# A Review of Integrated Pest Management (IPM)in Australian Cotton

Prepared by Crop Consultants Australia and IPM Technologies Pty Ltd.

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# Aim

This report is one part of a project "*Novel Options and Strategies for Integrated Pest Management in Australian Cotton*". It is a review of the management strategies currently being used in Australia for the control of pests in cotton in the different production regions.

# Summary

This project combined the extensive network of Crop Consultants Australia (CCA) in the cotton industry with the experience of IPM Technologies as the dedicated IPM research company bringing a new perspective to the Australian cotton industry. This report has been prepared jointly by CCA and IPM Technologies.

The information collected in this project shows that there is widespread awareness of Integrated Pest Management (IPM) in the Australian cotton industry and that there is a far reduced use of insecticides in Australian cotton production now than before the availability of Bt-cotton. Control of the key pests, *Helicoverpa* and mirids, is currently achieved with very few insecticide applications, and there is awareness that secondary pests such as whitefly, mealybugs and mites can be flared by the application of broad-spectrum insecticides. Although there is widespread awareness of IPM, there are differing levels of commitment to minimal use of insecticides using an IPM approach between both districts and individuals.

At present there are no immediate problems with pest management because:

(i) *Helicoverpa* and other caterpillars are well controlled by Bt-cotton,
(ii) Mirids can be controlled with fipronil or sulfoxaflor (*Transform®*) (although with some variations in effectiveness of sulfoxaflor) and
(iii) Other pests such as whitefly, mites, thrips, mealybugs and green vegetable bug are not regarded as major pests across the industry and can still be controlled.

However, this state of pest management is not guaranteed to continue and is at risk from several factors, as follows:

(i) Resistance to Bt-cotton by *Helicoverpa* is possible and has occurred in other countries,
(ii) The continued availability (registration) of fipronil cannot be relied upon, and the alternative of sulfoxaflor (Transform®) is also potentially not secure if it is considered to be a neo-nicotinoid. Sulfoxaflor has been banned in the European Union[1] and
(iii) The importance of minor pests is seen by some as increasing and could be flared by either seasonal conditions or use of broad-spectrum insecticides.

The industry should maintain its strong commitment to reducing the risk of *Helicoverpa* developing resistance to Bt-cotton and develop improved control of mirids without the use of broad-spectrum insecticides. Both of these issues have the potential to cause serious problems for the industry in the

[1] https://www.pan-europe.info/press-releases/2022/04/european-commission-bans-bee-toxic-sulfoxaflor-insecticide-one-less-bee

future.  Control of pests such as whitefly, mealybugs, mites and thrips can be achieved primarily by biological and cultural control methods, and this should be encouraged.

Crop Consultants Australia maintains a strong commitment to informing practising agronomists and promoting their uptake of IPM.  Equally for growers, the CottonInfo network is a critical vehicle for extension of research and industry knowledge.  There is considerable scope for future collaboration between CottonInfo and CCA to deliver the targeted messaging that has been identified as being necessary in this report. As the industry faces an increasing number of younger members who don't possess the legacy knowledge of historical pest management challenges, there will be an increasing need for tailored extension in the area of IPM.

There is always more that we can learn, and ongoing research will be critical to address the pest issues that the industry faces in the future. CCA also believes that future research and extension in IPM should be supported through cross industry programs. Pest management systems need to be considered across all different crops being grown in each region. There is considerable scope for the cotton and grains industries to collaborate on pest management projects, and in some regions could also involve horticulture industries.

# 1. Introduction

Key pests of cotton in Australia include *Helicoverpa armigera, H. punctigera* and several species of Miridae, particularly the green mirid (*Creontiades dilutus*). There is also a range of other insects and mites that are of differing levels of importance to growers and advisors in the different regions. Prior to the use of Bt-Cotton (Ingard® then Bollgard®) *Helicoverpa* caterpillars were the major pest in Australian cotton but now, mirid bugs are generally considered to have become the pests of most concern. As a result, the emphasis of research has shifted from studies on *Helicoverpa* to the biology and management of mirids (eg. Cappadonna *et al* 2021).

Mirids in Australian cotton are highly mobile native species that feed on a range of native plants and also other crops. Research by Cappadonna *et al* (2019) concluded that the green mirid in particular originated in arid lands of central Australia as well as from more local areas. A range of mirids are also serious pests of strawberry crops in southern Victoria (Page and Horne 2014), and these are likely to have a different set of host plants.

This review was to look at the management methods being used for the control of all invertebrate pests in Australian cotton in the different production regions. One way that we did this was by running a series of interactive workshops with advisors in different cotton growing regions. These were originally planned to be all conducted in-person, but inter-state travel restrictions meant that this was not always possible and so many were conducted via Zoom. We also arranged meetings with researchers and follow-up discussions with a range of people with different roles in the industry. This allowed us to gauge what control methods were being used and what aspects of research were being implemented.

# 2. Workshops and Interviews

Workshops were conducted with practising agronomists from the major cotton production centres (Dalby, St George, Goondiwindi, Griffith, Warren, Narrabri and Moree). The participants were predominantly experienced consultants, most of whom were members of Crop Consultants Australia, and had a working knowledge of IPM principles. In addition, discussions were held with researchers in Narrabri (CSIRO) and Toowoomba (DAF, Qld). Each workshop consisted of an initial presentation on IPM by IPM Technologies and then an interactive workshop facilitated by CCA (Doug McCollum and/or Leisl Coggan). This involved the construction of a matrix listing the pests of concern to participants with an outline of all available control measures (in the categories of biological, cultural and pesticide options). Participants nominated the measures that they currently used or would consider and their thoughts on each possible option. The workshop summaries for each location are presented in Appendices 1-7.

Although the participants in each workshop would have been familiar with the term IPM, it was important to present what my view on IPM looks like. Even in the scientific arena, Bajwa and Kogan (2002) listed 67 published definitions of IPM and so I felt it important to describe IPM according to my own perception. The initial presentation on IPM gave examples of IPM in different crops from the experience of IPM Technologies and described the reasons why the different groups were interested in looking at IPM.

Two meetings were held with researchers involved in the cotton industry in March 2022. The first was with three researchers from CSIRO, held at Narrabri (March 30) and the second was with two researchers from The Queensland Department of Agriculture and Fisheries, Qld and a crop consultant in Toowoomba (April 1).

In addition to these meetings, short discussions were held with a range of others in the industry that were neither (currently) researchers or consultants and included growers and industry leaders.

The results of the workshops and discussions are discussed for each category below.

## 2.1 Pests

The workshops identified a range of pests of various importance to consultants and growers in different regions. Mirids, especially green mirids, were considered by all groups to be the main pest of concern. Bt cotton effectively deals with all caterpillar pests, but for those growing non-Bt crops then *Helicoverpa* and cluster caterpillar were listed as pests to be dealt with. There were some consultants that believed that *Helicoverpa* still needed to be sprayed with insecticides on occasion, if there was a large egg-lay at a time when fruiting sites were vulnerable. This was in part because the caterpillars needed to eat some plant material for the Bt to be effective, and so could potentially cause damage, or because of less than desired expression of the Bt at certain times.

Several other pests nominated were sucking pests (like mirids) and included whitefly, mealybugs, aphids, green vegetable bugs and other stink bugs. The remaining pests that were regularly nominated were two-spotted mites and thrips, and some consultants also nominated wireworms as being of concern. Many of these pests either have already developed resistance to many insecticides or are capable of doing so very rapidly, and so they remain a potentially serious problem in the future.

The relative importance of this range of sucking bugs has increased with the use of Bt cotton but the direct damage to the cotton fruiting positions caused by green mirids make this the pest of most concern. Green Vegetable Bug is considered a sporadic issue, which affects certain regions more than others and is often a problem in fields adjacent to watercourses.

It is worth noting that there was little feedback received about the impact of soil pests. The industry uses insecticidal seed treatments and ground applied insecticides with planting to target pests such as wireworms, earwigs, crickets and symphylans. The removal of products such as phorate and chlorpyrifos would create challenges for the industry as there are limited alternatives currently available.

## 2.2 Biological Control Agents

Consultants in all the workshops nominated a range of predatory and parasitoid species that they believed had an impact on pests of cotton. These were not always regarded as highly effective but there certainly was awareness of the potential impact of biological control agents. There were some generalist predators (such as spiders and assassin bugs) that were thought to prey on at least the younger stages of mirids but were unlikely to deliver full control. Beat-sheets are often used to monitor for the presence of pests and beneficial species. It is likely that the impact of parasitoids is underestimated with this method as they are invisible inside their hosts for much of their life and adults are highly active. However, this method would be useful in assessing the presence of predatory species.

There was general agreement that parasitoids of whitefly (particularly *Eretmocerus*) and predatory mites and thrips that attacked pest mites had a major impact on these pests. Similarly, green lacewings and *Cryptolaemus* ladybirds were thought to be important in controlling mealybugs. Parasitoid wasps, including *Trichogramma*, were known to attack a range of species. One recent development is the release of commercially reared *Eretmocerus* wasps that are placed in capsules and distributed by plane. Some growers and advisors are already using this approach to manage whitefly problems in cotton without the use of insecticides for this pest.

## 2.3 Cultural Controls

The most significant cultural control being used at present is the choice of variety, which being Bt cotton controls *Helicoverpa* and other lepidopteran pests. A key to slowing the development of resistance is the use of non-Bt crops as refuges and so there are plantings of other species such as pigeon pea or non-Bt cotton. This is discussed further below.

It was also recognised that some crops, such as lucerne, were attractive to mirids and cotton planted adjacent to such crops were likely to face increased pressure from mirids. There was not general agreement on crops other than cotton that were highly attractive to mirids. It was suggested that pigeon pea refuges are a preferred host and may be contributing to mirid numbers in adjacent cotton. This information is supported by published literature (Cappadonna, Hereward and Walter 2021). The use of lucerne as a potential refuge for beneficial species was remembered as having been trialled many decades ago but abandoned primarily due to its attractiveness to mirids.

Weed control, including removal of old cotton plants, was recognized as being important to assist in the control of many pests. In particular, destruction of ratoon cotton crops is an accepted practice to reduce the risk of mealybug outbreaks. There was less appreciation of the role that provision of nectar sources could play in increasing the impact of beneficial species.

## 2.4 Pesticides

Workshop participants were asked what insecticides they could choose from and which they were most likely to use (if any) for each pest that had been nominated in that workshop. Each insecticide or miticide nominated was given a rough rating of their likely impact upon beneficial species, based on the experience of IPM Technologies in other crops. This is not a precise assessment of beneficial disruption as is presented in the Cotton Pest Management Guide 2022-23 Impact of insecticides and miticides, predators, parasitoids and bees in cotton table (CRDC, CottonInfo, 2022) or that produced for the vegetable industry and available from the Biological Research Company. The results are shown in Appendices 1 to 7.

In addition to the financial cost of insecticides and miticides there is also the expense and time constraints of spray application. Insecticides (particularly targeting mirids) are often applied in conjunction with herbicides in order to achieve greater time and financial efficiencies in farming operations.

It appeared from the workshops that Bt cotton is currently effective for controlling caterpillar pests and therefore the application of foliar insecticides is usually not required. Organic and conventional crops still require control of caterpillars, but they represent a very small part of the total industry[2]

## 2.5 Pesticides used in Australian Cotton (Historical)

A range of insecticides, predominantly broad-spectrum organophosphates and synthetic pyrethroids, was used for many years targeting *Helicoverpa* in Australian cotton, prior to the availability of Bt cotton (Ingard and then Bollgard). The introduction of Bt-cotton resulted in a much-reduced application of insecticides. Wilson *et al* (2013) estimated that the average number of insecticide applications per crop had reduced from 12 – 16 times in 2005 to 0-3 times in 2013. Growing cotton without the use of insecticide applications is possible[3]. However, this reduction in the use of insecticides has also resulted in an increase in the importance of sucking bugs such as mirids (Whitehouse 2011).

Resistance management for insecticides used in cotton has decreased in focus over time. The Insecticide Resistance Management Strategy (IRMS) was rarely mentioned in our workshops. This may be because the most recent industry concerns have been with products used for control of Silver Leaf Whitefly, and we have just had consecutive seasons with low incidence of Whitefly. There is an ongoing need for vigilance with observing IRMS guidelines to ensure that the impact of pests such as Whitefly and Mites does not increase due to loss of chemistry in future.

## 2.6 Resistance Management Strategies for Bt-cotton

Just as pest species such as *Helicoverpa* can develop resistance to synthetic insecticides, it is also possible for them to become resistant to toxins produced by *Bacillus thuringiensis* (Bt). This has occurred in the past with *Plutella xylostella* (diamondback moth) found to develop resistance to Bt sprays (Tabashnik *et al.* 1990). This resistance has been documented in field populations in many countries including the USA, Central America, China, Malaysia, Japan, Thailand and the Philippines (Tabashnik *et al.* 1998). *Helicoverpa* species also developed resistance to the original 2 varieties of Bt-cotton in several countries including the USA (Reisig and Kurtz 2018). Tabashnik *et al*. (1998) noted that resistance to Bt in *Heliothis virescens* showed "striking parallels with the diamondback moth".

*Spodoptera frugiperda* (fall armyworm) is a relatively recent arrival into Australia and although not of particular concern in cotton, it affects many grasses including maize and sweetcorn. It has developed resistance to many insecticides including Bt crops (Storer *et al* 2010; Farias *et al* 2014; Huang *et al* 2014; Aguirre *et al* 2016). *Spodoptera litura* (cutworm) has been present in Australia for

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[2] https://cottoninfo.com.au/publications/insect-case-study-growing-cotton-without-using-insecticide-using-ipm-control-pests

[3] Cotton Info: Insect Management Case Study – Growing Cotton without Insecticide: using IPM to control pests

many years and has also been shown to be capable of developing resistance to Bt (Barkhade and Thakare 2010; Yinghua, S. *et al*.).

Bollgard 3® technology provides 3 different genes to control *Helicoverpa* spp. but is predominantly reliant on a single gene for controlling *Spodoptera* spp. It is noted that with the recent expansion of cotton into northern Australia there will be increased selection pressure on *Spodoptera* spp. which are often more significant pests than *Helicoverpa* spp. To counter the development of resistance to Bt-cotton, researchers and industry have recommended using areas of non-Bt-cotton as refuges where there will be a reservoir of a susceptible population[4]. This is mandated in Australia under the Resistance Management Plan (RMP) and often pigeon pea is planted as a refuge. Industry compliance with the RMP is critical in maintaining successful control of *Helicoverpa* spp. In countries that have not followed this advice (eg. India), resistance to Bt-cotton has developed (Tabashnik and Carriere 2019). Studies indicate that less than 40% of U.S. farmers in 2016 complied with refuge requirements for growing Bt- cotton (Reisig 2017).

Other Bt-crops such as corn are also widely grown in the USA however conversely, the use of non-Bt refuges has decreased. Bt and non-Bt variety mixtures have been promoted as being equivalent to planting entire crops of non-Bt plants (called "refuge in a bag"). While popular with farmers and seed companies there is also an opinion that this is accelerating the development of resistance to Bt[5]. Having both corn and cotton Bt-crops in the USA presents an increased risk of *Helicoverpa* resistance. This is particularly so if there is non-compliance with planting of refuge crops and if the "refuge in a bag" strategy is not as effective as is believed.

In the absence of a formal survey of growers, the general consensus of workshop and interview participants was that in Australia there is a high level of compliance with the RMP, including regional guidelines regarding the planting of refuge crops.

## 2.7 Control of Mirids

In all workshops, mirids were ranked as the main pest to be controlled and Bollgard® cotton was relied upon to control *Helicoverpa* and all other lepidopteran pests. Control of mirids is achieved by the participants largely by the application of insecticides. The most commonly used insecticides (fipronil and dimethoate) are broad-spectrum and potentially cause the of loss of beneficial species and flaring of secondary pests. Although there are less disruptive options such as flonicamid (Mainmain®) and sulfoxaflor (Transform®), these are not regarded by all to be effective.

There was a consensus that fipronil was disruptive to beneficial species, however, there was also an opinion expressed that it could be used safely without flaring secondary pests such as whitefly, mites and mealybugs. This is potentially due to high temperatures and extreme UV degradation in some regions combined with lower rates being used.

Even prior to the development of BT-cotton, there has been substantial industry and government funded research into identifying strategies to reduce the use of broad-spectrum insecticides in Australia. Economic thresholds for control of mirids are well established in the industry (Miles 1995

[4] https://cottoninfo.com.au/stewardship
[5] https://www.dtnpf.com/agriculture/web/ag/crops/article/2016/06/02/refuge-bag-corn-may-speed-bt-2

cited in Sequeira 2019). Work on mirid biology and control, especially using thresholds, has continued in Bt-cotton since that time (eg. McColl *et al* 2011; Sequeira 2019; Grundy, 2022).

There is acknowledgement over many years that growers or advisors are in large part not using these thresholds correctly (Whitehouse 2011; Sequeira 2019; Grundy 2022). Feedback from the workshops indicated that there was a range of attitudes to the use of thresholds for mirids, with some strongly supportive and others quite sceptical of the science

Potential reasons for this reluctance to fully adopt the developed thresholds include;

- perceived complexity,
- perceived risk of inaccurate counts,
- different thresholds at different stages of plant growth and for different regions,
- dynamic and not static thresholds, and
- the perceived risk of damage (with associated blame for advisors).

These factors are related to the risk perceived by advisors and growers as part of the decision-making process. Growers' attitudes are guided by their experience of needing to control a pest if it is present. The risk from the advisor's side is being responsible if there is a loss as a result of inaction. This makes the recommendation not to spray much more difficult or stressful than a recommendation to apply insecticides.

Factors that advisors consider in addition to thresholds for mirids include:

- Expectations of the grower;
- Availability of sprayers;
- Weather conditions;
- Retention of flowers/ bolls (70%+), and
- Timing of mirid sprays with herbicide applications to avoid additional spray application costs.

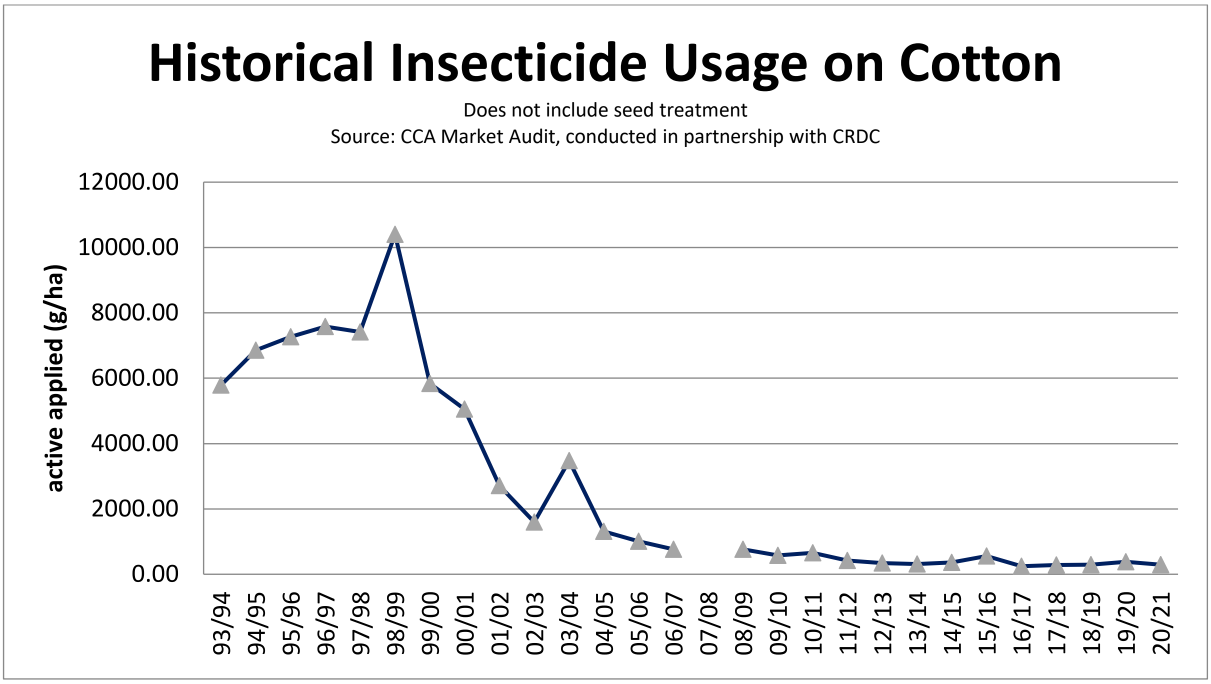
# 3. IPM in Australian Cotton

Integrated Pest Management is the integration of biological, cultural and pesticide control methods in a compatible way. All available tools are used instead of only relying on pesticides to achieve control of pests. The tables developed in each workshop (Appendices 1 – 7) tried to define the range of pests of concern and then the set of control options that could be utilized.

The tables that were produced indicate that participants were aware of the impact that beneficial species and cultural options could have on pests of cotton. There was also an awareness that the most powerful tool that is currently available for control of *Helicoverpa* is a cultural control- Bt cotton (a variety) but that it could be lost if the pest develops resistance. The need for high compliance with refuge requirements is understood within the industry.

The number of insecticide applications has been reduced markedly since the introduction of Bt-cotton (Figure 1). Insecticide applications for mirids are the major concern, primarily because they are (in most instances) not compatible with the populations of biological control agents required to manage other secondary pests. Insecticide and miticide applications are still used by some for these other pests such as mites, whitefly or mealybug. While there are some pesticides that are suitable for use with IPM in cotton, the pests concerned develop resistance extremely quickly meaning that the risk of them losing effectiveness in future is high.  There is already documented resistance in some regions.  It is also possible that the use of fipronil and dimethoate will be restricted in the future.

## Figure 1 Historical Insecticide Usage on Cotton




So, while there is good control of pests in cotton at present and an IPM approach is seen by most that we met during this project as desirable and achievable, there is still a need to improve.  This could involve the development of alternative control methods for mirids or to further encourage adoption of IPM practices to either avoid or better manage secondary pests.  Avoiding resistance to Bt-cotton is being managed well, unlike in some other countries, and the effort here needs to be in maintaining and improving that management.

The cotton industry has a large focus on resistance management for Bollgard® cotton, but it is vital to also maintain attention to the need for a resistance management strategy for insecticides. The potential exists for development of resistance to products being used for control of pests such as Silver Leaf Whitefly, even under a lower overall selection pressure regime than previously used. The use of non-chemical control measures in conjunction with effective pest monitoring and observance of resistance management guidelines is recommended to ensure the ongoing effectiveness of insecticides that are currently used.

# 4. Areas of potential further research or extension

To achieve some of the goals mentioned above the topics below could be considered.

## 4.1 Extension methods

During this project, discussions were held with consultants (in workshops), researchers and other in the industry (listed above). To inform industry about the results of research, the main focus of extension is on crop consultants. While all in industry can access information that is made available via CottonInfo, it appears that there is an expectation that consultants will interpret and apply the findings of research. This may be an artefact of the project methodology, but it is certainly the view held by researchers and other project participants.

This approach has the benefits of a smaller number of individuals to target rather than trying to inform and convince every farmer. These consultants are professional and have local knowledge and influence. There is an expectation by both farmer and advisor of a good outcome from advice given in terms of pest management and yield. Decisions that seem risky (such as not applying an insecticide when pests are present or when another pesticide is being applied) are therefore difficult to make.

One approach that we in IPM Technologies have found to work well in other crops (from broad acre cropping to strawberries) has been to involve researchers, advisors and farmers together in a participatory research approach (Horne, Page and Nicholson 2008). This approach is based on the provision of advice to the grower that an advisor may not feel comfortable providing. The responsibility for the advice is shifted to the researcher and all three participants can see the outcome. Such a trial would typically be done on one field or other agreed area in the first instance and then larger areas as confidence grows.

This approach would still use consultants as the main conduit for information to industry, but the involvement of growers willing to participate in such demonstration trials would change the perceived risk. Most people taking part in this study (in workshops or discussions) agreed that it was difficult to get grower involvement in pest management discussions and that this has long been the case. Attempts that have been made to address situation have had mixed results. Based on IPM Technologies assessment, it would be worthwhile trying again to achieve greater grower involvement.

## 4.2 Capacity Building

A key insight from this project has been the identification of differences in the knowledge base of more experienced growers and agronomists compared to the new generation. This is at least partly attributable to the fact that they have been through crises in pest management and have an awareness of the need for a longer-term approach to insect management.

CCA has been focusing on the provision of specific events for younger agronomists in our industry. These provide a “safe space” for them to engage with researchers and other industry experts and to learn about the importance of building their own knowledge network as part of their career development. We would like to deliver capacity building activities in the future that connect and inform the newer agronomists of the principles of Integrated Pest Management, along with crop scouting methods, thresholds, insect identification and resistance management strategies. There is considerable scope for CCA to collaborate with Cottoninfo, as well as CSIRO, state agriculture departments and universities to ensure that we target a consistent message and avoid duplication of activities.

## 4.3 Insecticides

The impact of insecticides and miticides, predators, parasitoids and bees in cotton table (commonly referred to as the Beneficial Disruption table (CRDC, CottonInfo, 2022) is available in the Cotton Pest Management Guide 2022-23 (CRDC, CottonInfo, 2022). This guide is updated annually and provides important information on the relative impact of pesticides (particularly insecticides and miticides) on the range of beneficial species found in Australian cotton. The information contained in the table is extensive and is considered a highly valuable resource by industry. Sub-lethal testing could be carried out for some products, but this is an expensive and very time-consuming exercise. Updates providing information on new products (actives) as they become available should continue.

There were a few issues regarding insecticides that are worthy of clarification. One is to identify the reasons for the perceived poor performance of flonicamid (Mainman®) against mirids in cotton. This product is successfully used against the same pest in other crops and is not disruptive to most beneficial species. The label rate used in cotton is however substantially lower than in those other crops. It would be worth investigating some of the following factors that might be the cause of poor results described by some in the industry:

- rate used,
- impact of different spray application parameters,
- target size or age,
- dilution with crop growth, and
- degradation times.

If the reasons could be identified, then the industry may have an alternative IPM compatible insecticide to use. While price is currently also a major impediment to its use, this may change in the future and a thorough investigation of this product is recommended.

A significant gap also exists with controlling stink bugs. Currently available insecticides are highly disruptive to beneficial species and make it difficult for growers to control them in an IPM system. An option that could be investigated for this situation is tau-fluvalinate (Mavrik®). Note that this product is not registered for use in cotton. It is highly disruptive to many beneficial species but is not so disruptive to many species of Hymenoptera or has a short residual. It could be worth assessing the impact of this insecticide on both stink bugs and *Eretmocerus*. It may be possible to use this insecticide to control bugs without disrupting parasitoids of whitefly if the results are positive. This would be useful in situations where *Eretmocerus* is the main beneficial species of interest and stink bugs, and whitefly are the main pests of concern.

## 4.4 Degradation times in different regions

The impact of pesticides on beneficials is not just measured by acute toxicity but also by residual impact. Comparison of different products could be made in field conditions in different locations to assess the relative residual activity of some pesticides against key beneficial species.

## 4.5 Alternative to pigeon pea

It was mentioned several times in workshops (and in the scientific literature) that mirids are attracted to pigeon pea crops. Is there another crop that can be used as a refuge planting that is not so attractive to mirids?

Crop Consultants Australia maintains a strong commitment to promoting uptake of IPM by practising agronomists. The association believes that future research and extension in IPM should be supported through cross industry programs. Pest management systems need to be considered across all different crops being grown in each region. CCA has expressed that there is considerable scope for the cotton and grains industries to collaborate on pest management research and adoption, and in some regions could also involve horticulture industries.

CCA is also supportive of ongoing research into IPM and pest management more generally at all levels. There is a need for more understanding of insect pest ecology, greater use of modelling and methods to predict population dynamics, and ongoing education of growers and advisors. This is particularly the case with younger members of our industry that have not experienced a crisis in pest management yet. Resistance monitoring for insecticides and miticides is critical as an early warning system to enable proactive approaches when these issues inevitably arise. The cotton industry has a proud record of concurrently improving production and sustainability. The collaboration that has led to this success in the past will continue with the new generation of supported growers, advisors and researchers.

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# Appendices

1 Dalby Workshop

2 St George Workshop

3 Goondiwindi Workshop

4 Griffith Workshop

5 Warren Workshop

6 Narrabri Workshop

7 Moree Workshop

*Note: Pesticides listed are simply options that may be considered and not all may be registered.  Colour codes are given to indicate compatibility with biological control agents nominated.*

## 1. Dalby Workshop IPM in Cotton September 2021

| Pest | Beneficial | Cultural | Pesticide |
|---|---|---|---|
| Green Mirid<br>- Other mirids | Spiders; Green lacewings;<br>Damsel bugs; Shield bugs<br>Egg parasites | Planting time,<br><br>Avoid lucerne,<br><br>Weed control<br><br>Hygiene (removing old crop),<br><br>Plant health | Dimethoate, Fipronil<br>Transform, (Starkle, Skope)<br>Mainman |
| Whitefly (Silverleaf) | *Eretmocerus*<br>*Encarsia*<br>*Nesidiocorus* | | Pegasus, Admiral, Chess,<br>(Movento)<br>(Starkle, Skope) |
| Mealybugs | Green lacewings<br>Wasps; Ladybirds<br>Predatory bugs | | Applaud, (Movento) |
| Aphids | Lacewings, ladybirds,<br>Hoverflies, wasps | | Dimethoate, (Movento)<br>Pirimor, Seed Dressings |
| Cluster caterpillar | *Trichogramma; Microplitis,*<br>Predatory bugs | | SP's<br>Steward<br>Altacor |
| Thrips<br>- WFT | Predatory mites, Predatory thrips, Predatory bugs (*Orius*) | | -<br>Dimethoate,<br>Seed Dressings |
| Green Vegetable Bug<br>Cotton Stainer Bug | Egg parasitoids, Tachinid flies, | | Shield |
| Mites | Predatory mites, Predatory thrips, *Stethorus.* | | Propargite<br>Oils |
| | | | |

## 2. St George Workshop    IPM in Cotton    November 2021

| **Pest** | **Beneficial** | **Cultural** | **Pesticide** |
|---|---|---|---|
| Green Mirid<br>- Other mirids | Spiders; Green lacewings; Damsel bugs; Shield bugs<br>Egg parasites | Control ratoons (esp for mealybug) = Hygiene (removing old crop)<br><br>Avoid lucerne, Faba beans, Safflower (especially for mirids)<br><br>Weed control, Clean boundaries<br><br>Plant health | Fipronil<br>Transform, (Starkle, Skope)<br>Mainman |
| Whitefly (Silverleaf) | *Eretmocerus*<br>*Encarsia*<br>*Nesidiocorus* | | Admiral,<br>(Movento)<br>(Starkle, Skope) |
| Mealybugs | Green lacewings<br>Wasps; Ladybirds<br>Predatory bugs | | Applaud, |
| Aphids | Lacewings, ladybirds, Hoverflies, wasps | | Dimethoate, (Movento), Transform<br>Pirimor, Chess, Mainman,<br>Seed Dressings |
| Mites (6-spotted mite, 2-spotted mite) | Predatory mites, Predatory thrips, *Stethorus.* | | Vertimec<br>Acramite |
| Green Vegetable Bug<br>Cotton Stainer Bug | Egg parasitoids, Tachinid flies, | | Shield, Starkle |
| Helicoverpa | Wasps; Lacewings, Predatory Bugs | “Bollgard” | Vivus<br>Coragen |
| | | | |

## 3. Goondiwindi Workshop IPM in Cotton December 2021

| **Pest** | **Beneficial** | **Cultural** | **Pesticide** |
|---|---|---|---|
| Green Mirid<br>- Other mirids | Spiders; Damsel bugs; Shield bugs<br>Egg parasites | Control ratoons (esp for mealybug) = Hygiene (removing old crop)<br><br>Trap Crops, eg chick peas (esp for mirids)<br><br>Weed control, Clean boundaries<br><br>Plant health | (Fipronil) – low rate<br>Transform, (Starkle, Skope)<br>Mainman<br>(Dimethoate) – low rate |
| Whitefly (Silverleaf) | *Eretmocerus*<br>*Encarsia*<br>*Nesidiocorus* | | Admiral, Applaud<br>(Movento)<br>(Starkle, Skope)<br>Exirel |
| Mealybugs | Green lacewings<br>Wasps; *Cryptolaemus* releases<br>Predatory bugs | | Applaud,<br>Oils |
| Aphids | Lacewings, ladybirds,<br>Hoverflies, wasps | | Dimethoate, Pegasus, (Movento),<br>Transform<br>Pirimor, Chess, Mainman,<br>Seed Dressings |
| Mites (6-spotted mite, 2-spotted mite) | Predatory mites, Predatory thrips, *Stethorus* ladybirds | | Vertimec<br>Acramite<br>Paramite |
| Green Vegetable Bug<br>Cotton Stainer Bug | Egg parasitoids, Tachinid flies, | | Shield, Starkle |
| Helicoverpa | Wasps; Lacewings, Predatory Bugs | “Bollgard” | Vivus<br>Coragen |
| Other caterpillars | “ “ | | Coragen |

4. Griffith Workshop IPM in Cotton March 2022

| **Pest** | **Beneficial** | **Cultural** | **Pesticide** |
|---|---|---|---|
| Mirids<br>- Apple Dimpling Bug? | Spiders<br>Predatory bugs<br>Parasitoid wasps | Trap crop<br>Avoid lucerne nearby<br>? Pigeon pea | Mainman<br>Transform, Starkle, Indoxacarb<br>Fipronil, Dimethoate |
| Whitefly | *Eretmocerus* wasps<br>Predatory bugs | “ “<br>Weed control<br>Area wide management | Admiral, Applaud (not ladybirds)<br>Pegasus<br>Sp’s ; OP’s |
| Helicoverpa<br>- armigera<br>- punctigera | Parasitoid wasps (*Trichogramma* and others)<br>Predatory bugs<br>Red and blue beetles | Bollgard<br>Refuges | Vivus, Altacor, Dipel<br>Abamectin |
| Fall Armyworm?? | “ “ | - | Fawligen, Altacor, Dipel<br>Abamectin |
| Thrips | Mites, thrips, predatory bugs | Increase humidity, decrease dust | Entrust<br>Dimethoate |
| Mites | Thrips, mites, *Stethorus* ladybirds | | Vertimec, Pegasus<br>Dimethoate |
| Aphids | Lacewings, ladybirds, hoverflies, Parasitoid wasps | Nectar Source,<br>Weed control | Movento (mites) |
| Green Vegetable bug | Egg parasitoids | Location affects pest levels | Skope, Shield |
| False wireworms | Carabid beetles | Rotation, Tillage practices | Seed dressing |

## 5. Warren Workshop IPM in Cotton March 2022

| **Pest** | **Beneficial** | **Cultural** | **Pesticide** |
|---|---|---|---|
| | | Balanced nutrition, not just high N | |
| Mirids<br>- Green Mirid only | Spiders<br>Predatory bugs<br>Parasitoid wasps | Trap crop<br>Avoid lucerne nearby | Mainman, Oils<br>Transform, Starkle, Indoxacarb<br>Fipronil, Dimethoate |
| Whitefly<br>- Silverleaf and Greenhouse | *Eretmocerus* wasps<br>*Encarsia* wasps<br>Predatory bugs (*Nesidiocorus*)<br>?Inoculative releases? | " "<br>Weed control<br>Area wide management | Admiral, Applaud (not ladybirds)<br>Pegasus, Neoicatinoids<br>SP's ; OP's<br>Movento<br>Movento (mites) |
| Green Vegetable bug<br>Shield bug/ stink bugs | | Location (near watercourses) affects pest pressure | ?Border sprays?<br>?Mavrik? (safe to wasps) |
| Helicoverpa<br>- armigera<br>- punctigera | Parasitoid wasps (*Trichogramma* and others)<br>Predatory bugs<br>Red and blue beetles | Bollgard<br>Refuges<br>Trap crop? | Vivus, Altacor, Dipel<br>Emmamectin, Indoxacarb |
| Thrips | Mites, thrips, predatory bugs | Increase humidity, decrease dust | Entrust<br>Dimethoate |
| Mites | Thrips, mites, *Stethorus* ladybirds | | Vertimec,<br>Dimethoate |

## 6. Narrabri Workshop IPM in Cotton March 2022

| Pest | Beneficial | Cultural | Pesticide |
|---|---|---|---|
| | | Canopy height; Nectar source | |
| Mirids<br>- Green Mirid only | Spiders<br>Predatory bugs | Trap crop<br>Avoid lucerne nearby | Mainman, Oils<br>Transform, Steward, Shield<br>Fipronil, Dimethoate |
| Whitefly<br>- Silverleaf only | *Eretmocerus* wasps<br>Predatory bugs (*Nesidiocorus*)<br>Inoculative releases being used | " "<br>Weed control | Admiral, (not ladybirds)<br>Oils<br>Movento<br>Movento (mites) |
| Helicoverpa<br>- armigera<br>- punctigera | Parasitoid wasps (*Trichogramma* and others)<br>Predatory bugs<br>Red and blue beetles | Bollgard<br>Refuges<br>Trap crop? | Vivus, Altacor, Dipel<br>Emmamectin, Indoxacarb<br>Skope |
| Thrips | Mites, thrips, predatory bugs | Increase humidity, decrease dust | Entrust<br>Dimethoate |
| Mites | Thrips, mites, *Stethorus* ladybirds | | Vertimec,<br>Dimethoate |
| Aphids | Wasps, Ladybirds, Hoverflies, Lacewings | Weed control | Pirimor, Mainman<br>Pegasus<br>Skope, Dimethoate |
| Mealybugs | Wasps; Green lacewings | Control volunteer cotton | Mainman |
| Green Vegetable bug<br>Shield bug/ stink bugs | Egg parasitoids<br>Shield bugs<br>Spiders | Location (near watercourses) affects pest pressure | ?Border sprays?<br>?Mavrik? (safe to wasps)<br>SP's |

## 7. Moree Workshop IPM in Cotton March 2022

| Pest | Beneficial | Cultural | Pesticide |
|---|---|---|---|
| Mirids<br>- Green Mirid only | Spiders<br>Predatory bugs | Adjacent crop, including pigeon pea,<br>Potential to manage perimeter<br>(Trap crop) | Mainman, Oils<br>Transform, Steward, Shield<br>Fipronil, Dimethoate |
| Green Vegetable bug<br>Shield bug/ stink bugs | Egg parasitoids<br>Shield bugs<br>Spiders | Location (near watercourses) affects pest pressure | ?Border sprays?<br>?Mavrik? (safe to wasps)<br>SP's |
| Whitefly<br>- Silverleaf only | *Eretmocerus* wasps<br>Predatory bugs (*Nesidiocorus*)<br>Inoculative releases being used | " "<br>Weed control<br>Use sunflowers to establish *Eretmocerus* | Admiral, (not ladybirds)<br>Oils<br>Movento<br>Movento (mites) |
| Helicoverpa<br>- armigera<br>- punctigera | Parasitoid wasps (*Trichogramma* and others)<br>Predatory bugs<br>Red and blue beetles | Bollgard<br>Refuges<br>Trap crop? | Vivus, Altacor, Dipel<br>Emmamectin, Indoxacarb<br>Skope |
| Aphids | Wasps, Ladybirds, Hoverflies, Lacewings | Weed control | Pirimor, Mainman<br>Pegasus<br>Skope, Dimethoate |
| Mealybugs | Wasps; Green lacewings | Control volunteer cotton | Mainman |
| Thrips (WFT) | Mites, thrips, predatory bugs | Increase humidity, decrease dust | Entrust<br>Dimethoate |
| Mites | Thrips, mites, *Stethorus* ladybirds | | Vertimec,<br>Dimethoate |
| Rutherglen bugs | | Furrow plus water; border management | Border spray (juveniles)<br>Soap spray (adults) |
| Symphylans | *Hypoaspis* type mites | Rotation | nil |