Review of Insecticide Resistance Management Strategy principles

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The voluntary insecticide resistance management strategy (IRMS) was initiated in the early 1980s to manage pyrethroid and endosulfan resistance in *Helicoverpa armigera*. It has since evolved to include aphids, mites and whiteflies.

As new insecticides and resistance problems have developed, the requirements of the IRMS have changed. We are now trying to manage resistance to more than 17 different chemical groups.

While increasing the number of chemistries available to control pests potentially reduces selection and hence the potential for resistance, individual chemical users applying the same chemistries at different times across the season, increases the potential for resistance. In addition, chemical use on non target insect species may have adverse effects on resistance in those species.

Consequently, chemical use must be carefully managed and the methods used to do that vary with different insect species according to their ecology and life cycle. To illustrate the different strategies taken we have grouped pests into long life cycle insects (primarily Helicoverpa species) and short life cycle insects (aphids, mites and whiteflies), as the strategies for these two groups have some important similarities and differences.

Long life cycle insects — Helicoverpa

The major resistance management principles for Helicoverpa species include restricting the use of insecticides within defined time periods and restrictions on the number of consecutive and total applications. For ideal resistance management, chemicals should be windowed for use over a time period equal to the life cycle length of Helicoverpa species to restrict selection to only one generation.

This was the tactic originally taken for pyrethroid resistance management with other non pyrethroid chemicals used to control earlier and later generations. Windowing of chemistries remains central to current strategies but has evolved to include changes in pest control and the practicalities of cotton production — including more chemistries, softer chemistries and beneficial manipulation, emergence of resistance in other pests and the costs associated with controlling multiple pests. The result is much less restrictive windows for most chemistries.

Insecticide resistance management has evolved from managing one primary pest, *Helicoverpa armigera* to include aphids, mites and whiteflies.

Now windows are usually kept to a non ideal two generations in length. But this is offset by maximum limits for both consecutive sprays and total number of sprays (to encourage rotation of chemistry).

In the 2004–05 IRMS, some chemistries used for Helicoverpa species control are available for longer than two generations. This is due to the practical considerations mentioned above, particularly multiple pest control which often requires longer windows.

For example Intrepid is available for use against Helicoverpa and mites and available for most of the cotton season. This leaves the potential use period for this chemical at more than two generations long, but the risk this presents is minimised by its general low use by the industry, and an IRMS restriction of one use because of the resistance potential in mites.

In developing strategies for managing resistance, attempts have been made to restrict the time period a chemical is used in one area and across all the areas.

It is not good resistance management to have a chemical starting its use in Emerald in early November, then being used in the central areas from the end of December, and then in the southern regions towards the end of their season in March — thus allowing chemical use across the entire cotton growing season. This is because Helicoverpa species can move between areas, particularly given favourable weather conditions.

The strategy also considers chemical use in crops other than cotton. For example, it is recommended that Tracer and Steward use in chickpeas be restricted to give a break of at least one Helicoverpa species generation before product use in cotton to avoid the selection of consecutive generations.

Chemicals used in other summer crops are also taken into account in the IRMS. For instance, in southern regions Tracer is available earlier in the season than other regions to coincide with the period of greatest use in sweet corn. By aligning use across different crops, chemical availability is restricted in time, ensuring adequate periods of no use to minimise selection pressure.

The strategy can also be adjusted to support IPM systems for particular areas. In 2004–05 the Darling Downs will follow a separate strategy to support the conservation and use of Trichogramma, an egg parasite. As Tracer is very toxic to Trichogramma, use shall be restricted to early in the cotton season when damage is less detrimental to population build-up.

This placement will not give a gap between Tracer use in chickpeas and cotton of one generation. Although this may not initially seem to be good resistance management, it must be remembered that Steward is more likely to be used in chickpeas than Tracer. So the real risk is low, particularly when weighed up against the benefits of Trichogramma parasitism. Nevertheless, resistance in the Darling Downs will be closely monitored and the risk of this strategy assessed.

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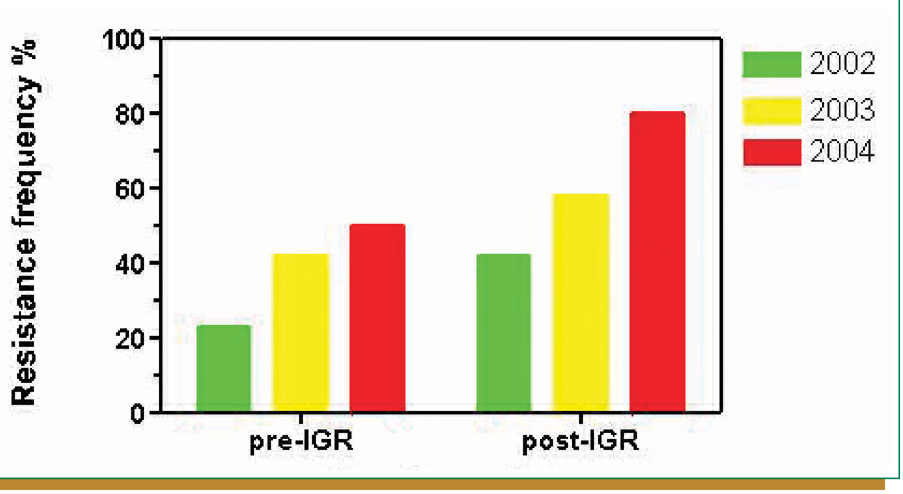
FIGURE 1: Silverleaf whitefly populations can develop resistance quickly to insecticides as illustrated here where pyriproxyfen resistance frequencies increase after only one spray



Short life cycle insects — aphids, mites, whiteflies

Managing resistance in short life cycle pests is based on chemical rotation. That is, no consecutive use of the same chemical or chemical group, and restricting the number of applications from any one group.

This is important because short life cycle pests reproduce quickly. The average adult-to-adult time for aphids is every five days, mites every eight days and whiteflies 16 days. Such short life cycle times mean that consecutive sprays can easily select multiple generations.

Managing resistance in aphids is further complicated because of their method of reproduction. Under Australian conditions cotton aphids reproduce parthenogenically — that is female aphids produce young that are clones of themselves. A resistant aphid surviving a spray will produce resistant offspring as will their offspring and so on. As a result, resistance can develop very quickly, producing resistance hotspots. Rotation of insecticides is imperative to prevent resistance by aphids.

Aphid management is additionally complicated by cross resistance between pirimicarb (a carbamate) and omethoate and dimethoate (organophosphates). While these chemicals do belong to different groups, for aphid control they must be considered as belonging to the same group, and must not be rotated with each other. This is considered in the 2004–05 aphid IRMS by providing a gap between these two chemistries to avoid consecutive use. Rotation to a different chemical group if aphids again require control after a pirimicarb application will help to control any resistant survivors. This will help ensure that omethoate/dimethoate will be effective if required for aphid control later in the season.

When spraying to control an insect pest it is important to be aware that you may inadvertently select for resistance in another. For example, pyrethroid use early-season can select for pyrethroid resistant cotton aphid even though pyrethroids are not registered for use on aphids.

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This can result in aphid clones that are resistant to pyrethroids/endosulfan/pirimicarb/omethoate/dimethoate and which cannot be controlled by virtually any OP, carbamate or pyrethroid insecticide. This puts a lot of pressure on the few remaining alternatives and for this reason (among others) pyrethroid use early season against *H. armigera* is not recommended.

Resistance management for aphids must also take into account the use of some insecticides as both seed treatments and foliar sprays. This is particularly so for the neonicotinoid group which includes the seed treatments Gaucho (imidacloprid), Amparo (imidacloprid) and Cruiser (thiamethoxam) and the foliar sprays Confidor (imidacloprid), Actara (thiamethoxam) and Intruder (acetamiprid). If one of these seed treatments is used, the first foliar spray cannot be also from the neonicotinoid group, otherwise there would be selection for resistance to the same group by both the seed treatment and foliar spray over several generations.

Another short life cycle pest is the silverleaf whitefly (B-biotype *Bemisia tabaci*) that has required specific control and management in central Queensland cotton. Unfortunately, silverleaf whitefly arrived in Australia already resistant to most chemistries used for their control.

In Australia, effective control has relied on strategic use of the insect growth regulator (IGR) Admiral (pyriproxyfen), made available for use in cotton under permit (this permit is currently under review for the 2004–05 season). Worryingly, research has shown that pyriproxyfen resistance can be selected in one generation, so for effective resistance management, use must be limited to one early season spray to slow whitefly population growth while allowing beneficial numbers to build up.

The beneficials help keep whitefly populations under control — even resistant individuals. Early season broad spectrum sprays against whitefly must be avoided because they remove beneficials that would otherwise keep whitefly in check. In addition, increased pressure on IGRs by larger whitefly populations induced by lack of beneficials due to insecticide use could render pyriproxyfen useless.

Additional insecticide resistance management tools

Other methods of insect control that do not rely on insecticides are also encouraged and promoted within the IRMS. These form part of an integrated pest management system and include conservation of beneficial populations, pupae busting and good farm hygiene.

Beneficial populations can help maintain pest species below threshold levels, reducing chemical use and hence resistance selection. Beneficials do not discriminate between susceptible and resistant individuals and so can be useful for cleaning up any resistant survivors following a spray.

To help beneficials survive, the strategy includes strategic placement of soft chemistry early in the season when beneficial conservation is most important. If disruptive chemistry is used early, beneficials are killed and aphid, mite and whitefly outbreaks often result.

The harder chemistries do have an important role as they provide an effective rotation to remove individuals resistant to the softer chemistries. But they are best placed later in the season when their disruption of beneficials has less likelihood of leading to serious secondary pest outbreaks.

Pupae busting is another non chemical tool that can help resistance management. Helicoverpa pupae that diapause under cotton at the end of the season will have come from populations selected with insecticides throughout the season. They have the potential to carry resistance between seasons.

Control by cultivation significantly aids resistance management. This is why pupae busting is compulsory in Bollgard II and strongly encouraged for conventional cotton.

Finally farm hygiene and weed control is also encouraged as weeds can act as alternative hosts for overwintering resistant pest populations. Even farm gardens have been identified as a source of resistant cotton aphid.

Other IRMS features

The IRMS for cotton pests is proactive, rather than reactive. Its aim is to stop resistance developing rather than trying to fix it after it develops.

The strategy is also adaptive — that is, it is adjusted in the light of information on efficacy, resistance results and mechanisms, and use patterns, with new chemistries included as they become available. But it should be noted that the strategy should not be unduly influenced by season to season variation, as next season may be the complete opposite of what was experienced the season before, particularly in terms of pest pressure and species composition.

Every season such data are considered by the Transgenic and Insect Management Strategy (TIMS) committee when producing the IRMS. The TIMS committee consults technical experts and representatives from all facets of the industry across all regions, and attempts to balance restrictive but effective resistance management against flexible but less effective options. The greater the adherence to the strategy, the greater chance we have of stopping or delaying resistance development and maintaining the chemistry we have to control all pests of cotton.

***NSW Department of Primary Industries and Australian Cotton CRC.**