Why manage insecticide resistance in *Helicoverpa armigera* in the Northern Grains region?

***Helicoverpa armigera* is a significant pest in the Northern Grains Region, impacting pulses, oilseeds, coarse grains, and occasionally winter cereals. Control of *H. armigera* is complicated because field populations are resistant to a number of insecticide groups, placing increased pressure on the products that are effective. Insecticide resistance management strategies (RMS) are designed to minimise the selection pressure for resistance and prolong the useful life of insecticides.**

Chickpea and mungbean are presently the crops in which *H. armigera*, and other pests, are managed most intensively with insecticides. For this reason, the management of insecticide resistance in *H. armigera* is focused on these crops. Chickpea and mungbean crops are an important component of northern region farming systems with an average combined annual value of over $650M. The loss of key insecticide groups including Group 22A (indoxacarb; e.g. Steward®); Group 28 (chlorantraniliprole; e.g. Altacor®); Group 6 (emamectin benzoate; e.g. Affirm®) in these crops will have significant impacts on the cost of growing these crops and the ability to produce quality grain.

Table 1. Chickpea and mungbean average annual production NSW and QLD between 2009 and 2019 (ABS 2019).

	Yield (t)	Production (t/ha)	Price ($/t)	Value
Chickpea	893,337	1.26	660	$ 589,602,310
Mungbean	66,000	0.87	1080	$ 71,280,000

Annual insecticide resistance monitoring in *H. armigera* populations by NSW DPI has shown increasing levels of resistance to indoxacarb, low levels of resistance to chlorantraniliprole (Figure 1), and no evidence of resistance in emamectin benzoate or spinetoram.

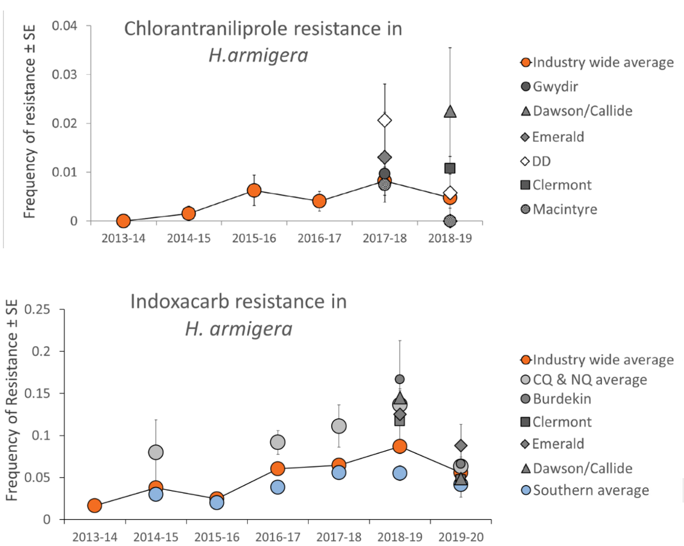

Figure 1. Chlorantraniliprole and indoxacarb resistance 2013–2019.

Summary

Having access to effective chemistry for *H. armigera* management is worth up to $24M annually in chickpea and mungbean crops in the Northern Grains Region, which provides a strong incentive for the grains industry to take measures to manage the risks of developing insecticide resistance. The Helicoverpa RMS for grains aims to reduce selection pressure on indoxacarb and chlorantraniliprole, the selective chemistries most widely used in crops across the Northern Grains Region.

Survey responses suggest that growers and agronomists are currently taking the risk of resistance seriously, with the all respondents recognising the importance of rotating insecticide chemistries to prolong their effective lifespans. Many agronomists are particularly concerned about the risks of resistance to chlorantraniliprole, due to its widespread use over a number of different crops.

Overall the current Helicoverpa RMS was identified as being highly suitable in achieving this goal. However there were suggestions it may be challenging to achieve suitable alignment of the RMS with crop development in some seasons, particularly in late planted chickpea crops, and that alternative selective chemistry such as Affirm®, may need to be windowed in the future as its use increases.

These results illustrate why it is vital that the grains industry implements a RMS for *H. armigera*. Whilst the greatest risk appears to be in the Belyando, Dawson/Callide and Central Highlands regions, all Northern Grains Region growers are encouraged to adopt the current RMS. *H. armigera* moths are highly mobile and we know from past research that movement occurs between all eastern Australian cropping regions, meaning that resistance genes can easily spread between central Queensland, the Darling Downs, Northern NSW and beyond.

Whilst the majority of the Northern Region has not had a winter crop since the Helicoverpa RMS was first introduced in 2018, central Queensland growers and agronomists have managed to plant and harvest chickpea and mungbean crops, making them well placed to judge the suitability and effectiveness of the RMS.

This case study will focus on grower and agronomist awareness and use of the 2018 *Resistance management strategy for Helicoverpa armigera in Australian grains*, their understanding of its importance and the expected industry economic cost of resistance.

Queensland Government

Methods

Economic analysis

Using historical records of planted hectares and tonnages for chickpea and mungbeans in NSW and QLD (Table 1) the following comparisons were made to evaluate the current industry benefits of access to effective chemistry for *H. armigera* control:

1. The expected incidence of helicoverpa requiring chemical control was estimated from the percentage of years when sprays were necessary and the historically affected area (Table 2).
2. Potential losses when crops were not managed for Helicoverpa and the losses that occur under management with insecticides (Table 3).

Table 2. Expected helicoverpa incidence*.

	Average annual area		Incidence (% years sprays needed)	Area affected (% area sprayed in those years)
	planted (ha)	sprayed (ha)		
Chickpea	793,380	35,702	25%	18%
Mungbean	83,356	44,345	95%	56%

Although total average chickpea hectares planted annually were vastly higher than mungbeans, a combination of lower occurrence of *H. armigera* requiring control in winter, and less hectares needing to be sprayed, resulted in a higher proportion of mungbeans hectares sprayed, with management likely to include an insecticide spray for *H. armigera* in 95% of years.

Table 3. Impact of *H. armigera* on pulses*

Crop	Average annual area sprayed (ha)	Yield loss	
		Potential	Managed
Chickpea	35,702	25%	3%
Mungbean	44,345	46%	3%

These economic values were used to contrast grower and agronomist attitudes towards resistance management, to gauge whether industry is (i) aware of the cost of resistance and (ii) basing their decisions on an informed knowledge of the risk associated with current management practices.

Note: Incidence, area affected, and managed and potential yield loss in Tables 2 and 3 have been adapted from Murray *et.al.* 2013

Medium helicoverpa larvae in mungbeans.

Industry survey

A survey to determine the awareness and attitude of growers and agronomists towards the Helicoverpa RMS in the Northern Grains Region was conducted in 2019.

The survey asked:

1. If they had previously experienced issues controlling *H. armigera* due to insecticide resistance.
2. How they ranked the importance of:
   - economic thresholds,
   - in-crop sampling,
   - range of insecticide options
   - managing resistance in *H. armigera*.
3. If they were aware of the Helicoverpa RMS for grains, particularly for chickpea and mungbean.
4. If they had used the Helicoverpa RMS for grains in the past 2 years, and in which crops.
5. If there were concerns about current practices in their region which may be increasing the resistance pressure on insecticides.

There was also opportunity within the survey to provide further feedback on the RMS.

Results

Given the reliance on chemical control in managing *H. armigera* in pulse crops in the northern region, we can confidently attribute the difference between managed (3%) and potential losses (25–46%) to the use of effective chemistry. Using average yields and prices from Table 1 and sprayed hectares, managed yield loss, and potential yield loss from Table 3, it is possible to calculate the annual benefit of access to effective chemical options for the control of helicoverpa.

Average chickpea and mungbean yields with current *H. armigera* management practices and 3% loss are 1.26 and 0.87 t/ha respectively; the current economic output can be calculated $29.6M for chickpeas and $41.6M for mungbeans annually. However, under a scenario where there are no effective *H. armigera* control options due to insecticide resistance, average yield in crops affected by *H. armigera* would be 22% lower in chickpeas and 42% lower in mungbeans, reducing the average annual economic output to $23.1 and 23.7M respectively.

In the areas impacted by *H. armigera*, the annual benefit of effective insecticides options is therefore over $6.5M for chickpeas, and almost $18M for mungbeans (Table 4).

These figures should provide strong incentive for growers and agronomists to adopt the Helicoverpa RMS, as each year for which resistance is delayed, and insecticides continue to provide effective control, is potentially worth $24.4M to industry.

Survey results support that growers and agronomists in the northern grains region are taking the threat of insecticide resistance developing in H. armigera seriously, with 100% of surveyed stakeholders aware of the Helicoverpa RMS and supporting the idea of rotating chemistries to prolong access (Table 5).

Table 4. Comparison of economic value of northern region pulse crops under current management compared with a scenario of no effective helicoverpa control options.

Crop	Annual averages		Current		Potential		Benefit of control
	Sprayed area (ha)	Price ($/t)	Production (t/ha)	Value	Production (t/ha)	Value	
Chickpea	35,702	660	1.26	$ 29,689,783	0.98 (-22%)	$ 23,158,030	$ 6,531,752
Mungbean	44,345	1080	0.87	$ 41,666,562	0.49 (-42%)	$ 23,749,940	$ 17,916,621
Total							**$ 24,448,373**

Table 5. Survey results from agronomists and growers in the Northern Grains Region.

Question	Positive response
Have previously experienced with insecticide resistance	86%
Aware of Helicoverpa RMS	100%
Have used the RMS in pulse crops	71%
Concerned about practices which may cause resistance	86%

The majority of survey respondents indicated that they had previous experience with insecticide resistance, largely with *H. armigera* in cotton in the late 1990s. Agronomists with less than 20 years of industry experience are unlikely to have had direct experience in dealing with insecticide resistance in the Northern Grains Region.

All agronomists and growers surveyed were aware of the Helicoverpa RMS, with almost all indicating that they would use it when making decisions or client recommendations. Those who had not yet used the Helicoverpa RMS overwhelmingly indicated it was because they had not managed chickpea or mungbeans crops in the preceding 2 years, rather than any concerns with its content or practical application.

Economic thresholds, in-crop sampling, range of insecticide options, and managing H. armigera resistance were all regarded as important factors, unsurprisingly as each are inherently linked in *H. armigera* control.

Some consistent themes emerged in the additional feedback growers and agronomists provided, including general concern about the overuse of Altacor® (chlorantraniliprole; Group 28) among survey participants, due to its wide range of registered crop options and long residual activity. There was a commonly expressed hope that its registered crop range does not expand further to include sorghum, as this would result in widespread use in both summer and winter crops.

There were some further concerns that in years with widespread late chickpea plantings, vulnerable chemistries would be used over extremely large areas, and that the windowing of products in the RMS may not match the periods of crop susceptibility to helicoverpa in all regions. This suggests that the RMS may need to be flexible and adjusted to fit with seasonal and regional cropping calendars in order to be practical and relevant for industry.

Survey respondents indicated that they had used other selective chemistries, primarily Affirm® (emamectin benzoate; Group 6), as a third option when required, but preferred to rotate between Steward® (indoxacarb; Group 22A) and Altacor®. Despite this, a number of respondents identified that current pricing made Affirm® a very attractive selective option, which is likely to result in increasing use in future years. If usage increased, then they were supportive of this product also being windowed to ensure its longevity.

Finally, despite the strong support from survey participants towards the Helicoverpa RMS, and a general feeling that most in the industry were doing the right thing, many identified practices which are likely to put the sustainability of all insecticides at risk , including:

- Cutting rates to reduce cost, or to stretch existing product out over more hectares, and
- Multiple uses of the same product within a 2-week window.

The fact that such practices, which increase the risk of resistance development, are relatively commonplace in the northern grains industry, illustrates that ongoing support for industry is required to reinforce the importance of the Helicoverpa RMS in effectively and sustainably managing this pest.

Insecticide resistance and control

The impact of practical resistance on efficacy can vary from none to severe. The effects on pest control depend on the initial frequency of resistance genes in the population, the degree of dominance of those genes and the level of selection pressure.

Resistance controlled by dominant genes will increase rapidly in populations because all carriers of will be able to survive a field rate of insecticide. In the case of indoxacarb, known genes for resistance are genetically dominant, which means that frequency can increase rapidly because resistance is expressed equally in all carriers of resistance.

Australian industry supports preemptive resistance surveillance in *H. armigera* to reduce the risk of lost productivity due to reduced insecticides efficacy. Resistance monitoring results show that we are currently in the 3rd stage of field-evolved resistance for indoxacarb, and implementing management tactics to prevent escalation to the next level (expected field failures; Table 6) is critical.

Table 6. Resistance categories ranging in severity from incipient (1) and early warning (2) to practical resistance (3-5)*.

Category	% resistance	At risk insecticides for H. armigera
1. Incipient resistance	<1%	Bt, emamectin benzoate
2. Early warning	1-6%	chlorantraniliprole, indoxacarb (SQ & NSW)
3. Field failures possible	6-20%	indoxacarb (CQ & NQ)
4. Field failures expected	20-50%	carbamates
5. Field failures reported	>50%	pyrethroids

*adapted from Tabashnik *et. al.* 2014.

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

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

KEY N (green) No restrictions; W (white) DO NOT USE during this period; O (orange) No more than one application per crop per season; B (blue) No more than two applications per crop per season

The *Helicoverpa armigera* RMS (2018).

Further information and references

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Contact details

Melina Miles
T (07) 4529 4169
M 0407 113 306
E melina.miles@daf.qld.gov.au

Lisa Bird
T (02) 6763 1128
M 0438 623 906
E lisa.bird@dpi.nsw.gov.au

A helicoverpa larva in chickpea.

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