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INSECTICIDE RESISTANCE MANAGEMENT AND INVERTEBRATE PEST IDENTIFICATION FACT SHEET

GRDC
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NORTHERN REGION

APPROACHES TO KEY INSECT PESTS OF NORTHERN GRAINS

Integrated pest management (IPM) reduces reliance on insecticides, limiting the opportunity for resistance and promoting populations of beneficial species.

KEY POINTS

- Long-term reliance on broad-spectrum insecticides for invertebrate pest control is not sustainable.
- Sustainable insect pest management is underpinned by: correct pest identification, crop monitoring, economic thresholds and the use of selective insecticides where possible.
- Prophylactic or 'insurance' sprays can speed up the development of resistant pest populations.
- Beneficial insects make a valuable contribution to the suppression of many key pests.
- Implementing IPM improves triple bottom line outcomes – economic, environmental and social.

Why use an integrated approach?

Since the 1950s, the widespread use of synthetic pesticides has increased selection pressure for chemical resistance in pests, and also decreased the numbers of beneficial predators and parasites of crop pests.

This impact on beneficial invertebrates has also contributed to secondary pest outbreaks and more frequent pest outbreaks.

These detrimental factors can be minimised by the use of IPM.

PHOTO: JOE WESSELS

The spined predatory bug nymph is an important predator of helicoverpa, loopers and other caterpillar pests of grain crops.

IPM combines a range of tactics that can provide long-term pest control. These include biological, chemical and cultural practices.

However, to make IPM work requires a basic understanding of the relationships between pest and beneficial insects, of how different control tactics interact, and economic thresholds – the amount of insect damage that is tolerable before it becomes an economic issue.

Ideally, IPM uses selective control options that specifically target pests so as not to harm beneficials, which can continue to predate on the pest insects.

For growers unfamiliar with putting IPM into practice, the key is to draw on the experience of other growers and specialist consultants and develop a long-term strategy.

The starting point is knowing what pest threats exist or may exist, and develop manageable steps that increasingly make IPM the cornerstone of your crop protection.

A handy starting point is *Crop Insects: The Ute Guide Northern Grain Belt Edition* and the book *Good Bug? Bad Bug?* (see Useful Resources). These provide identification references and information on pest damage, thresholds, monitoring and biocontrol.

If it is too daunting to adopt IPM across the whole farm, applying the principles to one or two paddocks has proved for some growers to be a successful way to start.

Also courses on implementing IPM in grain crops are available through state departments of agriculture, often in collaboration with key industry associations (see Useful Resources).

Putting IPM into action

1 Recognise your insects

Accurate identification of beneficial and pest species is fundamental to IPM.

For example, loopers and helicoverpa are often confused, but they differ greatly in their pest status and insecticide susceptibility. Loopers are leaf-feeding pests while helicoverpa are flower and pod-feeding pests. Loopers are susceptible to most caterpillar-specific insecticides, including *Bacillus-thuringiensis (Bt)*-based biopesticides (eg Dipel®), but only helicoverpa are susceptible to the nucleopolyhedrosis virus (NPV)-based biopesticides VivusMax® and Gemstar®.

As well as being able to accurately identify a particular insect, some understanding of the biology and life cycle of target pests – and beneficial species – is also important. Knowing what causes pest populations to increase or decrease will influence control decisions. Insect populations will fluctuate within and between seasons. These fluctuations are driven by weather, presence of hosts, crop growth and the predator-prey interaction between pest and beneficial species.

Knowledge of a pest's life cycle and how the pest interacts with the crop will guide decisions about how and when to monitor a crop, and when you may need to intervene with controls.

For instance, green vegetable bug (GVB) adults often bask on the canopy top in the early morning, but retreat out of sight as the day warms up. For this reason, visual inspections often greatly underestimate GVB populations. They are best sampled with a beat sheet.

To recognise your insects:

- become familiar with the pests most likely to be a problem in your region;
- identify the most appropriate monitoring technique for each pest, as economic thresholds are based on standardised sampling protocols (see Monitor insect populations);
- determine when crops are at most risk and be familiar with crop growth stages (Table 1) to ensure crops are monitored at critical times;

Slowing resistance

Repeated exposure of pests to sub-lethal doses of insecticides hastens the selection for resistance in pest populations. Surviving pests carry genes that confer insecticide resistance. Repeated insecticide applications increase the proportion of resistant individuals in a pest population, until the majority are resistant to that particular insecticide.

In the northern region, Helicoverpa armigera *has developed resistance to most older insecticide groups. Consequently, the allowable number of sprays per crop of many newer insecticides is restricted to reduce the risk of further resistance developing in this major pest. Any IPM measures that reduce the need to spray for helicoverpa also reduce the risk of this pest developing resistance to newer, more IPM-compatible insecticides.*

Other northern grain pests with pesticide resistance issues include redbanded shield bug, Piezodorus oceanicus *(below left), and bean podborer,* Maruca vitrata *(below right), (resistance to synthetic pyrethroids – SPs) and spider mites (resistance to organophosphates – OPs).*

PHOTOS: JOE WESSELS

- use a 10-times magnification hand lens or basic dissecting microscope to accurately identify smaller pests or pests in their juvenile stages;
- use reference guides (*Crop Insects: The Ute Guide Northern Grain Belt Edition*; *Good Bug? Bad Bug?)* to ensure correct identification of pests, beneficial insects, and spiders; and
- keep a record of pest density and other relevant observations.

Many pests are detectable during multiple stages of crop development, but are most prevalent as listed in Table 1 (see page 4).

Timely information on pest outbreaks and tips for identifying and assessing the risk to crops are available each season on the Beat Sheet Blog (see Useful Resources).

Corn earworm Helicoverpa armigera. *Major flower and pod pest. Has four pairs of ventral prolegs.*

Soybean looper Thysanoplusia orichalcea. *Minor-moderate leaf pest. Has two pairs of ventral prolegs.*

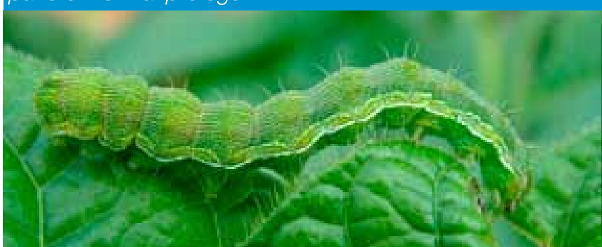

PHOTO: HUGH BRIER

PHOTO: JOE WESSELS

On initial inspection these caterpillars look the same, but they are different and inflict very different damage. Illustrated pest guides, such as the book Good Bug? Bad Bug? *and* Crop Insects: The Ute Guide Northern Grain Belt Edition, *will help with their correct identification.*

Beneficial species

Beneficial species, sometimes referred to as 'natural enemies', help to control insect pests and are key to developing a successful IPM strategy. Many beneficial species are native to Australia, while others such as the key silverleaf whitefly (SLW) parasitoid *Eretmocerus hayati* and helicoverpa egg parasitoid *Trichogramma pretiosum* were introduced.

Maintaining this valuable, natural, crop defence requires a judicious use of pesticides.

Beneficial species can be divided into three main groups:

- **parasites (parasitoids)** – which lay their eggs on or in the pest host. The parasitoid larvae eventually kill the host. Most parasitoids are specialised, attacking only one or a few pest species. Parasitoids generally target a particular life stage: eggs, a specific juvenile stage, pupae or adults;
- **predatory insects and spiders** – some are generalists preying on a range of pests, while others are specialised, for example, ladybirds feed on aphids and SLW nymphs, but not caterpillar larvae. Birds and insectivorous bats are also useful predators; and

- **bacteria, fungi and viruses** – these are microorganisms that attack and infect insects causing disease outbreaks in pest populations.

2 Know the control thresholds for pests in your crops

Given sufficient time, beneficial insects are capable of bringing even large pest outbreaks under control, but not always in time to prevent economic crop damage. This is because beneficial populations nearly always lag behind pest populations.

In many instances, beneficial insects can prevent pests reaching damaging levels if they are not disrupted by non-selective pesticides and if pre-emptive sprays with broad-spectrum pesticides are not applied to below-threshold pest populations.

Pest populations are most effectively kept below economic threshold (ET) levels when several beneficial species are active.The ET is the point where the value of likely crop damage equals the cost of control.

Monitoring pest populations to determine size relative to an established ET will guide decisions about if and when control may be warranted.

Monitoring beneficial insects can also be a guide as to whether or not a pest population is increasing, declining or static. However, the pest population is the focus of decision-making when using ET – simply because not enough is known about the impact of specific beneficial insects, and spiders, to factor them into management decisions.

The ET is the economic break-even point. Control with pesticides is only worthwhile (in most cases) if the pest population exceeds the ET. If a pest population is at or near threshold, but static or in decline, then spraying can be postponed.

Economic thresholds are available for most of the key pests (refer to the Beat Sheet Blog and/or *Insect and mite control in field crops* under Useful Resources).

3 Monitor insect populations

Populations of pests and beneficials need to be monitored:

- before planting;
- during the growing season; and
- following control treatments to determine the control's effectiveness.

Ideally, each species should be recorded by life-stage. Regular sampling records should help identify trends in pest and beneficial populations over time.

Details to be recorded for a paddock should include:

- density of key pests and beneficial species, by life-stage if relevant;
- distribution of insects within a paddock for example, patchy, field-edge only, evenly distributed;
- crop health and growth stage and any crop stress, nutrition, disease or insect damage symptoms; and
- presence of alternative hosts for key pests, for example, weeds or volunteer crops.

Many pests, including caterpillars, mirids, pod-sucking bugs, SLW, aphids and thrips and their predators/parasitoids, can breed on alternative hosts before moving into a crop. Check weeds, volunteer crops and vegetation near the paddock for pests and beneficial species.

Pests that live in the soil and under stubble can carry over between crops and attack emerging crops. Examples include wireworms, cutworms, white fringed weevils, earwigs and slugs.

Check for these by removing stubble and sampling in the top five centimetres of soil. Wireworm activity can be checked with grain baits placed in the field prior to planting. Slug traps can be used. Look for damage symptoms on underground stems and roots. Check for carry over pests prior to planting. Refer to previous year's records of pest incidents to help assess risk for a specific paddock.

At crop emergence the impact of some pests can be assessed from changes in the plant stand. Critical plant density (rather than insect numbers) can be used to decide whether the pest warrants control. For example, false wireworm will reduce seedling density to a point where areas of the crop may need to be re-sown to avoid significant yield loss.

However, note that seedling damage doesn't automatically result in yield loss. The capacity of the crop to compensate needs to be factored in when weighing up the relationship between insect pest activity and potential yield loss. For example, mungbean seedlings damaged by cereal thrips superficially appear to have suffered severe herbicide damage, but in most cases this has no impact on yield or time to harvest. By comparison, severe beanfly and helicoverpa infestations can kill a large percentage of seedlings and have a substantial impact on yield.

Pest populations or damage must be assessed randomly throughout a crop, not just at one point or along one edge. Sample at least five random sites across the whole crop, and take five random samples at each location. Look for edge effects as some pests (for example, monolepta) may concentrate along the edge of a crop closest to their previous host.

Take care not to spread disease when sampling growing crops. Some foliar diseases such as rusts and aschochyta can be spread by sampling infected crops and then sampling clean crops.

Be aware that many pests can suddenly arrive in a crop, often following a storm front (such as helicoverpa and Rutherglen bugs) or once the crop reaches a stage attractive to the pest (for example, pod-sucking bugs in flowering/pod-setting pulses).

Monitor the crop for pests and beneficial invertebrates:

- weekly during the vegetative stage of crop growth in cool weather, but twice weekly during the vegetative stage in hot weather; and

PHOTO: JOE WESSELS

Rebecca Creagh demonstrates the beat sheet technique for all except short chickpea crops. Drape the sheet over plants in the adjacent row to prevent insects being flung through these plants and escaping. Shake plants vigorously from the central metre of sampled row with a one-metre-long beat stick, then fold plants out of the way and count insects shaken onto the sheet.

- twice weekly during the most susceptible crop stages, i.e. flowering, pod-set and grain fill.

Table 1 summarises which pests to look for in northern grain crops at different crop stages.

The beat sheet is the most effective sampling method for most pests in row crops. The move to wider row spacing (0.75 to 1 metre) has facilitated the use of beat sheets for insect sampling.

A variation of this beat technique is the use of a bucket to sample sorghum heads for helicoverpa and Rutherglen bug. In this case, individual sorghum heads are beaten against the inside of a bucket to dislodge and contain the pests for counting.

Sweepnets can be used to sample insects in broadacre crops or in crops with narrow row spacing. They are most effective in shorter crops with a soft canopy or with an open canopy where the sweepnet is able to readily dislodge pests. Pests tend to concentrate at the top of the canopy – for example, mirids in flowering mungbeans.

Sweepnetting is not an effective way to reliably estimate the density of pests and beneficials in tall crops and crops with dense canopies, especially for pests feeding below the canopy top. These would include pests such as pod-sucking bugs in soybeans and helicoverpa in chickpea.

Visual sampling is used for other species that are not readily dislodged from plants, or are immobile and entrenched. Examples include silverleaf whitefly (SLW) nymphs on the underside of leaves, and bean podborer larvae in mungbean flowers.

It is important to follow standardised sampling protocols because the economic thresholds for most pests are based on these.

Details are available from local agriculture departments and agronomists, and on the Beat Sheet Blog (see Useful Resources).

4 Select appropriate control methods

An integrated approach to pest control includes the use of biological and cultural options and selective insecticides, coupled with the use of economic thresholds. Selective insecticides are essential for IPM as they do not kill non-target pest and beneficial species. The objective is to use tactics that maximise the effectiveness of beneficials and that minimise both crop loss and treatment costs.

Table 1 Northern grain and pulse pests: what to check for, when. Thresholds where available can be found on the Beat Sheet Blog, www.thebeatsheet.com.au

Crop establishment	Vegetative stage	Flowering	Pod/Seed set and grain fill
Sorghum			
Crickets Cutworm Earwigs True and false wireworms	Armyworm	Helicoverpa Sorghum head caterpillar Sorghum midge	Helicoverpa Rutherglen bug
Winter cereals – wheat, barley			
Blue oat mite Brown wheat mite Cutworm Scarabs Slugs	Aphids	Aphids	Armyworm Helicoverpa
Chickpea			
Cutworm			Helicoverpa
Summer pulses – adzuki, mungbean, navy bean, pigeon pea			
Bean fly – worst in navy bean Cutworm Seedling thrips	Aphids Helicoverpa Loopers Lucerne crown borer Silverleaf whitefly – navy bean only	Aphids Bean podborer Cluster caterpillar Flower thrips Helicoverpa Loopers Mirids Silverleaf whitefly – navy bean only Spider mites	Aphids Bean podborer Cluster caterpillar Helicoverpa Loopers Mirids Podsucking bugs Silverleaf whitefly – navy bean only Spider mites
Soybeans			
Cutworm Sugar cane armyworm – if planted into cane trash	Aphids Cluster caterpillar Grass blue butterfly Helicoverpa Loopers Silverleaf whitefly Soybean moth	Aphids Cluster caterpillar Loopers Grass blue butterfly Helicoverpa Mirids Monolepta beetles Silverleaf whitefly Spider mites	Aphids Cluster caterpillar Field crickets Helicoverpa Loopers Monolepta beetles Podsucking bugs Silverleaf whitefly Soybean moth Spider mites
Peanuts			
Peanut scarabs – no economic damage at this stage but will reach damaging size by harvest Whitefringed weevil – peanuts following previous weevil host	Aphids Helicoverpa Silverleaf whitefly – rarely	Aphids Helicoverpa Lucerne leafhopper Mirids Silverleaf whitefly – rarely Spider mites	Aphids Cluster caterpillar Etiella Helicoverpa Lucerne leafhopper Peanut scarabs Silverleaf whitefly – rarely Spider mites White fringed weevil Wireworms
Sunflower			
Cutworm Wireworm	Loopers	Helicoverpa Rutherglen bug	Rutherglen bug
Maize			
Crickets Cutworm Earwigs True and false wireworms	Jassids (vectors of wallaby ear)	Helicoverpa	
Canola			
Earth mites (BOM, RLEM)	Diamond back moth	Aphids Diamond back moth	Aphids Diamond back moth Helicoverpa Rutherglen bug

Spined predatory bug attacking helicoverpa larva in vegetative soybeans. Spraying above-threshold populations of helicoverpa at this crop stage with a biopesticide such as VivusMax® or Gemstar® conserves predatory bugs and other important beneficial insects. This buffers the crop from subsequent attacks from helicoverpa and other major pests including silverleaf whitefly. In the longer term, and if adopted on an area-wide basis, this approach also conserves grower's money as pest outbreaks become less frequent.

PHOTO: NATALIE MOORE

Cultural

Cultural controls identified by research to encourage predators or beneficial species include:

- conservation of remnant grasslands and native vegetation adjacent to cropping paddocks, which provide a source of refuge for beneficial species;
- planting crop borders or shelter belts with grasses or shrubs that encourage biodiversity (including beneficial species of insects, birds, bats) and which buffer against negative insecticide impacts; and
- replacing cultivation with no-till and stubble-retention practices that provide refuge to beneficial species (but can harbour slugs and other pests that may require specialised management).

Cultural controls that minimise the likelihood of damaging pest outbreaks include:

- using crop rotations of host and non-host crops, which reduce pest populations by breaking the continuity of their hosts.
- managing crop health to maximise the crop's capacity to compensate and minimise the impact of pest infestations;
- timing crop planting so that susceptible stages are not exposed to high pest pressure such as late-season pest build up;
- removal of weeds or other plant materials that host pests in-crop or over winter, particularly in fallows; and
- harvesting crops early – for example when peanuts are threatened by increasing aflatoxin levels due to etiella damage, or desiccating where there is a continuing risk of damage, such as in chickpea crops that put on a late growth flush when the main crop of pods is maturing.

Biological

Biopesticides, also called biological pesticides, are insect diseases (fungal, bacterial and viral) that have been produced specifically for use against insect pests.

One of the advantages of biopesticides is that they are very selective. Unlike many broad-spectrum chemical insecticides, biopesticides only kill a single pest species, or a distinct group of insects for example, caterpillars.

Another major benefit of biopesticides is that they provide an alternative to synthetic insecticides to which the target pest may have developed resistance, such as *Helicoverpa armigera* to synthetic pyrethroids (SP)s.

By specifically targeting pests without harming beneficial species, biopesticides allow predators and parasitoids to help suppress pest numbers. In some cases, it is the combined impact of the biopesticide and the beneficials that gives the required level of pest control – for example, nucleopolyhedrosis virus (NPV), trichogramma (egg parasitoids) and microplitis (larval parasitoids) controlling helicoverpa in sorghum.

Using biopesticides

As biopesticides are mostly specific to their target, correct identification of the pest species is essential.

Examples of commercially available biopesticides include *Bt* products (for example, Dipel®) to control caterpillar pests, while NPV products (for example, VivusMax® and Gemstar®) only control helicoverpa species (native budworm and cotton bollworm/corn earworm).

Some biopesticides need to be ingested by the target pest before they become active therefore good coverage at the time of application is critical. Biopesticides may on their own be less effective than conventional insecticides, but combined with the activity of beneficial invertebrates, a similar overall impact can be achieved.

Biopesticides may be most effective on particular life-stages, such as small larvae, and this needs to be known to ensure sampling data is adequate when making a decision about whether a biopesticide is a viable option, and for determining the optimum timing for application.

Biopesticides may work more slowly than knockdown synthetic insecticides. But be aware that although the larvae take longer to die, they do not continue to feed once infected, so damage ceases. Experience with the use of biopestides is important in developing the skills and confidence to use them effectively.

Using chemical insecticides

IPM does not exclude the use of chemical insecticides. Insecticides are still the mainstay of much of our pest management. However, IPM encourages the use of selective insecticides that do not adversely impact on beneficial species. This enhances the potential for biological control to contribute to insect pest control.

For instance, using indoxacab instead of methomyl to control helicoverpa in flowering soybeans greatly reduces the risk of flaring SLW, as indoxacab has far less impact on key SLW parasitoids such as *Eretmocerus hayati*.

Seed dressings and in-furrow application of broad-spectrum insecticides can reduce non-target insects' exposure to the insecticide. It may also delay the need for a foliar application, and give beneficial insects and spiders time to build up and exert greater control of pests.

If broad-spectrum insecticides are the best, or only, option, ensure application is well-timed to maximise control of the pest. For example, for pod-sucking bugs in pulses when the crop is susceptible to significant damage, delay spraying until podfill rather than acting when the pests first appear in the crop.

FREQUENTLY ASKED QUESTIONS

What should I spray?

'Softer' insecticides and biopesticides (if registered for the target pest) are preferable to the older broad-spectrum chemistry, which will have unwanted off-target effects and may lead to secondary pest outbreaks and the need for additional sprays.

However, a decision to control pests by spraying should always be carefully considered. A comprehensive insect monitoring and identification program should be a vital part of a cropping program, and understanding the role of beneficial insects and economic thresholds will make decisions easier.

When should I spray?

Spray timings will depend on the pest species targeted, its breeding cycle, plant growth stage and the potential for beneficial species to control or suppress the pest.

Use insecticides only when necessary. Prophylactic 'insurance' sprays speed up the development of resistant pest populations and can be replaced by regular crop monitoring in most instances.

When are my crops at greatest risk?

Crops are susceptible to crop loss at different critical stages, which is why being familiar with the calendar of key pest incidents (Table 1) and regular crop monitoring are critical. Adverse growing conditions for example, dry or cold or excessively hot spells can make crops less able to compensate for insect damage and more susceptible to yield loss.

I had above-threshold mirids (1/m²) in early-flowering mungbeans last week, but due to rain, I can't spray them until today. Is my crop already ruined?

As mirid numbers were relatively low at early flowering (<2/m²), and as only seven days have elapsed since their detection, yield will not be reduced, provided you spray now to prevent further damage. However, first recheck the crop. If other pests are now present, particularly helicoverpa and bean podborer, adjust your insecticide selection accordingly. Unless mirid numbers are quite high, mungbeans can compensate for early damage, particularly in a wet year. They can tolerate above-threshold mirid populations for short periods (≤7 days), because the mirid threshold is based on damage inflicted over a much longer, 28-day period.

What is the likelihood I will have a spray failure?

Correct pest identification and good spray coverage of insecticides or biopesticides will decrease the risk of a spray failure. Spray failure caused by insecticide resistance is a constant concern with Helicoverpa armigera for example, SPs and carbamates. If a spray failure occurs, do not reapply the same insecticide or another from the same group.

MORE INFORMATION

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USEFUL RESOURCES

Crop Insects: The Ute Guide Northern Grain Belt Edition
Ground Cover Direct, www.grdc.com.au/director/events/bookshop, 1800 110 044, ground-cover-direct@canprint.com.au

Good Bug? Bad Bug?
www.thebeatsheet.com.au and Queensland DAFF offices (Toowoomba, Kingaroy), Pulse Australia and Soy Australia

The Beat Sheet Blog
www.thebeatsheet.com.au

Managing Insect Pests in Field Crops
Queensland Department of Agriculture, Fisheries and Forestry
www.daff.qld.gov.au/26_3510.htm

Insect and Mite Control in Field Crops
NSW DPI, 2011, www.dpi.nsw.gov.au/agriculture/broadacre/guides/insect-mite-crops

GRDC Pestlinks
www.grdc.com.au/pestlinks

P Horne and J Page, Integrated Pest Management for Crops and Pastures
CSIRO Publishing, 2008, www.publish.csiro.au/pid/5840.htm

Beneficial Insects: The Back Pocket Guide (Northern Region)
Ground Cover Direct, www.grdc.com.au/director/events/bookshop, 1800 110 044, ground-cover-direct@canprint.com.au

Weather Essentials for Pesticide Application
www.grdc.com.au/director/research/protection

YouTube
www.youtube.com/user/theGRDC
(Search 'Hugh Brier' and other items on insect identification and sampling)

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