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RESISTANCE MANAGEMENT STRATEGY FOR *HELICOVERPA ARMIGERA* IN AUSTRALIAN GRAINS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

PHOTO: DAVID McCLENAGHAN

Helicoverpa armigera larva

KEY POINTS

- *Helicoverpa armigera* is a pest of many commodity crops, including pulses, oilseeds, coarse grains and winter cereals, as well as cotton and some vegetable crops..
- Crop damage from this pest is more significant in summer and winter pulses, maize, sorghum, canola, linseed, safflower and sunflowers.
- *H. armigera* is also problematic because of its capacity to develop resistance, which reduces the effectiveness of commonly used insecticides.
- Historical insecticide resistance from over-use of broad-spectrum insecticides resulted in devastating consequences for the Australian cotton industry.
- Selective insecticides for *H. armigera* control are now widely registered in grain crops.
- However, there is an urgent need to strategically manage the threat of resistance to maximise control and maintain efficacy of available chemistries.

Helicoverpa armigera and insecticide resistance

H. armigera is a major pest of grain crops and represents a significant challenge for the grains industry given the ongoing reliance on chemical control methods. *H. armigera* reduces yield of pulses, oilseeds, coarse grains and occasionally winter cereals. Economic losses result from larvae feeding directly on the reproductive structures of crops (seeds and grain). Grain quality may also be downgraded through unacceptable levels of damage. Although widely distributed and recorded in all states and territories within Australia, *H. armigera* is more common in the northern and coastal regions of eastern states, particularly in warmer areas.

There are over 200 insecticide products registered in Australia against *H. armigera* for grain, cotton and vegetable crops. The majority are from 3 chemical sub-groups with broad-spectrum activity: carbamates (Group 1A); organophosphates (Group 1B); and synthetic pyrethroids (Group 3A). Organophosphates are not registered for use against *H. armigera* in Australian grain crops. Insecticides from Group 6 (emamectin benzoate), Group 22A (indoxacarb) and Group 28 (chlorantraniliprole) have become more widely used in pulses due to their high efficacy and low impact on beneficial insects.

Control is complicated because field populations are resistant to numerous insecticide groups. Due to these factors, timing of chemical applications and coverage are critical issues, and growers need to understand how to minimise yield loss without increasing resistance levels. This Resistance Management Strategy (RMS) should guide growers' selection of control options and provides best practice recommendations including product windows and use restrictions to manage resistance in *H. armigera*.

Resistance management & minimisation strategy

The aim of the strategy is to minimise the selection pressure for resistance to the same chemical groups across consecutive generations of *H. armigera*. The design of the strategy is centred on chickpeas and mungbeans. Currently, and for the foreseeable future, insecticide use in these crops is likely to have the greatest impact on the selection for resistance in *H. armigera* populations. However, the principles of this RMS can be applied to other grain crops.

The strategy is primarily built around product windows for chlorantraniliprole and indoxacarb because:

- chlorantraniliprole (Altacor®) is at risk from high levels of over-reliance in pulses, but resistance frequencies are currently low; and
- indoxacarb (e.g. Steward®) is at risk due to genetic predisposition (high level genetic dominance and metabolic mechanism) and pre-existing levels of resistance in NSW and Queensland. In addition, the use of indoxacarb in pulses is expected to increase.

There are two RMS regions:

- northern region – Belyando, Central Highlands, Dawson and Callide (see Table 1); and
- central region – Balonne, Bourke, Burnett, Darling Downs, Gwydir, Lachlan, Macintyre, Macquarie and Namoi (see Table 2).

There is no RMS for the southern or western grain regions of Australia

There has been little formal monitoring of *H. armigera* in the southern and western grains regions (Victoria, Tasmania, SA and WA). These regions have little broadacre summer grain crop production and biological indicators suggest the risk of *H. armigera* occurring at densities that may result in control failures is low. If required, the central region RMS may be used for *H. armigera* management in summer crops in southern and western grains regions.

Use of broad-spectrum insecticides

The early use of synthetic pyrethroids (SPs) in winter pulses (August to early September) in this RMS assumes that early infestations of *Helicoverpa* will be predominantly *H. punctigera*. This species is susceptible to SPs. If adopting this strategy, be aware of the following risks:

- recent monitoring with pheromone traps has shown that *H. armigera* can be present in all parts of the northern region from early August;
- reduced efficacy of SPs when *H. armigera* is present can be masked when treating very low population densities (<2/m^2); and
- even low-level populations of *H. armigera* when treated with SPs will select for further resistance.

TABLE 1 Best practice product windows and use restrictions to manage insecticide resistance in *H. armigera* in the northern region.

Northern region: Belyando, Central Highlands, Dawson & Callide

Selectivity	Insecticide	June				July				Aug				Sept				Oct				Nov				Dec				Jan				Feb				Mar				April				May			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Increasing ↑	*Bacillus thuringiensis* (Bt)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Helicoverpa viruses	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Paraffinic oil Note 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SELECTIVITY	Chlorantraniliprole Note 2,3	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	1	1	1	1	✗	✗	✗	✗
	Indoxacarb Note 4	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Spinetoram Note 2,4,5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Emamectin benzoate Note 2,4,5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Carbamates Note 2,4,6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Decreasing ↓	Pyrethroids Note 2,4,7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

TABLE 2 Best practice product windows and use restrictions to manage insecticide resistance in *H. armigera* in the central region.

Southern Queensland, central and northern NSW regions: Balonne, Bourke, Burnett, Darling Downs, Gwydir, Lachlan, Macintyre, Macquarie and Namoi

Selectivity	Insecticide	June				July				Aug				Sept				Oct				Nov				Dec				Jan				Feb				Mar				April				May			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Increasing ↑	*Bacillus thuringiensis* (Bt)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Helicoverpa viruses	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Paraffinic oil Note 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SELECTIVITY	Chlorantraniliprole Note 2,3	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗
	Indoxacarb Note 4	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	1	1	1	1	1	1	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Spinetoram Note 2,4,5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Emamectin benzoate Note 2,4,5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Carbamates Note 2,4,6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Decreasing ↓	Pyrethroids Note 2,4,7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

KEY ✓ (green) No restrictions ✗ (white) DO NOT USE during this period 1 (orange) No more than one application per crop per season 2 (blue) No more than two applications per crop per season

ADDITIONAL INFORMATION Note 1: Some *n*C27 paraffinic spray oils can be used to suppress *Helicoverpa* populations and are best used as part of an IPM program. Note 2: Observe withholding periods (WHP). Products in this group have WHP 14 days or longer. Note 3: Maximum one spray of chlorantraniliprole alone or in mixtures per crop per season. Note 4: Refer to label for warning of insecticide risk to bee populations. Note 5: Maximum two consecutive sprays alone or in mixtures per crop per season. Note 6: Moderate resistance is present in *H. armigera* populations – field failures likely. Note 7: High resistance is present in *H. armigera* populations – field failures expected.

Integrated pest management is a central feature of resistance management

The use of integrated pest management (IPM) tactics for *H. armigera* management is integral to achieving a reduction in insecticide use and helping to minimise resistance selection pressures. Examples of IPM tactics for *Helicoverpa* include minimising the risk of pest build-up on in-crop weeds, pupae-busting stubbles where pupae are overwintering (especially corn/maize, late sorghum, summer mungbeans), spraying only when pest populations exceed economic threshold, and using the softest insecticides available to preserve beneficial insects.

When using insecticides, monitoring is key to better targeted spraying and effective management. The use of pheromone traps (which attract male moths) can provide an early warning of moth migration into an area or their emergence from local winter diapause. Traps should be set up in late winter/early spring. The beat-sheet is the most commonly used sampling tool in the northern region. Obtain an estimate of pest and beneficial insect numbers by taking at least 5 to 10 beatsheet samples from across the field.

Sweep netting is a quick and easy method to sample some crops but is more subjective. Take a minimum of 5 sets of 10 sweeps and calculate the average number of larvae per 10 sweeps.

Other general recommendations

- Avoid repeated use of insecticides from the same chemical group against *H. armigera* or other pests, as this will increase selection pressure for resistance development, not only in *H. armigera* but also in other species;
- Comply with all directions for use on product labels including applying the recommended label rate. **DO NOT cut rates and DO NOT exceed the maximum number of allowable applications per crop per season**.
- Do not re-spray a crop in the same season where a known spray failure has occurred using the same product or another product from the same chemical group.
- Where possible, avoid use of SPs and organophosphates (OPs) for control of other crop pests. Instead use target-specific 'selective' chemicals such as pirimicarb for aphids and Bt or virus for caterpillars, which will help to preserve beneficial insects.
- Ensure the target pest is identified correctly so the most effective insecticide and rates are used. Misidentification and incorrect insecticide selection results in poor control and contributes to selection for resistance.
- Assess *H. armigera* and beneficial populations by regular monitoring to determine if chemical control is warranted.
- Consider the impact on target and non-target pests and beneficial insects when applying insecticide sprays.
- Ensure spray rigs (both ground and aerial) are calibrated properly and sprays achieve good coverage, particularly in crops with a bulky canopy.
- Monitor post-treatment pest populations for evidence of loss of field efficacy and report field failures.

TABLE 3 Explanatory notes for product windows in all regions.

Insecticide	Number of insecticide windows	Duration of insecticide windows	Maximum number of applications/crop/season
Chlorantraniliprole (Altacor®)	2	10 weeks	1
• 10-week windows restrict selection to a maximum of 2 consecutive generations of *H. armigera* (includes 2–3 weeks residual beyond the end of each window i.e. 12–13 weeks total exposure). • Start date of first window correlates well with historical data relating to average daily temperatures that result in early pod-set. • Exposure of 2 consecutive generations is offset by long non-use periods (8 weeks in the central region and 18 weeks in the northern region). • Use is not recommended in spring mungbeans as there is less likelihood of both *H. armigera* and bean pod borer being present.			
Indoxacarb (e.g. Steward®)	Northern – 3 Central – 2	6 weeks	1
• 6-week windows restrict selection to a single generation of *H. armigera*. • Each window is followed by a non-use period of a minimum of 6 weeks. • Indoxacarb is an important early season rotation option for chickpeas and faba beans, and provides a robust selective alternative to Altacor® when *Helicoverpa* pressure is high.			
Bacillus thuringiensis	1	Season long	No restrictions
***Helicoverpa* viruses**			No restrictions
Spinetoram (e.g. Success Neo®)*			2
• Low resistance risk and not widely used.			
Emamectin benzoate (e.g. Affirm®)*	1	Season long	2
• Very low resistance frequency and not used widely. • However, emamectin benzoate is a good option for rotation to spread resistance risk away from Altacor®. • BUT industry needs to become more confident with using this product for it to be of value in resistance management.			
Carbamates	1	Season long	1
Synthetic pyrethroids			
• *H. armigera* resistance is present at moderate to high levels, but one strategic application per season in regions where *H. punctigera* predominates in early spring may be effective. • Carbamates are a rotation tool for indoxacarb and Altacor® either early season in chickpeas or late season in mungbeans.			

*Resistance monitoring for selective products is a key component of the RMS and changes in resistance frequencies may result in the introduction of product windows for those insecticides not currently windowed.

FREQUENTLY ASKED QUESTIONS

Why doesn't this grains RMS have the same windows as the cotton IRMS?

The RMS for grain crops is not intended to 'sync' with the cotton IRMS. Recommended windows for use in grains and cotton do not align, and the level of insecticide used for *Helicoverpa* control in cotton is relatively small in comparison with the areas of winter and summer grain crops potentially treated each year. It is considered that insecticide use patterns in cotton pose little risk to the ongoing management of resistance, relative to the risk posed by year-round, high level use in grains. For further information on the cotton IRMS go to: https://www.cottoninfo.com.au/publications/cotton-pest-management-guide.

Will resistance develop to emamectin benzoate and spinetoram if their use is not windowed?

Insecticides that are not windowed, such as emamectin benzoate and spinetoram, are currently not considered to be at high risk of resistance development based on low frequencies of resistance in field populations of *H. armigera*. However, if usage patterns of these insecticides increase then selection for resistance it is also likely to increase.

Which beneficial insects should I be looking out for and can they control *Helicoverpa armigera*?

There are a large number of beneficial insects that will attack the eggs, larvae and pupae of *H. armigera* and contribute to suppression of this pest (and other crop pests). These include predators (e.g. damsel bugs, red and blue beetles, ants, lacewings) and parasitoids (e.g. *Trichogramma*, *Microplitis*, *Ichneumon* wasps and Tachinid flies). Growers are encouraged to monitor trends in beneficial populations and avoid the use of unnecessary insecticide applications.

Why are product windows common to all areas in southern Queensland and central and northern NSW?

H. armigera moths are highly mobile and have the capacity to move between all areas in the central region, potentially increasing the risk of further exposing cohorts of insects previously selected for resistance.

What is the likelihood that I will have a spray failure?

The risk of spray failures is high for SPs and carbamates due to historical resistance to these products. The risk of spray failures due to resistance is currently low for the selective products indoxacarb, chlorantraniliprole and emamectin benzoate. If spray failures of these products occur, first check the application was made correctly. These products are primarily active by ingestion, which means the larva has to eat plant material treated with the insecticide. To achieve a high level of efficacy, the insecticide must be applied with excellent coverage. This means that attention to water volume, nozzle selection and speed in relation to crop canopy and weather conditions is critical. In addition, *Helicoverpa* larvae will not feed if temperatures are below 12°C. Application under cooler conditions may result in reduced or slower rates of larval mortality. If application is ruled out as a reason for unsatisfactory control with selective products and you suspect resistance, contact your local entomologist.

How do I prevent spray failures into the future?

This RMS is designed to minimise selection pressure for resistance to the same chemical group across consecutive generations of *H. armigera*. The use of a broad range of IPM options will reduce over-reliance on any one chemical group. Growers should use recommended economic thresholds and avoid prophylactic sprays. Following these recommendations and complying with label instructions will minimise the risk of spray failures occurring as the result of insecticide resistance and maintain effective insecticide control of *H. armigera* into the future.

This strategy was developed by the National Insecticide Resistance Management (NIRM) working group of the Grains Pest Advisory Committee (GPAC), and endorsed by CropLife Australia. GPAC is a GRDC-funded project which provides strategic advice to the GRDC on pest issues. NIRM, chaired by Dr Paul Umina, is responsible for developing insecticide resistance management strategies for a number of grain pests. The group's representative membership ensures engagement of agro-chemical industries, researchers, advisers and CropLife Australia.

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USEFUL RESOURCES

Science behind the Resistance Management Strategy for *Helicoverpa armigera* in Australian grains, NIRM, https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies

***Helicoverpa*,** QDAF, https://ipmguidelinesforgrains.com.au/pests/helicoverpa

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