Managing resistance: Your IRMS and RMP questions answered

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Resistance is the greatest threat to the continued availability and efficacy of any insecticide available for use in cotton, including the Bt proteins in transgenic varieties. The Australian cotton industry's Insecticide Resistance Management Strategy (IRMS) seeks to manage the risk of resistance in *Helicoverpa spp*., aphids, mites and whitefly, both in conventional and Bollgard II cotton.

Additional resistance management requirements are also in place to minimise the risk that *Helicoverpa spp*. will develop resistance to the insecticidal proteins in Bollgard II.

The Resistance Management Plan (RMP) for Bollgard II is designed to prevent *H. armigera* from developing field-scale resistance. This is important as the two insecticidal genes in Bollgard II are likely to be the base to which newer insecticidal genes are added. This means that the protection of Bollgard II also represents the protection of future investment in transgenics for the Australian cotton industry.

In 2004–05, more than 200,000 hectares or about 70 per cent of the industry was planted to Bollgard II. In 2005–06 this will increase to about 80 per cent. Given the high proportion planted to Bollgard II, some stakeholders are questioning the importance of maintaining a focus on resistance to conventional insecticides through the IRMS.

In this article we address the questions most often asked about the impact of Bollgard II on management of resistance to conventional insecticides. We also answer some common questions dealing with various aspects of the RMP for Bollgard II.

More technical information on the key elements of the IRMS and the RMP can be found in the 2005–06 Cotton Pest Management Guide (CPMG), a link to which will appear on the Cotton CRC web site.

Even with the large uptake of Bollgard II cotton, pupae busting remains a critical component of the strategies to control insect resistance. (Photo by Louise Rossiter)

How do insects develop resistance?

Genes for resistance naturally occur at very low frequencies in insect populations and remain rare until they are selected for with a toxin. Once a selection pressure occurs, such as an application of a pesticide or exposure to Bollgard II, resistance genes can increase in frequency because the pests carrying them are more likely to survive and produce offspring.

If selection continues, the proportion of resistant insects may increase to the point where the pest cannot be effectively controlled by that pesticide or transgenic toxin.

Will the large uptake of Bollgard II reduce populations *Helicoverpa*?

H. armigera is closely linked with cropping regions so it is possible that a reduction in numbers of this pest will occur over time. In most seasons, the majority of moths are locally generated. And in many regions, cotton is a reliable and significant host for *H. armigera*.

So Bollgard II may act as a 'sink' and influence the overall population size. But this species uses hosts other than cotton and, even with widespread use of Bollgard II, population sizes may be more strongly influenced by the abundance of alternative hosts.

Each year, *H. punctigera* moths migrate from outside the cotton growing regions. As these moths are largely generated in other environments, Bollgard II will have little effect on the size of these populations, especially early in the cotton season following the annual spring migration.

What is the scientific basis of the IRMS?

The IRMS aims to minimise selection across consecutive generations of the pest. This is achieved by:

- Using 'windows' to restrict the time that the pest is exposed to a group of chemicals;
- Restricting the number of applications of the same type of chemical;
- Rotating the application of different types of chemistries; and,
- Pupae busting and employing good farm hygiene to prevent resistant individuals from surviving through winter.

Pest life cycles determine the length of the 'windows' around which the IRMS is

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built. As the life cycles of *Helicoverpa spp*. and the sucking pests are very different, a strategy applied for one will not necessarily manage resistance for others.

A Troubleshooting Committee (TTC) was established by the Transgenic and Insect Management Strategy (TIMS) Committee to act on its behalf to respond quickly to requests to vary the IRMS temporarily for specific regions. The TTC is not able to approve major changes to the Strategy — that is the role of the TIMS Committee. The process for requesting a within-season change to the IRMS is outlined in the CPMG.

What is the scientific basis of the RMP?

The RMP is comprised of five components that interact to effectively slow the evolution of resistance. These are:

- Using refuges to produce Bt susceptible moths to dilute resistance;
- Limiting exposure to Bt by restricting planting dates;
- Controlling volunteer and ratoon plants;
- Restricting the use of foliar Bt; and,
- Mandatory cultivation of crop residues.

Where exceptional circumstances exist, the APVMA (if approached by Monsanto on behalf of a growers' association) will consider requests for a variation to the planting window. If a request is approved, the variation only affects the planting window component of the RMP for the requestee/s. All other components of the RMP remain the same.

How does the migration of moths within a season impact on resistance management?

H. punctigera: Immigrants from inland Australia and other areas will generally not have been exposed to pesticides or transgenic cotton and so effectively dilute any resistance in local *H. punctigera* populations.

H. armigera: Recently, some genetic work showed *H. armigera* moths moving up to 1200 kilometres between regions. Insecticide or Bt resistance in one region can therefore rapidly spread to other regions by moth migration. The IRMS accounts for moth movement between different cotton growing regions by limiting the time period over which most insecticides are available and trying to have consistency in the IRMS across regions.

This reduces the chance that a moth which has survived insecticide treatment as a grub and migrated between regions would lay eggs that would also be exposed to the same insecticide group.

Moth migration also affects the Bollgard II RMP. So a key criteria in evaluating variations to the Bollgard II planting window is the distance between the cotton growing region requesting the change and the nearest significant planting of Bollgard II.

Do we need an IRMS when large areas are planted to Bollgard II?

Large areas of Bollgard II will not change the gene frequencies for resistance to conventional insecticides being carried by *H. armigera* moths. The same proportion of resistant and susceptible moths will continue to lay eggs in cotton — conventional or Bollgard II.

So the likelihood of resistance development (an increasing gene frequency) to foliar and soil applied insecticides remains the same, even if the overall size of the *H. armigera* population is reduced.

What is the purpose of refuge crops?

The aim of a refuge crop is to generate significant numbers of susceptible moths (SS) that have not been exposed to selection by Bt proteins. Moths produced in the refuge crops will disperse to form part of the local mating population where they

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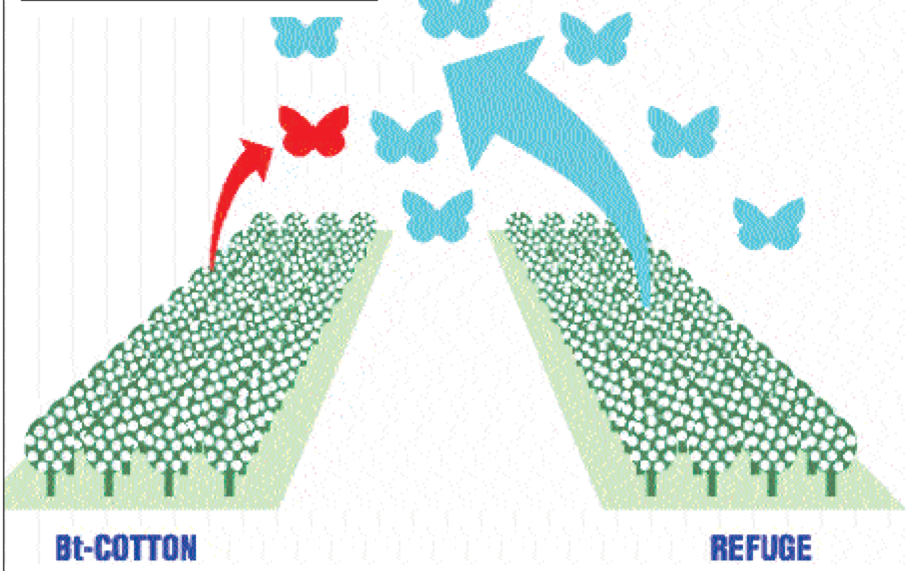

Moths produced from refuges dilute resistance genes in the population. (Diagram by Gary Fitt).

may mate with rare resistant moths (RR) that emerge from Bollgard II crops.

This dilution effect reduces the chance that resistant moths will meet and mate and so can slow the rate at which resistance evolves — the refuge is the counter balance to the selection for resistance that occurs in Bollgard II crops.

This strategy should be effective because resistance to the Bt proteins is functionally recessive, at least for the cases of Bt resistance identified so far. So the offspring of such matings, known as heterozgotes (RS), are controlled by Bollgard II cotton when they are young (larger heterozygotes are less well controlled by Bollgard II).

It is crucial that the timing of the production of moths from refuges matches that from Bollgard II crops. For this reason, refuge crop options (sorghum, corn) which produce moths for a shorter period than cotton, need to have several staggered plantings to extend the period over which moths are produced.

Do Bollgard II refuges also manage resistance to other insecticides?

For many of the conventional insecticides (to which resistance has already developed), resistance mechanisms are functionally dominant. Heterozygotes (RS) are almost as resistant as the fully resistant (RR) individuals and can survive the insecticide application. So they probably make up a large part of the surviving population. In such circumstances of a dominant resistance, the dilution effect created by refuges is far less effective.

How were the current requirements for refuge crops determined?

The relative sizes of refuge crops required in the RMP are based on models

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and knowledge of the relative numbers of Helicoverpa moths which can be generated from different crop types. The likely moth productivity of the different refuge options has been determined through large-scale field experiments over several seasons.

Only refuge options that have been assessed in this way are currently approved by the APVMA. A refuge of 10 per cent unsprayed cotton was considered as the reference point. For instance, an average pigeon pea crop produces twice as many moths as the same area of unsprayed cotton, so the pigeon pea refuge option requires only half the area (five per cent) of an unsprayed cotton refuge.

What makes a refuge effective?

Looking after refuges, including weed control, timely irrigation and all factors that make the refuge 'attractive' to female moths laying eggs, is the key to ensuring that they are effective. Managing resistance is a population level activity, and every refuge makes an important contribution to the overall RMP for the district, valley, and, because *H. armigera* disperse widely, for the whole industry.

To help ensure the refuge strategy is working properly, during the 2005–06 season Monsanto will audit the quality of refuges on every farm that grows Bollgard II to ensure that they are well maintained.

Why can't a conventional crop from a neighbouring property act as a refuge?

It is the responsibility of Bollgard II growers to produce and maintain their own effective refuge. In some cases, a conventional crop grown on a neighbouring property may satisfy the requirements of a refuge for Bollgard II. But the crop may not be managed in a way that complies with the RMP. Since growers cannot control the management of a neighbour's crop, it is not sensible to rely on these areas as refuges for Bollgard II.

Is there an alternative to growing refuges for resistance management?

A mechanism that dilutes the proportion of resistant (RR) versus susceptible (SS) moths in the population will always be a requirement of the RMP. There may be innovative and cost effective alternatives and some are currently being investigated.

In the meantime, it is important to recognise that the costs associated with refuge crops are an investment in the longer term value of transgenic technology for the industry. Growing an attractive refuge should be considered as an integral part of growing Bollgard II.

The moth productivity of different refuge options has been determined by experiment.

Is pupae busting still important for resistance management?

Cultivating between seasons is an effective, non-chemical method of preventing resistant pupae from surviving from one season to the next. It is still important to pupae bust in conventional cotton because the large uptake of Bollgard II will not significantly influence the rate that *H. armigera* will develop resistance to conventional chemistry.

Although we expect few larvae to survive in Bollgard II, those that do are likely to be resistant and must be killed so that the next generation of moths (emerging the following spring) are not enriched with resistant individuals.

Why is it important to control volunteers or ratoon cotton plants?

It is important to prevent the establishment of conventional cotton in Bollgard II fields. This is because larvae can grow on the conventional plants and then move onto Bollgard II. If this occurs, larger heterozygote larvae may survive on Bollgard II while susceptible larvae that move on to these plants will die.

The heterozygote survivors could contribute to increasing the frequency of resistance genes in the *H. armigera* population. By removing conventional volunteers from Bollgard II fields, heterozygote (RS) larvae will not have an opportunity to grow large enough to survive on Bt plants.

The presence of Bollgard II volunteer plants in a conventional crop selects for Bt resistance. Heterozygous larvae that grow on the conventional cotton may move onto and survive on Bollgard II volunteers, whereas susceptible larvae (SS) that move on to these plants will die.

So those volunteers or ratoon Bollgard II plants may lead to an increase in the frequency of resistant individuals (both RS and RR) in the population. If the field happens to be a designated refuge crop then the presence of Bollgard II volunteers will be diminishing the value of the refuge.

Why is it important that foliar Bt sprays are not used on refuges?

Foliar Bt sprays select for resistance to the same toxins present within Bollgard II. By preventing the use of foliar Bt on all refuges (sprayed and unsprayed) the likelihood of producing moths that are susceptible (SS) rather than resistant (RR) to the Bt proteins is maximised.

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