

Integrated Pest Management (IPM) in cotton

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Introduction

Successful pest management aims to keep pest populations to levels that do not cause economic damage and to maintain profitability year after year.

The key challenge to long term effective management is conserving and utilising beneficial insects for pest control and preventing over-reliance on chemical control of pests that will lead to insecticide resistance and render insecticidal control options ineffective. Insecticide resistance can destroy an industry and the collapse in 1975 of the cotton industry in the Ord River Irrigation Area in Western Australia is testament to this. History has shown repeatedly that reliance on a single tactic will result in resistance problems, and the cotton industry in eastern Australia has been seriously challenged by insecticide resistance in its 50 year history.

What is IPM?

Integrated Pest Management (IPM) is a concept developed in response to problems with managing pests, insecticide resistance and environmental contamination. The basic concept of IPM is to use knowledge of pest biology, behaviour and ecology to implement a range of tactics throughout the year in an integrated way that suppresses and reduces their populations. This approach considers tactics to suppress or avoid pests across the farm and surrounding areas, and tactics to manage pest and beneficial insect populations in the crop, including the responsible use of insecticides.

Because all pests have other animals that eat them, such as predators or parasites (known as beneficials or natural enemies), building and conserving populations of beneficials is at the heart of IPM. To conserve natural enemies, a pest management decision needs to be well informed, supported by good sampling, valid control thresholds and knowledge of the beneficials present and their activity. Finally, if insecticides are required, they are selected based on the Insecticide Resistance Management Strategy (to avoid resistance), how effective they are on the pest (to ensure adequate control) and their risk (soft) to the beneficial population (so beneficials can be conserved).

The outcome of an effective IPM system is long term stable management of pests and beneficials, reducing the risk of resistance, so that economic losses of crop yield and quality and threats to human health and the environment can be minimised. Elements of best practice IPM are:

1. Know your enemy and your friends.
2. Take a year around approach.
3. Think of the farm and surrounding vegetation as a whole system.
4. Have good on-farm hygiene.
5. Consider options to escape, avoid or reduce pests.
6. Sample crops effectively and regularly.

7. Aim to grow healthy crop.
8. Evaluate pest abundance against established thresholds.
9. Choose insecticides wisely to conserve beneficials.
10. Apply good resistance management principles.

Developing an IPM strategy

As part of your plan to grow cotton, identify IPM resources on your farm and tactics you may use up front to conserve beneficials and suppress pest populations across the farm. Consider your in-crop risks and identify how different tactics will be applied in-crop for different pest scenarios. Identify what your overall IPM goals will be, some examples include:

- Start each cotton season with low/no pest populations.
- Avoid unnecessary insecticides especially early season.
- Follow the cotton industry's IRMS for all insecticides.
- Make non-crop areas more productive for beneficials.
- Avoid pest outbreaks that are generated within the farm.
- Minimise impact on bees and beneficials.
- Participate in Area Wide Management.

Communicate your IPM goals and planned tactics with entire farming team.

As insecticides still play an important role in an IPM system, develop and implement a chemical handling application management plan (CHAMP), formerly PAMP, to minimise the risks associated with pesticide application specific to your farm. A CHAMP will help to establish good communication with everyone involved and interested in the application of pesticides, both pre-season, and during the season, as well as ensuring appropriate application techniques and procedures are used and that sufficient record keeping is kept. For more information and assistance in developing a CHAMP consult the *myBMP* website.

What can I do to suppress pests on my farm? Upfront tactics

1. Know your enemy and your friends

'The enemy of your enemy is your friend'! Knowledge of pest species, their damage and beneficials and the pests they feed on is critical in evaluating the potential for economic loss.

Knowledge of pest ecology can identify sources of potential infestation and non-insecticidal management strategies to control the pest before problems develop. For instance, management of weed hosts may reduce pest abundance. Consider how your IPM strategy can target different mechanisms of pest survival. For information about key pests and mites of Australian cotton go to page 5. Refer to the Cotton Production Manual and the 'Guide to Pests and Beneficials in Australian Cotton Landscapes' for more information.

If you would like to participate in workshops or training on IPM, contact your CottonInfo Regional development officer (see inside back cover).



Brown mirid (L), green mirid (centre) and apple dimpling bug are known to damage squares to varying degrees and apple dimpling bug is generally regarded more as a predator of heliothis eggs and mites. (Photos 1, 2 M Khan, DAFF Qld; 3 C. Mares, CSIRO)

2. Take a year round approach

Seasonal conditions and farming practices during the winter months can have a big influence on summer pest population.

Divide the year up into logical phases and consider what actions could be taken in each phase to reduce overall risk as well as later phases, refer to the IPM calendar pages 6–7. Take into account factors such as (i) crop history (eg for some pests if a field had a problem with that pest last year it may be more prone to the same pest next year – mites are an example), (ii) crop sequences that encourage build up and movement of the same pest between crops (eg late soybeans will inherit silverleaf whitefly populations from nearby maturing cotton), (iii) management of weeds in fallows and crops (iv) planning ahead for likely insecticide needs so selective options are available when needed, (v) having a plan for sampling crops and ensuring information is on hand for pest identification and thresholds. Seasonal conditions are a major driver of outbreaks of pests. For example, a wet winter and spring will increase the risk of a number of key cotton pests because they are able to survive on hosts (often weeds) that grow on the unseasonal rainfall. Conversely, a wet summer in southern regions of Australia may promote the likelihood of winter pest outbreaks. Being aware of how the conditions may influence pest pressure will help assess the risk of pest outbreak.

3. Think of the farm and surrounding vegetation as a whole system

Insects live in landscapes, not on farms. Management across farms can impact on both pests and beneficials. This extends beyond cropping land, as areas of complex, perennial vegetation can be an important host for beneficials.

Consider this situation – if you were to spray all of the fields on your property at once with a disruptive insecticide there will be a large decline in the abundance of predators and parasites in those fields. This places those fields at risk because other secondary pests not controlled by the insecticide may then increase without being controlled by beneficials. Also pests which enter the crop after the insecticide has decayed will survive better and potentially cause more economic damage. If beneficials are killed by sprays where will new beneficials come from to re-establish in the crop?

One source of beneficials could be unsprayed crops on the farm or nearby farms – reinforcing the notion that it is only sensible to control pests in the fields where they warrant control. This ‘site-specific’ management means unsprayed fields will harbour beneficials and are a source of beneficials to re-colonise sprayed fields. To build beneficials across the farm, apply IPM principles to manage all crops, not just cotton.

Another source of beneficials is native vegetation both on farms and in the region. When it comes to pest management, ‘Veg is Valuable’ as an important source of beneficials. This is especially so because these areas are permanent and usually complex, range of species and layers, and so provide continuous prey as well as habitat for beneficials year round, whereas cropped fields may be fallow for long periods. When looking to enhance IPM value of areas of vegetation consider the following:

- Managing for groundcover and diversity
- Prioritise connectivity
- Enhance habitat with water ways
- Weed out pest hosts, especially volunteer cotton.

The Cotton Pest and Beneficial Guide and Cotton Production Manual provide more information on enhancing natural assets to improve IPM values.



Think of the farm and surrounding vegetation as a whole system. (Photo: Greg Kauter, formerly Cotton Australia)

Area Wide Management (AWM) acknowledges that insects are mobile and that the management regimes used on one farm can have implications for the surrounding locality. Sharing your strategies and coordinating tactics with neighbouring cotton growers as well as other farmers will increase the success in implementing IPM. These may include weed management, conserving beneficials, delaying use of disruptive insecticides, reducing the risk of drift between farms, shared adherence to IRMS, planting windows, maintenance or enhancement of local native vegetation areas and the planting of trap 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 build rapport.

4. Have good on-farm hygiene

Many cotton pests rely on weed hosts and cotton volunteers prior to migrating into cotton fields.

Pests that gain the greatest advantage from weeds are those that are unable to hibernate/over winter when conditions are unfavourable, such as spider mites, cotton aphids, mirids and silver leaf whitefly. Some weeds and cotton volunteers or ratoons can also act as a reservoir for plant viruses such as Cotton Bunchy Top disease which can cause significant loss of yield. Weed hosts should be managed in non-crop areas such as field borders, roadways, irrigation channels and in perennial vegetation and pastures, as well as in fallows. Refer to pages 5–37 for details of hosts of key insect and mite pests of Australian cotton.

Cotton volunteers are the worst weeds in terms of pest risk. A ‘zero tolerance’ approach to cotton volunteers throughout the year is required – refer to page 118 for more information.

5. Consider options to escape, avoid or reduce pests

Pre-season planning to reduce pest risks can help to identify upfront opportunities to suppress or avoid the incidence of pests throughout the season.

Field selection

Consider proximity to other host crops, as well as sensitive areas such as watercourses, pastures and buildings, relative to the prevailing wind direction. The Bollgard II trait may be most appropriate for fields adjacent to sensitive areas. Conventional cotton may benefit from being embedded amongst Bollgard II cotton and rotation crops. In this situation pest loads are diluted across all the crop area. The conventional crops may gain some protection by Bollgard II crops intercepting some of the *Helicoverpa* population and surrounding 'low spray' Bollgard II crops can act as sources for rapid re-entry of beneficials if sprays are required on the conventional crops. Bollgard II crops adjacent to conventional cotton crops may also suffer boll damage from large *Helicoverpa* larvae (4-6 instar) unaffected by Bt toxin, migrating from conventional crops to cause damage to the adjacent Bollgard II crops. Conventional crops (particularly unsprayed refuge) and Bollgard II crops should be separated by at least 20m buffer or should not be planted side by side on the same field.

As part of field selection, stubble loads and soil pest activity should be monitored in the lead up to planting. 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.

Varietal selection

Select a variety that suits the growing region in terms of season length. Choosing a variety and growing conditions that favour vigorous establishment can help reduce the need to rely on seed or at-planting treatments and protect the crop from pests to which no effective insecticidal options are available.

The okra leaf shape reduces the rate at which silverleaf whitefly 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 those pests, which in turn lowers the need to spray for other pests.

Seed treatment

Seed treatments provide prophylactic protection against early season/establishment pests. In general they are less disruptive to beneficial populations than spraying the crops with a foliar insecticides because most options available are not very selective. Prior to using a seed treatment be aware of and plan how the resistance risks will be managed.

Seed bed preparation and strategic planting time

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. Planting during optimal temperatures for germination, contributes to this early vigour, and can reduce the need for prophylactic insecticidal seed treatments, as well as improve tolerance towards seedling disease and herbicides.

Very late planted crops which have delayed maturity can be susceptible to influxes of pests such as whitefly at the end of the season.

Create a diversion

Summer trap cropping aims to concentrate a pest population into a smaller less valuable area by providing the pest with a host crop that is more highly preferred and attractive than the crop you are aiming to protect, for example lucerne can be used as an effective trap crop for mirids. In Central Queensland, pigeon pea is used as a summer trap crop as part of the RMP for Bollgard II cotton.

Spring trap cropping with chickpeas is designed to attract *Helicoverpa armigera* adults as they emerge and reduce the first generation through strategic crop destruction. It is important to ensure that the chickpea crop does not become a nursery for multiple generations of moths.

Pupae busting

In NSW and Southern Qld, cultivation of cotton fields through winter kills diapausing *H. armigera* pupae in the soil, and has proven to assist in the management of resistance. Pupae busting is required following harvest of Bollgard II cotton (see page 75) and is recommended by the industry's IRMS for all cotton (page 66).

Build bigger populations of beneficials

Careful farm management and planning can enhance beneficial populations and increase their contribution to controlling pests. The abundance of beneficials in a cotton crop is affected by food resources, mating partners, proximity to other sources of habitat, climatic conditions and insecticide sprays. In addition to enhancing opportunities to build beneficials in nearby habitat, such as rotation crops and perennial vegetation, tactics to attract and build beneficials early in the crop should be considered.

The application of food sprays in cotton crops enables beneficial insects (particularly predators) to be attracted, retained and conserved in the crop. There is currently only one type of food spray commercially available for use in cotton. Predfeed is a yeast based food spray that attracts beneficial insects and should be applied when a cotton field does not have enough beneficial insects (see Table 1).

The abundance of beneficial species can be increased through purchase and release of predators and/or parasitoids in the crop. While this practice is widespread in other industries, this has not been demonstrated as effective in cotton. Planning is required to ensure that introduction can be timely. Lacewings and lady beetles are predators of a range of insect pests, and are highly effective against mealybug where there are no effective insecticidal options. *Trichogramma* spp. can be purchased and released into crops. Two or more releases one week apart are suggested. If possible the best method is to release the *Trichogramma* spp. into a nearby flowering sorghum or maize crop rather than into cotton. This will provide the *Trichogramma* spp. with enough *Helicoverpa* spp. eggs to carry over the population, given the very short life cycle.

TABLE 20: Food sprays and spray additives

| Active ingredient | Formulation | Application rate of product | Trade name | Marketed by | Comments |
|--------------------------------|-------------|-----------------------------|------------|--------------------|--|
| Food concentrate (yeast based) | WP | 2.5 kg/ha | Predfeed | Growth Agriculture | Beneficial insect attractant. Apply prior to increase of pests. See label for notes on spray coverage. |

What can I do to manage pests in my crops?

Active tactics

6. Sample crops effectively and regularly

Regularly sample and correctly identify pest and beneficial populations. Observe beneficial activity (eg thrips in mite colonies, parasitized aphid mummies, ladybirds, hoverfly, lacewing larvae in aphid colonies).

Ensure you can identify key pests, beneficials and types of plant damage. The Cotton Pest and Beneficials Guide is available by contacting your regional CottonInfo team member. Some insects are difficult to see with the naked eye – a 10X power hand lens in your pocket is an invaluable tool to quickly and simply check pest species. These are available from Australian Entomological Supplies. Some species, such as greenhouse whitefly and SLW cannot be differentiated in the field. Refer to relevant insect and mite pest section (pages 5–37) for industry contacts on who can help with identification.

If you suspect you have an exotic pest or disease on your farm, immediately contact the Exotic Plant Pest Hotline 1800 084 881.

Count pests and beneficials, and measure crop health. These three pieces of information form the backbone for making pest control decisions.

DECISION MAKING PROTOCOL (predators to pest ratios)

Conventional crops

| Ratio | Helicoverpa spp. | Action |
|---------|-----------------------------|--|
| > 0.5 | < 2 | Do nothing. |
| 0.4–0.5 | < threshold (mostly eggs) | Yeast based food spray might be applied. |
| 0.4–0.5 | < threshold (mostly larvae) | Sugar based food spray and biological insecticide or petroleum spray oil (PSO) |
| < 0.4 | > threshold | Selective insecticide. |

Bollgard II crops

The predator to pest threshold is essentially the same as above with a slight addition. If in the next check after a food, PSO or biological spray, Helicoverpa neonate numbers are above threshold, mix PSO with soft chemical and apply to crop

| Ratio | Helicoverpa spp. | Action |
|------------------------|------------------|---|
| Increasing | ≥ threshold | Repeat food /biological spray mixture |
| No change or 0.42–0.45 | ≥ threshold | Selective pesticide (possibly mix with PSO) |
| 0.4 | > threshold | Selective pesticide (possibly mix with PSO) |

For more information on the use of PSOs see the Research Review 'Use of Petroleum Spray Oils to Manage Cotton Pests in IPM Programs' available from www.myBMP.com.au

How to sample for pests and beneficials

There are a range of sampling techniques available. Make sure you familiarise yourself with these techniques and use those that are appropriate for the economic threshold, and the crops, pests and beneficials. Refer to the relevant key pest section for more information about recommended technique and monitoring frequency.

Visual sampling: This involves looking at the entire plant, including under leaves, along stems, in squares and around flowers and bolls.

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.

D-vac sampling is more common as a research tool, however, can be used as an additional method when sampling beneficial insects and spiders.

Sweep net sampling: This method can be used as an alternative to the beat sheet when the field is wet. Sweep netting is an effective method for sampling flighty insects such as mirids, and each sample consists of 20 sweeps along a single row of cotton using a standard (380 mm) sweep net.

It is generally not possible to make a decision about whether control is needed based on just one check. The decision making system needs to be flexible to allow for the action of beneficials and natural mortality. 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 or pest ratio to be determined.

How much to check

Fields are rarely uniform in crop growth and attractiveness to insects. For example mealybugs are more likely to build up in areas of plant stress, such as water-logged tail drains, while other pests may be more likely to lay eggs in areas of lush growth. Awareness of such areas and their size helps you to determine how many sample points are required in a crop.

Visual sampling: Check at least 30 plants or 3 to 4 separate metres of cotton per 50 ha.

Beat sheet sampling: Preliminary studies indicate that you need to beat at least 8–10 metres per field.

Sweep net sampling: Preliminary studies indicate that you need to take at least 6 sweep net samples per field.

Note: Increasing the number of samples will increase the level of accuracy. For some pest species there are specific recommendations, see pages 5–37.

Monitoring predators and levels of parasitism provides useful detail for IPM decision making. Where high levels of beneficials are recorded, this can provide confidence in delaying an insecticide. Refer to Table 21 'Friends in the field' for which beneficials target what prey.

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 or pest ratio to be determined.

TABLE 21: Friends in the field

| | Heliothis | Aphid | Mealybug | Spider Mites | SLW | Green Mirid | Jassids | Thrips | Notes |
|--------------------------------------|-----------|-------|----------|--------------|-----|-------------|---------|--------|--|
| Red and blue beetle | X | X | | | | | | | Also predator of slow moving insects; The larvae feed on small worms and other soil organisms. |
| Lady beetles | X | X | X | X | X | | X | | Scale insects. |
| Apple dimpling bug (yellow mirid) | X | | | X | X | | | | Can cause damage, but threshold is 5 times greater than green mirids. Monitor fruit retention. |
| Damsel bug | X | X | | X | | X | | | |
| Big Eyed bug | X | | | X | X | | | | |
| Brown smudge bugs | X | | X | X | X | | | | |
| Glossy shield bug | X | | | | | | | | And other caterpillars. |
| Predatory shield bug | X | | | | | | | | And other caterpillars. |
| Minute pirate bugs | | | | X | X | | | X | |
| Assassin bug | X | | | | | X | | | And other caterpillars. |
| Lacewings | X | X | X | X | | | | X | Larvae is the predator, but need adults to lay on the crop to get the predatory larvae. |
| Spiders | X | | | X | X | X | X | | Spiders can eat both good and bad insects. |
| Parasitoids | X | X | X | | X | | | | Species of parasitoid are specific in pests targeted. Monitor for parasitized pests. |
| Hoverfly larvae and Silverfly larvae | | X | | | | | | | The adult will lay on your crop when there are aphid colonies. |
| Thrips | | | | X | X | | | | Can be an early season pest. |

Guidelines for the predator to pest ratio

Predator to pest ratio for sucking pests have not been determined. However, the ratio for *Helicoverpa* spp. has been determined and given below for both conventional and Bollgard II cotton crops. The most common predators found in cotton farms feed on a wide range of pests and are therefore classified as general predators. Therefore, the predator to prey ratio calculated for *Helicoverpa* spp. may also be enough to manage other secondary pests. Monitor fruit retention and damage in addition to the use of the ratio.

Calculation of the predator to pest ratio per metre for *Helicoverpa* spp:

The predator to pest ratio is calculated as –

$$\text{Ratio} = \frac{\text{predators}}{(\text{Helicoverpa spp. eggs} + \text{VS} + \text{S})}$$

where VS = very small and S = small larvae

The calculation does not include *Helicoverpa* medium (M) and large (L) larvae since many of the common predatory insects are not effective on these life stages.

Total predators per metre (visual check) should be used in calculating the predator to pest ratio. However, to be confident in the ratio, at least three insects of the most common predators (ladybird beetle, red and blue beetle, damsel bug, big eye bug, assassin bug, brown shield bug and lacewings) should be present.

Incorporating parasitoids into spray decisions

Parasitoids are important beneficials in Australian cotton farming systems. These useful insects are easily overlooked because they are often small or secretive. There are a range of parasitic wasps and flies that attack *Helicoverpa* spp., green vegetable bugs, aphids and whiteflies. Recently parasitism of solenoposis mealybug by *Aenasius bambawalei* (Hayat) has been confirmed in Australia. Parasitised mealybugs are easily identified by a dark brown pupal case within the white mealybug.

Trichogramma spp. wasps are egg parasitoids capable of causing high mortality of *Helicoverpa* spp. in crops. The wasp lays an egg(s) inside

a *Helicoverpa* spp. egg and the hatch wasp larva(e) feeds on the egg, preventing hatching. To monitor egg parasitism by *Trichogramma* spp. collect brown eggs and keep them at room temperature (about 25°C) until they hatch (healthy) or turn black (parasitised).

The predator to prey ratio calculation does not incorporate parasitoids particularly *Trichogramma* spp. (egg parasitoid).

Beneficial insect to pest ratio:

$$\frac{\text{predators}}{(\text{eggs} - (\% \text{ parasitised}) + \text{VS} + \text{S})}$$

The same decision making protocol as on previous page is used.

7. Aim to grow healthy crop

A healthy cotton crop will be more able to recover from pest damage and reach its yield potential. It is important to include an assessment of plant damage when making pest management decisions because insect numbers alone may not give an accurate indication of the need for control.

Growing a healthy cotton crop optimises both its yield potential, fibre quality and capacity to compensate for pest damage. While yield (and quality) potential will largely be determined by a range of factors. IPM provides a strategy to help manage the risk of economic losses due to pests, in the current season, as well as future crops.

Monitoring crop as well as insects

It is important to include an assessment of plant damage when making pest management decisions because insect numbers alone may not give an accurate indication of the need for control. Cotton plants have a significant ability to recover from damage, especially early season damage with no reduction in yield or delay in maturity. Plant monitoring in conjunction with regular insect monitoring allows an assessment of the effects of pests that might be difficult to detect in regular sampling. Plant monitoring can assist in decision making where pest levels are just below threshold or where there are combinations of pests present. Acceptable damage levels will vary depending on yield expectations and climatic conditions.

Damage monitoring for pests should be conducted regularly and includes:

- Leaf area loss or discoloration;
- Tip damage;
- Fruit retention or fruiting factor; and,
- Boll damage.

Refer to 'Key Insects and Mites of Cotton Section' for pest specific damage thresholds. Fruit load is a key aspect in determining crop yield and maturity. The loss of fruit during squaring and early flowering is less critical to yield than fruit loss later in the season. It is well documented that excessive early fruit loss can delay final maturity. However, it is also known that holding too much fruit can reduce crop growth, as the plants use their resources to fill the bolls they have set rather than continuing to grow and set more fruit. This is referred to as premature cut-out which results in reduced yield potential.

Cotton development can be predicted using daily temperature data (day degrees). Monitoring crop vegetative and reproductive growth compared to a potential rate of growth and development enables crop managers to determine when growth is not optimal and manage accordingly.

The CottASSIST Crop Development Tool (CDT) is a web based tool that helps to determine whether the rate of crop development is meeting its potential. Using the CDT, the development of squaring nodes, vegetative growth rate, fruit development and nodes above white flower can each be

tracked to assist with crop management decisions. The user enters real crop data as the season progresses, and the tool accesses local climate data to calculate accumulated day degrees (DD) for that location. The tool displays this in graphical and tabular formats alongside theoretical potential or optimum development. Decisions relating to insect thresholds, growth regulation, nutrition and irrigation scheduling can all be aided by a clear understanding of how crop development is progressing. CottASSIST can be accessed at <https://cottassist.com.au/> or through www.myBMP.com.au

What to monitor?

Leaf damage

Research on seedling cotton (up to 6 nodes) has found that loss of leaf area did affect maturity, but only treatments with more than 80% loss of leaf area were affected.

Development of squaring nodes

For most Australian cotton varieties it is expected that the first fruiting branch will develop on about the seventh mainstem node. On a well grown crop, by the time of first flower (~750 DD) there will be about 8 squaring nodes. Fewer than 8 will often reduce yield potential. Measuring squaring nodes can provide early indication of stress in time for remedial action. Once flowering commences it may be too late to recover. Squaring node development can be tracked using the CottASSIST Crop Development Tool.

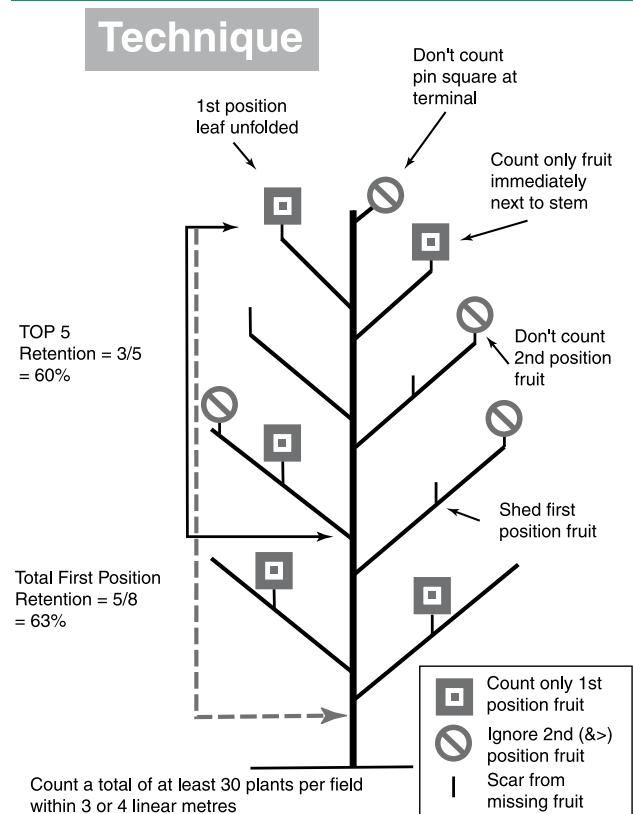
Fruit development

It is important to ensure that crop growth translates into fruit production at a rate that will help to attain a profitable yield. The CottASSIST Crop Development Tool's fruit development graph displays the number of observed squares or bolls (/m) plotted against a potential rate of fruit development based on the day degree accumulation after sowing.



Good communication before and during the season is key to successful IPM. (Photo: Amanda Thomas)

FIGURE 1: A technique for checking fruit retention



Nodes above white flower (NAWF)

At the time of first flower, there should be about 8 squaring nodes above the flower, or 8 NAWF. The bolls produced on these fruiting branches will contribute a large proportion of final yield. Once boll set commences and the crop is allocating resources to the developing fruit, the rate at which the crop can produce more squaring nodes is in decline.

Once there are 4 or fewer NAWF, the crop is said to be 'cut-out'. This signifies that the crop has ceased putting resources into further vegetative growth and that yield potential is dependent on the retention of fruit already produced. NAWF can also be tracked using the CottASSIST Crop Development Tool.

Vegetative Growth Rate (VGR)

VGR is the industry recommended approach for identifying excessive growth. The VGR tracks the rate of change in plant height relative to the rate of node development.

VGR is calculated using the following equation:

$$\text{VGR (cm/node)} = \frac{\text{This week's height (cm)} - \text{Last week's height (cm)}}{\text{This week's node number} - \text{Last week's node number}}$$

Measurements of height and nodes should start as the crop approaches first flower and continue whilst squaring nodes are being produced. VGR can be tracked using the CottASSIST Crop Development Tool. In making a decision as to whether Mepiquat Chloride can help, it is important to consider causes behind any excessive growth.

Refer to Cotton Production Manual for more information.

First position fruit retention

Monitoring first position fruit retention is a technique that is best used from squaring to early flowering. It is a quick way to estimate early signs of pest damage.

% First position fruit retention =

$$\frac{\text{Count first position fruit (either top five or all fruiting branches)}}{\text{Count total fruiting branches}}$$

Monitor both tipped and non-tipped plants using the dominant stem, not vegetative branches.

Aim to have first position fruit retention of 50–60% by first flower. Low retention (<50%) increases the risk that yield or crop maturity will be affected. However, very high fruit retention, in excess of 80% may also be associated with premature crop cut-out. For the first five fruiting branches on the plant, first position fruit retention can be as low as 30% without affecting yield or maturity, however such levels should trigger close monitoring and a reduction in thresholds. Refer to Figure 1 (page 56).

Final retention at maturity

Boll numbers will vary according to variety, stage of growth and yield potential. At the end of the season a crop will hold less than 50% of all possible fruiting sites. First position retention will vary from 50–70%. Variety and boll size will also affect final yield.

Fruiting factor

Fruiting factors allow total fruit load to be monitored throughout the season. Fruiting factors should be used when first position retention falls below recommended levels (i.e. 50–60%), to ensure excessive fruit loss has not occurred or in situations where a crop is heavily tipped out and retention is difficult to determine.

From 10–14 days after flowering, the monitoring of first position fruit retention may be less relevant than fruit counts. The fruiting factor technique allows a rapid interpretation of the fruit counts. The technique considers both fruit present and the number of fruiting branches (potential fruit development).

To save time in monitoring the fruiting factor, only count first and second position fruit (squares and bolls), from the main stem and the first dominant vegetative branch. In irrigated crops this should account for 90% of the fruit that will be picked.

To determine the fruiting factor for a crop, simply divide the fruit count by the number of fruiting branches.

$$\text{Fruiting factor} = \frac{\text{Total fruit /m}}{\text{Total number of fruiting branches/m}}$$

The ideal fruiting factor will increase throughout flowering as the plants produce a large number of squares. As the crop matures there is a natural reduction in fruit numbers and the fruiting factor declines.

Eventually, at maturity the fruiting factor approaches 1.0, which represents the natural maximum fruiting load that plants can carry through to yield.

A key period for measuring fruiting factors is at around early flowering. Values between 1.1 and 1.3 will provide optimum yield potential. Values less than 0.8 or greater than 1.5 can reduce yield.

GUIDE TO USING FRUITING FACTORS THROUGHOUT THE SEASON

| Stage of growth | Fruiting factor |
|-----------------|-----------------|
| Pre flowering | 0.8–1.0 |
| Flowering | 1.1–1.3 |
| Peak Flowering | 1.3–1.4 |
| Boll maturity | 1.0 |

GUIDE TO USING FRUITING FACTORS AT FIRST FLOWER

| Fruiting factor at first flower | Impact on yield and maturity |
|---------------------------------|--|
| < 0.8 | High risk of yield decline and maturity delay (particularly in cooler regions) |
| 1.1–1.3 | Optimum for yield |
| > 1.5 | Risk of premature cut out and yield decline. |

8. Evaluate pest abundance against established thresholds

Economic thresholds based on research, are available for most major pests in cotton. These thresholds should be used in conjunction with information on forecast, crop stage, plant damage and beneficial abundance to make decisions about the need to spray.

Economic thresholds are usually derived from experiments where pest densities are manipulated so that the relationship between pest abundance or amount of damage and yield can be established. Once this is known it is possible to determine the pest density or damage level at which control must be implemented to prevent economic loss. Thresholds, should be considered in context of other factors that may influence the need to spray. For instance, if pest abundance is just over threshold but damage is low and beneficial populations are high it is practical to delay control several days. This is a low risk strategy to allow time for beneficials to control the pests to below threshold levels, thereby avoiding a spray and reducing

insecticide costs and selection for resistance. Conversely, if pest damage is high and there are low numbers of beneficials (perhaps due to an earlier spray) then immediate control with an insecticide may be the best option. In cotton a 'beneficial to pest ratio' has been developed for *Helicoverpa* spp. to assist these decisions by indicating a ratio above which the pest is likely to be effectively controlled by the beneficial population.

Ensure that the threshold use is appropriate for the crop stage, sampling method and region. For example the mirid threshold accounts for the reduced ability to compensate for damage in cool regions, variation in yield loss due to crop stage and differences in effectiveness of different sampling techniques. The mirid threshold also provides crop damage levels that need to be considered in conjunction with pest and beneficial population.

Thresholds for cotton aphid, two-spotted mite and silverleaf whitefly are based on cumulative population changes, and require comparison of multiple samplings to determine if action thresholds have been reached. CottASSIST provides threshold tools that support management decisions.

Knowledge of the pest and the environment is important in determining whether a spray is warranted. For example two spotted mite populations can be suppressed by cool conditions, however will increase rapidly when it is hot and dry, and so consideration of the forecast conditions should be part of the decision. While some thresholds only require monitoring of one lifecycle stage, it can be useful to be aware of all lifestages. For example, the silverleaf whitefly threshold is based on presence/absence of adult whitefly, however monitoring nymphs can help to identify if a population has built up within the crop, or has migrated in recently.

9. Choose insecticides wisely to conserve beneficials

IPM strategies aim to balance the contribution of beneficials with the need to protect the crop from significant loss. Where insecticide control is warranted, use the most selective effective insecticide (soft on beneficial insects), adhere to the IRMS and consider a reduced rate mixed with either salt or spray oils.

Selecting an insecticide

Spraying is often the final resort in an IPM program, however product choice will have a large impact on the strategy for the remainder of the season. When choosing an insecticide (or miticide) in addition to the efficacy against the targeted pest, it is very important to consider the 'selectivity'. Some insecticides are very selective and have very little impact on beneficial insects (often referred to as 'soft') while others are highly disruptive to beneficial populations ('broad-spectrum' or 'hard'). The relative selectivity of all insecticides available for use in cotton can be found in table 3 pages 8–9. Refer also to the IRMS (see pages 66–69)

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. According to Table 3, pages 8–9, the newer neonicotinoid product, clothianidin (tradenam Shield), will reduce populations of lady beetles (aphid predators) and *Eretmocerus* wasps (whitefly parasitoids) but conserve predatory bugs and thrips (mite predators). In contrast the low rate of fipronil (multiple tradenames such as Regent) with salt will reduce predatory bug populations, and conserve lady beetles, but have an unknown impact on the key wasp parasitoids of whitefly. It is important to note that for many products Table 3 (pages 8–9) considers rate as well as product. Lower registered rates of a product may provide sufficient efficacy against the target pest, while minimising impact on beneficials.

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.

Bees are particularly susceptible to many of the insecticides used on cotton farms, such as abamectin, fipronil, indoxacarb, pyrethroids and profenofos. 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 neighbouring vegetation which is being foraged by bees. Always look for and follow label directions regarding impact on bees and refer to page 145 for more information on how to manage the risk to bees.

Consider alternatives

Consider the use of reduced rates of synthetic insecticides mixed with either salt or petroleum spray oils. In some instances this will provide greater selectivity and better efficacy.

The use of biopesticides such as NPV (Gemstar, Helicovex, Heliocide and Vivusmax) foliar Bt, petroleum spray oils (PSOs) or semiochemicals, such as the moth attractant Magnet to manage *Helicoverpa* and other sucking pests can help to conserve beneficial insects, minimise insecticide use and make it less likely to flare other pests.

**Cotton IRMS:
The FIRST place to go when selecting a spray**

Cotton IRMS

1 - Find your region

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2014/15

BEST PRACTICE PRODUCT WINDOWS AND USE RESTRICTIONS TO MANAGE INSECTICIDE RESISTANCE IN APHIDS, SILVERLEAF WHITEFLY, MITES AND HELICOVERPA SPECIES.

2 - What stage are you in?

STAGE 1: 15 Dec 2012 | STAGE 2: 15 Jan 2013 | STAGE 3: 15 Feb 2013 | STAGE 4: 15 Feb 2013

WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2-7.8, pages 10-46

| INSECTICIDE | MODE OF ACTION | SELECTIVITY | RESTRICTIONS |
|---|----------------|-------------|--|
| Excluded Bollworm & leafworms | | | Excludes Bollworm & leafworms |
| Helicoverpa (Caterpillar, Weevil) | | | Avoid season long use of low rates. |
| Pyrimicarb | | | NON CONSECUTIVE APPLICATIONS. |
| Paraffinic Oil (Caterpillar, Blight) | | | No restrictions |
| Phenacarb | | | Filter 1620 DDO in a salvage situation, if knockdown is required before use. |
| Phenacarb @ planting insecticide | | | Note 1 |
| Etobexate (Paraffinic) | | | Note 1 |
| Imidacloprid (Aphid) | | | Ground only, NDW only. |
| Decolol | | | No restrictions |
| Amorphaeus silica (Aphid) | | | NON CONSECUTIVE APPLICATIONS. |
| Chlorpyrifos (Aphid) | | | NON CONSECUTIVE APPLICATIONS. |
| Phosphotriester (Aphid) | | | Note 1 |
| Indoxacarb (Caterpillar) | | | NON CONSECUTIVE APPLICATIONS. |
| Spinetoram (Mite) | | | Note 1 |
| Abamectin | | | Note 1 |
| Emamectin (Aphid) | | | Note 1 |
| Propargite (Mite) | | | NON CONSECUTIVE APPLICATIONS. |
| Amilstar | | | Note 1 |
| Fipronil | | | Note 1 |
| Neonicotinoids (Aphid, Caterpillar, Weevil, Blight) | | | NON CONSECUTIVE APPLICATIONS. |

3 - What is the softest option?

4 - Have you reached the maximum number of applications?

5 - Have you met your other requirements?

The IRMS is published annually in the Cotton Pest Management Guide.

Late season pest problems can sometimes be avoided by a successful defoliation. The silverleaf whitefly 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.

Application

Ensure spray applications are accurate, timely and triggered by pest thresholds. Always follow label directions. Understanding how different insecticides work, can help when considering how efficacious they will be in a given situation. For example 'contact' insecticides, must be absorbed by the pest, and so application method (eg nozzle selection, higher water rates and use of ground rig) may improve impact on the pest. Systemic pesticides can be moved (translocated) throughout the plant where they kill chewing or sucking insects. Some insecticides only target particular stages of a pest lifecycle. For example the insect growth regulators, pryiproxifen (tradename Admiral), does not kill adult silverleaf whitefly, however prevents egg hatching and progression from larval to adult stage, as well as sterilising of adult female insects. As this means it takes a while for the population to decline (maybe 10–14 days) before long term effective control of all life stages is achieved, this should be factored in, both in terms of managing honey dew risk from silverleaf whitefly, as well as assessing spray efficacy.

Pests such as aphids and mites often infest the edges of a field, not the entire field area. Consider 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.

10. Apply good resistance management principles

Resistance management strategies and IPM strategies are complimentary. IPM aims to support resistance management by reducing the need to spray. Similarly, resistance management supports IPM by ensuring that the key insecticides as well as traits that are need to control pests remain effective.

In cotton, where insecticide resistance has been a major problem there are well defined industry sanctioned Insecticide Resistance Management Strategies (IRMS) (pages 66–69). Responsible stewardship of Bollgard II is also important. Refer to the Resistance Management Plan (pages 70–81).

These guidelines are based on: Integrated Pest Management in Cotton – a commonsense approach and Integrated Pest Management Guidelines For Australian Cotton II.

III

Insecticide & Bt Resistance Testing

In-season testing of field populations of



Helicoverpa – Mites – Aphids – Whitefly

Sharon Downes/Lisa Bird
02 6799 1500

Grant Herron
02 4640 6471

Jamie Hopkinson
07 4688 1152

to monitor changes in resistance across the industry

Providing information critical to pest management

Learn about resistance, species composition and parasitism levels on your farm.

Arrange delivery of collections by contacting the people above.



**This document is part of a larger publication -
The Cotton Pest Management Guide for Cotton 2014 - 15**

The complete document can be found on the CRDC or myBMP web sites during the 2014-15 Australian cotton season

www.crdc.com.au

or

www.mybmp.com.au

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ISSN 1442-8462

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