

Integrated Pest Management

By **TRACEY LEVEN (CDRC)**

What is Integrated Pest Management (IPM)?

IPM is the use of all available tactics and resources to reduce the frequency with which pest outbreaks occur on your farm and your reliance on insecticides for their management. IPM is both pre-emptive and responsive. It requires some lateral thinking and some basic knowledge of how insects behave. Upfront tactics work to reduce the incidence of insect pests on your farm. Active tactics enable you to suppress populations in-crop at levels that protect its quality and yield. IPM is a whole year, whole farm approach to managing pests which firstly requires you to devise a plan, taking stock of the resources available to you.

Have a plan

When it comes to pests, fore warned is fore armed. Assess the attributes of your farm and develop an IPM plan as part of your decision to grow cotton. Your plan will become a good reference point during the growing season if tough decisions need to be made. A plan can be as simple as setting a budget for expenditure on pest control for the upcoming season, however this may undervalue your farm's potential and your ability as a pest manager. Challenge yourself to set goals in your plan that will be relevant for many seasons and help you work towards your overall goals for the farm business. Working with others, such as those who provide you with advice, to set your goals, can be an excellent way of ensuring everyone is working to the same priorities for

BEST PRACTICE

- Recognise and foster resources that lower the survival of pests on your farm between cotton seasons.
- Know what's going on in your crop – regularly monitor crop growth, insect presence and insect damage.
- Conserve beneficial insects in your crop by avoiding 'insurance sprays' and choosing a selective option when an insecticide is needed.
- Follow the IRMS to protect the value of insecticide technologies for the future.
- Work as part of a team – with others in your farm business and with neighbouring farms – to keep people safe, to protect your environment and to get the greatest value out of the resources you invest in pest management.

the farm business. Some examples of IPM goals that your business may aspire to are:

- Starting each cotton season with low / no pest populations on the farm.
- Avoiding 'insurance' sprays.
- Following the cotton industry's IRMS when an insecticide is required.
- Making non-crop areas of the farm more productive.
- Avoiding pest outbreaks that are generated within the farm.
- Accommodating apiarists' use of the landscape.
- Strengthening relationships with neighbours.
- Recognise Your Resources

Insects and mites move around the landscape for basic reasons – to find food, to find a mate, to find a favourable place for their juveniles to thrive, because they are blown by wind or because they're seeking shelter from harsh weather. Your IPM resources are the attributes of your farm that act to make these basic needs difficult for pests to satisfy, or conversely easier for them to satisfy away from the crop you are aiming to protect. Thinking about IPM in this way, spending money on insecticides during the season isn't the only way to get 'bang for your buck' in pest management. Insecticides have the advantage of being very targeted, but their influence is very short lived compared to investment in tactics that constantly suppress pests' capacity to thrive.

Veg is valuable

Insect pests live a life of chance. Their short lifecycles and impressive reproductive capacities are essential for them to survive given the equally impressive number of ways they meet their death. Complex vegetation, that is, vegetation made up of lots of plant types, rarely experiences insect outbreaks. In complex veg, the forces working against insect pests are either superior to or in balance with the forces working in their favour. Crops, by their definition lose the advantages inherent in complex veg, but can benefit significantly from having it nearby.

Insect predators – include birds and bats but are mostly other insects and spiders – prefer to live in complex vegetation. This is in part due to its permanence. Perennial native vegetation connects insect predators to crops – both in space and time. The role predators can play in pest suppression in crops is dictated by their ability to persist within a landscape and to move between habitats across the landscape. The following principles can be used to guide you in managing complex vegetation to lower the incidence of insect pests on your farm and enable you to start the season with low pest risk.

Manage for groundcover and diversity

Predators will keep pace with prey / pest populations where vegetation is complex. Complex vegetation has many layers (i.e. trees, shrubs, grasses and herbs) and a range of different plant species in each layer. The

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understory layer of grasses and herbs is most easily changed through management and season. The presence of livestock can result in simplification of the species if grazing periods are too long or there are too few watering points. In time, allowing stock to graze selectively can not only result in loss of the best species, but bare areas will also occur. Drought can result in similar degradations or exacerbate the impacts of grazing management over time.

Loss of groundcover and species diversity favours the establishment of weeds. Many of the annual broadleaf weeds of cropping, such as marshmallow (*Malva parviflora*), milk/sowthistle (*Sonchus oleraceus*), in winter and bladder ketmia (*Hibiscus trionum*) and thornapples (*Datura spp.*) in summer, are better hosts for pests than they are for their predators. When weeds take over beneath trees and shrubs, these areas can become net exporters of pests rather than net exporters of predators.

When planning revegetation, either to rejuvenate areas that are run down or to return a strategic area of crop or pasture to complex, perennial vegetation, prioritise the incorporation of trees and shrubs that flower prolifically. Eucalypts and melaleucas attract feeding insects that are not pests of cotton, which in turn attract a broad range of predator insects that will move into cotton. If seeding of ground species is possible, look to establish a mix of tussocky and sprawling grass together with a mix of winter and summer active legumes. Leaving logs, dead trees and litter where they fall will enhance the habitat for a range of predators.

Prioritise connectivity

The size and configuration of native vegetation in the landscape is important. Small, isolated remnants provide 'stepping stones' across the landscape, but the most effective natural pest control is attained from well-connected areas of native vegetation located nearby the crop. Native vegetation corridors or 'bridges' between remnants facilitate the dispersal of beneficial insects through the landscape and provide local habitat when crops aren't present.



Manage grazing to preserve species diversity. (Photo: Tracey Leven, CRDC)



Prioritise connectivity – insects live in the landscape not on farms. (Photo: Guy Roth)

Where there is little remnant vegetation in an area, focus revegetation efforts on the creation of corridors that link areas together. Fence line plantings, wind breaks and roadside verges can provide effective habitat for beneficials and facilitate movement into and between crops. Plant species diversity and perenniality is as important in corridors as it is in larger areas of vegetation to favour predators over pests.

Enhance habitat with water

More insect species will inhabit vegetation located near a water source. Semi-permanent or permanent water increases and stabilises vegetation condition, especially during drought. Selecting sites for revegetation that incorporate water sources, e.g. channels, storages, or table drains along road sides, will increase the role of vegetation in your farm's natural suppression of pests.

Most irrigation farms growing cotton are designed to retain some storm water runoff on the farm. In addition to the value of the water itself, this attribute of farm design significantly reduces risks to the environment from pesticide residues that move in water. Closed water systems have in the past enabled cotton growers to retain regulatory access to pesticides.

Channels that are nude of vegetation maximise the reticulation capacity of the system in major events. However, establishing perennial vegetation such as cumbungi and grasses on some channel areas, significantly improves the capacity of the system to breakdown pesticide residues on farm. Where water flows more slowly, residues are filtered out by the vegetation and broken down by the enhanced microbial activity associated with vegetated areas. Vegetating distances of 100-200 metres of channel can link habitats for insect movement, reduce erosion risk and protect the environment beyond your farm from pesticide residues.

Different pesticides breakdown in different ways. Strategically combining vegetation on some channels flowing into non-vegetated storage areas means the

system will be efficient at both microbial and UV degradation of pesticides.

Riparian vegetation is highly valuable habitat for insect predators. Floodplain woodlands such as those dominated by river red gum, coolibah and black box rely on floodwater to persist and remain in good condition in semi-arid environments.

For more information:

Pest and Beneficial Insects in Australian Cotton Landscapes, 2011

Growing Trees on Cotton Farms: A Guide to Assist Cotton Farmers to Decide How, When, Where and Why to Plant Trees – available from CRDC, Narrabri

Managing Riparian Lands in the Cotton Industry – available from CRDC, Narrabri

Your neighbours

Insects live in landscapes, not on farms. Area Wide Management (AWM) acknowledges that insects are mobile, and that the management regimes used on one farm have implications for the surrounding locality. By sharing your strategies and coordinating tactics, neighbouring cotton growers have in the past increased their success in implementing IPM.

AWM is relevant when neighbours have identified that they have goals in common. These may be the aim to reduce the early season build-up of pests on a regional/district scale, reduce the mid-season population pressure on susceptible crops or to prevent pest carryover from the end of one cotton season to the start of the next. Tactics that are more effective when implemented in concert with neighbours are weed management, planting windows, selecting insecticides in line with the industry IRMS and post season cultivation of diapausing *Helicoverpa* pupae (Bollgard II Resistance Management Plan). In many neighbourhoods farmers also need to work together towards longer term projects such as to connect areas of remnant vegetation across the landscape. A critical aspect of AWM is to bring together farmers based upon geography, even if from a range of different enterprises, including cotton and other dryland crops.

A key element of most groups that have worked well has been regular meetings before and during the season to share information, discuss strategies and their knowledge of pest presence.

For more information:

IPM Guidelines for Cotton Production Systems in Australia and Cotton Pest Management Guide

Rotation crops

A monoculture of cotton over a wide area reduces the opportunity for insect predators to persist in the landscape beyond the life of the crop. While complex, perennial vegetation offers the most stable habitat for predators, rotation crops also play a key role in linking areas of habitat – perennial veg and cotton – through time and space.

Rotation crops are hosts for a range of pests, some in common with the pests of cotton. Crop selection is based on markets and seasonal outlook, but consequences

for pest management should be factored into decision making, particularly the use of insecticides. The same principles of IPM apply in all crops. Many crops have strong capacity to grow more leaf or fruiting sites to compensate for pest damage. Base spray decisions on recommended thresholds because these take into account the capacity for compensation. If an insecticide is needed, judge the value of selective options not just on their price but flow on effects for other crops on the farm. The lower your farm's total use of insecticides, the greater the local persistence of insect predators.

Where rotation crops are grown at the same time as cotton, try to align insecticide selections with the Cotton IRMS.

For more information: Refer the Crop Rotations Chapter 17.

Varietal tolerances

Select a variety that suits the growing region in terms of season length. Early vigour is an important characteristic. A number of pests, such as thrips and symphyla can only cause economic damage to cotton when vigour is lacking and early growth is slow. Choosing variety characters and growing conditions that favour vigorous establishment can reduce the need to use insecticidal seed treatments and protect the crop from pests to which no effective insecticidal options are available.

Another plant characteristic that lowers the ability for pests to thrive on cotton is leaf shape. The okra leaf shape reduces the rate at which silverleaf whitefly, cotton aphid and two-spotted mite populations are able to increase in cotton.

The Bollgard II trait is ideally suited to IPM as the level of control of *Helicoverpa* spp. provided by the plant reduces the need to spray for these pests, which in turn lowers the need to spray for other pests. Without the primary disruption of from larval sprays, insect predators are able to establish and build over successive generations, keeping their prey populations in check.

Upfront tactics

Weed management

Weed management is perhaps the most undervalued tactic in IPM. Many cotton pests rely on volunteer cotton plants and weed hosts prior to migrating into cotton fields. Pests that gain the greatest advantage from weeds are those that can't hibernate when conditions are unfavourable. Cotton aphids, mirids and silverleaf whitefly are pests that have to constantly find host plants to survive.

Mild, wet winters create the highest risk of pest carryover from one cotton season to the next mainly because of the abundance of host plants in these conditions.

For pest suppression leading into each cotton season, weeds need to be managed in fallow fields, along field borders and irrigation channels and in perennial vegetation and pastures. Control with herbicides can provide robust, fast solutions, but in non-crop areas

costs are difficult to justify and conditions do not always favour their application. Over time, aim to vegetate non-crop areas with perennial, non-host species. Summer growing species that produce a bulk of growth in late summer will suppress the emergence and establishment of winter weeds much more effectively than bare ground. Take care in autumn to manage grazing pressure in pastures to maintain groundcover for winter.

In areas where herbicides are used, winter weed control should begin in late autumn and continue through winter and into spring. Combinations of herbicide and tillage, such as in a double knock, can increase the control of species with tolerance or resistance to herbicides.

Cotton volunteers are the worst weed in terms of pest risk. A 'zero tolerance' approach to cotton volunteers between crops will yield benefits to the farm in pest suppression, lower risks of insecticide and Bt resistance carryover, significantly lower risks of virus outbreak in the next crop and lower likelihood of new or exotic pests getting established.

Field selection

When selecting fields for planting cotton, consider the proximity to sensitive areas – such as watercourses, pastures and buildings – relative to the prevailing wind direction. The Bollgard II trait maybe most appropriate for fields adjacent to sensitive areas. Conventional cotton may be best placed embedded amongst Bollgard II cotton and rotation crops, where pest loads are diluted across all the crop area. When spraying is required for larvae control, the surrounding crops will also act as sources for rapid re-entry of insect predators.

As part of field selection, stubble loads and soil pest activity should be monitored in the lead up to planting. The presence/absence of soil pests can have a strong bearing on crop establishment, particularly if there's high probability that soil moisture conditions and average daily temperatures will be variable. There are no insecticidal control options for symphyla or nematodes – field selection is an important component of managing the rare but serious risks associated with these pests.

Also worthy of consideration is whether the intended location of cotton fields creates 'stepping stone' linkages between areas of crops and vegetation to enable movement of insect predators through the landscape.

Seed bed preparation

As an IPM tactic, seed bed preparation has become increasingly important in recent seasons. The small seed size of the high yielding Sicot 74 varieties demands specific attention at planting. Vigorous, healthy, early growth enables crops to recover from what can at the time appear to be significant early season damage from soil dwelling pests such as wireworm, mealy bug and symphyla. When plant vigour is strong and growth is rapid, cotton can fully recover without reduction in yield or delay in maturity.

For more information: Refer to Crop Establishment Chapter 4.

Planting time

In each cotton region there is a period when soil temperatures become optimal for cotton germination, 14°C, at planting depth at 9:00 am for three consecutive days and forecast temperatures are rising. Planting in these conditions reduce the need for prophylactic insecticidal seed treatments. By limiting the risk of cold shock (minimum temperature $\leq 11^\circ\text{C}$), plant growth rates will be such that seedlings outgrow pest damage. These conditions also increase seedling immunity to diseases and herbicides. However the planting decision is often a compromise to balance other limitations in the system, such as availability of planting moisture and the occurrence of these weather conditions relative to the overall length of the season.

Very late planted cotton has less yield potential and is more susceptible to pests such as whitefly which can be difficult and expensive to control. In areas susceptible to whitefly, coordinated planting windows can provide a period free from host crops to reduce population build up as well as preventing late crops from being inundated by mass movements of adults from senescing, defoliated or harvested crops.

Create a diversion

Trap cropping can assist in resistance management, as well as IPM, depending on the pests targeted and the timing of their use. Trap cropping aims to concentrate a pest population into a smaller area that is costs less to manage by providing the pest with an area of host crop that is more highly preferred and attractive than the crop you are aiming to protect. It is an IPM tactic that can be utilised on a farm level or area wide basis, either way it requires strategic planning and management to be effective.

Lucerne can be used as an effective trap crop for green mirids and aphids, as these insects prefers lucerne over cotton. Planted in strips within fields or along field edges, or in a field adjacent to a cotton fields, lucerne can effectively serve as a trap for mirids and aphids as well as enhancing the build-up of beneficial insects.

For strip configurations, strips at least 8 metres wide are required for every 300 rows of cotton. The configuration should be chosen to fit in with machinery and equate to about 2.0-2.5% of the field area. Alternatively, lucerne can be grown on the borders of a field, using an area equivalent to 5% of the field, or can be planted in a field adjacent to cotton.

In Central Queensland cotton growers use summer trap crops of pigeon pea as part of the RMP for Bollgard II cotton. A summer trap crop aims to draw *Helicoverpa* spp. away from the Bollgard II crop and concentrate them in a small area where they are controlled. In the RMP the trap crop is destroyed with slashing and cultivation.

For more information:

Agronomic management of lucerne in cotton systems, refer to cotton's Weedpak publication, Section 14.

Communicate responsibilities and expectations

While IPM aims to reduce the farm's reliance on insecticides, they inevitably still play a role. Risks associated with their use need to be actively managed. The core best management practice for safe and responsible pesticide use is to develop a pesticide application management plan (PAMP). Developing a PAMP helps identify the risks associated with pesticide applications specific to your farm situation and the practices that are to be put in place to minimise the risks. Implementing a PAMP makes everyone involved in a pesticide application aware of and understanding of their responsibilities.

A PAMP has two essential functions:

- Establishes good communication with all involved in the application of pesticides. This communication is required both pre-season and during the season. It should exist between the grower, the applicator, the consultant, farm employees and neighbours.
- Establishes the application techniques and procedures that are to be used on your farm.

Good record keeping is essential for demonstrating the implementation of your PAMP. Records enable farm management to check the effectiveness pesticide applications, to comply with regulatory requirements and to demonstrate due diligence.

For more information;

Refer to the Pesticide Management module in *myBMP*.

Monitoring

There are several important purposes of crop monitoring:

- Determining whether the crop is growing optimally.
- Detecting the presence of insects – pests and predators – through the field.
- Finding evidence of insect damage to the crop

Monitoring data provides the basis on which tactical decisions about pest management can be made in-crop.

Making well informed and rational pest management decisions will provide the best opportunity to protect yield and minimise the need to spray and incur further pest control costs.

Check frequently

Crops should be checked at least twice weekly, with different emphasis depending on the time of the season. Early season emphasis should be on plant growth and signs of damage.

Once squaring commences, emphasis is across plant growth, fruit retention, insect presence and signs of damage.

Once the economic yield of the crop is set (cutout), emphasis is on insect presence and signs of damage.

It is generally not possible to make a decision about whether insect control is needed based on just one check. Good decision making requires the use of time series data so that rates of pest population development and



Industry training in sampling techniques is available. (Photo: Paul Grundy)

movement can be compared with both changes in insect predator numbers and the time remaining in the season during which the crop is susceptible to damage.

Determining whether crop growth is optimal

Cotton development can be predicted using daily temperature data (day degrees). The CottASSIST Crop Development Tool (CDT) uses this knowledge to enable crop managers to check the vegetative and reproductive development of their cotton crops compared to a

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potential rate of growth and development. A crop manager can use this information as a prompt to further explore why the crop may not be on track, and manage the crop accordingly.

Finding evidence of insect damage

Damage monitoring includes; leaf loss (important from establishment up to the 6 true leaf growth stage), growing point damage; loss of squares/flowers and boll damage. The type of damage encountered will provide clues as to which insects are responsible – which can help to target monitoring for pest presence. The type of damage inflicted by each of cotton's main insect pests is described in the Insects Chapter of the Cotton Pest Management Guide.

Detecting the presence of insects – pests and predators

There are a number of sampling techniques that have been thoroughly evaluated by industry research and are associated with the thresholds for insecticide intervention. Visual and Beat Sheet sampling are the most commonly used techniques – each has different strengths – meaning it is optimal to use a combination of both techniques.

Beat sheet sampling: A sheet of yellow canvas 1.5 m × 2 m in size is placed in the furrow and extended up and over the adjacent row of cotton. A metre stick is used to beat the plants 10 times against the beat sheet, moving from the base to the tops of the plants. Insects are dislodged from the plants onto the canvas and are quickly recorded. This method is excellent for detecting nymph and adult beetles and bugs – some of which are pests while others are beneficial.



A yellow nightstalker eating a mirid. (Photo: Mary Whitehouse, CSIRO)

Visual sampling: Involves systematically looking at upper and lower surfaces of leaves, along stems and inside squares, flowers and bolls. This method is excellent for detecting the eggs of pest and predator species as well as small sucking/rasping pests such as thrips, aphids, mites and silverleaf whitefly.

Insect numbers should be recorded either as numbers per metre or as a percentage of plants infested to easily compare numbers with the appropriate industry threshold and to allow a predator to prey (pest) ratio to be determined.

For more information:

Collecting and recording data about insect pests is described in the Insects Chapter of the Cotton Pest Management Guide.

Active tactics

Build bigger populations of beneficial insects

Predatory insects, parasitic insects and spiders consume pests. Collectively they are known as 'beneficials'. When abundant, beneficials considerably reduce pest numbers preventing the need for insecticides. The abundance of beneficial insects in a cotton crop is affected by food resources, mating partners, proximity to other sources of habitat, climatic conditions and insecticide sprays. For an IPM system to work effectively, both the attraction and conservation of beneficial insects is critical.

In cotton, lag phases in the build-up of beneficial populations reduce the ability for pest managers to utilise their services. Lags occur when the rate at which the pest population increases is initially faster than the rate at which the beneficial population increases. During the lag period, the crop may suffer economic damage from the pest. Lags are minimised where nearby habitat – rotation crops and perennial vegetation – creates higher starting populations of beneficials, where prophylactic application of insecticide can be avoided and where any insecticides that are needed are highly selective.

The abundance of some beneficial species can be increased through mass releases. Beneficials can be purchased for release in the crop. Lacewings and lady beetles are predators of a range of insect pests and are good candidates for mass releases in cotton. Both lacewings and lady beetles will preferentially feed on aphids. (A common spotted ladybird can consume up to 2,400 aphids in her lifespan!) When aphids are not available, they will feed on other small insects such as mites, moth eggs and mealy bug. For pests such as mealy bug, where there are no effective insecticidal options, beneficials play a particularly critical role and releases can offer significant value for money.

For more information:

Visit the website: the Association of Beneficial Arthropod Producers Inc (ABC Inc) – www.goobugs.org.au

Download: Pests and Beneficials in Australian Cotton Landscapes – www.crdc.com.au

Browse: Spotlight, "Buying in Bugs," Spring 2012 Edition – www.crdc.com.au

Choose insecticides wisely

When choosing an insecticide, in addition to the efficacy against the target pest, it is very important to consider its selectivity. Some insecticides have very little impact on beneficial insects while others are highly disruptive. The relative selectivity of all insecticides available for use in cotton is tabulated in the Insects Chapter of the Cotton Pest Management Guide.

The selectivity of the insecticide helps to assess the risk that following its use, populations of other pests may 'flare' (increase rapidly). For example, where a mirid population has increased above threshold during flowering and an insecticide is required, the best choice depends not only on your budget, but the product's selectivity relative to the types of beneficials you have

and want to conserve. Within the IRMS there are several options available at this time with differing selectivity profiles. The newer neonicotinoid product, clothianidin (tradename Shield), will reduce populations of lady beetles (aphid predators) and Eretmocerus wasps (whitefly parasitoids) but conserve predatory bugs and thrips (mite predators). In contrast fipronil (multiple tradenames such as Regent) will reduce predatory bug populations, conserve lady beetles and thrips, but have an unknown impact on the key wasp parasitoids of whitefly.

Increases in populations of non-target pests such as aphid, mite and whitefly may follow insecticide applications if the beneficial populations keeping them in check are disrupted. Also consider the use of reduced rates of synthetic insecticides mixed with either salt or spray oils. In some instances this will provide greater selectivity and better efficacy.

Ensure spray applications are accurate, timely and triggered by pest thresholds.

Pests such as aphids and mites often infest the edges of a field, not the entire field area. Discuss with your consultant whether it is possible to manage this type of infestation by only spraying the field borders. This may enable beneficial populations to keep pace with the remainder of the pest population in the field.

Be kind to bees

Bees collect nectar from cotton's extrafloral nectaries (under leaves) as well as from the flowers so they may forage throughout much of the season. Insecticide use makes cotton crops a high risk environment for bees. Bees are particularly susceptible to insecticides such as fipronil, abamectin, indoxacarb and pyrethroids. The productivity of hives can be damaged if direct contact with foraging bees occurs during the application, if foraging bees carry residual insecticide back to the hive after the application and when insecticide drifts over hives or over neighbouring vegetation that is being foraged by bees.

The annual Cotton Pest Management Guide provides additional information about insecticide risks to bees. The relative toxicities of cotton insecticides to bees are tabulated in the Insects Chapter and residual toxicity risks for bees are identified in the Spray Application chapter.


With good communication and good will, it is possible for apiarists and cotton growers to work together to minimise risks to bees, as both the honey industry and cotton industry are important to regional development.

The pesticide risk to bees can be reduced by:

- Applying pesticides toxic to bees in the evening when bees are not foraging;
- Notifying the apiarist when beehives are in the vicinity of crops to be sprayed to allow removal of the hives before spraying. Beekeepers require as much notice possible, preferably 48 hours, to move an apiary;
- Avoiding micro-encapsulated formulations such as that



Coolibah trees (*Eucalyptus microtheca*) are a primary source of nectar and pollen for honey bees. These trees grow on the black soil plains along many of the river courses in the cotton growing areas. When heavy budding occurs, beekeepers often move large numbers of hives into cotton growing areas for honey production. Budding and flowering only occurs in response to good spring rains meaning the timing is likely to coincide with the time when insecticides are used in cotton. In northern NSW the buds appear in November and the trees begin to flower mid-late December finishing about the end of January. Budding and flowering times vary by a few weeks in southern and central Qld areas.



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used for lambda-cyhalothrin. These are particularly hazardous because the micro-capsules can be transported back to the hive along with the pollen;

- Inform contract pesticide applicators operating on the property of the locations of apiaries;
- Paying particular attention to windspeed and direction, air temperature and time of day before applying pesticides;
- Using buffer zones as a mechanism to reduce the impact of spray drift or overspray in vegetation used by bees; and,
- Avoiding drift and contamination of surface waters where bees may drink.

Communicate with neighbours

During the season, active communication between neighbours, farm employees, your consultant and the applicator is essential to successfully implement your Pesticide Application Management Plan (PAMP) and achieve your IPM goals.

Follow the IRMS when selecting pest control options

Resistance occurs when application of insecticide removes susceptible insects from the population leaving those individuals that are resistant. Mating between these resistant individuals or cloning of the resistant individual, gradually increases the proportion of resistance in the pest population as a whole. Eventually this can render an insecticide ineffective, leading to field control failures. Resistance can be due to a specific trait that is already present in a small portion of the pest population or due to enhancement of the insect's natural defence mechanisms.

Management of resistance is essential to ensure that valuable insecticides remain effective. The Australian cotton industry has developed an Insecticide Resistance Management Strategy (IRMS) for this purpose. The IRMS is designed to both delay resistance development and to manage existing resistance. Some core principles used in the IRMS include:

- Rotation between chemical groups with different modes of action.
- Limiting the time period during which an insecticide can be used. This restricts the number of generations of a pest that can be exposed to selection in each season.
- Limiting the number of applications, thereby restricting the number of selection events.

Spraying for one pest can simultaneously select resistance in another pest that is present, even though that pest may only be present at sub-threshold levels and not be specifically targeted. For example, if dimethoate is used to control mirids, aphids present at low levels are also being selected for resistance. Resistance is selected very quickly in aphids because they reproduce by cloning. In this instance, dimethoate not only selects for resistance to this chemical but also selects for a cross resistance to pirimicarb, even though it is from a different group of chemicals. The decision to use dimethoate for

mirids, leaves few options available for reliable aphid control. Hence the IRMS windows dimethoate for use late in the season and recommends not using dimethoate and pirimicarb in the same field.

Selective insecticide use is consistent with the IRMS, as this helps conserve beneficial insects. Insecticides appear in the IRMS in order of their selectivity – the most selective at the top of the chart available for use early season and the least selective at the bottom available for use at the end of the season.

For more information:

Go to the Stewardship chapter in this Manual.

View the Cotton IRMS in the annual Cotton Pest Management Guide – www.crdc.com.au

Resistance monitoring

Resistance monitoring for *Helicoverpa* spp., two-spotted spider mites, aphids and silverleaf whitefly, is conducted each year by the cotton industry and provides the foundation for annual review and updating of the IRMS. All growers and consultants have access to this industry service to investigate suspected cases of resistance.

For more information:

Aphids, mites and mirids: Dr Grant Herron, NSW DPI, 02 4640 6471

Silverleaf Whitefly: Dr Jamie Hopkinson, QDAAF, 07 4688 1152

***Helicoverpa* spp.:** Dr Lisa Bird, NSW DPI, 02 6799 2428 & Dr Sharon Downes, CSIRO, 02 6799 1576

Resistance management for Bollgard II cotton

Resistance management for Bollgard II cotton is critical due to the season long selection of *Helicoverpa* spp. to the Bt toxins produced by Bollgard II. Since commercial use of the first Bt toxin, Cry1Ac, began in Australia in 1996, there has been over 2,500 days of selection across 3,050,000 hectares. Such prolonged, intense selection creates enormous opportunity for resistance to become common in the population. To counter this, a proactive Resistance Management Plan (RMP) is in use to preserve the effective life of Bollgard II. The RMP requires the use of planting windows to limit the duration of selection each season, refuges to dilute resistance that is selected during the season and pupae busting or trap crops to destroy resistant individuals at the end of each season. Each of the elements of the RMP is highly compatible with IPM and their implementation should be of high priority in the farm's IPM plan.

For more information:

Refer to the Stewardship chapter in this manual.

Defoliation

The timing of defoliation can be an important IPM tool. Late pest infestation problems can sometimes be avoided by a successful defoliation. The Silverleaf Whitefly Threshold Matrix illustrates that control of whitefly to protect crop yield and quality is required between peak flowering and 60% open bolls. As the crop approaches the point where it can be defoliated, the reliance on insecticide intervention declines.

Pupae busting

In NSW and southern Queensland, *Helicoverpa* spp. spend the winter in the soil as pupae and emerge as moths in spring to mate and lay eggs. Pupae under cotton at the end of the season have a higher probability of carrying insecticide and Bt resistance. Their destruction has proven to assist in the management of resistance.

Pupae busting is required following harvest of Bollgard II cotton and is recommended in the industry's IRMS for all cotton.

For more information:

Refer to the Stewardship chapter of this manual and to the Insects chapter of the Cotton Pest Management Guide.

Zero tolerance for regrowth and volunteer cotton plants

Regrowth of cotton after harvest (ratoon cotton) provides habitat for nearly all cotton pests – *Helicoverpa* spp., spider mites, green mirids, mealy bug and aphids. Regrowth should be controlled by slashing, root pulling and/or mulching to prevent pests being carried between

seasons. Control around field edges, along roadways and in irrigation channels is as important as control within cropping fields. In areas with low accessibility this will require hand chipping.

While weather doesn't always permit, prioritise 'zero tolerance' throughout winter right up until cotton planting. Regrowth cotton is also the major risk for carry-over of Cotton Bunchy Top (CBT) disease. Cotton aphids feeding on infected plants through winter can spread CBT to adjacent cotton crops in the spring. However without a source of infected plant material, aphids will not continue to be infected and lose the ability to transmit the disease as they move around.

The Technology User Agreement for Bollgard II cotton requires the control of cotton regrowth.

For more information:

Requirements for managing Bollgard II volunteers are described in the Insects chapter of the Cotton Pest Management Guide.

Options for managing cotton volunteers and ratoons are described in cotton's Weedpak.



Maintain a zero tolerance for regrowth and volunteer cotton. (Photo: Lewis Wilson)