the most damaging pod-sucking bug in pulses, due to its abundance, widespread distribution, rate of damage and rate of reproduction. It is one of the most recognised agricultural pests in Australia.

Identification: Adult GVB are bright green and shield-shaped, and are 13-15 mm long. Adult GVB have three small white spots at the front of the scutellum (between their shoulders). Yellow and orange GVB colour variants are occasionally encountered. Over

[2] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[3] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

wintering adults are purple brown in colour. GVB emit a foul smell when disturbed to deter predators.

GVB eggs are laid in rafts (50-100 eggs per raft) and are circular in cross section. Newly laid eggs are cream but turn bright orange prior to hatching. Parasitised GVB eggs are black.

GVB nymphs vary in colour. Newly hatched nymphs (1.5 mm long) are orange and brown (sometimes black). Later instars are green or black, with white, cream, orange and red markings. Final (5th) instar nymphs have fewer spots (more base colour, green to black), and have prominent wing bugs. Younger nymphs are round or oval rather than shield shaped and usually aggregate in large clusters. Older nymphs are more widely dispersed.

Life cycle: Eggs take 6 days to hatch at 25°C. Nymphs don't usually reach a damaging size until mid to late pod-fill. Usually only 1 generation develops on a summer legume crop. Nymphs require pods containing seeds to complete their development and the podding phase of most summer legumes is only slightly longer in duration than GVB's life cycle. There are 5 nymphal instars with a total development time of about 30 days. Development is faster at temperatures higher than 25°C but there is considerable nymphal and adult mortality at temperatures over 35°C.

Risk period: Adult bugs typically invade summer legumes at flowering, but GVB is primarily a pod feeder with a preference for pods with well developed seeds. Nymphs are unable to complete their development prior to pod-fill. Soybeans remain at risk until pods are too hard to damage (i.e. very close to harvest). Damaging populations are typically highest in late summer crops during late pod-fill (when nymphs have reached or are near adulthood).

Damage: Pods most at risk are those containing well-developed seeds. While GVB also damages buds and flowers, soybeans can compensate for this early damage. Damage to young pods cause deformed and shrivelled seeds and potentially reduces yield, although this is often compensated for by an increase in weight of undamaged seeds. Seeds damaged in older pods are blemished and difficult to grade out, reducing harvested seed quality, particularly that destined for human consumption (edibles). GVB can even damage seeds in 'close-to-harvest' pods (i.e. pods that have hardened prior to harvest). Bug damaged seeds have increased protein content but reduced oil content and a shorter storage life (due to increased rancidity). Bug damaged seeds are frequently discoloured, either directly as a result of tissue breakdown, or because of diseases such as Cercospora (purple seed stain), which may gain entry where pods are pierced by bugs.

Small GVB nymphs are far less damaging than older nymphs which become progressively more damaging as they progress to adulthood. Final instar nymphs are nearly as damaging as adults.

Sampling and monitoring: Inspected crops twice weekly for GVB from flowering until close to harvest. Sample crops for GVB in the early to mid morning. Beat sheet sampling is only effective monitoring method. The standard sample unit is five one metre non-consecutive lengths of row within a 20 m radius. Convert all bug counts per row metre to bugs/m^2 by dividing counts per row metre by the row spacing in metres.

At least six sites should be sampled throughout a crop management unit to accurately determine adult GVB populations. GVB nymphs are more difficult to sample accurately as their distribution is extremely clumped, particularly during the early nymphal stages (1st-3rd instars). Ideally, at least 10 sites (with five non-consecutive row metres sampled per site) should be sampled to adequately assess nymphal populations.

Thresholds: Pod-sucking bug thresholds in edible or culinary soybeans (destined for human consumption) are determined by seed quality, the maximum bug damage permitted being only 3%. GVB thresholds typically range from 0.3-0.8/m^2 depending on the crop size (seeds per m^2) and when bugs are detected. Because thresholds are determined by % damage, the larger a crop (the more seeds per unit area), the more bugs that are required to inflict critical (threshold) damage, and the higher the threshold. For crushing and stockfeed soybeans with lesser quality requirements, the threshold is doubled. Thresholds are expressed in adult equivalents.

Chemical control: Bugs should be controlled during (but not prior to) early podfill before nymphs reach a damaging size. Pesticides are best applied in the early to mid morning to contact bugs basking at the top of the crop canopy.

Cultural control: Avoid sequential plantings of summer legumes as bug populations will move progressively from earlier to later plantings, eventually building to very high levels. Avoid cultivar and planting time combinations that are more likely to lengthen the duration of flowering and podding.

Natural enemies: GVB eggs are frequently parasitised by a tiny introduced wasp Trissolcus basalis. Parasitised eggs are easily recognised as they turn black. GVB nymphs are attacked by ants, spiders and predatory bugs. Final (5th) instar and adult GVB are parasitised by the recently introduced tachinid fly (Trichopoda giacomellii).[4]

Redbanded shield bug (RBSB), Piezodorus oceanicus

Redbanded shield bugs in Australia were previously classified as *Piezodorus hybneri* and more recently as *P. grossi*.

Figure 3: Red-banded shield bug adult (female), nymph and twin-row egg raft with hatching nymphs. (Photo: Australian Oilseeds Federation)

Pest status: Major, widespread, regular. RBSB is 75% as damaging as GVB in summer pulses but is usually not as abundant. However, it is more difficult to control with current pesticides.

Identification: Adults are similar in shape to GVB but are smaller (8-10 mm long) and paler, with a noticeable band across their shoulders. Females have a pink (not red) band across their shoulders. In contrast, males have an off-white band across the shoulders and pale yellow lines along their side.

Eggs are laid in distinctive twin row rafts with 15-40 dark elliptical eggs (in cross section), ringed by small spines. Newly hatched nymphs are orange with black markings and similar to newly hatched nymphs of many other shield bugs. Larger nymphs are pale green with dark red and brown markings in the centre of their back. Late autumn nymphs may turn a pale pink-brown colour.

Damage: Damage is similar to that caused by GVB, with early damage reducing yields, and later damage reducing the quality of harvested seeds. Thresholds: Convert to GVB equivalents to determine damage potential ie. multiply counts by 0.75.

Monitoring: As for GVB. Look for the distinctive twin-row egg rafts that indicate RBSB presence.

Chemical control: No insecticides are specifically registered against RBSB in Australia. Recent trials suggest pesticides currently registered against GVB are ineffective against RBSB. However, control can be improved, albeit to a moderate 50-60%, with the addition of a 0.5% salt (NaCl) adjuvant.

Natural enemies: Spiders, ants, and predatory bugs are major predators of RBSB, particularly of eggs and young nymphs with mortality of these stages sometimes

4 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

exceeding 90%. Eggs may be parasitised by the tiny wasp, Trissolcus basalis. Adults are infrequently parasitised by the recently introduced tachinid fly Trichopoda giacomellii.[5]

Large brown bean bug, Riptortus serripes Hemiptera: Alydidae

Distribution: Native to Australia.

Similar Riptortus species occur in Asia, India and Africa.

Pest status: Major. As damaging as GVB. More frequent on the coast, with a liking for the Vigna legumes (e.g. adzukis, cowpeas and mungbeans, as well as soybeans).

Identification: An elongated dark brown bug, 16-18 mm long (not including legs and antennae) with long antennae and a bright yellow stripe along each side. This stripe is more pronounced in males and less distinct in females, which have a 'rounder' body than males. Riptortus serripes's body narrows in the middle and it has a spine on each 'shoulder'. It also has large robust and spiny hindlegs. When it is flying, the bright orange top of the abdomen is revealed.

Nymphs are dark brown and similar in outline to ants. However close inspection shows they lack the very narrow 'waist' and biting mouthparts (jaws) typical of ants.

Eggs are a dark purple-brown in colour and are laid singly or in small clusters. They are slightly elliptical with a flattened top and rounded base and are 1.5 mm long.

Figure 4: Adult female (16 mm) (left). 4th instar nymph (9 mm) (right).

May be confused with:

- Small brown bean bug, *Melanacanthus scutellaris*, which is considerably smaller (10-12 mm) and not as robust.
- Rice or paddy bug, *Leptocorisa acuta (Thunberg)*. Rice bugs are pale green or brown, reach 15 mm in length, and are very slender with thin hindlegs.

Life cycle: Riptortus invade summer legumes at flowering and proceed to feed and lay eggs. This pest lays scattered single eggs. There are 5 nymphal stages with nymphs reaching a damaging size during mid to late podfill. Development times for Riptortus eggs and nymphs are about 8 and 17 days respectively (25 days total) at 26°C. Overwintering *R. serripes* shelter in curled up dead leaves.

Host range, risk period and damage: As for GVB. *R. serripes* is as damaging as GVB.

Monitoring: The beat sheet method is not totally satisfactory for *R. serripes* because it is very flighty, particularly during the hotter parts of the day. Crops should be sampled during the early morning. Crop scouts should also familiarise themselves with the appearance of flying (and escaping) Riptortus adults and include these in sampling counts.

[5] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Chemical control: *R. serripes* is likely to be controlled by synthetic pyrethroids which are registered against GVB.[6]

Small brown bean bug, Melanacanthus scutellaris Hemiptera: Alydidae

Figure 5: Female (12mm) (left), 1st instar nymph (middle), eggs (right). (Photo: Australian Oilseeds Federation)

Distribution: Native to Australia.

Pest status: Major. This pest can be as damaging as GVB.

Identification: The small brown bean bug is an elongated brown bug, 10-12 mm long (body only) with long antennae and a cream stripe along each side. This stripe is often less distinct in females, which are 'rounder' than males. Males also have a prominent pale patch in the scutellum. The small brown bean bug has a short spine on each 'shoulder' (less pronounced than on *Riptortus sp*.), and moderately robust and spiny hind legs (thinner than those of *Riptortus sp*.).

Nymphs are dark brown to black and similar in outline to ants. However close inspection shows they lack the very narrow 'waist' typical of ants. The shiny olive green eggs are laid in small clusters. The eggs are slightly elliptical with a flat top and a rounded base and are 1.0 mm long.

Life cycle: Small brown bean bugs invade summer legumes at flowering where they commence feeding and lay eggs. This bug lays scattered single eggs (up to several hundred per female). There are 5 nymphal stages and nymphs usually reach a damaging size to coincide with mid to late podfill. Development times for eggs and nymphs are about 6 and 20 days respectively at 260C.

Damage: The small brown bean bug is as damaging as GVB and the large brown bean bug.

Monitoring and control: As for the large brown bean bug *Riptortus serripes*.[7]

Brown shield bug, Dictyotus caenosus (Westwood) Hemiptera: Pentatomidae

Figure 6: Eggs, brown shield bug (8 mm), 4th instar nymphs, glossy shield bug (12 mm) – a predator. (Photo: Australian Oilseeds Federation).

Distribution: Native to Australia.

6 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Pest status: Minor but difficult to control pest.

Identification: Brown shield (or brown stink) bug (BSB) adults are shield shaped and are matt mid brown (ie. not glossy). At 8 mm long, they are noticeably smaller than the green vegetable bug.

Newly hatched nymphs are orange with black markings and similar to newly hatched nymphs of many other shield bugs. Larger nymphs have a dark brown (sometimes almost black) head and thorax, and a pale brown abdomen with transverse dark brown and pale (almost white) markings at its centre. There is also a transverse pale band at the front of the abdomen. BSB lays eggs in either small twin rows or small irregular rafts containing 10-16 eggs. Eggs are pale cream and similar in shape to GVB eggs.

May be confused with: Glossy shield bugs, (Cermatulus nasalis) which are slightly larger and a predatory species. Brown shield bug eggs and nymphs are distinct from those of Cermatulus.

Life cycle: BSB invade summer legumes at flowering and proceed to feed and lay eggs. Nymphs usually reach a damaging size during mid to late podfill. There are 5 nymphal stages.

Damage and control: The brown shield bug is less damaging than other bugs with only 20% of GVB damage recorded. There is anecdotal evidence this species is (like Piezodorus) also difficult to control with current pesticides but that control can be improved (to 50-60%) with the addition of a 0.5% salt (NaCl) adjuvant.[8]

7.1.3 Silverleaf whitefly (SLW), *Bemisia tabaci biotype B.*

Silverleaf whitefly (SLW) poses a threat to soybeans in most regions in NE Australia. However the exotic SLW parasite *Eretmocerus hayati*, together with native parasites and predators, will stabilise SLW populations, provided they are not disrupted by the overuse of non-selective pesticides.

Distribution: SLW is widespread in tropical and subtropical Australia. In southern Queensland and northern NSW, SLW is most abundant in coastal regions with milder winters and a continuum of hosts. However, SLW is also abundant in more-inland regions such as the Emerald irrigation area of central Qld., the St George irrigation area of SW Qld., and the north-west slopes of NSW.

Pest status: Always a potential major risk in a susceptible crop such as soybeans, particularly in regions where broad spectrum insecticides are widely used.

Figure 7: SLW adults (1.2 mm) and pupating (red eye) nymph on leaf underside. Note the gap between the adult's wings.

[8] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Figure 8: SLW adults sheltering under soybean leaflet.

Figure 9: Green house whitefly adult and GHW nymph. Note the nymph's long filaments, absent on SLW. (Photos: Australian Oilseeds Federation)

Identification: Adults are 1.5 mm long with powdery white wings and a pale orange body. Their folded wings don't quite touch revealing the body when viewed from above. SLW eggs are small and spherical and sit on a short stalk. Eggs are initially pale yellow but turn brown with age. High egg densities give the impression the leave's (undersides) are covered with brown velvet. The nymphs (or scales) are pale cream/yellow and are flat and oval shaped. Nymphs cease feeding and metamorphose to winged adults during the late 4th instar which is called the pupa or 'red eye' (because of prominent red eye spots). The lifecycle takes 18-30 days from egg lay to adult depending on temperature.

May be confused with: SLW can only be differentiated from other strains of *Bemisia tabaci* by biochemical testing. The larger greenhouse whitefly (1.5mm) has wings that obscure the body when viewed from above and a nymphal stage with long waxy filaments.

Host range: Of the summer pulses, soybeans and navy beans are preferred SLW hosts. Other favoured hosts include capsicums, cotton, cucurbits, dolichos, milk thistle, poinsettia, rattlepods, sunflowers, sweet potatoes and tomatoes.

Risk period: Soybeans maturing during late summer and autumn are at greater risk of attack because invading SLW have had more time to increase from low over-wintering populations. As a rule, the earlier crops are infested the greater the risk. Crops remain attractive to SLW until mid pod-fill. As photosynthetic assimilates are redirected from leaves to fill the pods, leaves become unattractive to SLW and adults leave the crop to find more attractive hosts.

Damage: SLW can reduce plant vigour and yield by the sheer weight of numbers removing large amounts of plant photosynthate from the leaves. Severe infestations in young plants can stunt plant growth and reduce yield potential. Later infestations can reduce the number of pods set, seed size, and seed size uniformity, thus reducing yield and quality. As a rule, the impact of SLW is worst in drought stressed crops. In heavily infested soybeans, both pods and seeds are often unusually pale. While seed colour is unlikely to be of concern in grain soybeans (harvested seeds being naturally pale), pod and seed discolouration are a major marketing problem where pods are picked green (e.g. vegetable soybeans and green beans).

SLW often secrete large amounts of sticky honeydew. Adult females produce more honeydew than other stages and nymphs produce more honeydew when feeding on stressed plants. Honeydew in itself is not a major problem, but sooty mould developing on honeydew shields leaves from sunlight and reduces photosynthesis. Sooty mould's impact is greatest from early to mid podfill when SLW activity is greatest at the top of the canopy (i.e. on leaves with the greatest photosynthetic activity). Rain and overhead irrigation wash honeydew off leaves, lessening the risk of sooty mould.

Monitoring: SLW eggs, nymphs and resting adults are mainly found on the underside of leaves. Flying SLW adults are readily observed when crops with high populations are disturbed. The presence of honeydew and sooty mould may also indicate SLW attack, but can be due to aphid feeding. SLW eggs are laid on younger leaves, so by the time eggs develop to large nymphs in crops with high growth rates, leaves with the greatest visible SLW nymphal activity are further down the plant. This may be as many as 5-7 nodes below the plant top. As vegetative growth slows, plant nodes with greatest nymphal activity move progressively upwards to the canopy top.

Thresholds and chemical control: There are no validated thresholds for SLW and no pesticides are specifically registered for SLW control in summer pulses in Australia. Use the softest options possible for other pests, especially early in the life of the crop, to encourage SLW parasites and predators.

Cultural control: Where possible, avoid successive plantings of summer pulses to prevent movement from early to late crops. Avoid planting summer pulses in close proximity to earlier maturing SLW hosts such as cotton and cucurbits. Where damaging SLW populations are evident in other crops early in the season (early summer), or in regions with a history of consistently damaging widespread SLW activity, consider planting a pulse type less attractive to SLW (e.g. mungbeans or adzukis (*Vigna sp*.), rather than soybeans). However in most regions, this should not be necessary.

Control SLW weed hosts such as rattlepod and milk thistle. Irrigate crops to reduce moisture stress which makes crops more susceptible to SLW damage. Overhead irrigation also washes off sooty mould and drowns adult SLW. Narrow leafed and smooth leafed (less hairy) cultivars may be less attractive to SLW. However, the latter attribute may leave crops more vulnerable to aphid attack.

Natural enemies: SLW nymphs are parasitised by native species of Encarsia and Eretmocerus (both very small wasps). In the early to mid 2000's, CSIRO made widespread releases of the exotic parasite Eretmocerus hayati. The parasite is now well established and, in conjunction with native SLW parasites and predators, has stabilised SLW populations in many soybean crops. Nymphs parasitized by Eretmocerus are an opaque honey colour while those parasitized by Encarsia are dark. Look for discoloured nymphs to monitor SLW parasitism in your crop.[9]

9 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.1.4 Soybean stemfly (*Melanagromyza sojae*)

Figure 10: Adult, larvae, parasite and exit hole of Soybean stemfly (Melanagromyza sojae)

A major outbreak of this pest occurred in soybeans in the Casino region of NSW in 2013. Since then, stemfly populations have declined in the Casino region, most likely due to parasitism, significant levels of which were observed in late summer of 2013. Stemfly have also been detected in other soybean growing regions, including the South Burnett in South-East Qld, but not in damaging numbers. It is likely that the pest will be always present in coming seasons, but hopefully only periodically in really damaging numbers.

Soybean stemfly adults are small (2 mm) and black with reddish eyes and are very similar to bean fly (*Ophiomyia phaseoli*) which is a major navy bean pest. Eggs are laid in the leaves and larvae tunnel down the petioles to reach the stem. Unlike beanfly, stemfly larvae tunnel in the stem pith and make a distinctive exit hole before pupating. Note that stemfly damage looks very similar to that caused by crown borer and etiella. Note also that the feeding in the pith has little if any effect on plant health.

Many infested crops near Casino exhibited a 'sudden death' syndrome during early podfill (leaf yellowing and plant death). However, the real culprit in many instances was most likely soil borne disease such as charcoal rot and phomopsis. These diseases are triggered by plant stress and inoculum build-up due to successive soybean crops in many paddocks.

There are no well-defined stemfly thresholds. In navy beans the beanfly threshold is one tunnel per plant in seedling plants. But in soybeans, stemfly normally attack older plants. Only spray if stemfly are present in 'reasonable' numbers (numerous larvae per plant) and there are increasing unhealthy plant symptoms that are NOT disease related. Note that diseases such as charcoal rot and phomopsis are manifested by poor root development, distinctive stem discolouration and leaf discolouration and death, and eventual plant death.

If you do spray, target the larvae before they reach the stems. Once inside the stems, larvae cannot be controlled as they are feeding on non-vascular tissue. Note that Casino crops that were sprayed with the beanfly rate of dimethoate (800 mL/ha) in 2013, experienced an explosion of white fly numbers, from already very high levels.

If you do spray, leave an unsprayed strip to evaluate the efficacy of the spray on the pest and plant health, and its impact on secondary pests such as whitefly.[10]

[10] H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

7.2 Moderate, less frequent and minor pests

7.2.1 Cluster caterpillar *Spodoptera litura* (often referred to as 'spods')

Figure 11: Egg mass. (Photo: Australian Oilseeds Federation)

Figure 12: Spodoptera litura moth. (Photo: Australian Oilseeds Federation)

Figure 13: Small clustering larvae (5 mm). (Photo: Australian Oilseeds Federation)

Figure 14: Large larvae (30 mm). (Photo: Australian Oilseeds Federation)

Distribution: Cluster caterpillar is more common in tropical and coastal soybean growing regions.

Pest status: Moderate. Not quite as damaging as helicoverpa and less frequent. It has been reported as causing significant damage to soybeans in coastal Qld.

Identification: Moths are larger than helicoverpa with a 40 mm wingspan and brown forewings with criss-cross cream streaks.

The eggs are laid in a furry cream mass on the underside of leaves. Young larvae 'cluster' together and are translucent green with a darker thorax. Middle-sized larvae are smooth-skinned with a pattern of red, yellow, and green lines, a dark patch on the hump behind the head, and dark spots along each side. Large larvae are initially brown with three thin pale yellow lines down the back: one in the middle and one on each side. They have a row of black dots along each side, and a row of conspicuous dark half-moons along the back.

Final instar larvae are darker and can exceed 50 mm in length. All larvae have 4 pairs of ventral prolegs, and are more solid than helicoverpa with fewer body hairs.

May be confused with: Small to medium larvae (10 mm) may be confused with helicoverpa larvae, but differ by the 'hump' behind the head, and the row of dark spots along each side.

Host range: Adzukis, mungbeans, navy beans, peanuts, pigeon pea and soybeans.

Life cycle: Egg masses are laid on leaves. Young larvae feed on leaves but older larvae may feed on flowers and pods. Larvae pass through 6 larval stages and take 2-3 weeks to develop, depending on temperature. Larvae pupate in the soil.

Risk period and damage: Crops are most at risk at flowering and podding. Small larvae window leaves, but older larvae chew holes in leaves. Older larvae also attack flowers and pods.

Monitoring and control: As for helicoverpa. Look also for egg masses and clusters of young larvae. In pre-flowering crops, control is warranted if defoliation exceeds (or is likely to) 33%. Tolerable defoliation drops to 15-20% once flowering and podding commences. NPV does not control cluster caterpillars and they can't be controlled with Bt unless they are very small.

Natural enemies: As for helicoverpa and loopers.[11]

11 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.2 Bean podborer *Maruca vitrata* (previously *Maruca testulalis*)

Figure 15: Large larvae (16 mm). (Photo: Australian Oilseeds Federation)

Distribution: A cosmopolitan tropical pest found that is most abundant in tropical and subtropical Australia.

Pest status and damage: Usually not a pest in soybeans, but tunnelling in stems has been reported in soybeans in coastal Qld.

Identification: Bean podborer moths have a 20-25 mm wingspan and a slender body. They have brown forewings with a white band extending two-thirds down the wing from the leading edge. Inside this band near the leading edge is a white spot. The hindwings are predominantly a translucent white with an irregular brown border. When at rest, they adopt a characteristic pose with outspread wings and the front of the body raised up. Larvae are pale cream with two rows of distinctive paired black markings on their back.

Host range: Favoured hosts include adzukis, mungbeans, cowpeas, pigeon peas but not soybeans.

Life cycle and damage: In favoured hosts, larvae feed initially in buds and flowers before moving to the pods. Soybeans are not a favoured host and the only reported damage to date has been tunnelling in the stems of coastal soybeans. After completing their development (10-15 days from egg hatch), larvae exit pods and pupate in the soil.

Monitoring and control: Look for tunnelling and associated larval frass in soybean stems. No thresholds are set as this pest is not regarded as a problem in soybeans.[12]

Altacor® (chlorantraniliprole) is very effective against podborers, killing larvae hidden inside the buds. However larval death is not immediate. While feeding stops very quickly, larvae remain moribund for 3-4 days (shrunken and darkened), before dying. This moribund state is also observed in helicoverpa and other caterpillars.

The key to successful control is to monitor the crops closely from early budding and target larvae before they move from the flowers to the pods. Cultural controls include getting rid of legume weed hosts such as sesbania. Other favoured hosts include pigeonpea and adzukis.[13]

12 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

13 H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

7.2.3 Etiella (lucerne seed web moth), *Etiella behrii*

Figure 16: Etiella (12 mm). (Photo: Australian Oilseeds Federation)

Figure 17: Large (10 mm) larvae in a very small peanut pod. (Photo: Australian Oilseeds Federation)

Figure 18: Etialla-damaged soybean pod. (Photo: Australian Oilseeds Federation)

Distribution: Etiella is found throughout Australia. Etiella larvae were found in significant numbers (up to 10 larvae per square metre) in vegetative soybean crops on Queensland's Darling Downs in 2013, and in low numbers (<1/sqm) in a DAFF soybean trial at nearby Kingaroy.[14]

Pest status: Etiella is an important pest of peanuts and lentils. In soybeans, it is mostly a problem in natto beans (Japanese fermented soybeans).

Host range: Etiella infest many pulses including peanuts, mungbeans, adzukis, lima beans lentils and soybeans. Rattle pods are favourite weed hosts.

Identification: Moths are small (12 mm long at rest, 20-22 mm wingspan) and uniquely coloured. They are grey brown in colour with a distinctive white stripe along the leading edge of each forewing, and an orange band across each forewing. Their wings fold back along the body when resting. Moths have a prominent 'snout'.

The eggs are small (0.6 mm diameter), cream and flattened. Small larvae are cream or pale green, lack stripes, and have a dark head. Mid-sized larvae are pale green or

14 The Beatsheet, Etiella outbreak in vegetative soybeans on the Darling Downs: http://thebeatsheet.com.au/crops/pulses/soybeans/etiella-outbreak-in-vegetative-soybeans-on-the-darling-downs/

cream, with pale brown or reddish stripes. Larger larvae are characteristically green with pink or reddish stripes and a brown head. Larvae in the pre-pupal stage can be aqua blue or dark pink with no stripes.

May be confused with: Non-pest *Etiella spp*. which feed on rattle pods.

Life cycle: Eggs are laid on pods and flowers and are very hard to detect. Newly-hatched larvae bore into pods leaving a near-invisible entry hole. The lifecycle can be completed in 4 weeks at 30°C.

Risk period and damage: Etiella is a spasmodic but important pest of specialist soybeans in drier regions (e.g. natto soybeans on the Darling Downs) due to near zero damage tolerance. Crops may be infested from flowering onwards, but are at greatest risk during late podding. Etiella larvae consume far less than larger caterpillar species such as helicoverpa, so seeds are usually only partially eaten out, often with characteristic pin-hole damage. This damage is difficult to grade out and its unattractive appearance reduces seed quality.

Etiella normally attack pods, but in 2013 and 2014, larvae caused significant damage to the auxiliary buds (precursors of the floral buds) and stems of vegetative soybeans in southern Qld and northern NSW. Similar but not as widespread stem damage was reported in mungbeans. In some South Burnett soybean crops in 2014, etiella activity continued well into late podfill, populations peaking at >40 larvae/m^2.

A study of etiella damage in a late podfill crop of South Burnett soybeans found the majority of larvae fed on only one seed, consuming the seed totally, and confining their activity to one seed cavity. This means there is very little impact on seed quality as the seed remnants are lost at harvest. In soybeans, one seed totally eaten equates to 2 kg/ha per larva/m^2. In contrast, the yield loss per helicoverpa /m^2 is 40 kg/ha.[15]

Monitoring and control: More emphasis needs to be put on early detection of infestations. In vegetative crops, the early warning signs are damaged and dying auxiliary buds, as well as increasing moth activity.

In heavily infested mungbeans on the Darling Downs, etiella moths were extremely difficult to catch in sweep nets, making it difficult to estimate moth density. The alternative would be to use traps, be they pheromone, bait or light traps. Further development is required to refine the design/use of these to make them more user-friendly.[16]

15 H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

16 H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

7.2.4 Large mystery planthopper *Oteana lubra* (Cixiidae)

Figure 19: Oteana lubra (Cixiidae)

Very high numbers of a large planthopper (*Oteana lubra*) (no common name and formerly *Oliarus lubra*) were reported in the 2014-2015 summer in mungbeans on the Darling Downs and in North West NSW. The bulky hoppers are 9-10 mm long and pale brown/grey with a fluffy white rear end (Figure 19). They have been observed in previous years in low numbers (usually <1/m^2) in mungbeans and soybeans, however in 2014-2015 populations in excess of 100 per 20 sweep net sweeps were observed in some crops. This most likely equates to an absolute population in excess of 20/m^2. All hoppers sampled were adults (i.e. there were no nymphs). This is because the nymphs of this planthopper group are root feeders, often of grasses.

Damaged pods suggest the planthoppers are not as damaging as first feared. Close examination of mungbean pods from heavily-infested crops revealed numerous feeding stings on the external pod wall, but extremely few stings on the seeds, or on the inside pod wall.

7.2.5 Loopers

Green loopers

Soybean looper *Thysanoplusia orichalcea*

Tobacco looper *Chrysodeixis argentifera*

Vegetable looper *Chrysodeixis eriosoma*

Figure 20: Soybean looper (40 mm). (Photo: Australian Oilseeds Federation)

Figure 21: Soybean looper moth (40 mm wingspan). (Photo: Australian Oilseeds Federation)

Figure 22: Tobacco looper. (Photo: Australian Oilseeds Federation)

Distribution: Green loopers occur in all soybean growing regions.

Identification green loopers: The soybean looper moth has distinctive brown forewings with a large bright golden patch. The tobacco and vegetable looper moths have dark brown forewings with small silver 'figure eight' markings. All species have a 40 mm wingspan. Looper eggs are a pale yellow green and are flatter than helicoverpa eggs. Larvae move with a distinctive looping action and have only two pairs of ventral prolegs. Green loopers taper noticeably towards the head. Larvae are mostly green with white stripes though colours can vary. Soybean loopers are more prominently striped, particularly when medium sized, when they often have dark stripes and can be confused with helicoverpa larvae. Larvae can reach 45 mm in length. Unlike helicoverpa which pupate in the soil, loopers usually pupate on the plant under leaves in a thin silken cocoon. Pupae are dark on top and pale underneath.[17]

[17] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Brown loopers

Bean looper or Mocis	*Mocis alterna*
Sugar cane looper	*Mocis frugalaris*
Three barred moth	*Mocis trifasciata*
(no common name)	*Pantydia sp.*

Figure 23: Bean looper (26 mm) (left), bean looper moth (32 mm) (right). (Photo: Australian Oilseeds Federation)

Figure 24: Larvae of Pantydia sp. moth (30 mm). (Photo: Australian Oilseeds Federation)

Figure 25: Three barred moth (45 mm wingspan). (Photo: Australian Oilseeds Federation)

Distribution: *Mocis sp*. loopers occur in Africa, Asia and Australia. The bean looper is native to Australia. Brown loopers are most common in tropical and subtropical coastal soybean growing regions.

Identification: Moths have 30-50 mm wingspans, *Mocis trifasciata* being the largest species. Sugar cane looper moths are brown and have a diagonal dark line with a pale inner edge across each forewing. The other loopers are grey or brown with dark bands and markings on all wings. Eggs are globular and pale green and are larger than helicoverpa eggs.

Larvae vary in colour and can be cream, charcoal, bright orange or brown. The bean looper varies most in colour and larvae may have dark stripes along their back and often have a cream or yellow band along each side. Larvae can reach 40-50 mm in length with *Mocis trifasciata* the largest species. Larvae have 2-3 pairs of ventral prolegs, move with a looping action, and are more slender than helicoverpa, particularly in the younger stages. A distinctive feature of Mocis larvae is their forward sloping and striped heads. Larvae pupate inside curled leaves.

The following applies equally to green and brown loopers:

Pest status: Mostly minor pests feeding mainly on leaves. However high looper populations can inflict economically-damaging levels of defoliation.

Risk period and damage: Loopers can attack crops at any stage but are greatest risk during flowering and podding. Soybeans are least tolerant of defoliation at these stages. Looper leaf damage is different to helicoverpa damage, the feeding holes being more angular rather than rounded. Loopers rarely attack soybean flowers and pods.

Monitoring and thresholds: Use a beat sheet to check crops twice weekly during the vegetative, flowering and podding stage until crops are no longer susceptible to attack. In pre-flowering crops, looper control is warranted if defoliation exceeds (or is likely to) 33%. Tolerable defoliation drops to 15-20% once flowering and podding commences.

Control: Products containing helicoverpa NPV do not control loopers. However, Bt (e.g. Dipel) will control even medium loopers (15-20 mm long). For chemical control options refer to the APVMA website.

Natural enemies: Loopers are frequently parasitised by braconids (*Apantales sp*.) with scores of parasite larva developing per looper host. Predatory bugs, tachinid flies, and ichneumonid wasps also attack loopers. The use of Bt (Dipel) will help preserve beneficial insects. Outbreaks of looper NPV are frequently observed in crops with high looper populations. However, larvae are usually not killed by virus until they are medium-large (instars 4-5). Looper NPV is not the same as helicoverpa NPV and the latter has no impact on loopers.[18]

7.2.6 Common grass blue (butterfly) *Zizina labradus* Lepidoptera: Lycaenidae

Also known as grass blue and lucerne blue.

Figure 26: Egg (1 mm diameter). (Photo: Australian Oilseeds Federation)

18 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

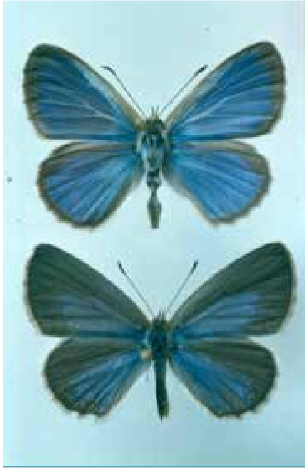

Figure 27: Male (top) and female common grass blue butterflies. (Photo: Australian Oilseeds Federation)

Figure 28: Larvae (10 mm) and windowing damage. (Photo: Australian Oilseeds Federation)

Figure 29: Hoverfly larvae (10 mm), a key aphid predator. (Photo: Australian Oilseeds Federation)

Distribution: Native to and spread throughout Australia including Tasmania.

Pest status: Mostly minor but frequently causes significant damage to soybeans in inland NSW and Qld.

Identification: The adult's wings are pale dull blue on top with dark grey edgings (wider in the females). They lack tails and eye spots. The undersides of the wings are brown with soft markings. The eggs are relatively large (1 mm diameter) are bluish and flattened with a central depression, and are laid singly. The small green slug-like larvae reach only 10 mm in length. Larvae are pale green with a central pale stripe and often with pale patterning on their back. Their head is difficult to see as it is usually tucked out of sight.

May be confused with: Larvae are sometimes confused with hoverfly (*Diptera: Syrphidae*) larvae, which are also 'slug like', are of similar size, and may be similarly coloured and patterned. Both may also be found on leaf terminals. However, hoverfly larvae are more tapered towards the head, often wave the front of their body from side to side, and are aphid predators. Other lycaenid larvae are also similar in outline and colour, particularly those of the bean flower caterpillar *Jamides phaseli*. The adults can be distinguisghed from other lycaenids such as the pea blue, *Lampides boeticus*, by their lack of eyespots and tails.

Host range: Feed on most pulse legumes but most common in soybeans. They also feed on lucerne.

Life cycle: Eggs are laid singly on leaves. Larvae mostly feed on leaves. Larvae pupate in loose webbing under leaves.

Risk period: Can attack at any stage. Less vigorous drought stressed plants are at greatest risk as terminals are more likely to be attacked.

Damage: Larvae feed mostly on leaves and terminals, but occasionally feed on flowers. Damaged leaves may be windowed. Excessive terminal loss results in pods being set too close to the ground, which makes harvesting difficult.

Monitoring: Check crops with a beat sheet, look for larvae inside terminals, and for large numbers of the distinctive (and pretty) blue butterflies.

Action level: Control if terminal loss exceeds 25%.

Control: Most products targeting helicoverpa (except Helicoverpa virus) will also control this pest.[19]

7.2.7 Leaf miners and webbers

Soybean moth Aproaerema simplexella (previously Stomopteryx simplexella)

Pest Status: Mostly minor. Soybean moth is common in soybeans but is usually only present in low numbers with only the occasional leaf slightly webbed and folded to provide a shelter for larvae. However, they spasmodically occur in very high numbers inflicting significant leaf damage, and on rare occasions can destroy crops by denuding all the leaves.

Identification: Moths are small (6 mm long) with narrow dark wings with a transverse white band. Caterpillars are small (up to 7 mm long) and are grey green with a dark head. Larvae are usually found feeding inside the leaves (i.e. in leaf mines, which are straw coloured). The small eggs are often laid on leaf veins.

Damage and control: Soybean moth larvae initially feed inside mine leaves and sometimes emerge to feed externally, folding and webbing leaves together. Larvae normally only cause cosmetic damage but heavy infestations can make multiple leaf mines per leaf resulting in leaf death.

Infestations are favoured by hot, dry weather, with crops under severe moisture stress most at risk. Crops near trees are often more severely infested.

Monitoring: Scout crops regularly for the early warning signs of rare plague events - numerous small, pale patches (leaf-mining) on the leaves and large numbers of soybean moths around lights at night. Indicative threshold is based on defoliation (i.e. 33% pre flowering and 15-20% during early podfill).

Control: Control will rarely be required and no specific registrations exist for soybean moth. Abamectin (registered in soybeans against mites) gave good control of this pest at the mite rate (300 mL/ha) in recent DAFF trials.[20]

19 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

20 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Figure 30: Soybean moth (6 mm). (Photo: Australian Oilseeds Federation)

Figure 31: Soybean moth larvae (7 mm). (Photo: Australian Oilseeds Federation)

Figure 32: Severe leaf damage. Note numerous leaf mines. (Photo: Australian Oilseeds Federation)

Figure 33: Typical light folded-leaf damage, (Photo: Australian Oilseeds Federation)

Legume webspinner or bean leafroller *Omiodes diemenalis* (previously *Lamprosema abstitalis*)

Pest status: Minor. Widespread in coastal regions but rarely at damaging levels.

Identification: The distinctive moths are brown with bright yellow patches and an 18 mm wingspan. Larvae roll and web leaves together, and are considerably larger than larvae of the soybean moth. Young larvae are pale green with dark heads. Older larvae are shiny green with pale brown/orange heads and reach 15 mm in length.

May be confused with the soybean moth and bean podborer larvae.

Host range: Soybeans, mungbeans, adzukis and navy beans.

Risk period and damage: Legume webspinners are widespread in coastal regions but rarely at damaging levels. Crops are usually at greatest risk during early podding. The larvae are leaf feeders, webbing leaves together. Silken webs and frass are indicative of webspinner attack, but other leaf webbers cause similar symptoms.

Monitoring and control: Larvae will be sometimes detected when beat sheet sampling. Also inspect webbed leaves and look for the characteristic frass. The threshold is based on tolerable defoliation (i.e. 33% pre flowering and 15-20% during early podfill). Control is rarely required.[21]

Figure 34: Legume webspinner (18 mm wingspan). (Photo: Australian Oilseeds Federation)

Figure 35: Larvae (14 mm), note pale. (Photo: Australian Oilseeds Federation)

Figure 36: Large (7 mm) larvae and typical frass (pooh).

21 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.8 Beetle pests

Monolepta or redshouldered leaf beetle or Monolepta australis

Figure 37: Monolepta beetles and damage. (Photo: Australian Oilseeds Federation)

Distribution: Throughout northern Australia. Particularly abundant in coastal cane-growing regions where larvae feed on sugarcane roots.

Pest status: Monolepta can arrive suddenly in large numbers, inflicting rapid defoliation and flower loss.

Identification: Beetles are 6 mm long and are yellow with a distinctive dark red (purple) band across the shoulders and two red/purple spots on the ends of the wing covers. The flaccid, yellowish eggs are small (< 1 mm across) and oval. Larvae are white, 5 mm in length, slightly flattened with hard brown plates at both end.

Host range: Adults feed on a broad range of plants including soybeans, navy beans, mungbeans and peanuts. Other hosts include avocado, cotton, lychee, macadamia, mango, strawberry, and numerous ornamentals. Larvae feed underground on roots of sugarcane and pasture grasses.

Life cycle: Eggs are laid in the soil surface, mainly in pastures and sugar cane. Larvae feed on the grass roots and pupate in the soil. The life cycle takes about 2 months in summer and there are 3-4 generations annually. Adults usually emerge from the soil after heavy rains following a dry spell. If larval populations in the soil are high, the multitude of emerging beetles will form an aggregation and swarms may migrate into nearby soybean crops.

Risk period and damage: Monolepta are common in sugar cane areas. They can arrive suddenly in large numbers, infecting rapid defoliation and fewer losses. Soybeans are at greatest risk during flowering. Infestations are most likely after heavy rainfall events. Monolepta attack leaves and flowers with very high populations (e.g. > 50/m^2) shredding leaves and denuding crops of flowers.

Monitoring and thresholds: Monolepta are readily assessed visually or with a beat sheet but can be difficult to count as they are extremely flighty. Estimate the number of groups of 5 or 10 beetles on the sheet to get a 'ball park' population estimate. Check crops after heavy rainfall that may trigger the mass emergence of adults. Thresholds are not yet established but populations greater than 20/m^2 can cause significant damage in flowering crops. Defoliation thresholds are the same as for leaf feeding caterpillars.

Control: Monolepta beetles are readily controlled with Steward® (indoxacarb) at 200mL/ha. Spot treatment of borders close to cane may be sufficient. If possible, plant soybeans away from key Monolepta hosts such as sugar cane.[22]

[22] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Lucerne crown borer or zygrita Zygrita diva

Lucerne crown borer is often a problem where soybeans are grown in close proximity to lucerne, and in edamame beans.

The pest has been on the increase in recent years, with reports of up to 90% of plants infested and early plant deaths in some crops. Areas infested ranged from coastal Qld to Central NSW, and included the Darling Downs. Damage was worse in early planted (Oct/Nov) crops. In some crops, larvae girdled plants prior to pupation as early as February when crops were only at the pod set stage. The resultant plant deaths severely reduced yield. This premature pupation was triggered by prolonged high temperatures and low rainfall, both of which lead to crop stress which is a major trigger for early pupation in crown borer.[23]

Identification: Adults are 15 mm long and bright orange with black legs and long black antennae. They usually have two prominent black spots on their wing covers, but these may be absent or more spots can be present. The similar shaped, mottled brown Corrhenes stigmatica (also a stem borer) is less common. Larvae of this species are cream with a wide head and are up to 25 mm in length.

Host range and life cycle: This pest can be found in soybeans and lucerne as well as in phasey bean and sesbania. Infestations occur when eggs are inserted in the stems of young soybeans, usually from flowering onwards. Larvae tunnel up and down through the pith in the stem, but usually pupate in the tap root.

Risk factors and damage: Soybean crops in the tropics, or growing in abnormally 'hot' summers, or in close proximity to lucerne are at greatest risk from crown borer. Proximity to lucerne increases the risk of early infestation. Larval feeding has little impact on yield but prior to pupating, plants are internally ringbarked or girdled above the pupal chamber causing plant death above the girdle and plants in thin stands may lodge before harvest. In southern Queensland, this usually occurs after seeds are fully developed (physiological maturity) with no yield loss. In tropical regions, larval development is more rapid and there can be considerable crop losses. Crown borers are very damaging to 'edamame' soybeans where green immature pods are harvested by mechanical pod pluckers, the weakened stems of infested plants being plucked into the harvester as well.

Figure 38: Zygrita larvae (12 mm). (Photo: Australian Oilseeds Federation)

Monitoring and control: Break open stems to look for larvae and eaten out and brown discoloured pith. There are no effective chemical controls as larvae in the stems are protected from insecticides. Avoid planting soybeans close to lucerne and, if in an at-risk region, consider later plantings to shorten crop development. In the tropics, consider winter plantings. Also avoid thin plant stands to reduce the lodging of damaged plants. Currently there are no pesticides registered for Zygrita in soybeans. Trying to control the only vulnerable stage, the adults in early vegetative crops, with non-selective pesticides, would greatly increase the risk of silverleaf whitefly attack.[24]

Figure 39: Zygrita adult (15 mm). (Photo: Australian Oilseeds Federation)

[23] H Brier, M Miles (2015), Emerging insect threats in northern grain crops: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

[24] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Soybean aphid Aphis glycines

This exotic pest was detected in Australian soybeans during the 1999-2000 season. It is more prevalent on the coast than in inland crops and more abundant in cooler summers.

Identification: The soybean aphid is small (to 2 mm long) and has a very bright, translucent green body. This aphid also has black siphunculi and a pale cauda.* No other aphid on soybeans has the same size and colour combination.

Damage: Aphids are normally not a major threat to soybeans but populations should be monitored. In the unusually cool summer of 2007/08 severe aphid outbreaks occurred in the Bundaberg region. Aphids are more prevalent on the coast than inland. Cast off (white) aphid skins are evidence of past infestations. Heavily infested plants may be covered in sooty mould growing on honeydew secreted by the aphids. Such infestations can reduce yield significantly and delay harvest maturity. Infested plants can have distorted leaves. Crops become less attractive to aphids after early podding. The adult, winged-form of the aphid, is able to travel long distances on prevailing wind currents.

Monitoring: Look for aphid colonies on the upper stems, leaflets and terminal leaves. In heavily infested crops, cast off aphid skins, sooty mould and large ladybird populations are indicative of soybean aphids. However the latter two can also indicate significant whitefly activity.

Chemical control is rarely required in most seasons due to the significant impact of natural enemies, especially ladybirds and hoverfly larvae. While, soybean aphids can be controlled with systemic pesticides, no products are specifically registered for this pest in Australian soybeans. In the USA, the soybean aphid threshold is set at 250 aphids per plant from budding to podding. As a rule of thumb, once soybean aphids are present on the main stem, populations are in excess of 400 aphids per plant. During the vegetative stage, avoid 'hard' pesticides against other pests, as these pesticides may kill ladybirds and 'flare' the aphids.[25]

*Figure 40: *Siphunculi (or cornicles or honey tubes) are a pair of upward and backwardly pointing tubes on the top of an aphid's back/abdomen. The cauda is a 'tail-like' structure, usually present below and between the siphunculi on the last abdominal segment. (Photo: Australian Oilseeds Federation)*

25 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.9 Mirids
Hemiptera: Miridae

Green Mirid *Creontiades dilutus*

Brown Mirid *Creontiades pacificus*

Distribution: The green mirid is widespread and endemic to Australia but the brown mirid also extends into Asia.

Pest status: Mirids are only a minor to moderate pest of soybeans. This contrasts with their major pest status in mungbeans.

Identification: Mirid adults are 6-7 mm long with elongated bodies, long legs (especially the hind legs) and long antennae. Green mirid adults are pale green and sometimes have reddish flecking on their legs. Adult brown mirids have two distinct colour forms. The brown form is predominantly light brown with darker pigmentation on their hind legs, and the green form is mostly bright green with dark red (purple-brown) pigmentation of the head, hindlegs and parts of the thorax.

Mirid nymphs are smaller, elliptical-shaped and lack wings. Young nymphs have antennae much longer than their body. First instar nymphs are pale brown/orange but later instars are pale green. Green mirid nymphs have pale antennae while brown mirid nymphs have distinctive reddish (brown) antennae with white banding.

Hosts: Mirids attack a wide range of summer legumes including adzukis, mungbean, navy bean, peanuts, pigeon pea, and soybeans. Other hosts include cotton, horticultural crops and lucerne.

Life cycle: Mirids may be present at any stage from seedlings to podding. Populations are often low during the vegetative phase, but increase rapidly after budding. Over 80% of mirids in flowering legumes may be nymphs and populations in excess of 10 per m^2 are not uncommon. Populations frequently decline once flowering ceases. Pale, elongated eggs are laid singly into plant tissue with a small area of the egg exposed. There are usually 5 nymphal stages. Mirid development from egg to adult is very rapid at high temperatures and takes only 16 days at 30°C. Egg development is relatively slow, and makes up 37% of total development time.

Risk period: Soybeans are potentially at greatest risk during budding, flowering and early-podding. However, soybeans are at far less risk of economic damage than susceptible hosts such as mungbeans. Low mirid populations are often present in vegetative soybeans but there is no evidence they cause 'tipping' of vegetative terminals as occurs in cotton. Influxes of mirid adults often follow north-west winds in spring.

Damage: Mirids attack buds, flowers and small pods. However soybeans are less susceptible to mirids than mungbeans. Mirid populations of up to 5/m^2 had no impact on soybean yield in recent DAFF trials. For this reason, mirid thresholds in soybeans are far higher than in mungbeans.

Monitoring: Mirids are very mobile pests and in-crop populations can increase rapidly. Crops should be inspected twice weekly from budding onwards until post flowering. The preferred monitoring method is the beat sheet. Sample 5 one-metre lengths of row (not consecutive) within a 20 m radius, from at least 6 sites throughout a crop. Avoid sampling during very windy weather as mirids are easily blown off the beat sheet.

Thresholds: The mirid thresholds for soybeans is 5-6 mirids per m^2.

Chemical control: Dimethoate at 500 mL/ha (all summer pulses) or indoxacarb at 400 mL/ha (soybeans and mungbeans only). Dimethoate is often applied at lower than label rates (e.g. 200-250 mL/ha). These rates give excellent mirid control but have far less impact on most beneficials. The addition of salt (0.5% NaCl) as an adjuvant, maintains the performance of dimethoate at lower rates. The rate of salt used (0.5%) has no phytotoxic effect on soybeans.

'Hard' water can markedly lower the effectiveness of dimethoate and should be countered by adding a buffering agent such as Li700. Indoxacarb is not recommended for mirids in soybeans because its label warns against using it against mirid populations >2/m^2 which is far lower than the threshold. [26]

Figure 41: Green mirid adult (7 mm). (Photo: Australian Oilseeds Federation)

Figure 42: Brown mirid nymph (3 mm). (Photo: Australian Oilseeds Federation)

7.2.10 Two-spotted or red spider mite *Tetranychus sp.*

Pest status: Two spotted or red spider mites (the same species) can cause severe damage, particularly during hot, dry weather, but are not a problem in most crops. Mite outbreaks are often the result of 'hard' pesticide sprays (targeting other pests) which kill the mites' natural enemies.

Identification: Adult mites are 0.5 mm long, have 8 legs, and in summer are usually yellow-green with a large dark green spots on each side of the body. The overwintering form is red with dark spots. Nymphs are similar but smaller in size.

Feeding behaviour and damage: Mites initially invade the lower leaves and gradually move to the top of the plant as populations build up. They make fine webbing on the underside of the leaves, and feed by a rasping and sucking action. Infested leaves take on a speckled appearance. In severe cases, the damaged leaves turn yellow-brown before they wither and drop from the plant.

Heavy infestations during flowering and early pod formation result in early leaf senescence and may significantly reduce seed size and yield. Heavy mite infestations during pod-fill hastens leaf drop and brings on early senescence. Yield loss from mites can be as high as 30%, with the late maturing, longer season varieties most as risk.

Control: Abamectin currently gives effective control. The threshold is 30% leaves infested. While still registered, dimethoate no longer provides effective control as mites are now resistant to older miticides. As mites have the potential to also develop abamectin resistance, every effort should be made to avoid flaring mites with non-selective insecticides.[27]

Figure 43: Red overwintering form of the two spotted mite. The summer form is green with two dark spots. (Photo: Australian Oilseeds Federation)

[26] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[27] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.11 Field Crickets

Black field cricket	*Teleogryllus commodus*
Brown or inland field cricket	*Lepidogryllus parvulus*

Pest status: Spasmodic pests capable of inflicting serious pod damage that looks like mouse damage.

Identification: Both are typically cricket shaped, with long powerful jumping hind legs, large jaws and long antennae. The black field cricket is larger (30 mm) and darker than the brown field cricket.

Behaviour and damage: Field crickets shelter in cracks in the soil and can cause serious losses in soybeans, particularly in areas with heavy cracking soils. Field crickets often attack seedlings but late summer infestations chew holes in pods to eat the developing seeds. Plagues are most common when mild winters are followed by warm, dry summers.

Monitoring: Check crops for crickets at dusk or at night when they are most active. Cricket activity can also be monitored with light traps. Alternatively, place hessian bags overnight at regular intervals across the paddock. In the morning check for crickets sheltering under the bags.

The best way to determine whether mice (and not crickets) are the culprits is to also check crops at night or to use mouse bait cards. If little mounds of damaged pods are found on the ground throughout the crop, then mice are most likely the culprits, as this is classic rodent food-hoarding behaviour.

Control: Grain baits are recommended for in-crop control of crickets. Use a mix of 4L Lorsban® (50% a.i.) with 5L sunflower oil and 100 kg cracked wheat. Combine the Lorsban and oil before adding the grain then let the mix 'set' for 6-8 hours before spreading 2.5 kg of the bait mix per hectare. Use sorghum if cracked wheat is not available. Ideally the grain should be cracked into small pieces, but not ground to fines. Some aerial applicators will supply a similar bait mix. Note that control with baits is difficult in soybean crops with dense canopies.[28]

Figure 44: Black field cricket (30 mm) (left), cricket damage to pods (right). (Photo: Australian Oilseeds Federation)

[28] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.12 Black field earwig *Nala lividipes*

Pest status and identification: Periodically cause serious damage to seedling crops. Black field earwig are most prevalent in areas with cracking soils. They are elongated, 15 mm long, with short wing covers and large pincers at their rear. Do not confuse BFE with the much larger (20 mm) light brown predatory earwig.

Damage and control: These soil-dwelling insects feed on the germinating shoots. and on recently emerged seedlings which they ringbark at ground level. In-crop treatments with chlorpyrifos grain baits can provide a degree of control.[29]

Figure 45: Black field earwig (14 mm). (Photo: Australian Oilseeds Federation)

7.2.13 Slugs

Pest status: Increasing in zero till crops in wetter seasons. The wet spring early summer conditions of 2010/11 have favoured the return of a pest not seen for many years – slugs! Damaging slug populations, reported in seedling crops in northern NSW and southern Queensland, have totally destroyed some crops. Later slug infestations have attacked soybean pods.

Risk factors: Increased zero/minimum till and stubble retention practices which favour slug and snail development and survival. Increased organic matter provides an increased food source, especially to young slugs (and snails). Other high slug risk factors include prolonged wet weather, trash blankets, weedy fallows and a previous slug history. Slugs are best controlled before the crop is planted.

Monitoring: Determine the slug risk in your paddocks prior to planting. Monitor regularly so slug numbers can be detected early prior to planting, as there are more control options at this time. To estimate slug numbers, place wet carpet squares, hessian sacks or tiles on the soil surface. They should at least be 32cm x 32cm (10% of a square metre). Place slug pellets under them and check after a few days. Count the number of slugs under and around each square. Multiply the numbers by 10 to get an estimate of slugs per square metre.

Thresholds: If an average of more that one (1) slug per trap is found, the slug problem is significant. If more than eight (8) slugs are found per trap the problem is severe.

[29] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Timing of control: Slugs are best controlled before the crop is planted. Ideally, fallows should be bare so the only food source for slug is the baits. For this reason, baits applied post-emergence are less effective than pre-emergent baits, as slugs often prefer the emerging seedlings.

Chemical control: Take action if there is significant slug activity in the pre-crop fallow, 2 weeks before planting. Two equally effective bait types are registered for slug control in field crops, those based on metaldehyde (e.g. SlugOut) and those based on an iron chelates (EDTA complex), (e.g. Multiguard).

Metaldehyde based baits are highly toxic to mammals and birds (Schedule 5 poisons) and must be spread evenly to avoid heaping which attracts non target animals. Metaldehyde based products are registered in pulses for use prior to and up to the 4 leaf stage.

Iron chelate based baits are specific to slugs and snails (molluscs) and slaters (crustaceans) and have low toxicity to mammals and birds (no poison schedule). They have no impact on carab beetles which are key snail predators and hence are the preferred IPM option. Iron chelate based compounds are registered for use in the bare fallow prior to planting, and also in crop boundaries.

Protecting animals and birds: While of low toxicity, iron chelate baits are attractive to some animals and birds. The bait's mild alkalinity may cause certain animals to vomit, especially dogs. For this reason, spread the bait evenly to avoid heaping which might attract dogs and birds.

Insecticides sprays for other soil pests: Sprays targeting armyworms and cutworms are ineffective against slugs. Where there is extreme slug pressure, baits alone will not bring slugs under control.

Cultural control: Cultural practices which discourage slugs and snails include cultivation (2 shallow discings) to bury trash and levelling the seedbed with a roller to crush clods. Don't use press wheels as these create a humid furrow in the soil. These strategies are at odds with zero/minimum till and stubble retention practices aiming to conserve soil moisture. However, cultural practices to reduce high slug numbers may have to be employed periodically, as chemical control alone is unlikely to eliminate slugs in farming systems that retain stubble blankets.

Slug identification: To help build up a national slug incidence data base, and to determine which species are causing problems in NE Australia, please collect and forward slugs to Australian slug expert Michael Nash at CESAR, Bio21 Institute, Melbourne University, 30 Flemington Rd., Parkville, Victoria 3010. Ph 0383 442 521. Mob 0417 992 097 manash@unimelb.edu.au . Post/courier slugs in a jar with moist paper and record the location (including GPS coordinates). Also record the soil type, paddock history (e.g. zero or minimal till or regular cultivation) and the paddock's cropping history.[30]

Figure 46: Slug (25 mm). (Photo: Australian Oilseeds Federation)

30 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.2.14 Mouse plagues

Mouse damage to soybeans is an ongoing and costly problem in many areas such as the Darling Downs. Soybeans are especially vulnerable, as they are often the last of the summer crops to mature and as a consequence are the only food available. Crop damage from mice is often unnoticed until it is severe. Signs of mouse activity include chewed stems or damage to seed pods. Debris such as seed husks at the base of plants suggests the damage to seed pods has been caused by mice rather than insects or birds. You can also monitor mice with mouse bait cards.

Zinc phosphide grain baits are now registered for use in soybeans and other grain crops. It is an inorganic compound that rapidly breaks down in the presence of the stomach acids to release the toxic gas phosphine. Mouse death usually occurs within two hours of ingestion.

Contact BioSecurity Queensland on 13 25 23 or refer to the QDAF website for further details on the use of these baits.[31]

7.3 Thresholds for control

Economic thresholds are one of the cornerstones of Integrated Pest Management (IPM). They help to rationalise (and thus limit) the use of pesticides and are one of the keys to profitable pest management. The development of economic thresholds requires knowledge of pests, their damage, and the crop's response to damage. Economic thresholds are available for most, but not all, pests in soybeans.[32]

An economic threshold (ET) is defined as: 'the pest population likely to cause damage equal in value to the cost of control (pesticide plus application)'.

Such a population can be defined as the "critical" or "break even" population. Spraying is only recommended when insect numbers exceed the ET (i.e. when the value of damage is likely to exceed the cost of control). This classical definition applies for crop/pest scenarios where yield loss is the critical factor governing spray decisions (as opposed to situations where potential quality reduction and price discounts are the critical driving factor).

There are sound economic and biological reasons for only spraying above-threshold pest populations. Firstly, you are financially worse off if you spray below-threshold populations. Secondly, unnecessary spraying with non-selective insecticides puts crops at unnecessary risk from non-target pests, particularly helicoverpa and whiteflies, and can lead to yet more spraying. Finally, unnecessary spraying hastens the development of pesticide resistance in helicoverpa and other pests.

Thresholds are usually specified as the number of insects found per unit crop area (or length of row) using a specified (standard) sampling technique. In soybeans and other summer pulses, the recommended sampling method is the beat sheet, and thresholds are expressed in terms of pests per square metre (pests/m^2). If other row-based sampling methods are used, thresholds are often expressed in terms of 'beat sheet equivalents'/m^2. If your row spacing is other than one (1) metre, convert your pest counts/m to pests/m^2 by dividing them by the row spacing in metres. [33]

31 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

32 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

33 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.3.1 Yield-based thresholds

Table 1: Soybean yield loss thresholds by crop stage

Crop stage	Pest	Threshold	Comments
Seedling/early vegetative	Helicoverpa & grass blue butterfly	25% terminal loss	Terminal loss more likely if crops are moisture stressed
Mid-late vegetative	Helicoverpa	6/m²+*	Lower threshold in early vegetative crops or take action if terminal loss exceeds 25%
Vegetative	Spodoptera, loopers & grass blue butterfly	33% defoliation or 25% terminal loss	Terminal loss most likely if grass blue larvae present
Budding, flowering	Thrips	4-6 per flower	Open and inspect flowers
Budding, flowering & early podding	Mirids	5/m²+	Trials show no yield loss for mirid populations up to 5/m²
Budding to podding	Spodoptera	3/m²+	Not as damaging as helicoverpa
	Loopers	15-20% defoliation	
	Soybean aphids	250 aphids per plant	Visual - check upper leaves & stem
Budding to late pod fill	HELICOVERPA	See Table 2	Based on yield loss model below; inspect flowers and terminals for small larvae
Early to late podfill	PODSUCKING BUGS	See Table 3	Thresholds for crushing are double those for edible beans

Note:
+ Thresholds are based on beat sheet sampling and are expressed in pests/m².
* Replaces 33% defoliation threshold which still applies for other caterpillar species.

Table 2: Economic yield thresholds for helicoverpa in podding soybeans*

Control cost ($/ha)	Helicoverpa thresholds* (larvae/m²) at soybean crop values listed below ($/t)									
	$350	$400	$450	$500	$550	$600	$650	$700	$750	$800
$15	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5
$20	1.4	1.3	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6
$25	1.8	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8	0.8
$30	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9
$35	2.5	2.2	1.9	1.8	1.6	1.5	1.3	1.3	1.2	1.1
$40	2.9	2.5	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.3
$45	3.2	2.8	2.5	2.3	2.0	1.9	1.7	1.6	1.5	1.4
$50	3.6	3.1	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6
$55	3.9	3.4	3.1	2.8	2.5	2.3	2.1	2.0	1.8	1.7
$60	4.3	3.8	3.3	3.0	2.7	2.5	2.3	2.1	2.0	1.9

* Threshold based on a measured yield loss of 40 kg/ha for every larva per square metre. Cross-reference the cost of control versus the crop value to determine the economic threshold (ET), e.g. if the cost of control = $35/ha and the crop value =$450/t, the ET = 1.9.

Spray helicoverpa only if they exceed the threshold which is the break even point.

Table 3: Economic quality threshold for green vegetable bug (GVBAEQ) in edible soybeans*

Potential yield (t/ha)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Nato soybeans	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Normal soybeans	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6

*Threshold based on a rate of damage of approximately 80 harvestable seeds per adult bug per square metre. Spray bugs at the 2% action threshold, before the critical 3% damage level is reached. This allows for other insect damage not caused by posdsucking bugs. Note that thresholds increase in 'larger' crops as more bugs are required to inflict a given percentage (%) of damage. When mixed bug populations are present (adults & nymphs) convert their damage potential to green vegetable bug adult equivalents (GVBAEQ).[34]

[34] H Brier, J Wessels, K Charleson (2013) Good Bug? Bad Bug? http://ipmworkshops.com.au/wp-content/uploads/GoodBadBug-Mar2013.pdf

Yield-based economic thresholds (ETs) are used in situations where the value of the damage caused by an insect pest is in direct proportion to the numbers of that pest present in a crop (eg. 1 heliothis/m^2 causes a certain amount of yield loss, 2 heliothis/m^2 causes twice as much yield loss, etc). Yield based thresholds in pulses are used for mirids, helicoverpa and loopers. Where the amount of damage per pest is known (i.e. has been quantified), the ET can be calculated using the following generic equation:

$$\text{Economic Threshold (pests/m}^2\text{)} = \frac{C}{V \times D}$$

where C = cost of control including application ($/ha)
V = crop value ($/tonne)
D = damage per pest (t/ha for every pest/m^2)

Spraying is only recommended when insect numbers exceed the ET (i.e. when the value of likely damage exceeds the cost of control). Just how far above the ET a pest population is before action is taken is a matter of individual judgement, how confident you are in your sampling, likely crop value, and the cost of control.

While the amount of damage caused per insect is relatively constant (in the models if not real life), both the value of the crop and the cost of control can vary. Therefore a true economic threshold accommodates fluctuations in pesticide prices and crop value. Thresholds can therefore vary for different pesticides. As a rule of thumb, the lower the cost of control, and the higher the crop value, the lower the threshold, and vice versa.

Below is an example of an economic threshold calculation for helicoverpa in soybeans, where the damage factor (D) at podding has been determined as being 50 kg/ha (0.05 t) for a density of one (1) larvae per square metre of crop. If a crop with an estimated value (V) of $500/t is to be aerially sprayed with a product costing $28/h (C = cost of pesticide plus application is ≈ $28 + $15 = $43/ha), then:

$$\text{Economic Threshold (pests/m}^2\text{)} = \frac{C}{V \times D}$$

$$= 43 \div (350 \times 0.05)$$
$$= 1.7 \text{ helicoverpa larvae per m}^2$$

Where crop values and spray costs vary markedly, thresholds can be easily determined and compared by referring to threshold charts specific to the pest in question.[35]

7.3.2 Nominal thresholds

Where the damage factor (D) is unknown, pests are assigned a nominal or fixed threshold, based on the experience and gut feelings of consultants and researchers. While some nominal thresholds are reasonably close to the mark, they fall down in situations when crop values and spray costs vary widely. An example of a nominal threshold is the set threshold of 3 cluster caterpillars/m^2 in podding soybeans. [36]

7.3.3 Benefit:Cost Ratio

One commonly used rule of thumb in IPM programs is the adoption of a Benefit:Cost Ratio (BCR) of 2:1, meaning that action is only taken when the value of likely damage prevented is twice the cost of control. This rule is most feasible where the cost of control is low.

An example of this is the ground rig application of dimethoate for mirids ($8/ha). In effect, a 2:1 BCR doubles the action threshold and by default, reduces the number of sprays applied. Most growers would presumably rather spend $8/ha to save $16 worth of crop loss/ha (i.e. an $8 'profit'/ha - than spend $8/ha to save $8/ha – a $0 net profit/ha).

35 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

36 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

A cost benefit of 2:1 is acceptable where the cost of control is low, but not where control costs are high. For example, if cost of control is $60/ha, it is unlikely that an additional $60/ha worth of damage would be accepted by most growers before they responded. In this scenario, the BCR might be reduced to 1.3 - equivalent to wearing an extra $20/ha before treating the pest problem (i.e. spending $60 to save $80 worth of damage). However, exactly what BCR values are adopted is a matter for negotiation between consultants and their clients.[37]

7.3.4 Defoliation thresholds

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

By factoring in the cost of control, higher defoliation levels could probably be tolerated. But, in practice, if leaf feeding is severe then action might be required before defoliation reaches the threshold. This is especially the case where biopesticides are employed as they are best targeted against relatively small larvae (ideally < 7 mm long) and in many cases a 50-60% kill would suffice to avoid yield loss.

Crop status will have a large bearing on decisions made in these situations. The larger the crop, the less % defoliation occurs for a given number of leaf feeding pests. Rapidly growing, healthy crops are at lesser risk. Smaller drought-stressed crops face the risk of terminal damage and are more affected by sap-sucking pests like aphids and whiteflies.

Note that for helicoverpa in vegetative soybeans, the 33% defoliation threshold has been replaced by a yield-based threshold of 6 larvae/m^2 (reduce this threshold in seedling/early vegetative crops).[38]

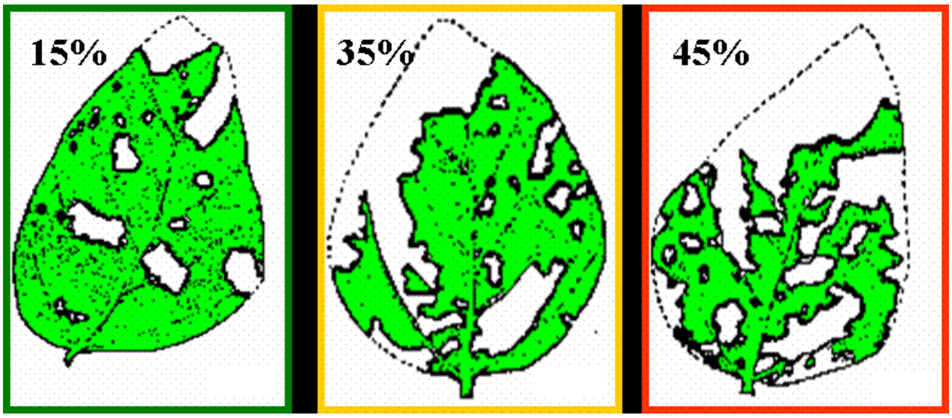

Figure 47: Different levels (%) of defoliation are shown in the figure below. Note how the measured defoliation seems to be less than that suggested by the observer's eye. (Source: Australian Oilseeds Federation)

7.3.5 Quality-based or preventative thresholds

A preventative pest threshold is a pest population that is less than the pest population required to cause 'critical damage' in a crop. In this context, 'critical damage' occurs when a certain quality standard (such as % damaged seeds) is breached and attracts significant discounts. The threshold is set lower than the critical pest population to avoid this quality reduction'.

Since seed quality is the critical pricing factor in summer pulses including edible soybeans, preventative thresholds are used for podsucking bugs rather than a yield-based threshold.

[37] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[38] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Example: In an 'average sized' (1500 seeds/m^2) crop of edible soybeans, >3% of seeds are damaged when GVB numbers exceed 0.6 adult bugs per square metre. Thus 0.6 GVB per square metre is a critical pest population in edible soybeans. In practice, action is usually taken before the critical population is reached, usually when populations reach 70% (0.7) of the critical population, in this case at 0.4/m^2. In practice also, GVB populations increase as podfill progresses, and will be many times greater by pod ripening. But because the threshold is based on bug damage spread over a 35 day period, there is some leeway in delaying spraying slightly without compromising crop quality.

If bug populations exceed this critical level of 3% damaged seeds, the bonus for edible quality is lost and crop value can be downgraded by up to $400/ha (i.e. by many times the cost of control). The preventative or action threshold in soybeans is therefore set at 2% bug damage to ensure the critical damage level is not reached or exceeded.

This type of threshold is therefore quite different from a yield-based threshold where there is no hefty monetary penalty if the threshold is slightly exceeded.

Because quality thresholds are usually very low, thorough scouting for podsucking bugs is essential. Inadequate sampling may very likely underestimate bug numbers.

For helicoverpa, seed staining in holed pods is not an issue. Recent mungbean trials show that each larva only stains 10% as many seeds as a GVB and the same is likely to apply in soybeans.[39]

7.3.6 Thresholds for immature pests

Since most crop damage is caused by large caterpillars, bug nymphs, and adult bugs, the question is often asked about how to factor young larvae and nymphs into thresholds and damage estimates.

For caterpillar pests, thresholds often assume that small larvae will complete their development if not controlled, thus inflicting the maximum possible damage. However, in practice many larvae are attacked by predators, killed by disease, or even just blown off the crop before they reach a damaging size. For this reason, there is more leeway in decision making if the majority of caterpillars present are only small (i.e. more might be tolerated), particularly if large numbers of predators are present, and naturally occurring disease is observed. The high early mortality of small larvae is also likely to cancel out any sampling inefficiencies. One way to assess if natural control agents are effective in your crop is to assess changes in larval size, as well as numbers. If the majority of larvae remain small, then most larvae are being 'taken out' before they reach a damaging size.

For podsucking bugs, small nymphs are less damaging than large nymphs and are more susceptible to attack by ants and spiders. The damage potential of green vegetable bug nymphs has been scientifically determined to quantify their overall damage potential in adult GVB equivalents. While large nymphs are nearly as damaging as adults (90% or greater for instars 4 and 5), the damage potential of young nymphs is very low (10 and 25% for instars 1 and 2 respectively) because many will not survive to adulthood. However, recent sampling trials (April 2009) show that beat sheet sampling significantly underestimates the number of small nymphs (instars 1 and 2) by approximately 90%, medium nymphs (instar 3) by 30%, and adults by 50%. In contrast, beat-sheet counts for large nymphs (instars 4 and 5) are pro rata (i.e. all large nymphs present are detected). As a result, nymphal mortality is assumed to be cancelled out by sampling inefficiency, and the conversion factors to adjust nymph counts to adult equivalents have been revised.

Multi-pest situations: Where a number of pests causing similar damage are present, it is easier to express their combined damage potential in 'standard-pest equivalents'. A classic example is for podsucking bugs, where green vegetable bug (GVB) is the designated 'standard bug', and other species are converted to adult GVB equivalents. Podsucking bugs of different ages can also be converted into GVB equivalents to

39 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

determine the damage potential. This is much easier than having a separate threshold for each species, and is the only workable solution where more than one species is present.

If a number of podsucking bug species of varying ages are present, calculate the damage potential in GVB adult equivalents as follows.

Converting pod sucking bugs to (1) Green Vegetable Bug Equivalent (GVBEQ) and then to (2) Green Vegetable Bug Adult Equivalents (GVBAEQ):

1. Green vegetable bug equivalent

Green vegetable bugs (GVB) and brown bean bugs (BBB) are equally damaging to pulse crops but green vegetable bugs (GVB) are considered a more important pest due to their abundance, widespread distribution and rate of reproduction. The damage potential of other pod sucking bugs is not as great as GVB but they can cause severe damage when present in large numbers. To determine the damage potential of different pod sucking bug species, they must be converted to GVBEQ as shown in the table below:

Table 4: Damage potential of pod sucking bug species relative to GVB

Pod sucking bug species	Conversion to GVBEQ
Green vegetable bug (GVB) *Nezara viridula*	1.00
Brown bean bugs (BBB) *Riptortus & Melanacanthus* sp.	1.00
Redbanded shield bug (RBSB) *Piezodorus oceanicus*	0.75
Brown shield bug (BSB) *Dictyotus caenosus*	0.20

- For each bug stage (nymphs and adults) of each species, convert to GVBEQ by multiplying by the conversion factors above.
- For example – if three GVB and one RBSB are present in the crop then the GVBEQ of these bugs is (3 x 1.0) + (1 x 0.75) = 3 + 0.75 = 3.75 GVBEQ.
- If you also find two BSB, then the GVBEQ = 2 x 0.2 = 0.4 GVBEQ.
- The total number of GVBEQ in the crop are now 3.75 + 0.4 = 4.15 GVBEQ

2. Green vegetable bug adult equivalents (GVBAEQ)

In earlier practices, bug nymph beat-sheet counts were corrected for likely mortality, as well as their lower-than-adult damage potential. Sampling efficiency was assumed to be near 100% (based on US guidelines).

However, recent sampling trials show that beat sheet sampling significantly underestimates the number of small nymphs (instars 1 and 2) by approximately 90%, medium nymphs (instar 3) by 30%, and adults by 50%. In contrast, beat-sheet counts for large nymphs (instars 4 and 5) are pro rata (i.e. all large nymphs present are detected).[40]

As a result, nymphal mortality is assumed to be cancelled out by sampling inefficiency, and the conversion factors to adjust nymph counts to adult equivalents have been revised.

Using the example above - if you find that the three GVB and one RBSB are 2nd instars instead of adults and the two BSB are 4th instars – an additional calculation is required to convert these instars into adult equivalents. This is because bug nymphs are less damaging than adults.

The table below provides the conversion factors to convert instars to green vegetable bug adult equivalents. The previous example shows 3.75 GVB equivalents as 2nd instars and 0.4 GVB equivalents as 4th instars.

40 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Table 5: Conversion factors to calculate the damage potential of each bug-nymph instar in green vegetable bug adult equivalents (GVBAEQ)

Days to Harvest	Instar I	Instar II	Instar III	Instar IV	Instar V	Adult
28	0.44	0.61	0.76	0.87	0.96	1.00
35	0.54	0.69	0.81	0.90	0.97	1.00

Each instar is multiplied by the conversion factor and then added together to obtain the total damage potential. This can be calculated for 28 days or 35 days to harvest.

For example, at 28 days to harvest the overall Green Vegetable Bug Adult Equivalent (for the above figures) would be:

(3.75 GVBEQ x 0.61) + (0.4 GVBEQ x 0.87) = 2.29 + 0.35 = 2.64

In practice, spray decisions will be often made on the number of adult bugs alone. This is because when the sampling correction factor of 2 for beat sheet adult counts is applied, pre-corrected adult populations as low as 0.2-0.25/m^2 will be at threshold.[41]

7.3.7 Estimating/calculating crop size as required for podsucking bug thresholds

As podsucking bug thresholds are based on % bug damage, the threshold for your crop will depend on the size of the crop as measured by the number of seeds per unit area. The greater the number of seeds, the higher the threshold, and visa versa. The number of seeds can be determined as follows:

Researcher's method

- Determine the number of seeds per pod. Assess 10 random pods. There are usually 2-3 seeds per pod in soybeans, but some varieties may have 3-4 seeds.
- Estimate the number of pods per plant (assess 10 random plants, not just the biggest or tallest ones).
- Count the number of plants per metre (Use plant emergence counts).
- Calculated seeds per m^2 = seeds per pod x pods per plant x plants per metre
  row spacing (metres)

Experienced agronomist's method

- Estimate the crop's potential yield (kg/ha). (After looking at hundreds of crops, you should be on or very close to the money).
- Look up the number of seeds/kg for the variety in question (planting seed records).
- Calculated seeds/m^2 = (potential yield/10,000) x seeds/kg/ row spacing (m)

Well-grown crops should have at least 2000 seeds per square metre (2000/m^2). The action threshold for a 2000 seeds/m^2 crop is approximately 0.5 GVB/m^2, equivalent to an uncorrected beat-sheet count of only 0.25 GVB/m^2.[42]

41 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

42 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.3.8 Soybean thresholds at a glance

Table 6: Soybean thresholds based on beat sheet sampling and expressed in pests/m²

Pest	Crop stage	Threshold	Comments
Helicoverpa	Vegetative	6/m² new threshold*	Lower in early vegetative and seedling crops
Cluster caterpillar	Vegetative	33% defoliation	Refer to defoliation figure
Loopers	Vegetative	33% defoliation	Refer to defoliation figure
Mirids	Budding, Flowering & early Podding	5-6/m² (dimethoate)	Trials show no yield loss for mirid populations up to 5 per m².
Thrips	Budding, Flowering	4-6 per flower	Open and inspect flowers
Helicoverpa[B]	Budding to late Podfill	1-3/m²	Based on a yield loss model.
Cluster caterpillar	Budding to Podding	3/m²	Not as damaging as helicoverpa
Loopers[B]	Budding to Podding	15-20% defoliation	Refer to defoliation figure
Soybean aphids	Budding to Podding	250 aphids per plant	Check upper leaves & stem
Podsucking bugs[C]	Early to late Podfill	0.3-1.0 GVBAEQ/m² **	** Double thresholds for bugs in crushing beans.

Note: Thresholds are based on beat sheet sampling and are expressed in pests/m².

[A] Loopers are mainly leaf feeders in soybeans.

[B] Inspect flowers and terminals for small helicoverpa larvae.

[C] Expressed in green vegetable bug adult equivalents (GVBAEQ). Convert counts of other bug species and nymphs to GVBAEQ. One brown bean bug = 1GVB. One redbanded shield bug (*Piezodorus*) = 0.75 GVB.

* Replaces old 33% defoliation threshold which still applies for other caterpillar species.

Table 7: Economic threshold chart for helicoverpa in podding soybeans, based on a yield loss of 40kg/ha per larva per square metre (Rogers 2010). Cross-reference the cost of control versus crop value to determine the economic threshold (ET) (e.g. if the cost of control = $40/ha and the crop value =$600/t, the ET = 1.7). Spray helicoverpa only if they exceed the threshold which is the break even point.

Cost of Control ($/ha)	Thresholds (larvae/m²) at Soybean Crop Values listed below ($/t)									
	$ 350	$ 400	$ 450	$ 500	$ 550	$ 600	$ 650	$ 700	$ 750	$ 800
$ 20	1.4	1.3	1.1	1.00	0.91	0.83	0.77	0.71	0.67	0.63
$ 25	1.8	1.6	1.4	1.3	1.1	1.04	0.96	0.89	0.83	0.78
$ 30	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.00	0.94
$ 35	2.5	2.2	1.9	1.8	1.6	1.5	1.3	1.3	1.2	1.1
$ 40	2.9	2.5	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.3
$ 45	3.2	2.8	2.5	2.3	2.0	1.9	1.7	1.6	1.5	1.4
$ 50	3.6	3.1	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6
$ 55	3.9	3.4	3.1	2.8	2.5	2.3	2.1	2.0	1.8	1.7
$ 60	4.3	3.8	3.3	3.0	2.7	2.5	2.3	2.1	2.0	1.9
$ 65	4.6	4.1	3.6	3.3	3.0	2.7	2.5	2.3	2.2	2.0

Table 8: Economic threshold for green vegetable bug (GVB) in edible soybeans, based on a rate of damage of 80 harvestable seeds per adult bug per square metre. Spray bugs at the action threshold of 2% before the critical 3% damage level is reached. Note that thresholds increase in 'larger' crops as more bugs are required to inflict a given percentage (%) of damage. When mixed bug populations are present (adults & nymphs) convert their damage potential to green vegetable bug adult equivalents (GVBAEQ).

Note: Seeds per m^2 = Seeds per pod x Pods per plant x Plants per metre/row spacing (metres)

Crop size seeds/m²	GVBAEQ to damage 2% of seeds - the action threshold
500	0.13
1000	0.25
1500	0.38
2000	0.50
2500	0.63
3000	0.75
3500	0.88
4000	1.00
4500	1.13
5000	1.25

7.4 Management of insect pest

More information

http://finalreports.grdc.com.au/CSE111

Australian Oilseed Federation. Oilseed News 2008. Beneficials Can Beat Belligerent Bugs.

7.4.1 Sampling, scouting, monitoring and record keeping

Correct and timely crop scouting/checking is essential to:

minimise the risk of crop damage due to undetected pest outbreaks

maximise the chance of effective control of pests - 'spray small or spray fail'

In general, soybeans are at greatest risk of pest attack from budding onwards. However, crops should be checked twice weekly from the early vegetative stage onwards. This is so biopesticides can be used in a timely manner against small larvae, should the need arise. Avoiding hard pesticides during the crop's vegetative stage is a key IPM strategy in soybeans.

The recommended method for sampling is the beat sheet. This is the best method for detecting podsucking bugs and other key pests. Visual checking in buds and terminal structures may also be needed to supplement beat sheet counts of helicoverpa larvae and other minor pests. Sweep netting is hopeless in soybeans. Because of the soybean crop's dense canopy, only a tiny fraction of insects present in soybeans are captured in a sweep net.

A key problem with sampling soybeans is that many pests are very patchily distributed. Sufficient samples need to be taken to reasonably estimate the pest population. [43]

What is a beat sheet?

A standard beat sheet (also known as a beat cloth) is made from yellow or white tarpaulin material with heavy dowel in a sleeve along each side. Beat sheets are generally between 1.3–1.5 m wide by 1.5–2.0 m deep, the larger dimensions being preferred for taller crops.

The extra width on each side catches insects thrown out sideways when sampling and the sheet's depth allows it to be draped over the adjacent plant row. This prevents insects being flung through or escaping through this row. The use of smaller beat sheets, such as small fertiliser bags, can reduce sampling efficiency by over 50%. [44]

43 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

44 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

How to use the beat sheet

- Place the beat sheet with one edge at the base of plants in the row to be sampled.
- Drape the other end of the beat sheet over the adjacent row. This may be difficult in crops with very wide row spacing (1 metre or more) and in this case spread the sheet across the inter-row space and up against the base of the next row.
- Using a 1 metre long stick, shake the plants in the sample row vigorously over the beat sheet 5 – 10 times. This will dislodge the insects from the sample row onto the beat sheet.
- Reducing the number of beat sheet shakes per site greatly reduces sampling precision. Record type, number and size of insects on the beat sheet and record these on datasheets.
- One beat does not equal one sample. The standard sample unit is five (5) non-consecutive 1 m long lengths of row, taken within a 20 m radius (i.e. 5 beats = 1 sample unit). This should be repeated at 5-6 random locations in the field (i.e. 30 beats per field).
- The more samples that are taken, the more accurate is the assessment of pest activity, particularly for pests that are patchily distributed such as pod-sucking bug nymphs[45]

Other tips when using the beat sheet

- Pod-sucking bugs, particularly green vegetable bugs, often bask on the top of the canopy during the early morning and are more easily seen at this time.
- Some pod-sucking bugs (eg. brown bean bugs) are more flighty in the middle of the day and are more difficult to detect when beat sheet sampling. Other insects are flighty no matter what time of day they are sampled (e.g. mirids, Monolepta and ladybirds), so it is important to count them first.
- In very windy weather, mirids and other small insects are likely to be blown off the beat sheet.
- Using a beat sheet to determine insect numbers is very difficult when plants are wet.

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

The more samples that are taken, the more accurate is the assessment of pest activity, particularly for pests that are patchily distributed such as podsucking bug nymphs.

However, there is always a compromise between accuracy and practicality as the number of samples needed to accurately assess pest populations is usually far higher than is logistically feasible to collect. The following minimum numbers of samples are recommended.[46]

45 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

46 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Table 9: Minimum number of samples recommended for assessing pest populations in soybeans

Pest	Method	Sample unit	Minimum no. of sample sites recommended*
Helicoverpa	Beat sheet	5 x 1m	6**
Podsuckers#	Beat sheet	5 x 1m	6-10 #
Soybean aphids	visual	25 plants	6
Loopers	Beat sheet	5 x 1m	6
Monolepta beetle	Beat sheet	5 x 1m	6
Thrips	Open flowers	25 flowers	6

* As few as 5 sample sites may be necessary if the decision is clear cut eg. if populations are very high or extremely low.

** This is the number of sample sites. Multiply by 5 to get number of individual samples.

Nymphs are notoriously patchy in distribution, hence more samples are desirable.

Correcting podsucking bug beat sheet counts for sampling inefficiencies

Recent sampling trials in soybeans show that beat sheet sampling significantly underestimates the number of podsucking bugs sampled with the beat sheet. While sampling inefficiencies for small and medium nymphs are likely to be cancelled out by higher mortality for these stages, adult counts require a 2 times correction. So accept the bug nymphal counts as is, but multiply adult counts by 2.

Beat sheet sampling is also likely to underestimate the numbers of small caterpillars present. However, sampling inefficiencies are likely to be cancelled by increased mortality for the early caterpillar instars (up to 90%).[47]

Converting sample totals for different row spacing

Most thresholds are expressed as pests per square metre (pests/m^2). Hence, insect counts in crops with row spacing less than one 1 m must be converted to pests/m^2 as follows".

To convert to pests/m^2 divide the 'average insect count per row metre' across all sites by the row spacing in metres. For example, in a crop with 2 GVB/m on average, and 0.75 m (75 cm) row spacing, divide 2 GVB by 0.75 (i.e. 2/0.75 = 2.67 GVB/m^2).[48]

Keeping records

Accurately recording sampling data is critical for good decision making, and being able to review the success of control measures. Record or check sheets should show the following:

- numbers and types of insects found, including number of adults and immature stages
- size and stage of insects – this is particularly important for larvae and nymphs
- date and time
- weather conditions
- crop observations (e.g. crop stage, crop vigour). This is particularly critical if an insecticide treatment is required, as you need assess the efficacy of that spray with a post-spray check.[49]

Details of spray operations should include:

- date
- time of day

47 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

48 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

49 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

- conditions (wind speed, wind direction, temperature, presence of dew and humidity)
- product used, including batch number
- product rate and water rate
- method of application including nozzle types and spray pressure
- any other relevant details

Consider putting the data collected into a visual form that enables you to see trends in pest numbers and plant condition over time. Being able to see whether an insect population is increasing, static or decreasing can be useful in deciding whether an insecticide treatment may be required.

To facilitate acceptance in export markets, the soybean industry has developed a 'grower declaration form' where details including insecticides used, and spray and harvest dates are recorded. These forms MUST be filled in correctly. [50]

More information

http://finalreports.grdc.com.au/DAQ00003

7.4.2 Integrated Pest Management (IPM)

IPM is the term used for a wide range of tactics to (a) prevent pests from reaching damaging levels in crops and (b) if they do so, to manage the target pest in a way that is less likely to flare other pests such as silverleaf whitefly. By using a wide range of tactics to deal with pests, IPM removes the reliance on a single method of control, such as insecticides. IPM tactics include:

- conservation of natural enemies and introduced biological control agents
- through the use of soft selective pesticides and biopesticides
- regular crop monitoring of pest and beneficial insects
- the use of Economic Thresholds to rationalize pesticide use and avoid uneconomic sprays.
- host plant resistance including not spraying at crop stages when the crop is able to tolerate or compensate for significant pest damage, and the planting of resistant cultivars.
- cultural practices including agronomic practices that promote vigorous crops better able to tolerate pest attack, and crop hygiene.
- Area Wide Management to maximise the benefits of IPM practices.

The benefits of IPM are many and varied and include:

- regular scouting allow potential problems to be detected early and timely action to be taken
- IPM results in the strategic use of chemicals thus reducing health risks to growers and consumers
- strategic use of chemicals minimises the chance of pests developing resistance to pesticides
- reduced negative impact on the environment
- rhe use of soft pesticides conserves natural enemies to manage pests for free
- IPM leads to a more robust sustainable system that does not rely on one control method
- IPM allows growers to control insect pests in a more cost effective way[51]

IPM and pesticides

IPM does not necessarily mean the abandonment of pesticides for controlling pests. However IPM aims to reduce the frequency of pesticide applications. The use of

50 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

51 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

thresholds ensures sprays are applied only when required. Over use of pesticides hastens the development of insecticide resistance, can lead to a resurgence of target pests, can create new pests, may increase residues in harvested seed, and increases off-target contamination.[52]

Soft and hard pesticides

The adjectives "soft" or "selective" are frequently applied to pesticides in the context of IPM. Soft or selective pesticides kill pests but have a minimal impact on the beneficial insects attacking these pests. In contrast pesticides impacting on natural enemies are termed "hard", "non-selective" or "broad spectrum".

In practice there are varying degrees of softness and many products may be hard on one group of natural enemies, but relatively soft on another. The term "soft" does not imply a product to be of low toxicity to mammals, although many of the softest products, particularly bio-pesticides, have little or no impact on humans and other mammals.

The "hardness" of a product can often be mitigated by reducing the rate (where there is data showing no reduction in efficacy), or by delaying spraying for as long as possible. In general the later in the life of a crop a hard spray is applied, the less the likelihood of it flaring other pests, because there is less time between application and harvest.[53]

IPM and organics

IPM is not necessarily the same as organic pest management, though many organic options are compatible with IPM. In fact, not all organic options are IPM compatible. For example, many botanically derived products such as pyrethrum adversely affect beneficial insects. Another organic product NEEM contains an active ingredient that affects female reproduction in mammals.[54]

IPM and biological control

IPM is sometimes confused with classical biological control. Classical biological control involves the importation and release of exotic control agents (predators and parasites) to control (usually) exotic pests. This practice is used because there are no native control agents, or because the native ones are (or thought to be) ineffective.

IPM plays an important role in maximising the success of classical biological control. The reduction in the use of non-selective chemical sprays increases the survival of introduced control agents and hence their effectiveness, and improves their chance of establishment in a new environment.

One example of classical biological control in Australia is the introduction of the Cactoblastis moth to control prickly pear. A recent example in soybeans (and other crops) is the release of a small parasitic wasp, *Eretmocerus hayati* to control silverleaf whitefly.[55]

The soybean IPM strategy

The basic IPM strategy for soybeans is to avoid non selective pesticides for as long as possible in order to foster a build-up of predators and parasites (ie. 'go soft early'). This helps keep early pests in check and buffers the crop against pest attack during later crop stages.

52 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

53 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

54 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

55 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

The recommendation for vegetative crops is to avoid spraying wherever possible and to only use biopesticides against above-threshold caterpillar pests. Tolerating low level pest activity encourages natural enemies in vegetative crops and buffers the crop against pest attack during the more susceptible flowering and vegetative stages. For soybeans, avoiding early disruptive pesticides is critical for preserving *Eretmocerus hayati*, an introduced parasite of silverleaf whitefly. [56]

However, intervention may be required during podding, especially against pod-sucking bugs populations which peak during late podfill. Pod-sucking bugs cannot be ignored as they drastically reduce seed quality, as well as yield. Over 90% of seeds can be damaged if bugs are left unchecked.

Regular monitoring of pest numbers is critical in soybeans, especially with the onset of flowering and throughout podding, when crops become attractive to pod-sucking bugs, helicoverpa and other pests. [57]

What is needed for IPM to work?

Successful implementation of IPM requires growers to have knowledge of key components in the field that will guide sound decisions and forecasts.

These include:

- accurate pest and beneficial insect identification
- understanding pest lifecycles, biology and ecology
- understanding the impact of pest damage on crop quality at different pest densities
- knowing the effects of control methods on target pests, non-target pests and beneficial insects

Much of the essential knowledge can be gained from regular crop inspections, good record keeping and reading published information.[58]

7.4.3 Insecticides

Insecticides are a key pest management tool in soybeans. However unnecessary spraying, or selection of the wrong pesticide, can flare secondary pests, hasten the development of pesticide resistance, contaminate the harvested product, increase operating costs and reduce profitability. Both short and long term factors must be considered, even in a relatively short duration crop such as soybeans.[59]

Factors to consider when choosing an insecticide

- be aware of current insecticide groups/types, and of any recent de-registrations
- attributes of key registered insecticides
- key factors to consider when making the choice
- how to make rational post spray assessments
- legal aspects and responsibilities
- resistance status of groups/types

Insecticide groups

Insecticides can be grouped according to how they enter the target pest, their modes of action, and their chemical composition (insecticide group or family).

56 H. Brier (2010) Integrated Pest Management in Australian Mungbeans and Soybeans – Swings, Roundabouts and Conundrums: https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Brier_IPM_edited_paper.pdf

57 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

58 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

59 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Route of entry – how they enter the target pest

- contact
- ingestion
- inhalation (fumigants)

To be effective, contact pesticides need to be absorbed through the external body surface. This contact can be either directly at the time of spraying, or indirectly with the pest picking up dried spray residues as it moves over the surface of the plant.

Many insecticides have both contact and ingestion activity, though one may be more important than the other. Some newer generation 'soft' insecticides are only 'activated' inside an insect's gut. This is one reason they can have a reduced impact against many beneficial insects (e.g. Steward, TracerII).

Systemic pesticides are those that can be moved (translocated) from the site of application to another site where they become effective (e.g. insecticides that are absorbed by foliage and translocated throughout the plant). Chewing and sucking pests will then ingest the insecticide along with plant tissues or fluid. Dimethoate is an example of a systemic insecticide.[60]

Mode of action (i.e. how they kill pests and the body systems attacked)

- neurotoxins – most insecticides (e.g. pyrethroids, organophosphates and carbamates)
- metabolic inhibitors – interfere with essential body processes such as moulting
- insect growth regulators - are slower acting. Includes many of the newer generation 'soft' insecticides registered in cotton (but not pulses)
- pPhysical toxicants – such as oils, abrasive dusts
- biological infection – NPV (Helicoverpa virus) and Bt (bacterial toxin) - by ingestion, Beauvaria and Metarhizium fungi - through the pest's cuticle.[61]

Chemical structure (classification)

Insecticides are also grouped according to the chemical similarity, especially for the purpose of designing resistance management strategies.

The main insecticide groups to consider in soybeans and other summer pulse crops are:

- oxadiazines (e.g. indoxacarb (Steward EC) - a new generation product with low mammalian toxicity)
- Spinosyns (e.g. spinosad (TracerII) - a new generation low mammalian toxicity product – but which has been withdrawn from Australian grain/pulse crops for commercial reasons)
- Carbamates (e.g. thiodicarb (Larvin) and methomyl (Lannate, Marlin etc.))
- Organophosphates or OPs (e.g. chlorpyrifos (Lorsban), and dimethoate (Rogor))
- Synthetic Pyrethroids or SPs (e.g. deltamethrin (Decis), alpha cypermethrin (Dominex etc.))
- Biopesticides (e.g. NPV(ViVUSMax) and Bt (DipelSC)). Fungal biopesticides for bugs (e.g. *Beauvaria* and *Metarhizium*) are under development but are not yet registered.[62]

60 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

61 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

62 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Making the choice – factors to consider

When confronted with an above-threshold pest population, there are several factors to consider when selecting from the available insecticides. These include:

- is the product registered?
- efficacy against the target pest
- susceptibility of the crop to pest damage at the time in question
- impact on natural enemies
- resistance management status and conditions
- ability to control multiple target species
- withholding periods and export slaughter intervals
- toxicity to the environment and humans
- exclusion zones
- cost – both long and short term[63]

Efficacy

A well chosen insecticide is one that gives good control, while minimising negative side effects such as enhancing the development of resistance or flaring secondary pests. Efficacy is often judged by the percentage kill and speed of kill. While many contact insecticides have a rapid knockdown effect, others (particularly those that rely on ingestion) have a period, often measured in days, before maximum kill is achieved. Users need to be aware of these differences between products.

The stage or size of insect targeted also influences efficacy, with larger insects generally more difficult to control. For example, the 'Critical Comments' on the Steward label state 'Target brown eggs and hatchling (neonates to 1st instar) to small larvae (2nd instar) when they reach the economic spray threshold and before they become entrenched in pods'.

Another important factor in determining efficacy is the level of residual control provided. Some insecticides provide very little residual control (e.g. dimethoate, methomyl), while others can provide residual control in the order of weeks if conditions are favourable, and where there is not growth dilution (e.g. Steward). As well, the rate used also has a considerable impact. For example, dimethoate at very low rates (e.g. ≤ 150mL/ha has very little activity against mirid nymphs hatching after spraying). Efficacy also depends on your ability to get the chosen product onto the target site, whether that is on the insect directly or the plant surfaces from where the insect picks up the insecticide.[64]

Susceptibility of the crop to pest damage

If the crop is at a stage tolerant of considerable damage (e.g. 33% defoliation by loopers, or 7 Helicoverpa larvae/m^2 during the vegetative stage), there is no need for 100% pesticide efficacy. In this case a biopesticide with a 70% efficacy such as ViVUSMax for helicoverpa, or Dipel for loopers will suffice. This approach has 2 benefits - beneficial insects are conserved and more effective products such as Steward EC are reserved for later crop stages more susceptible to pest attack.[65]

Impact on natural enemies

Even in short duration crops such as mungbeans, there are benefits in choosing the softer option where possible. Going soft early with highly selective products (e.g. NPV or Bt conserves beneficial insects for later on when the crop is more susceptible to

63 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

64 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

65 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

attack). Going soft early reduces the risk of flaring pests such as helicoverpa, and the need for follow up sprays to control those pests. For example, a low rate of dimethoate (200-250 mL/ha with salt adjuvant) controls mirids and reduces the risk of subsequent helicoverpa attack. While helicoverpa outbreaks don't always follow a dimethoate spray, the risk of this occurring is greatly increased with the full dimethoate rate (500mL/ha).[66]

Resistance management strategies for your region or a particular product

In soybeans and other pulses, resistance management strategies place restrictions on the number of sprays per crop, rather than on the timing of applications (as in cotton). A specific example of a label restriction is:

From the Steward label: "No more than one (1) application per field for the crop's entire growth cycle".

Following the resistance management guidelines for helicoverpa in particular is essential to ensure that this pest does not develop resistance to any current or new products.[67]

7.4.4 Presence of other pests also requiring control

Selecting spray mixtures or products with dual or multi-pest activity (e.g. loopers and helicoverpa) may be important where more than one pest species requires control. When mixing pesticides, always check beforehand that products are compatible. If still in doubt, mix a small amount and look for sedimentation.[68]

Withholding periods and insecticide residues

Some products have relatively long withholding periods (WHPs) and producers should be aware of these. For example, Larvin (thiodicarb) and Steward (indoxacarb) have a 21-day WHP.

Harvesting a crop before the WHP has elapsed could increase the risk of exceeding minimum residue levels for particular markets. The presence or risk of residues may affect the marketability of the harvested product. The presence of excessive residues could jeopardise overseas markets for the whole Australian industry, especially if residues are from unregistered products.

Be aware of regulations regarding the feeding of contaminated crop residues to stock. Export Slaughter Intervals and related periods are not generally shown on the product label, and are best obtained from the manufacturer or SAFEMEAT. Note that the Export Slaughter Interval can be significantly longer than the withholding period.[69]

Toxicity to the environment and humans

Be aware that many older products, particularly the OPs (e.g. chlorpyrifos) and carbamates (especially methomyl) are extremely toxic (schedule S7) poisons, and should be handled with caution. Note that users have a community and industry responsibility to minimise environmental, animal, surrounding crop and human contamination. [70]

66 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

67 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

68 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

69 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

70 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Exclusion zones

Many pesticides have stipulated minimum distances that treated crops must be away from livestock, fodder crops, waterways etc (i.e. boundary zones inside which the above must be excluded). Always check the labels as the distances for some products can be 100 m or more. Note that exclusion zones are being reviewed by the APVMA, and may be revised upwards, especially for hazardous insecticides and crop-dehabillating herbicides such as 2,4-D.[71]

Cost

Cost can be important in determining which product is used. However, the cheapest is not always the best – or the cheapest. For example, synthetic pyrethroids are very cheap on a $/per application basis, but the combined impacts of insecticide resistance (especially in helicoverpa) and flaring of secondary pests, can lead to a need for additional sprays, costs and worries. In many cases, a single application of a more expensive but more effective and selective option will provide the best economy.

Never use products that are not registered nor have an APVMA permit for use in whatever crop you are growing.[72]

New generation insecticides, indoxacarb (Steward) and spinosad (Tracer II)

Steward EC (active ingredient - indoxacarb) and Tracer II (active ingredient - spinosad) are new more-selective insecticides targeting helicoverpa and other caterpillars. Both products have low mammalian toxicity (i.e. are much safer for human operators, domestic animals and wildlife). Indoxacarb is registered in soybeans and other pulse crops but Tracer II is being withdrawn from the Australian market for purely commercial reasons, and is most likely by now unavailable.

Steward is primarily an ingestion active product (i.e. it has to be eaten by larvae to be effective). Thorough coverage over the larval feeding surfaces (leaves, flowers and pods) is therefore important to achieve the best results. Steward also has some mirid activity, but is not recommended at high mirid pressure, and is best reserved for helicoverpa control. It is not registered or effective against GVB.

A key advantage of Steward is that it is moderately selective, with reduced impacts on non-target species (including many beneficial species) that may be important in suppressing helicoverpa and SLW populations below the economic threshold. Steward has some impact on predatory ladybirds but Queensland DAF (DPI) and CSIRO trials support the manufacturers' claims that products such as Steward have much less impact on a wide range of beneficial insects than older insecticide groups.[73]

Altacor (active ingredient Chlorantraniliprole) has highly effective control of Helicoverpa spp (bean podborer, soybean looper, bean looper). Key strengths are its robustness, control, length of residual in the crop and safety to key beneficial insects.

Biopesticides – NPV (ViVUSMax) and Bt (DipelSC)

NPV (ViVUSMax) and Bt (DipelSC) are highly selective caterpillar biopesticides. They are generally not as effective as chemical pesticides, but have an important IPM fit as they have no impact on beneficial insects. NPV has the added advantage in that it can re-infect other larvae well after the initial spray event. Because NPV is a 'living pesticide', there is also very little risk of helicoverpa developing resistance to NPV-based products. Note that ViVUSMax has superseded VivusGold and that the registered rate of the new-more concentrated formulation is much lower at 150 mL of product/ha than the 375 mL/ha rate registered for VivusGold.

[71] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[72] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[73] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Biopesticides are best suited to targeting moderate pest populations. High populations may be targeted if crops are at a less vulnerable stage (e.g. vegetative), and 60-70% control is sufficient to bring populations back to non yield-threatening levels.

NPV and Bt should not be used against medium-large (or larger) helicoverpa. Remember that NPV only kills helicoverpa! Bt should only be used against very small cluster caterpillars, but is effective against medium-large loopers.

AminoFeed should be added at 1L/ha for best results with both products. Both are broken down rapidly by ultra violet light (UV), so they are best applied when UV levels are lower (i.e. not in the middle of the day). However temperature is also critical. If temperatures are too low in the early morning, larvae will not feed, and the product may have broken down by the time temperatures rise sufficiently to allow feeding. The manafactures of VivusGold recommend applications ideally be made when temperatures are ≥ 250C, and definitely not when temperatures are < 180C.

Thorough coverage is essential when applying these ingestion-active products. Minimum spray volumes recommended for air and ground applications are 30L/ha and 100L/ha respectively. Considerable success has been achieved in coastal crops where spray volumes of 200-300L/ha have been applied with ground rigs. Maximise spray penetration into crops by using multiple fine* flat fan nozzles and setting the spray pressure of around 4 bars (*not > O2s). Spray volume can also be increased by using multiple nozzles.

Fungal-based biopesticide types are being developed for bug and mirid control. Beauveria and Metarhizium are fungi that occur naturally in the environment. These insect pathogens are harmless to humans and wildlife, and have little effect on beneficial insects. Fungi are unique biopesticides in that they infect insects through their cuticles. As with biopesticides, thorough coverage, target younger pests, and avoid strong sunlight (UV) also apply to fungal based products.[74]

Carbamates (e.g. Larvin, Lannate)

Larvin (active ingredient - thiodicarb) is commonly used for helicoverpa and looper control. While resistance levels within the H. armigera population to carbamates has declined in recent years, poor control is possible in late summer crops if it follows widespread use in earlier crops. Larvin may give some control of podsucking bugs but is not recommended as a primary bug pesticide.

Methomyl (e.g. Methomyl, Lannate, Marlin) is sometimes used against mixed helicoverpa and bug populations, but performs poorly against podsucking bugs, especially in crops with dense canopies. Commercial experience has shown poor results against GVB, possibly because of its short residual activity, and it is generally not recommended. Note that methomyl is extremely toxic, with a very low oral LD50. Breathing in the vapour or spray drift is particularly dangerous.[75]

Organophosphates or OPs (e.g. Dimethoate)

Organophosphates or OPs, an older pesticide group, contain some of the most toxic pesticides ever used (e.g. parathion). Except for chlorpyrifos (under permit in soil-insect baits) dimethoate (e.g. Dimethoate, Rogor) is now the only OP registered for use in pulses.

Dimethoate is a systemic pesticide that is very effective against mirids, most thrips (western flower thrips excepted), leafhoppers and aphids. However, dimethoate is not effective against podsucking bugs despite its being registered for their control.

At the full registered rate (≥500mL/ha) dimethoate has a marked impact on most key beneficial insects. However, QPI&F trials show that dimethoate at low rates (e.g. 200-

74 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

75 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

250 mL/ha) has markedly less impact on beneficials, while still being very effective against mirids. Dimethoate is less toxic to humans than earlier OPs, but every safety precaution must be taken when using this product.

Dimethoate is very sensitive to alkaline water and breaks down in less than 50 minutes in water with a pH of 9. If your water is alkaline, add a buffering agent such as LI700. [76]

Organochlorines (Cyclodeines) (e.g. Endosulfan)

ENDOSULFAN IS NO LONGER REGISTERED POST EMERGENCE IN AUSTRALIAN PULSES.

Synthetic Pyrethroids or SPs (e.g. Alpha-Scud, Ballistic, Cypermethrin, Dominex)

Synthetic Pyrethroids (SPs) are a very broad-spectrum group of insecticides. They kill pod sucking bugs, loopers, most other pests, and most beneficials. However, they are only effective against small *Helicoverpa armigera* larvae (up to 5 mm long) due to high levels of resistance of *H. armigera* to this group of products.

Synthetic pyrethroids are the most disruptive chemical group to beneficial insects and spiders, due to their broad-spectrum and residual activity. Pyrethroids can flare helicoverpa, mites, SLW and other pests.

With de-registration of endosulfan, deltamethrin (Decis) is now the only effective pesticide registered against GVB. Recent trial results show that redbanded shield bug (*Piezodorus oecanicus*) is not controlled by deltamethrin (nor alpha-cypermethrin) However, in QPI&F trials 60% control of *Piezodorus* was achieved when 0.5% salt (NaCl) adjuvant was added to tank mixes of deltamethrin.

Note: SPs are synthetic derivates of natural pyrethrum, as used in organic crops. Natural pyrethrum is also a broad spectrum pesticide but breaks down quickly after spraying and doesn't have the residual impact of the SPs. In general, SPs are less toxic than OPs, but more toxic to humans than natural pyrethrum.[77]

7.4.5 Post-spray assessments

Once crops have been sprayed for pests, it is essential to conduct post-spray assessments to ensure that a satisfactory level of control was achieved. Good control is usually >90% for chemical pesticides, and 70% for biopesticides. Post spray assessment should be done as soon as the specified re-entry period allows entry to the field. For most products this is 2-3 days after treatment (2-3 DAT). However with biopesticides, mortality may not occur until 5-7 DAT. Crops sprayed with chemical pesticides should be checked again at 7 DAT to check for re-invasion and biopesticide-sprayed crops again at 10-12 days. Regular twice-weekly sampling should continue until the crop is no longer susceptible to pest attack.

Sprays sometimes fail to work as effectively as required or expected. This can be due to several reasons (e.g. a bad batch of product, poor coverage, bad timing, adverse weather conditions, poor water quality, insecticide resistance, or too-high expectations of the product selected). Application problems (coverage, timing, water) and inappropriate product selection account for a large percentage of failures. Where a spray failure is suspected, detailed records can assist in trying to determine what might have been the cause of the apparent failure.

Spray failures are often due to heavy pest pressure. Where GVB pressure is high, crops are often re-infested by nymphs hatching from large numbers of GVB eggs present at but not controlled by spraying. This frequently occurs even where crops are sprayed with deltamethrin (e.g. Decis).

76 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

77 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Re-infestation will also occur where there is prolonged helicoverpa pressure and crops are sprayed with products which have no impact on moths, and have very little or no residual activity (e.g. biopesticides). Uncontrolled moths continue to lay more eggs which give rise to more larvae that survive because there are no pesticide residues to kill them. It is also possible that pests have come in (post-spray) from elsewhere, particular if there is a lot of activity in surrounding crops.

Apparent spray failures may also occur where pesticides are unable to reach the target pest, or where the damage has been inflicted before spraying occurs. An example of this is where small helicoverpa or podborer larvae are feeding inside flowers. Short residual pesticides such as methomyl usually break down before the majority of larvae emerge, resulting in imperfect control.[78]

7.4.6 Legal issues

Registration

Insecticide users should be aware that all insecticides go through a process called registration, where they are formally authorised (registered) by the Australian Pesticide and Veterinary Medicine Authority (APVMA) for use:

- against specific pests
- at specified rates of product
- in prescribed crops and situations
- where risk assessments have evaluated that these uses are:
- effective (against that pest, at that rate, in that crop or situation)
- safe in terms of residues not exceeding the prescribed MRL (Maximum Residue Level), and safe to the crop itself (no phytotoxicity).
- not a trade risk[79]

Labels

A major outcome of the registration process is the approved product label, a legal document, that prescribes the pest and crop situations where a product can be legally used, and how. Always read the label! The use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeded maximum residue limits (MRL) which can have trade implications and the risk of litigation.

Be aware that pesticide-use guidelines on the label are there to protect product (grain) quality and Australian trade by keeping pesticide residues below specified MRLs. MRLs 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 (WHP) (i.e. within the shortest time before harvest that a product can be applied)
- are not registered in the crop in question

All of the above have the potential to jeopardise the marketing of Australian pulse crops.[80]

78 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

79 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

80 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

MSDS

Material Safety Data Sheets (MSDS) are essential reading. They document the hazards posed by insecticides, and the necessary and legally enforceable handling and storage safety protocols.[81]

Permits

In some cases a product may not be fully registered but is available under a Permit with conditions attached, which often require the generation of further data for eventual full registration.[82]

APVMA

The national body in charge of administering these processes is called the APVMA (the Australian Pesticides and Veterinary Medicines Authority) and is based in Canberra.

From the APVMA website:

"The APVMA administers the national Registration Scheme for Agricultural and Veterinary Chemicals. The scheme registers and regulates the manufacture and supply of all pesticides and veterinary medicines used in Australia, up to the point of wholesale sale."

"The APVMA sets maximum residue limits (MRLs). An MRL is the highest concentration of an agricultural or veterinary chemical residue permitted in food or animal feed. MRLs are used to check whether chemical users are following the directions on the label. MRLs are usually set well below the level that would harm health. When an MRL is exceeded, it usually indicates a chemical is being misused, rather than a public health or safety concern."

"State and territory governments regulate the use of agricultural chemicals after they have been sold. These regulations cover:

- basic training requirements for users
- licensing of commercial pest control operators and ground and aerial spray operators
- residue monitoring
- arrangements to enforce the safe use of chemicals, including the use of codes of practice, spray-drift guidelines and other user awareness raising initiatives

State Government regulations are therefore relevant in determining the legality or otherwise of deviations from label conditions.

Where soybeans are grown in new production areas (e.g. coastal Queensland), they may encounter new pests for which registered chemicals (or permits) are not always available.

[81] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[82] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.4.7 Soybean insecticides

Table 10: Insecticides registered in soybeans – June 2012 (check the latest status on APVMA/ PUBCRIS websites)

Pest	Pesticide/ Hardness ✠	Trade names	Rate/ ha*	Registration status	WHP# (days)	Comments
Helicoverpa	indoxacarb	Steward	0.4L	®	21	Only 1 spray per crop*
	thiodicarb	Larvin	0.5L - 0.75L	®	21	Target larvae < 7mm for best results
	methomyl	Marlin, Nudrin	0.5-2L	®	7	Target larvae < 7mm for best results. Highly toxic to humans
	deltamethrin	Decis Options Ballistic	0.5L	®	7	Target larvae < 5mm for best results
	alpha-cypermethrin	Dominex 100	0.3-0.4L	®	7	Target larvae < 5mm for best results
	Helicoverpa NPV	Gemstar LC ViVUSMax	0.375L 0.150L	® ® - Pivot	NA	Target larvae < 7-10mm Preferred vegetative options
	Bt	Dipel, Farmoz Btk	1-4L	®	NA	Target hatchlings for best results
Loopers	methomyl	Marlin, Nudrin	1.5L	®	7	Only use post flowering. Highly toxic to humans
	deltamethrin	Decis Options Ballistic	0.5L	®	7	Only use post flowering
	Bt	Dipel, Farmoz Btk	1-4L	®	NA	Preferred option unless extreme pressure
Soybean loopers	indoxacarb	Steward	0.2L	®	21	Only 1 spray per crop*
	Bt	Dipel, Farmoz Btk	1-4L	®	NA	Preferred pre-flowering option
GVB	deltamethrin	Decis Options Ballistic	0.5L	®	7	Most effective option
	trichlorfon	Lepidex	1.2L	®	14	Shorter control than Decis
Mirids	dimethoate[P]	Dimethoate	0.5L	®	7	Very effective but rarely needed
	indoxacarb	Steward EC	0.4L + salt	®	21	Add salt (NaCl) @ 5g/L spray volume by ground (100L/ha) or 10g/L by air (30L/ha)
Aphids	dimethoate[P]	Dimethoate	0.5L	®	7	Act if >threshold by flowering
Jassids, Leafhoppers	dimethoate[P]	Dimethoate	0.34L	®	7	rarely a problem in soybeans
Monolepta beetle	indoxacarb	Steward	0.2L	®	21	Only 1 spray per crop*
Field cricket	chlorpyrifos	Chlorpyrifos 500	grain bait	®	NA	0.1L/2.5 kg grain bait
Two-spotted mite	abamectin	Tradelands abamectin 18EC	0.3L	®	28	Act if > 33% of plants infested. Using soft options against other pests greatly reduces the risk of mite attack.

WHP = withholding period (days).

* Maximum rate allowed for on label.

® = Registered.

Pivot = registered through central pivot.

ViVUSMax is a more concentrated NPV product than Gemstar, hence the lower rate.

Trade names listed are examples only & do not signify preference over products not listed (because of limited space).

[P] Permit 13155 – dimethoate against all pulse/grain pests it was previously registered for- valid to 5 October 2012.

Check the latest status of the dimethoate permit on the APVMA/PUBCRIS websites before using post 5 October 2012

✠ Softness/Hardness Note: 'Soft' products are selective, ie. have little to no impact on non-target species

From: Wilson et al. (2007) Impact of insecticides and miticides on beneficials in Australian cotton. Cotton Pest Management Guide 2007-08. pp. 29-30. CRC & NSW DPI Publication. ISSN1442-8792.

Highly Selective, ie. Extremely Soft	Moderately Selective, especially at lower rates	Hard - Disruptive to beneficials	Extremely Hard

7.4.8 Making control decisions

Making control decisions may seem daunting given: a) number of pests attacking soybeans; b) the uncertainty of what might happen if you do nothing; and c) the number of pesticide options available. However, decision making is easier if you break it down into the following logical steps.

What stage is the crop?

- This will tell you in advance what pests are likely to be a problem in the crop and if the crop is susceptible to a given pest at that stage.

For example, podsucking bugs won't be an issue in vegetative or even flowering crops

What pest(s) is/are present? – this is critical

- Is it one of the major pests (e.g. helicoverpa or podsucking bugs)?

These are the ones to worry about most. Make sure you can tell the difference between the major and minor pests, and beneficial insects

- Are there any other pests present - such as silverleaf whitefly?

Other pests might be controlled by whatever you spray the main pest with, alternatively they may not, or they could even be flared if the wrong pesticide is used

What size/stage are the pests?

- Pest size can be critical as some pesticides, particularly biopesticides, are only effective against the early stages of the target pest (e.g. ideally target helicoverpa ≤7mm with NPV).

Note that to catch pests when they are still small, you need to sample regularly, particularly in hot weather when pests grow more quickly.

What type of damage are you seeing?

- This will provide further clues as to the identity of the pest, and the severity of the infestation.

You need to ensure the pests are still present or haven't ceased feeding because they are pupating.

How large and vigorous is the crop?

- A large vigorous crop is better able to compensate for damage than a small stressed crop.
- A large soybean crop with a large number of set pods will suffer lower % seed damage than a small crop with fewer pods, for a given podsucking bug population.

So you will need to determine the number of seeds per square metre to determine the podsucking bug threshold for your specific crop.

Are the beneficials insects present keeping the pest/s in check?

- They may be holding other key pests in check – such as whitefly.
- Look for evidence such as parasitized whitefly nymphs, diseased caterpillars, predatory bugs attacking caterpillars, and the failure over time of small caterpillars to progress to large ones.
- If so, you need to consider a more selective option that has minimal impact on the beneficials and doesn't flare whitefly or other pests.
- Alternatively, the beneficials may do the job for you, so keep checking the crop to monitor their progress.
- Beneficials are often very good pest indicators.

If there are lots of ladybirds there will either be aphids or whitefly present in your crop.

Are the pests above threshold?

- If not, it is uneconomic to spray.
- If not much above threshold, you might consider a biopesticide if one is registered.

This would be particularly appropriate for helicoverpa in vegetative soybeans when a near perfect kill is not required, and a 60-70% kill will be sufficient to bring the population down below threshold (6/m^2).

- If pests are well above threshold, you will need a product with high efficacy (85-90% kill).
- Are you using the recommended sampling protocols so that your pest counts can be accurately compared to thresholds derived using the same sampling protocols?

Are there any resistance management guidelines for the pesticide you are considering?

- Have you used it previously in the crop?
- Remember that only one indoxacarb (Steward) spray is allowed per soybean crop.

How close to harvest is the crop?

- As you get closer to harvest pesticide withholding periods (WHP) must be considered.
- If time to harvest is shorter than the WHP for a particular pesticide, you can no longer legally spray that pesticide in the crop.

Will it be grazed post-harvest?

- If a crop is to be grazed post harvest, export slaughter intervals (ESI) may come into play.
- These can be markedly longer than the crop WHP.
- Export slaughter intervals also come into play if adjoining crops/pasture are contaminated.

Are you able to deliver the pesticide to the target?

- Do you have the right nozzles, spray volume and pressure to penetrate the canopy?
- Do you have good quality spray tank water, ie. close to neutral?

Are the meteorological conditions right for the pesticide you are using?

- Is the wind speed too low or high?
- Is it too cold or hot?
- Are UV levels too high?

What is the risk of off target contamination?

- What are the weather conditions – high wind speed, temperature inversions?
- Proximity to other crops/pasture – do you know what the exclusion zones are?
- How close is the neighbour's house?

What about your safety?

- Do you have adequate safety gear?
- Have you read the MSDS for the pesticide in question?
- Remember, some older pesticides such as methomyl are extremely toxic.

Post-spray assessments;

- Always make post spray assessments to determine the efficacy of whatever pesticide is applied.
- For fast-acting pesticides, check crops a soon as the re-entry period elapses.
- For slow acting pesticides (e.g. biopesticides) wait until significant mortality is likely.[83]

83 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.5 Beneficial insects

Natural enemies of insect pests are also referred to as beneficial insects. A natural enemy may be a predator or a parasitoid. Spiders, birds and insect diseases are also classified as natural enemies.

Predators consume several to many prey over the course of their development, they are free living and are usually as big as or bigger than their prey. Predators may be generalists, feeding on a wide variety of prey, or specialists, feeding on only one or a few related species.

Parasitoids are similar to parasites but, while true parasites usually weaken but rarely kill their hosts, parasitoids always kill the host insect. In contrast to predators, parasitoids develop on or within a single host during the course of their development.

Most parasitoids are highly host specific, laying their eggs on or into a single developmental stage of only one or a few related host species. They are often described in terms of the host(s) stages within which they develop. For example, there are egg parasitoids, larval parasitoids, larval-pupal parasitoids (eggs are laid on or in the larval stage of the host, and the host pupates before the host dies), true pupal parasitoids, and a few species that parasitise adult insects.

Conserving or encouraging natural enemies is important because a great number of beneficial species exist naturally and help to regulate pest densities. The widespread injudicious use of non-selective insecticides can decimate natural enemy populations and lead to a flaring of pests. The widespread use of non-selective pesticides can also negate classical biological control introductions, such as the tiny wasp *Erotmocerus hayati* imported by CSIRO to control silverleaf whitefly.

Among the practices that conserve and favour natural enemies are the following:

- Recognizing beneficial insects. Learning to distinguish between pests and beneficial insects is the first step in determining whether or not control is necessary.
- Minimizing insecticide applications. Most insecticides kill predators and parasitoids along with pests. Natural enemies are often more susceptible than pests to commonly used insecticides. However many newer pesticides are far more selective than the older products they are replacing.
- Using selective insecticides or using insecticides in a selective manner. Several insecticides are toxic only to specific pests and are not directly harmful to beneficials. For example; microbial insecticides containing different strains of the bacterium *Bacillus thuringiensis (Bt)*, are toxic only to caterpillars, certain beetles, or certain mosquito and black fly larvae.
- Maintaining ground covers, standing crops, and crop residues. Many natural enemies require the protection offered by vegetation to survive. Ground covers supply prey, pollen, and nectar (important foods for certain adult predators and parasitoids), and protection from the weather.[84]

Figure 48: White collared ladybird, key aphid predator. (Photo: Australian Oilseeds Federation)

[84] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

7.5.1 Use of the predator to pest ratio in spray decisions

The predator to pest ratio (as developed in cotton) gives a rough guide as to the potential impact of beneficials, especially against helicoverpa and similar caterpillars. Calculation of the ratio includes *Helicoverpa* eggs and very small (VS) plus small (S) larvae (1-7 mm) per metre assessed using visual and beat sheet sampling. It does not include medium (M) or large (L) larvae since many of the common small predatory insects are not effective on these stages (but predatory shield bugs still are). Total predators per metre are assessed using a beat sheet and visual check. To be confident in the ratio, at least 3 of the most common predators should be present per sample including ladybirds, red and blue beetles, damsel bugs, big-eyed bugs, assassin bugs, predatory shield bugs and lacewings.

The predator:pest ratio is calculated as:

Predators per metre/(helicoverpa eggs + larvae (VS + S))

If this ratio is 0.5 or higher, then predators will generally provide effective control of *Helicoverpa* spp. If the ratio is less then 0.5 then beneficials may still give useful partial control of helicoverpa, and should still be preserved through the use of soft selective pesticides if helicoverpa are above threshold.

Table 11: Key beneficial groups and the pests they attack[85]

Parasitoids	Pests Attacked
Ichneumonid wasps including orange caterpillar parasite, orchid dupe, two-toned caterpillar parasite and banded caterpillar parasite	Larva of noctuid caterpillars including helicoverpa, armyworms, cutworms and loopers except the banded caterpillar parasite which only parasitizes pupae
Microplitis wasps	Helicoverpa larvae – small to medium sized
Tachinid flies	Larva of noctuid moths
Trichogramma sp. wasps	Eggs of noctuid moths
Trichopoda flies	GVB and green stink bug (adults and 5th instar nymphs)
Predatory Insects and Spiders	**Pests Attacked**
Ants	Eggs and larvae of moths, bug nymphs
Apple dimpling bug	Moth (Lepidoptera) eggs, very small larvae and mites
Assassin bug	Range of insects including helicoverpa and mirids
Big eyed bug	Soft bodied insects, Lepidoptera eggs and mites
Brown smudge bug	Lepidoptera eggs, aphids, jassids and mites
Common brown earwig	Larvae and pupae of Lepidoptera
Damsel bug	Lepidoptera eggs and larvae, mites and mirid eggs
Glossy shield bug	Larvae of Lepidoptera
Hoverflies	Aphids
Lacewings	Aphids, Lepidoptera eggs and small larvae
Ladybeetles	Aphids, mites, Lepidoptera eggs and small larvae
Pirate bugs	Thrips and Lepidoptera eggs
Predatory shield bug	Lepidoptera larvae
Red and blue beetle	Lepidoptera eggs and small helicoverpa larvae
Spiders	Generalist predator, including moths, larvae, eggs, bug nymphs and other spiders. Very underrated predators.
Thrips	Mites

85 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Pathogens	Pests Infected
Bacteria eg *Bacillus thuringiensis*	Lepidoptera
Fungal diseases (including *Beavueria, Nomuraea rileyi* and *Metarhizium*)	Helicoverpa, loopers, cluster caterpillars, armyworms, mirids and podsucking bugs.
NPV (Nuclear Polyhedrosis Viruses)	Helicoverpa, loopers and cluster caterpillars NOTE: Different NPV viruses attack each of the above caterpillars. *Helicoverpa* NPV and its commercial derivatives (e.g. ViVUSMax and Gemstar) are specific to *Helicoverpa* sp.

7.6 Key parasitoids and predators

7.6.1 Large predatory bugs

Figure 49: Glossy shield bug (Cermatulus nasalis) adult (12 mm) and nymph (9 mm). (Photo: Australian Oilseeds Federation)

Figure 50: Spined predatory shield bug adult (11 mm) (Oechalia schellenbergii) and nymph (8 mm) (Photo: Australian Oilseeds Federation)

Figure 51: Large assassin bug (30 mm) (Photo: Australian Oilseeds Federation)

7.6.2 Small predatory bugs

Figure 52: Damsel bug (12 mm) (Photo: Australian Oilseeds Federation)

Figure 53: Big-eyed bug (3 mm) (Photo: Australian Oilseeds Federation Foundation)

Figure 54: Apple dimpling bug (2.5 mm) (Photo: Australian Oilseeds Federation)

Figure 55: Brown smudge bug adult and nymph (5 and 3 mm).

7.6.3 Predatory beetles

Figure 56: Three-banded ladybird adult

Figure 57: Three-banded ladybird larvae (7 mm).

Figure 58: White-collared ladybird.

Figure 59: Mealybug ladybird Cryptolaemus adult (4 mm).

Figure 60: Mealybug ladybird Cryptolaemus larvae (9 mm).

Figure 61: Red and blue beetle (5 mm).

Figure 62: Carab beetle (17 mm).

Figure 63: MS and larvae (16 mm). (Photos: Australian Oilseeds Federation)

7.6.4 Wasp parasitoids – of helicoverpa and other caterpillars

Figure 64: Trichogramma egg parasite.

Figure 65: Microplitis with pupae (5 mm) made by parasite after it has exited its dying helicoverpa host.

Figure 66: Microplitis pupae beside helicoverpa host.

Figure 67: Orange caterpillar parasite.

Figure 68: Orchid dupe parasite.(Photo: Australian Oilseeds Federation)

7.6.5 Fly parasitoids

Figure 69: Trissolcus wasp on GVB eggs, Trichopoda (8 mm) and eggs on GVB host.

Figure 70: Tachanid fly parasitoid of caterpillars Carcelia sp. (Photo: Australian Oilseeds Federation)

7.6.6 Hoverflies - key aphid predators

Figure 71: Hoverfly adult and maggot larvae (9 mm). Only the hoverfly larvae attacks its prey. (Photo: Australian Oilseeds Federation)

7.6.7 Lacewings – key aphid predators

Figure 72: Green lacewing adult (12 mm) and larvae (6 mm) with frass on back. Green lacewing eggs on stalks and brown lacewing adult (8 mm).(Photo: Australian Oilseeds Federation)