



**Industry &
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<http://www.dpi.nsw.gov.au/agriculture/field/field-crops/fibres/cotton/cotton-pest-management-guide>

Cotton Industry Biosecurity Plan

Compiled by Sharyn Taylor, Plant Health Australia; Susan Maas and Cherie Gambley, Department of Employment, Economic Development and Innovation; Lewis Wilson CSIRO and Greg Kauter, Cotton Australia.

In 2009, Plant Health Australia (PHA), Cotton Australia Ltd and the Cotton Industry Biosecurity Group reviewed the Cotton Industry Biosecurity Plan (IBP). This plan, originally released in 2006 was formulated by industry, state and federal governments and Plant Health Australia to assist with identification of biosecurity priorities and allocation of resources to critical areas and the generation of strategies to maximise adoption of recommended practices and awareness of new biosecurity threats.

WHY DOES THE AUSTRALIAN COTTON INDUSTRY NEED A BIOSECURITY PLAN?

Australia's geographic isolation has meant that it is relatively free of many pests that cause significant problems for cotton production overseas. Maintaining Australia's freedom from these exotic pests will help ensure the future profitability, sustainability and marketability of Australian cotton.

Industry biosecurity aims to minimise risks posed by exotic organisms. For this to be effective it relies on the involvement of all stakeholders – including growers, industry, government agencies and the public. Through the IBP the cotton industry has in place procedures to:

- identify the highest risk pests from overseas (threat identification and analysis);
- guard the industry against exotic pests (risk mitigation activities);
- know when an exotic pest has arrived (surveillance) and identify it (diagnostics); and
- deal with exotic pests if they are found (contingency plans).

To date, 12 key organisms have been identified as threats to the industry based on the economic risk they present should they become established in Australia. At this stage, only invertebrate pests and diseases have been identified as threats although weeds may be revisited at future reviews.

A copy of Version 2 of the Cotton IBP will be available from the PHA website biosecurity section from December 2009.

HOW HAVE THE PEST AND DISEASE THREATS BEEN DETERMINED?

The relative importance of potential pest problems have been ranked by experts in the IBG by estimating the level of threat associated with the probability of the pest's entry into Australia, factors influencing the pest's establishment and spread, the difficulty of identification and/or eradication, as well as the likely impacts of the pest on production and market access.

FARM BIOSECURITY

Cotton growers are the key to protecting Australian cotton crops from exotic insects and diseases. Growers should look out for unusual crop



Spotted anything unusual?

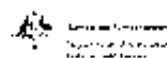
Image courtesy CSIRO

LOOK. BE ALERT. CALL AN EXPERT.

Cotton growers are the key to protecting Australia's crops from exotic insects and diseases like cotton leaf curl virus.

It is important that you are aware of the risk, and if you spot anything unusual on your crop you should always check it out and call your local entomologist, pathologist or the Exotic Plant Pest Hotline on 1800 084 881. The call is free (except from mobiles) and early detection will help protect your industry.

Visit www.planthealthaustralia.com.au for further information.



This project has received funding from the Australian Government through the Department of Agriculture, Fisheries and Forestry.



1800 084 881

symptoms and implement practices that prevent or minimise pest incursions.

Good farm hygiene – come clean, go clean – should be practiced on all farms regardless of whether pests or diseases are present. Pest control based on thorough monitoring will not only minimise the impact of pests on your crop but can also minimise the spread of an exotic pest before their presence is known or after they are identified. Diseases can be spread by animals, people and machinery so farm hygiene and restricting unnecessary people and vehicle movement around the farm will prevent disease spread. Volunteers and some weeds can harbour pests and diseases. Controlling weeds in non-crop areas around the farm reduces the potential for pest and disease build up.

Visits to farms overseas should be declared on re-entry to Australia. Prior to returning to Australia, wash all clothes and foot wear as well as hair which may carry fungal spores.

To assist provide information on Farm Biosecurity measures, PHA, in conjunction with Animal Health Australia, has initiated the Farm Biosecurity Program, which brings together a range of practices that to keep crops free of pests. For further information visit farmbiosecurity.com.au.

SURVEILLANCE IN THE COTTON INDUSTRY

A major part of implementing the Cotton IBP and Farm Biosecurity measures is surveillance for exotic plant pests. The key aim of surveillance is for detection of pests as early as possible. The benefits of early detection of a new pest to the cotton industry will be:

- an increased chance that eradication or containment within a limited area will be successful;
- reduced cost to industry and the surrounding community if eradication or containment can be achieved; and

– more rapid implementation of new management practices if eradication is not possible.

While AQIS has strict controls for the introduction of cotton plants and seeds at the border, many of these pests are small or difficult to see. There is still a chance of their accidental introduction as hitchhikers, such as in packing material or in soil or plants in poorly cleaned machinery and equipment. Some pests can also arrive on people's clothing, boots and hair or in accidentally or deliberately undeclared plant material.

Surveillance for several exotic pathogens is undertaken as part of routine assessment of cotton field trials by I&I NSW, QPI&F and cotton breeding programs.

REPORTING UNUSUAL PESTS

Any unusual plant pest should be reported immediately to your Department of Primary Industry (DPI) or by ringing the Exotic Plant Pest Hotline. Early reporting enhances the chance of effective control and eradication. It is important to note that suspect material should not be moved or collected without seeking advice from the DPI as incorrect handling could spread the pest or render samples unsuitable for identification.

HOW CAN WE LEARN MORE?

More information about prevention and control of pests and diseases can be found on the Cotton CRC website at www.cottoncrc.org.au

Further information on cotton industry biosecurity activities please contact Greg Kauter (02) 9669 5222 or go to www.cottonaustralia.com.au/research/biosecurity/

To view the Australian Cotton Industry Biosecurity Plan visit: www.planthealthaustralia.com.au/

Phone the Exotic Plant Pest Hotline on 1800 084 881.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Exotic pests and diseases of greatest threat to Australian cotton

COTTON BOLL WEEVIL (*ANTHOMONUS GRANDIS*)

Cotton boll weevil is specific to cotton and causes large yield losses due to damage to developing bolls and subsequent reduction in lint production. In the USA, control of cotton boll weevil using insecticides costs hundreds of millions of dollars.



Boll weevil (Jack Kelly Clark, University of California, www.ipm.ucdavis.edu)

SPIDER MITES (TETRANYCHID MITES)

Spider mites are in the group that includes ticks. They feed on the undersides of leaves, sucking out the cell contents. Their damage causes a characteristic bronzing of leaves, and if uncontrolled can dramatically reduce yield and fibre quality. Several species are found in Australian cotton, the most common of which is the two-spotted spider mite. However, overseas there are a range of other species that have different host preferences, cause more severe damage or have resistance to some of our key acaricides.



Adult female carmine spider mite, *Tetranychus cinnabarinus* (Jack Clark, University of California, www.ipm.ucdavis.edu)

INDIAN GREEN JASSID (*AMRASCA DEVESTANS*)

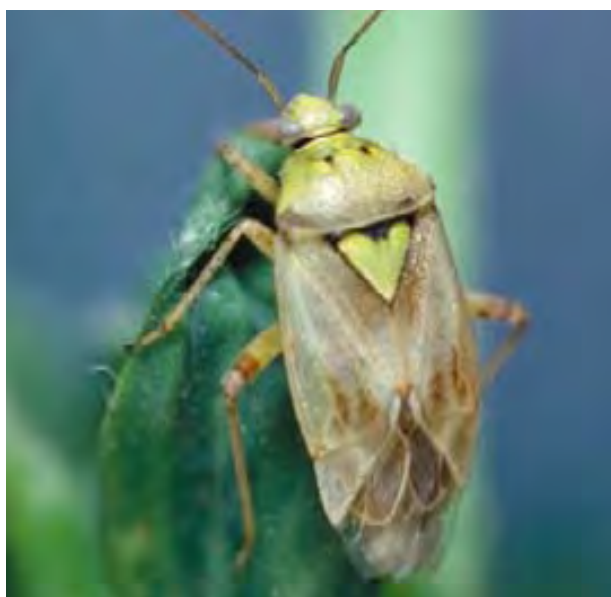
Indian green jassid is a sap-sucking insect pest that can cause yield losses of up to 25%. While several 'jassid' species are found in Australian cotton the damage they cause is relatively minor, rarely if ever affecting yield. Green jassids inject a toxin as they feed that causes leaves and bolls to drop and can stunt plant growth. Elsewhere green jassids can be managed using resistant varieties and insecticides. Hairy-leaved varieties are used in parts of Africa and the sub-continent where cotton is hand harvested to provide effective resistance against green jassids. Such varieties are not suitable for mechanical harvest as the leaf hairs cause excessive leaf trash in the cotton lint.



Indian green jassid (Industry & Investment NSW)

TARNISHED PLANT BUG (*LYGUS LINEOLARIS*)

The tarnished plant bug is a pest of over 250 plant species. In cotton, its feeding causes seed abortion, stem or leaf wilting and poor seed germination. It has 2–5 generations per year and can therefore quickly build up to high levels.



Lygus bug (Jack Kelly Clark, University of California, www.ipm.ucdavis.edu)

WHITEFLY (*BEMISIA TABACI* B-TYPE OR Q-TYPE)

Whitefly feeding results in a sticky residue, sooty moulds, reduced boll size and poor lint quality. Although the B-type whitefly is present in Australia there is a risk of other B-type strains and other biotypes, e.g. Q-type, entering the country with different insecticide resistance profiles. Whiteflies are also vectors of damaging exotic viruses such as cotton leaf curl disease.



Bemisia tabaci B-type (Neil Forester)

MELON APHID (*APHIS GOSSIPYI* EXOTIC STRAINS)

Aphids damage cotton by feeding on young leaves and bolls which can reduce yield. They produce a sticky residue that can cover leaves resulting in reduced photosynthesis and contamination of lint as bolls open, reducing the crop's value. This species may also carry exotic diseases such as blue disease. As well as the risk of disease, there is a risk that new aphid strains entering the country will have different insecticide resistance profiles, making control more difficult.



Melon Aphid (Lewis Wilson, CSIRO)

VERTICILLIUM WILT – DEFOILATING STRAINS

Australian strains of Verticillium wilt are described as mild in comparison to the defoliating strains that originated in North America but are now becoming more widespread. If established in Australia, management would be reliant on the use of resistant

varieties, with a lag of several years before adapted varieties were available.

COTTON LEAF CURL DISEASE (CLCuD)

CLCuD, sometimes referred to as Gemini virus, can cause yield losses of up to 35% in cotton. It is spread by a whitefly vector. There are at least seven different begomoviruses and several different DNA satellite molecules associated with CLCuD. A cotton plant needs to be infected with at least one begomovirus and one satellite to develop CLCuD.

Symptoms of CLCuD are seen on leaves and initially appear as a swelling and darkening of leaf veins, followed by a deep downward cupping of the youngest leaves then either an upward or downward curling of the leaf margins. Leaf-like structures (enations) on the veins are common and vary in size from only a few millimetres in diameter to almost the size of a normal leaf. These larger structures are often cup-shaped.



Leaf Curl Disease (Cherie Gambley, QPIF)

FUSARIUM WILT (*FUSARIUM OXYSPORUM* F. SP. *VASINFECTUM* – EXOTIC STRAINS)

Fusarium wilt is a fungal disease. Strains of Fusarium were identified in Australia in 1993 however the introduction of new strains (races) would increase the difficulty of management as new resistant varieties would be required.

External symptoms can appear in the crop at any stage but most commonly appear in either the seedling phase or after flowering when bolls are filling. Leaves appear dull and wilted before yellowing or browning progresses to eventual death from the top of the plant. Seedlings may either wilt and die or survive, but often with stunted growth. Adult plants may wilt and die, especially under conditions of stress. Some affected plants may re-shoot from the base of the stem. Lengthwise cutting of the stem from affected plants will show

continuous brown discolouration of the tissue. The internal discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecks. Sometimes the discolouration is visible in only one side of the stem. External symptoms do not always reflect the extent of discolouration in the stem.



Fusarium wilt causing vascular discolouration and root knots caused by nematodes. (Chris Anderson, I&I NSW)

TEXAS ROOT ROT (*PHYMATOTRICHOPSIS OMNIVORE*)

Texas root rot is an extremely damaging fungal disease with a wide host range. It causes sudden death of affected plants, usually during the warmer months. In cotton, infection can result in 100% crop loss. If this disease became established in Australia, control would be extremely difficult as management using rotations and fungicides is usually only partially effective.

Symptoms include yellowing or bronzing of leaves, leaves wilt and die; dead leaves usually remain on plant. At this stage, roots are dead and surface is covered with network of tan fungal strands.



Texas Root (Chris Anderson, I&I NSW)

BLUE DISEASE

Blue disease is a virus specific to cotton that can reduce yield potential by up to 20%. It is spread by a vector, the cotton aphid. It has been associated with plants infected with cotton leaf roll dwarf virus

(CLRDV) and has similarities with cotton bunchy top, anthocyanosis and cotton leaf roll. It is not known if the same pathogen causes all these diseases or if there are multiple pathogens causing similar symptoms. CLRDV was not detected from Australian cotton affected by cotton bunchy top disease. Cotton blue disease affected leaves tend to be smaller, thick, more brittle and leathery and have an intense green to bluish colour with yellow veins. Reddening of stem petioles and leaf veins can occur in some infections. Leaf edges tend to roll downwards and under and plants become stunted due to a shortening of the branch internodes and produce many branches, giving a bunchy zig-zag stem habit. Symptoms are more obvious in plants infected at an early age and stunting is more pronounced. Infected plants also produce smaller bolls and boll shed may occur. Single infected plants can be overlooked if overgrown by nearby healthy plants.

BACTERIAL BLIGHT (*XANTHOMONAS AXONOPODIS* OR *X. CAMPESTRIS* PV *MAVACEARUM* – EXOTIC STRAINS)

Although strains of bacterial blight are already present in Australia, they are no longer a problem due to varietal resistance. Exotic strains (races) occur, however, that are ‘hypervirulent’ and, if established in Australia, would cause large yield losses. The disease is seed borne allowing easy dispersal and introduction of new races into new areas. Bacterial blight is spread by high temperature, humidity and rainfall.

The initial symptoms include the undersides of leaves have angular water soaked lesions. Lesions dry and darken with age then leaves are shed. Black lesions spread along stem. Bolls often infected at base or tip. Lesions dry out and prevent the boll opening. The pathogen is capable of symptomless transfer and therefore could be undetected through quarantine.

Symptoms include yellowing or bronzing of leaves, leaves wilt and die; dead leaves usually remain on plant. At this stage, roots are dead and surface is covered with network of tan fungal strands.



Blue Disease (Ivan Bonacic INTA – EEA Sáenz Peña)

Integrated Pest Management (IPM) guidelines for Australian cotton II

Lewis Wilson and Sandra Deutscher, CSIRO; Robert Mensah and Annie Johnson, formerly Industry & Investment NSW.

These guidelines are a brief version of the *Integrated Pest Management Guidelines for Australian Cotton II*. For more details on any of the following pages please contact the Australian Cotton Research Institute for a copy of the *IPM Guidelines II*.

WHAT IS IPM?

IPM involves using all means of managing pest populations with the aim of reducing insecticide use whilst maintaining profitability (yield, fibre quality and crop maturity). IPM is a whole year approach to managing pests. This includes management of pests through the cotton growing season, and through the remainder of the year as well. For instance, decisions made in the autumn and winter can have a lasting impact on pest management throughout the year.

WHY DO WE NEED TO DEVELOP IPM PROGRAMS?

Over-reliance on synthetic insecticides creates problems, such as insecticide resistance of the major pests (particularly *H. armigera*), disruption of natural enemies of the pests leading to outbreaks of secondary pests such as mites, aphids or whitefly and other environmental consequences. These problems have cast doubt over the long-term viability of the traditional insecticide dominated approach to pest management.

A major goal for the cotton industry is to reduce dependence on foliar and soil applied insecticides. This can be achieved by developing an IPM program that integrates a range of pro-active management tactics, especially the conservation and use of natural enemies (predators and parasites) to control pests.

HOW DO WE IMPLEMENT IPM?

IPM involves integrating a range of tools and strategies for managing pests. These can be conveniently grouped in seven main objectives:

1. Growing a healthy crop
2. Keeping track of insects and damage
3. Preserving beneficial insects
4. Preventing insecticide resistance
5. Managing crop and weed hosts
6. Using trap crops effectively
7. Communication and training

These objectives are explained below and there is a Seasonal activity plan for IPM in Table 5 on page 46.

Objective 1. Growing a healthy crop

This objective covers the key issues for good crop agronomy and highlights how they interact with IPM.

Crop management can affect IPM. Growing a healthy cotton crop optimises both its yield potential and capacity to compensate for pest damage. In irrigated cotton, a healthy crop begins with good field preparation, soil moisture and plant establishment. Poor fertiliser or irrigation management can delay crop maturity and increase the length of time that the crop requires protection from pests, which can potentially increase insecticide resistance selection.

Field selection

When selecting fields for planting cotton consider proximity to sensitive areas such as watercourses, pastures, buildings, and the prevailing wind direction. Bollgard II® varieties may be appropriate for fields near sensitive areas. Another consideration would be the proximity of these cotton fields to other crops or orchards which can potentially act as a source for secondary pests such as mites, aphids or whitefly. Pest resistant varieties should be kept together, such as Bollgard II® or okra leaf types, rather than mixing them with other varieties. This reduces the chance of sprays applied to conventional fields disrupting fields that do not need spraying at that time.

Seed bed preparation

A tactic often mentioned by cotton growers in achieving an early crop is a good seed-bed, typified by friable, non-cloddy soil and firm, high, well-shaped beds. This helps achieve vigorous, healthy, early growth that tolerates seedling disease better and achieves early crop maturity and high yield potential. High beds also reduce the risk of waterlogging by encouraging good drainage. Planting cotton into standing stubble (wheat, sorghum) may offer some benefit in terms of soil condition, insect management and water infiltration. For more information see the publication *Planting cotton in standing wheat stubble*, available from the Cotton CRC web site www.cottoncrc.org.au

Selecting a variety

The cotton varieties planted should be matched to the region and likely pests and diseases (see seed company variety guides or websites). Select a variety that suits the growing region in terms of length of season. This will benefit the maturity timing of the crop which in turn will benefit fibre quality and

defoliation as well as reducing the exposure to late season pest attack. Shorter season varieties may also be considered as the shorter growing period reduces the time the crop needs to be protected from pest damage. Okra-leaf varieties have a degree of resistance to *Helicoverpa* spp., spider mites and silverleaf whitefly, which can potentially reduce the control needed for each pest by about one spray per season. Penetration of insecticides into the crop canopy is better with okra leaf cultivars, which can contribute to better control.

In areas following a wet winter or in fields with poor weed control, the risk of early season aphids increases. It may be advantageous to plant a Cotton Bunchy Top (CBT) resistant variety. This would reduce the need to control aphids at low densities to prevent the spread of CBT therefore also reducing the risk of selecting for insecticide resistant aphids. Bollgard II® cotton is ideally suited to IPM as the level of control of *Helicoverpa* spp. provided by the plant is usually sufficient to dramatically reduce the need to spray for this pest or other lepidopteran pests such as tipworm, especially early season.

Planting window

In each cotton region there is a period when soil temperatures become suitable for cotton germination, 14°C minimum at planting depth. Planting at this time usually maximises plant establishment and avoids the risk of cold shock (night temperature < 12°C). Cold shock slows early growth and reduces tolerance to herbicides, seedling diseases and early pests, especially thrips. Very late planted cotton has less yield potential and is more susceptible to pests such as whitefly and late season infestations of *H. armigera* both of which are difficult and expensive to control.

Coordinating planting in a region to a specified window avoids a wide spread of crop maturation, especially very late crops that require pest control over a prolonged period. Avoiding prolonged insecticide use helps manage insecticide resistance as it reduces the number of generations of the pest that are exposed to insecticides, therefore reducing the selection pressure for resistant pests.

Planting windows are critical to the success of area-wide management strategies. In areas susceptible to whitefly, coordinated planting windows can provide a period free from host crops to reduce population build up as well as preventing late crops. The 42 day planting window for Bollgard II® cotton is a critical component of the resistance management plan. In specific circumstances growers in a region can apply to the APVMA for a variation in the nominated start/

finish dates of their 42 day window. Details of this process can be found on page 63.

Optimising earliness

Although managing a crop for earliness is a good strategy, it does not always maximise yield. For more information on managing for early maturity, refer to the *Integrated Pest Management Booklet – Objective 1. Manage the crop for early maturity in the Australian Cotton Industry Best Management Practices Manual*.

Optimising water and nitrogen

Adequate water and nutrition will ensure healthy growth of plants that are more tolerant of pests and diseases. Too much nitrogen creates excessive cotton growth toward the end of the season and perhaps even the need for an extra irrigation. This makes the crop more attractive to pests, requiring additional inputs of insecticides (and mixtures of insecticides) for control, and application of high rates of growth regulators to retard growth. Too much nitrogen also undermines the effectiveness of the last generation trap crop by maintaining the attractiveness of cotton relative to the trap crop. Defoliation can also be more difficult and regrowth may harbour aphids.

Growth regulators

Excessive vegetative growth is a problem because it reduces the retention of fruit and delays maturity. Rank growth of plants also results in reduced efficacy of insecticides due to poor penetration of the canopy.

Optimal irrigation scheduling and nitrogen rates will generally prevent excessive vegetative growth, apart from during hot growing conditions. Appropriate use of growth regulators can help to reduce the likelihood of a rank crop that will not cut-out. Consult the guidelines published by the cotton seed companies to see if growth regulators are required.

Growth regulators are also used at or near cut-out, to reduce the amount of fresh regrowth and the attractiveness of the crop. This strategy is used to lessen the likelihood of late pest infestations and reduce the number of late season sprays.

See Cotton Seed Distributors (www.csd.net.au) calculating vegetative growth rates to determine crop needs.

Final irrigation

The timing of the last irrigation aims to ensure that boll maturity is completed without water stress, and at the same time prevent the occurrence of lush

vegetative growth in crops late in the season to avoid the crop being attractive to the *Helicoverpa* spp. and other pests such as aphids and whitefly. Regular assessment of crop maturity will allow the dates of last irrigation and defoliation to be predicted.

Defoliation

The timing of defoliation can be an important IPM tool, as late pest infestation problems can sometimes be overcome by a successful defoliation. The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65% of bolls are open. The other method of assessing physiological maturity is when there are 3–4 nodes of first position bolls above the highest cracked first position boll (last harvestable boll), known as nodes above cracked boll (NACB).

Objective 2. Keeping track of insects and damage

The purpose of crop monitoring is to determine:

- the pest(s) present
- the level of infestation
- the damage they are causing
- the level of beneficial insects
- expected response to control options
- environmental conditions
- the growth stage of the crop

This information provides the basis on which pest management decisions are made.

Check frequently

Crops should be checked frequently for pests, beneficials and for damage and fruit retention. Regular and frequent checking provides an overview of what is happening in a field in relation to pest and beneficials abundance and development. For more detailed information on checking frequency see 'Key insect and mite pests of Australian cotton' on pages 1–15.

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 to occur between checks, without the pest population developing to a stage where control is impractical or too expensive.

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.

MONITORING PESTS AND BENEFICIALS

Types of sampling techniques

Visual sampling: This involves looking at the entire plant, including under leaves, along stems, in squares and around 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. This method is difficult to use when the field and plants are wet.

D-vac sampling can be used as an alternative to visual checking to sample 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.

Comparison of methods: A recent study has shown that *Helicoverpa* spp., whitefly, mites, aphids, thrips and apple dimpling bug nymphs were best sampled visually, while the beat sheets were superior for the majority of other insects and spiders and the sweep net is particularly useful for sampling flighty insects such as mirid adults. Once the crop reaches 9–10 nodes, beat sheets can detect about 3 times the number of insects compared to visual sampling. Sweep nets can detect about 3 times the number of mirid adults as visual sampling, although only 1.6 times the number of mirid nymphs. These differences must be kept in mind when using the predator to pest ratio or pest threshold, as they are based on visual counts.

Refuge crops

Sampling of lucerne strips or other refugia crops to assess predator abundance should use a similar method but *d-vac* sampling is the most appropriate and fastest method to assess beneficial insect populations in lucerne.

How much to check

Fields are rarely uniform in crop growth and attractiveness to insects. Lush areas, such as near the head ditch, are more attractive to insects. 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 usually increases the level of accuracy. For some pest species there are specific recommendations, see pages 1–15.

Monitoring levels of egg parasitism

It is also important to consider natural levels of *Helicoverpa* spp. parasitism caused by parasitoids such as *Trichogramma* spp. and *Telenomus* spp.

The *Trichogramma* spp. wasps are egg parasitoids capable of causing high mortality of *Helicoverpa* spp. in crops. The wasp kills its host by laying an egg inside a *Helicoverpa* spp. egg. The resulting wasp larva then feeds on the developing *Helicoverpa* spp. larva killing it before it hatches.

The most accurate way to monitor egg parasitism by *Trichogramma* spp. is to collect brown eggs and keep them at room temperature (about 25°C) until they hatch (healthy) or turn black (parasitised). Collecting white eggs gives an under-estimate of parasitism because they may have just been laid and not had sufficient time to be found by *Trichogramma* spp..

Monitoring levels of larval parasitism

There are no obvious external signs on larvae parasitised by *Microplitis* spp., but medium larvae (13–15 mm in length) can be split to reveal if the internal parasitoid larva is present. This is a simple procedure and can provide useful information about the potential survival of medium larvae.

Bollgard II® sampling and management

Bollgard II® cotton must be monitored regularly for pests and fruit retention, similar to conventional cotton. Consecutive checks are essential for making decisions about managing *Helicoverpa* spp. in Bollgard II® crops, as the Bt toxin needs to be ingested before the larvae is controlled. Hence if the larvae population is over the threshold on a given check, then chances are that a large proportion of these will ingest the toxin and die before the next check. Bollgard II® does not control a range of pests, especially green mirids which must be monitored to assess if the population will cause yield loss.

MONITORING PLANT DAMAGE

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 can recover from a degree of damage, especially early season damage with no reduction in yield or delay in maturity. A vigorous, healthy crop can tolerate more damage from pests, without yield or maturity being affected, than a crop with poor vigour (as a result of herbicide damage or water stress for example).

Plant monitoring in conjunction with regular insect monitoring allows an assessment of the effects of mirids or other 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.

Fruit load, yield and maturity

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.

Dynamic thresholds

Decisions about pest control should take into account both pest numbers and plant fruit load. If retention data indicates that fruit load is too low then it may be necessary to lower the pest threshold. There are several causes of low fruit retention and it is important to identify the problem before action is taken. Low retention could be caused by cool weather, waterlogging, water stress or pests. The combined damage of several pests, each below threshold, may also cause low retention.

Reduce pest thresholds to half the standard level and control those pests exceeding the reduced threshold using the most selective option available. As retention recovers, return to standard pest thresholds. Alternatively, if retention is too high then it may be necessary to raise the pest threshold. This will allow some pest damage and help balance the vegetative and fruit development. This will also avoid yield loss due to premature cut-out. Such an approach treats the pest threshold as dynamic, that is, it varies according to how the plant fruit load is developing.

Check regularly

From the first week of squaring, monitor plant damage at least every 7 days and/or before spray decisions. It is important to monitor the level of fruit loss regularly so that measures can be taken before insect damage becomes excessive.

What to check

Count a metre of plants (not random plants) in 3 to 4 locations per field. If the crop is uneven increase the number of checks. Do not use the same metre of plants for insect checks.

Damage monitoring includes:

1. Leaf loss (up to the 6 true leaf growth stage)
2. Tip damage
3. Fruit retention or fruiting factor
4. Boll damage.

Crop Development Tool (CDT)

The CDT (formerly the Early Season Diagnostic tool) is a web based calculator 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. The tool displays this in graphical and tabular formats alongside theoretical potential or optimum. 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.

The CDT incorporates a data storage function that allows multiple crops to be set up by each user and accessed by an individual logon and password. To use the CDT tool go to the Cotton CRC website; www.cottoncrc.org.au

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. This becomes the first squaring 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.

Figure 1 shows the accumulation of squaring nodes from the CDT between ~500 and ~800 DD. A real crop to the left of the theoretical line is generally ahead in development. This could be due to low fruit retention, in which case pest thresholds should be reconsidered and the vegetative growth rate measured. Measurements below the line indicate development has been delayed, perhaps by factors such as seedling disease or herbicide damage. Resources such as nutrition and water should be monitored closely.

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 CDT's fruit development graph displays the number of observed squares or

bolts (/m) plotted against a potential rate of fruit development based on the day degree accumulation after sowing. An example is shown in Figure 2. Potential square development commences at 500 DD and boll development at 750 DD (first flower). The slopes of the boll and square development lines are not parallel as the tool assumes that there is some loss of fruit due to carbon stress, normal in crop growth (not pest, nutritional or water stress).

In Figure 2 the real crop is tracking ahead of schedule. This can occur under optimum growing conditions. Nutrition and water should be monitored closely as this crop is likely to experience high, early demands that could rapidly induce cut-out.

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.

In Figure 1 the rate of decline in NAWF for the real crop is consistent with the optimum. Very high early retention can cause the number of NAWF to decline more quickly. For crops tracking below the line, consider increasing pest thresholds. Crops above the line may have experienced physiological shedding or early boll loss due to pests, in which case thresholds may need to be reduced. 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.

Vegetative Growth Rate (VGR)

The plant growth regulator mepiquat chloride provides growers with a method to help avoid

Figure 1. An example of tracking a crop's accumulation of squaring nodes and then the decline in nodes above white flower from the CDT.

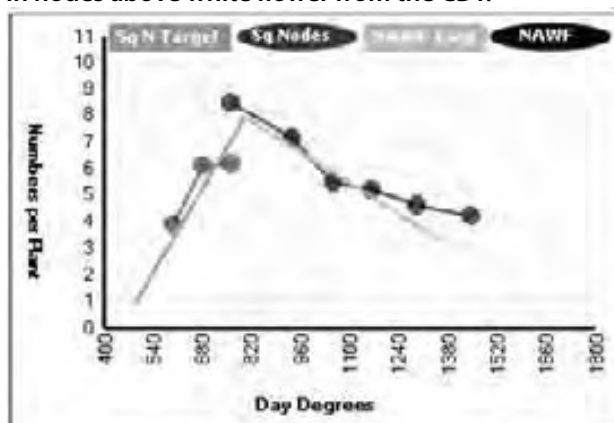
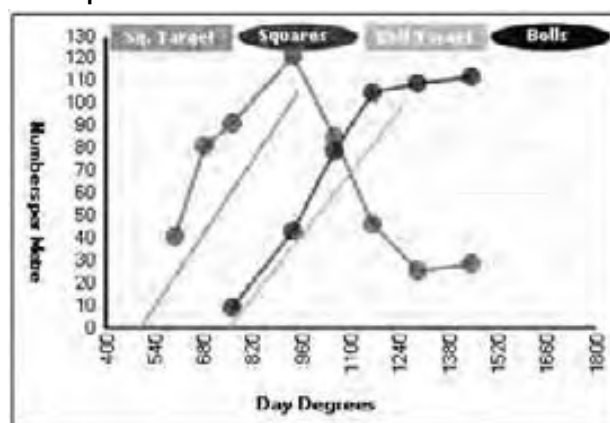


Figure 2. An example of tracking a crop's fruit development from the CDT.



excessive vegetative growth. The VGR tracks the rate of change in plant height relative to the rate of node development. Measurements should start as the crop approaches first flower and continue whilst squaring nodes are being produced. In Figure 3 the upper and lower boundaries represent the zone of desired vegetative growth rates across various regions and systems in Australia. Warmer regions and very fertile soils will have higher VGRs. The real crop is tracking below the lower boundary indicating that growth regulation is not required to maximise yield potential.

First position fruit retention

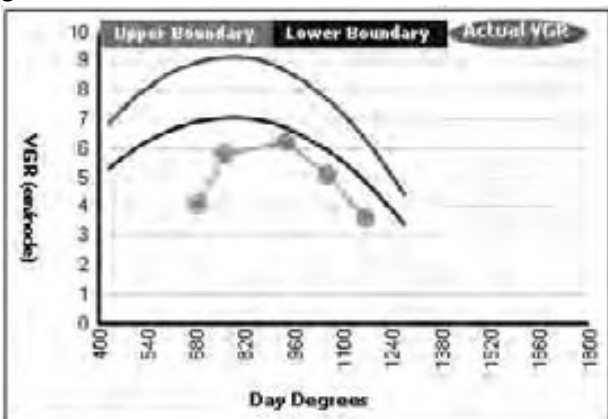
Monitoring first position fruit retention is a technique that is best used from squaring to early flowering. It is a quick way to estimate early signs of insect damage.

- Count the first position fruit on either the top five or all the fruiting branches. The first fruiting branch is the top most branch where the first position leaf is unfolded.
- Monitor both tipped and non-tipped plants.
- Monitor only the dominant stem, not vegetative branches (see Figure 4).
- The percentage of first position fruit present should be calculated dividing the number of first position fruit present by the number of fruiting 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 a yield penalty.

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.

Figure 3. An example of tracking a crop's vegetative growth rate from the CDT.



Final retention at maturity

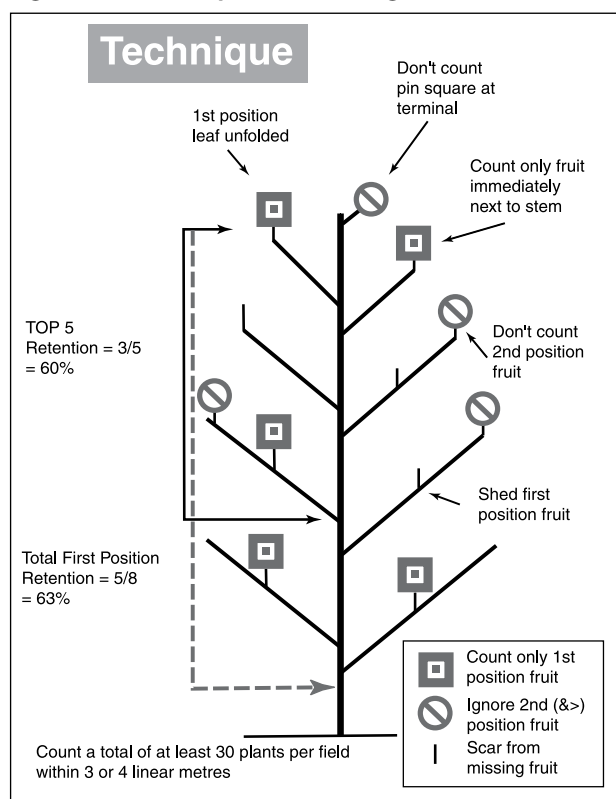
Boll numbers will vary according to variety, stage of growth and yield potential. At the end of the season a crop will hold less than 50% of all possible fruiting sites. First position retention will vary from 50–70%. Variety and boll size will also affect final yield.

Fruiting factor

Fruiting factors can be used throughout the season. They allow total fruit load to be monitored. Fruiting factors should be used when first position retention falls below recommended levels (i.e. 50–60%), to



Figure 4. A technique for checking fruit retention



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 changes throughout the growing season. The 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.

Objective 3. Preserving beneficial insects

Predatory insects, spiders and parasitic insects (beneficials) consume pests and other insects in order to develop and/or produce offspring. They can considerably reduce pest numbers thereby reducing the need to control pests using chemical insecticides. The abundance of beneficial insects is affected by food resources, mating partners, over wintering sites, shelter, climatic conditions and insecticide sprays. For an IPM system to work, the conservation of beneficial insects is critical. This can be achieved through the use or provision of natural or crop refuges (e.g. trees, pastures or lucerne strips).

In an IPM system which focuses on managing beneficials the following tools can be used;

- Predator/Pest ratio
- Incorporating parasitoids into spray decisions
- Beneficial releases
- Food sprays
- Lucerne strips
- Appropriate use of pesticides
- Beneficial Disruption Index
- Petroleum spray oils (PSO) mixed with a selective or biological pesticide.

Guidelines for the predator to pest ratio

The most common predators found in cotton farms feed on a wide range of pests and are therefore classified as general predators. The guidelines

described here make use of a predator to pest ratio to incorporate the activity of the predators into the pest management decisions.

Calculation of the predator to pest ratio:

The predator to pest ratio is calculated as;

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

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.

Decision making protocol in conventional cotton and Bollgard II® crops

Conventional crops

Ratio	<i>Helicoverpa</i> 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 (see section on lucerne on the following page)
< 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:

Ratio	<i>Helicoverpa</i> 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 the Cotton CRC.

Incorporating parasitoids into spray decisions

Parasitoids are important beneficials in Australian cotton farming systems. There are a range of parasitic wasps and flies that attack *Helicoverpa* spp.,

green vegetable bugs, aphids and whiteflies. These useful insects are easily overlooked because they are often small or secretive. The predator to prey ratio calculation does not incorporate parasitoids particularly *Trichogramma* spp. (egg parasitoid). For determining parasitism see page 32.

Beneficial insect to pest ratio

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

The same decision making protocol above is used.

Conserving and enhancing parasitoids

Maintaining habitat diversity. This can be achieved by growing a mixture of crops. Sorghum, maize and sunflowers are all good nursery crops for parasitoids. The capacity of sorghum and maize to act as parasitoid nurseries can be extended by growing staggered plantings. Some crops, such as chickpea, are not good nursery crops because the acidic chickpea leaves are toxic to the adult wasps.

Restricting insecticide use. Natural populations of *Trichogramma* spp., *Microplitis* spp. and other parasitoids that may be in the crop can be encouraged to build up by restricting the use of insecticides that may reduce their population. This applies to nursery crops such as sorghum as well as in cotton.

Releasing *Trichogramma* spp.

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 their very short life cycle.

Guidelines for use of food sprays

Food sprays cannot manage cotton pests on their own but combined with other IPM compatible tools they can help manage cotton pests and minimise synthetic insecticide use without sacrificing yield. Commercially, there are two food spray products;

1. Yeast based food spray (Predfeed®) attracts beneficial insects and should be applied when a cotton field does not have enough beneficial insects.
2. Sugar based food spray (Mobait®) retains beneficials that are already present.

Managing predators and mirids in lucerne

If there are lucerne strips or a centrally located lucerne crop on the farm, then before applying a food spray / biological insecticide spray to the cotton, check the lucerne strip or crop to determine numbers of predators and adult green mirids. If beneficial

insect numbers are high in the lucerne strips compared to cotton and numbers of adult mirids in the lucerne strips are low (< 5 per 20 metre d-vac sample), then slash half of each of the individual lucerne strips after applying the food spray/biological insecticide mixture sprays to the cotton. This action will enhance the movement of a large number of predators from the lucerne strips into the cotton, but will retain the mirids in the lucerne.

In contrast, if both predator and adult mirid numbers in the lucerne strips are high (> 5 mirids per 20 metres), do not slash or mow the lucerne strips or blocks when a sugar based food spray/biological insecticide mixture spray has been applied to the cotton since this will force too many mirids into the cotton where they may cause damage.

Appropriate use of insecticides

Tolerate non-economic early season damage

Minimising early season sprays helps to conserve the beneficial insect population. The cotton plant has the ability to tolerate a level of damage without affecting yield or crop maturity.

Site specific pest management

Many beneficial species frequently move in and out of cotton, other crops and non-crop habitats. It is important to manage pests on a field by field basis or by a small management unit, not an entire farm.

Pests such as aphids or mites often infest the edge of a field, not the entire field area. It is possible to manage this type of infestation by only spraying the field borders. This enables the beneficial population to re-establish or re-build much faster.

Choose insecticides carefully

Some insecticides have very little impact on beneficial insects including parasitoids.

The Beneficial Disruption Index (BDI)

The BDI provides a basis to measure or benchmark the 'softness' or 'hardness' of an individual field's insecticide spray regime at the end of the season. The BDI score for each insecticide is based on the overall impact of the insecticide on beneficial insect populations, as listed in Tables 3 and 4, on pages 40 and 42. The impact is expressed as a percentage reduction in beneficials after application of the chemical. A chemical that is more disruptive has a higher score or rank. The overall BDI for a cotton field is calculated by summing all the BDI scores for each insecticide used over the whole season. Note that scores for each component of spray mixtures are added together. The lower the overall rank for the season the less disruptive the spray regime is to beneficials.

Objective 4. Preventing insecticide resistance

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

Management of resistance is essential to ensure that valuable insecticides remain effective, the Australian cotton industry has developed the Insecticide Resistance Management Strategy (IRMS). The IRMS is designed to prevent resistance development, while managing existing resistance. Some core principles used in the IRMS include;

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

The *IRMS 2009/10* appears on pages 52–55, with explanation and answers to many frequently asked questions on pages 47–51.

Resistance monitoring

Resistance monitoring for *Helicoverpa* spp., two-spotted spider mites, aphids and silverleaf whitefly, is conducted each year by the cotton industry and provides the foundation for annual review and updating of the IRMS. **All growers and consultants have access to this industry service to investigate suspected cases of resistance.** For the contact details of the researchers running the resistance monitoring projects, refer to the advertisement on page 90.

Pupae busting

In NSW and southern Queensland, *Helicoverpa* spp. spend the winter in the soil as pupae and emerge as moths in spring to mate and lay eggs. Known as diapause, this resting pupal state is induced by decreasing daylength and temperature in late summer. Most of the pupae which over-winter in cotton fields are *H. armigera*. They are likely to have a high survival rate because of the low numbers of parasites. They have the potential to carry insecticide resistance, including Bt resistance, through to the next season. Therefore, it is important to pupae bust for their control.

Pupae are likely to be found in the top 10 cm of the soil surface. Cultivate to achieve disturbance of the soil sufficiently to destroy pupae or their emergence tunnels. The tillage required for;

- 1 m hills – till the whole hill;
- 2 m beds – till across the whole bed and almost down to furrow level;
- skip-row – till right across the soil surface.

Pupae busting Bollgard II® cotton fields is mandatory between picking and the end of July. Prior to the 2007–08 season the IRMS guidelines for pupae busting in sprayed conventional cotton were amended. Details of the amendments are presented on page 50.

Web tool to assist pupae busting decisions

The proportion of pupae entering diapause increases from low levels in March to high levels, almost 100%, by late April. However the rate of diapause induction varies from season to season and region to region. Knowing when diapause is induced is useful for identifying ‘high risk’ fields, i.e. those fields most likely to have diapausing pupae that should be targeted for pupae busting. On the Cotton CRC website, a web tool is available to help calculate the likely rate of diapause induction for your area, based on local climate data. An example of the web tool output is provided in Figure 5. See page 39. The tool is also able to compare the results for the current season with the long term average and hotter than average or cooler than average seasons.

The web tool can also be used to predict the rate of moth emergence from diapause in spring. This can assist in timing pupae busting operations to maximise their effectiveness. The breaking of diapause is influenced by temperature. The tool calculates the emergence percentage from the day after the threshold temperature of 18°C is reached. To use the tool go to; <http://cottassist.cottoncrc.org.au/DIET/DIETTool.aspx>

Trap crops and weed control

Trap cropping and weed control assists resistance management, as well as IPM, by reducing the size of the overall pest population which reduces the need to apply insecticides and reduces the selection pressure for the pest to develop resistance.

Resistance management for Bollgard II® cotton

Resistance management for Bollgard II® cotton is critical due to the season long selection of *Helicoverpa* spp. to the Bt toxins produced by Bollgard II®. A proactive Resistance Management Plan (RMP) has been developed to preserve the effective life of Bollgard II®. This plan is provided in full on pages 62–67 and many frequently asked

questions about the RMP are answered on pages 56–61.

Resistance management guidelines for all crops

Several other strategies that are relevant to cotton and other spring and summer crops can also help in managing resistance. These include:

1. Avoid cross selection for resistance. Spraying for one pest can be simultaneously selecting resistance in another pest that is present, even though that pest is at sub-threshold levels and not specifically being targeted. For example, if a pyrethroid is used to control a pest other than *Helicoverpa* spp. Do not follow up with another pyrethroid for *H. armigera* control as the first spray may have already selected for pyrethroid resistant *H. armigera*. This applies to all insecticides which target multiple pest species.
2. Selective insecticide use is preferable, consistent with the IRMS, as this helps conserve beneficial insects. Beneficials eat or parasitise resistant as well as susceptible pests. Beneficials can lower overall populations of insect pests.

Figure 5. Estimated rate of *Helicoverpa* entering diapause at Dalby from the 1st of March 2009.

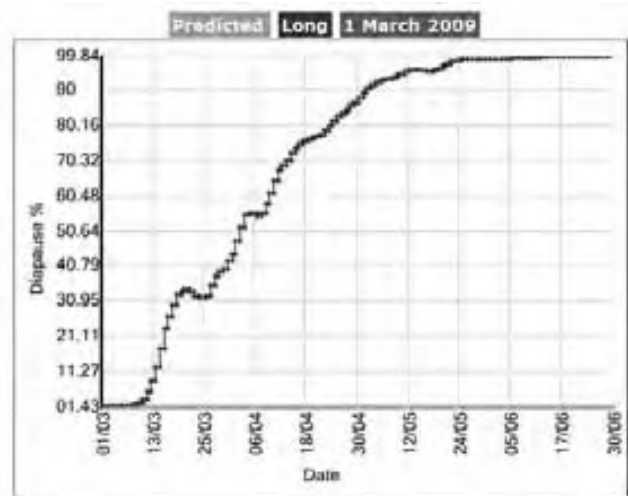


Figure 6. *Helicoverpa* moth emergence from diapause at Dalby run on the 30th of June 2009.

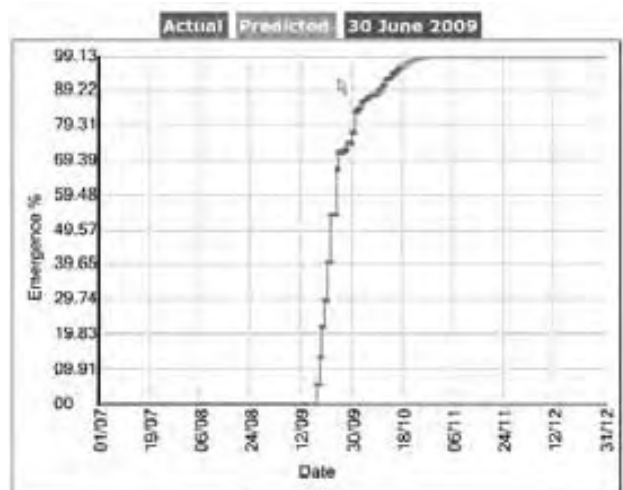


Table 3. Impact of insecticides and miticides on predators, parasitoids and bees in cotton

By Lewis Wilson^{1,7}, Simone Heimoana^{1,7}, Robert Mensah^{2,7}, Moazzem Khan^{3,7}, Martin Dillon⁵, Mark Wade⁴, Brad Scholz³, David Murray^{3,7}, Richard Lloyd³, Richard Sequeira³, Paul DeBarro⁵ Viliami Heimoana⁶ and Jonathan Holloway⁶. ¹ CSIRO Plant Industry, ² I&I NSW, ³ DEEDI, ⁴ CSIRO Entomology, ⁵ Formerly I&I NSW, ⁶ Formerly I&I NSW, ⁷ Cotton CRC.

Insecticides (in increasing rank order of impact on beneficials)	Rate (g a/ha)	Target pest(s)							Overall Ranking ⁹	Beneficials										Pest resurgence ¹²									
		Helicoverpa	Mites	Mirids	Aphids	Thrips	Silverleaf whitefly	Persistence ⁸		Total ¹ Predatory beetles	Red and blue beetle	Minute 2-spotted lady beetle	Other lady beetles	Total ² Predatory bugs	Damsel bugs	Big-eyed bugs	Other predatory bugs	Apple dimpling bug	Lacewing adults	Spiders	Total wasps	Eretmocerus 19	Trichogramma	Ants	Thrips	Mite	Aphid	Helicoverpa	Toxicity to bees ¹⁴
Bt ¹¹		✓						very short	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	-	-	-	VL	
NP Virus		✓						very short	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	-	-	-	VL	
Pirimicarb	250		✓				short	very low	VL	M	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	M	M	M	L	-	-	-	VL	
PSO (Canopy [®]) ¹⁶	2%	✓		✓			short	very low	VL	L	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	H	VL	-	-	-	VL	
Methoxyfenozide	400	✓					medium-long	very low	L	VL	L	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	-	-	-	VL	
Pyriproxyfen	50						Long	very low	M	-	M	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	-	-	-	L	
Etoxazole	38.5		✓				short	low	VL	VL	L	VL	VL	VL	VL	VL	VL	M	VL	VL	VL	VL	VL	L	-	-	-	VL	
Indoxa carb (low)	60			✓			medium	low	L	L	H	VL	L	L	H	H	M	VL	VL	VL	VL	VL	H	VL	+ve	-	-	-	
Indoxa carb (low + salt)	60			✓			medium	low	L	L	H	VL	L	L	H	H	M	VL	VL	VL	VL	VL	H	VL	-	-	-	-	
Indoxa carb (low + Canopy)	60			✓			medium	low	L	L	H	VL	L	L	H	H	M	VL	VL	VL	VL	VL	H	VL	+ve	-	-	-	
Rynaxypyr	52.5	✓					long	low	L	M	M	VL	VL	VL	VL	VH	VL	VL	VL	VL	VL	L	L	VL	+ve	-	-	-	
Dicofol ³	960		✓				long	low	L	-	-	L	L	L	L	L	L	L	L	L	L	L	-	VL	-	-	-	VL	
Amorphous silica ¹⁷	2500	✓					short	low	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	-	-
Spinosad	96	✓					medium	low	VL	M	L	VL	M	L	H	VL	VL	VL	VL	VL	M	H	H	H	H	-	-	H ¹⁵	
Diafenthiuron	350		✓				medium	low	M	H	VL	M	L	M	VL	H	VL	VL	VL	VL	L	L	L	L	L	-	-	M	
Pymetrozine	150			✓			short	low	M	M	M	L	L	L	L	H	M	L	L	L	L	L	L	L	L	-	-	VL	
Fipronil (v. low)	8		✓				medium	low	L	L	L	VL	L	L	M	L	M	M	M	M	L	L	L	L	L	+ve	-	VH	
Fipronil (v. low + salt)	8		✓				medium	low	L	L	L	VL	L	L	M	L	M	M	M	M	L	L	L	L	L	+ve	-	VH	
Indoxacarb ¹³	127.5	✓		✓			medium	low	H ¹⁴	L	VH	VL	L	L	VH	VL	VL	VL	VL	VL	L	L	L	L	L	-	-	H ¹⁵	
Abamectin	5.4	✓ ⁶					medium	moderate	L	M	H	VL	M	L	M	H	M	M	M	M	L	L	M	M	M	-	-	H	
Emamectin	8.4	✓					medium	moderate	L	VL	M	VL	H	H	H	H	H	H	H	H	M	M	M	M	M	-	-	H	

Table 4. Impact of insecticides at planting or as seed treatments on key beneficial groups in cotton

Insecticides	Rate (g ai/ha)	Main target pest(s)					Persistence ⁶	Overall ⁷	Beneficial group				
		WW	Mite	Mir.	Aph.	Th ⁵			Predatory beetles ¹	Predatory bugs ²	Spiders	Wasps and Ants	Thrips
At Planting													
Aldicarb	450		✓	✓	✓	✓	medium-long	very low ³	v. low	v. low	v. low	v. low	v. high
Phorate	600	✓	✓	✓	✓	✓	medium-long	very low ^{3,4}	No data	No data	No data	No data	v. high
Carbosulfan	750–1000	✓		✓		✓	medium-long	very low ^{3,4}	No data	No data	No data	No data	v. high
Chlorpyrifos	250–750	✓					medium	very low ⁴	No data	No data	No data	No data	No data
Seed Treatments													
Thiodicarb	500 g ai/100 kg seed					✓	short	very low ³	v. low	v. low	v. low	v. low	high
Thiodicarb + Fipronil	259 + 12 g ai/100 kg seed	✓				✓	short-medium	very low ^{3,4}	No data	No data	No data	No data	high
Imidacloprid	525 g ai/100 kg seed	✓			✓	✓	medium	very low ³	v. low	v. low	v. low	v. low	v. high
Imidacloprid	700 g ai/100 kg seed	✓			✓	✓	medium	very low ^{3,4}	v. low	v. low	v. low	v. low	v. high
Thiomethoxam	280 g ai/100 kg seed	✓			✓	✓	medium	very low ^{3,4}	No data	No data	No data	No data	v. high

1. Predatory beetles – ladybeetles, red and blue beetles, other predatory beetles.
2. Predatory bugs – big-eyed bugs, minute pirate bugs, brown smudge bugs, glossy shield bug, predatory shield bug, damsel bug, assassin bug, apple dimpling bug.
3. Except for effects on thrips which are predators of mites. Note that aldicarb and phorate will also control mites.
4. Based on observations with other soil or seed applied insecticides.
5. WW, wireworm; Mir., mirids; Aph., aphids; Th, thrips.
6. Persistence; short, 2–3 weeks; medium, 3–4 weeks; long, 4–6 weeks.
7. Impact rating (% reduction in beneficials following application); very low, less than 10%; low, 10–20%; moderate, 20–40%; high, 40–60%; very high, > 60%



Three banded ladybird*



Transerve ladybird*



Ladybird larva



Red and blue beetle*



Big-eyed bug*



Glossy shield bug



Predatory shield bug



Damsel bug*



Assassin bug*



Hoverfly



Green lacewing adult*



Lynx spider



Orbweaver spider



Orange caterpillar parasite



Normal and Parasitised eggs*

* Predators that can be used in calculating the predator to pest ratio.

For more information about beneficials check out the pest and beneficials guide on the website or the COTTONpaks CD version 2.1.

3. Ensure spray applications are accurate, timely and triggered by pest thresholds. Using plant compensation allows for the plant's capacity to recover from a degree of damage without loss, thereby avoiding insecticide applications to prevent non-economic damage.

Objective 5. Managing crop and weed hosts

Weed management

The potential for pests to over-winter on weeds, and infest the subsequent cotton crop early in the season, is often greatest when a mild wet winter occurs. Abundant growth of weeds in these conditions creates difficulties with their control. Ideally, management of weeds, in fallow fields, cropped fields, and in the borders and headlands should be undertaken early in winter and continue through the winter and spring as necessary.

Weeds provide over winter hosts for a number of pests including mites, whitefly, mirids, aphids, tipworm, cutworm and armyworm. The control of weeds also has implications for managing cotton diseases, as some weed species are disease hosts. For example bladder ketmia (*Hibiscus trionum*) is an alternate host for Fusarium wilt (*Fusarium oxysporum* var. *vasinfectum*).

Weeds also harbour beneficials. However, the potential problems that on-farm weeds may cause, by providing over winter hosts for pests and some diseases, generally outweighs their value as a refuge for beneficials. Growing of refuge crops for beneficials, such as lucerne, is an option available to growers who want to enhance beneficial numbers.

Most insect pests that attack cotton utilise one or more weeds, native plants or alternative crops as hosts. For more information see the sub-section *Overwintering habitat* for each pest in the *Key insect and mite pests of Australian cotton* starting on page 1.

Managing cotton regrowth

Regrowth of cotton after harvest (also called ratoon cotton) provides refuge for *Helicoverpa* spp., spider mites, green mirids, apple dimpling bugs and aphids. Regrowth should be controlled by slashing, root pulling and/or mulching to prevent pests being carried between seasons.

Regrowth cotton is also a risk for carry-over of the disease Cotton Bunchy Top (CBT). Cotton aphids feeding on these plants could then pick up CBT and spread it to adjacent cotton crops in the following season. Cotton regrowth also has implications for managing soil-borne diseases (see the Integrated Disease Management guidelines).

Technology Users Agreements for GM cottons require the control of cotton regrowth. For more information on the requirements for managing Bollgard II® volunteers, see pages 64–65, for Roundup Ready Flex® and Roundup Ready® volunteers see pages 104 and for Liberty Link® volunteers see page 102.

Rotation crops

Growing a range of crops can be seen as essential to providing a habitat for a variety of insects. Cotton in monoculture over a wide area provides a little opportunity for beneficials to thrive and persist.

The selection of a rotation crop has many implications for pest management. Rotation crops are hosts for a range of pests, such as mites (faba beans, safflower), aphids (faba beans, canola) or *H. punctigera* (chickpeas, canola). Some rotation crops may also affect carry over of disease or conversely provide a disease break as suggested in IDM guidelines.

Options for managing pests in rotation crops should also be considered. With no major initiative to structure insecticide resistance management in field crops other than cotton, follow the basic IPM principle to use as many methods as possible to manage pests.

For resistance management in rotation crops the guidelines in Objective 4 can be followed, see page 38.

Objective 6. Use trap crops effectively

Trap cropping is an IPM tactic that can be utilised on a farm level or area wide basis. Trap cropping aims to concentrate a pest population into a manageable area by providing the pest with an area of preferred host crop. When strategically planned and managed, trap crops can be utilised at different times throughout the year to help manage a range of pests. This assists resistance management as well as IPM, by reducing the size of the overall population which reduces the need to apply insecticides and reduces the selection pressure for the pest to develop resistance.

First generation or spring trap cropping

Spring trap crops are designed to attract *H. armigera* adults as they emerge from over wintering pupae in spring. Larvae arising from eggs laid in the crop are controlled using a biological insecticide or allowed to pupate and are controlled by cultivation. A trap crop, strategically timed to flower as pupae are emerging in spring combined with effective pupae busting in previous autumn can help to reduce the early season build-up of *H. armigera* in a district.

An ideal first generation trap crop is one that is; very attractive to *H. armigera*, is a good nursery for beneficials, does not host secondary pests or diseases, does not become a weed problem and is easy to establish and manage. Many winter crops have been trialled to measure their potential as a spring trap crop. Chickpea has consistently proven superior to all other crops in its ability to generate large numbers of *H. armigera*, however it is not a good nursery for beneficial insects. Chickpea has also proven to be agronomically robust, being suitable for both dryland and irrigated situations.

Growers must ensure trap crops do not become future nurseries of *Helicoverpa* spp., and so effectively controlling populations in the trap crop by timely destruction of the crop itself is required. Because the trap crop will not be harvested for yield, a fast knock-down insecticide is not required. Bio-pesticides like Bt and virus formulations may be well suited.

In Central Queensland there is minimal overwintering of *H. armigera* because temperatures are generally too warm to trigger diapause. Here spring trap crops are used to concentrate local *H. armigera* populations into areas where they can also be destroyed, at a time when there are few other hosts for the *H. armigera* to infest.

Summer trap cropping

Summer trap cropping has quite a different aim from that of spring trap cropping. A summer trap crop aims to draw *Helicoverpa* spp. away from a main crop such as cotton or mungbeans and concentrate them in a small area planted to another crop such as sorghum, pigeon pea or lab lab. Once concentrated into the trap crop, the larvae can be controlled.

Some summer trap crops may produce large numbers of beneficial insects that can then move into nearby crops, for example, the *Trichogramma* spp. in sorghum and maize.

The aim of a 'last generation' summer trap crop is to attract moths emerging from non-diapausing pupae under cotton. These pupae are likely to be more abundant under conventional cotton and will have had intense insecticide resistance selection on the cotton crop. Concentrating the eggs from these moths in the trap crop allows the resulting larvae to be controlled using biological insecticides such as a virus or by cultivation to kill the resulting pupae.

The trap crop would be planted mid season, to ensure that it was highly attractive to *H. armigera* late in the cotton season. The attractiveness of the cotton crop relative to the trap crop may significantly influence the potential effectiveness of this strategy.

In Central Queensland cotton growers are using summer trap crops of pigeon pea as part of the RMP for Bollgard II® cotton. More information on trap cropping requirements in Bollgard II® cotton is on page 67.

Objective 7. Communication and training

Communicate with neighbours

Communication with neighbouring primary producers is essential to develop a successful IPM program. It is just as important to communicate with non-cotton growing neighbours and if possible encourage your neighbours to reciprocate a level of communication.

Pesticide application management plan

Extract from 'Application of pesticides' booklet of the BMP manual.

The core best management practice for safe and responsible pesticide use is to develop a pesticide application management plan (PAMP). The PAMP will help ensure that everyone involved in a pesticide application has a clear understanding of their responsibilities. It also helps identify the risks associated with pesticide applications so that controls to minimise those risks can be put in place.

A PAMP has two essential aims:

1. Establishing good communication with everybody involved and interested in the application of pesticides. This communication is required both pre-season and during the season. It should exist between the grower, the applicator, the consultant, farm workers and neighbours.
2. Ensuring appropriate application techniques and procedures are used.

Supporting these aims is good record keeping – of each aspect of the PAMP itself, and the details of pesticide application. This record keeping is important to check the effectiveness pesticide applications, to comply with regulatory requirements and to demonstrate due diligence.

For more information and assistance in developing a PAMP consult the BMP manual and contact your Cotton Australia Grower Services Manager.

Area Wide Management (AWM)

AWM groups or IPM groups acknowledge that pest and beneficial insects are mobile, and that the management regimes to control pests imposed on a given field are likely to alter the abundance of beneficial insects and levels of insecticide resistance in pest populations in the surrounding locality. By communicating and coordinating strategies, AWM groups have successfully implemented IPM.

AWM for population management

AWM in the true sense primarily strives to reduce pest pressure by co-ordinating the efforts of growers in an area. The strategy is based on reducing the survival of over wintering, insecticide-resistant *H. armigera* pupae, reducing the early season build-up of *H. armigera* on a regional/district scale, and to reduce the mid-season population pressure on *Helicoverpa*-susceptible crops.

The main tactics are spring trap crops, conservation of beneficial insects and cultivation of diapausing pupae. A critical component is to bring together farmers from a range of different enterprises, including cotton and other dryland crops. As *H. armigera* is a pest common to most of these crops it is vital to have all types of growers involved if AWM is to succeed.

AWM or IPM Groups

These groups focus on communication and co-ordination to achieve agreed IPM goals. These may include conserving beneficials, delaying use of disruptive insecticides, reducing the risk of drift between farms 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.

For more information on getting a group started and/or maintaining momentum of a group see the IPM Guidelines II, or contact your regional cotton extension officer or district agronomist.

Meetings

Each winter, meetings are held in each major region to review resistance levels, IPM principles, computerised decision support programs, BMP procedures and other production issues. These meetings improve information exchange between growers, consultants, and research and extension personnel.

Training

The Cotton Production Course is a university based course consisting of four units. The course is available for part time external students at both undergraduate and graduate level. Coordinator – John Stanley (02) 6773 3758.

CottASSIST

Welcome Joe Farmer! Log out

CottASSIST

CottASSIST is a group of web tools designed to deliver the latest cotton research and integrate up-to-date information and assist with cotton management decisions. These web tools are mainly for use by growers and consultants within the cotton industry, although can be used by anyone interested in cotton production.

www.cottassist.cottoncrc.org.au

CottASSIST has been developed by CSIRO and Cotton Catchment Communities CRC Ltd.
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Table 5. Seasonal activity plan for IPM

Objective	Phases				
	Post harvest	Pre-planting	Planting to 1 flower per metre	1st flower to 1 open boll per metre	1 open boll per metre to harvest
1. Growing a healthy crop	Consider the best rotation crop for your situation. Test soil nutrient status to determine fertiliser requirements for cotton crop. Consider potential disease risks.	Seed bed preparation. Field and cotton variety selection. Plan irrigation and crop management strategies.	Consider planting window. Consider at-planting seed treatment, insecticides and other control options which do not disrupt beneficial insect activity.	Water management. Nutrient status. Growth control. Pest control.	Make final irrigation decisions. Defoliate when crop is mature. Keep on top of pests by using appropriate control options.
2. Keeping track of insects and damage	Sample cotton stubble for <i>Helicoverpa armigera</i> pupae after harvest.	Assess risk of wireworm, early thrips, mirids, mites and black field earwigs and decide on seed treatments, granular insecticides or in-furrow insecticide sprays.	Sample for pests, beneficials and parasitism rates in cotton as well as spring trap crop. Monitor early season damage. Track pest trends. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates. Track pest trends and incorporate parasitism into spray decisions. Monitor fruit load. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates in cotton as well as last generation trap crop. Monitor fruit load. Use pest thresholds and the predator to pest ratio. Cease pest control at 30–40% bolls open.
3. Preserving beneficial insects	Plant lucerne (strips or block) in autumn. Consider becoming involved in an IPM or AWM group. Discuss spray management plan with neighbours and consultant.	If planning to release <i>Trichogramma</i> during the season, plan to sow other crops e.g. sorghum. Consider growing a diverse habitat to encourage beneficials.	Sample for beneficials and parasitism rates. If chemical control of a pest is required, refer to the beneficial impact table. Keep track of your BDI and predator to pest ratio.	Sample beneficials. Consider releasing <i>Trichogramma</i> into sorghum. Keep track of your BDI and predator to pest ratio. Food sprays may be considered. Manage lucerne appropriately.	Sample for beneficials. Encourage beneficials to reduce late season resistant pests by using food sprays and low impact insecticides.
4. Preventing insecticide resistance	Pupae bust to control overwintering <i>Helicoverpa</i> and mites as soon as possible after harvest. Plant spring trap crop. Review resistance management results. Reduce the availability of aphid and whitefly hosts over winter.	Consider Bollgard II® refuge option. Consider choice of at – planting insecticides or seed treatment and implications for later aphid sprays.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.
5. Managing crop and weed hosts	Keep farm weed free over winter. Control cotton re-growth.	Carefully consider summer rotation crops (type and location). Keep farm weed free.	Keep farm weed-free.	Keep farm weed-free.	Consider winter rotation crops (type, location and the potential to host pests or diseases). Keep farm weed-free.
6. Using trap crops effectively	Plant spring trap crop. Consider flowering date to time planting.	Consider summer trap crop. Cultivate all chickpea trap crops by 30 September.	Consider last generation trap crop.	Monitor <i>Helicoverpa</i> populations in summer trap crop, control if necessary.	Destroy <i>Helicoverpa</i> eggs and larvae in last generation trap crop using biological sprays. Pupae bust last generation trap crop.
7. Communication and training	Consider becoming involved in an IPM or AWM group. Attend regional training and information seminars. Consider doing the IPM short course.	Communicate with neighbours and applicators to discuss spray management plans.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.

Insecticide Resistance Management Strategy (IRMS) for 2009/10

Louise Rossiter and David Larsen, *Industry & Investment NSW*; Sharon Downes and Lewis Wilson, *CSIRO*; Dave Murray and Melina Miles, *Department of Employment, Economic Development and Innovation*

The use of pesticides selects for resistance in pest populations. The cotton industry IRMS seeks to manage the risk of resistance in *Helicoverpa* spp., aphids, mites and whitefly, both in conventional and Bollgard II® cotton. Additional resistance management requirements are also in place for managing the risk of *Helicoverpa* spp. developing resistance to Bollgard II® (refer to pages 64–65). Below, the key elements of the IRMS are described and questions regarding the design and reasons for the IRMS are answered. In this document, the term ‘insecticide’ refers generally to pesticides used for insect or mite control.

CHECKLIST

1. Cultivate cotton and residues of alternative host crops as soon as possible after harvest to destroy overwintering *H. armigera* pupae. In Bollgard II® fields, cultivation must be completed before the end of July.
2. Use recommended pest thresholds to minimise insecticide use and reduce resistance selection. Refer to Table 2 on page 22–23.
3. Monitor first position fruit retention at flowering and aim to retain at around 60% or alternatively maintain a fruiting factor of between 1.1 and 1.3.
4. Delay using broad-spectrum sprays, such as organophosphates or pyrethroids, for as long as possible. These products reduce the abundance of beneficial insects and increase the chance of mite, aphid and silverleaf whitefly outbreaks.
5. Avoid early season use of omethoate or dimethoate. This is to prevent selection for organophosphate-carbamate cross-resistance in aphids. Avoiding early season use of these insecticides also reduces the risk of flaring other pests like silverleaf whitefly.
6. Do not apply a first foliar spray from the same insecticide group as a seed treatment. For sucking pests, consider the seed treatment as a ‘spray’ and alternate chemistries.
7. Monitor mite populations regularly after seedlings emerge. If established mite populations are present (5–10% of plants infested) avoid using broad-spectrum insecticides to control other pests. Instead use selective compounds or compounds that also control or suppress mites, either alone or in mixtures as required.
8. Avoid continuous sprays of any one mode of action group, including Bt products. (Rotate between chemical groups where possible). Do not exceed the maximum acceptable use limits indicated on the Insecticide Resistance Management Strategy charts for cotton (see pages 52–55).
9. Do not respray an apparent failure with a product of the same group – unless the failure is clearly due to factors not related to resistance, such as poor application, timing, etc.
10. Control weeds on farm to minimise alternative hosts for mites, aphids and silverleaf whitefly through winter and particularly in the lead up to cotton planting.
11. Comply with any use restrictions placed on insecticides used on other crops. This will reduce the chance of prolonged selection for resistance over a range of crops.

YOUR QUESTIONS ANSWERED

How was the 2009/10 IRMS decided?

The development of the Insecticide Resistance Management Strategy is driven by the Transgenic and Insect Management Strategies (TIMS) Committee. TIMS is a sub-committee of Cotton Australia. The results from the insecticide and miticide resistance monitoring programs, carried out during the season, are used to inform the committee of any field-scale changes in resistance levels. Extensive communication and discussion with cotton growers and consultants is undertaken in all regions of the Australian cotton industry before TIMS finalises their recommendations. Communication is critical for ensuring that the IRMS is practical and can be implemented.

What are the key changes in the IRMS this season?

There were a number of key changes to the IRMS for this season:

1. Darling Downs incorporated into the Central Regions IRMS enabling insecticide use windows to be uniform (thereby minimising selection pressure) across southern Queensland and northern NSW.
2. Southern Regions IRMS for Macquarie, Lachlan and Murrumbidgee allowing for earlier season pyrethroid use (Dec 15 – end of season) on *H. punctigera* populations in areas where silverleaf whitefly does not currently present a problem.
3. Central Regions: pyrethroids moved to start 1 month later (Jan 15 – end of season) due to effect on flaring silverleaf whitefly outbreaks.
4. Altacor windowed after an initial season wide use period last year –
Central and Southern Regions: Dec 1 – Feb 15
Northern Regions: Nov 15 – Feb 1.

5. Northern Regions: Steward moved to start 15 days later in the season in response to industry feedback, Dec 1 – Feb 15.
6. Shield (Clothianidin) added to the Neonicotinoid group.
7. Chemicals that are registered but currently commercially unavailable have been separated from the main body of the strategy and ‘greyed’ out to give greater clarity to those insecticides that are actually available for use.

Why is it important to follow the IRMS in Bollgard II® cotton?

Whenever insecticides are used there is selection pressure for resistance. The IRMS should always be consulted when making a spray decision, even in Bollgard II® cotton. This is irrespective of whether the decision has been motivated by above threshold populations of secondary pests, large *Helicoverpa* larvae migrating from refugia or extremely high *Helicoverpa* egg pressure. The IRMS has been designed to fit with IPM principles. Following the IRMS and implementing the Bollgard II® RMP is necessary to minimise all resistance risks to insecticides, miticides and the Cry proteins (in Bollgard II®).

How do insects develop resistance?

Resistance is an outcome of exposing pest populations to a strong selection pressure, such as an insecticide. Genes for resistance naturally occur at very low frequencies in insect populations. They remain rare until they are selected for with a toxin, either from an applied pesticide or from within Bollgard II®. Once a selection pressure is applied, resistance genes can increase in frequency as the insects carrying them are more likely to survive and produce offspring. If selection continues, the proportion of resistant insects relative to susceptible insects may continue to increase until reduced effectiveness of the toxin is observed in the field.

What do the chemical group numbers on the IRMS charts mean?

The numbers appearing beside chemical names or trade names on the IRMS chart are the international mode of action group numbers. To be consistent with insecticide product labels and international agreements among chemical manufacturers, TIMS also include these numbers when listing chemical groups.

Insecticides with the same mode of action kill pests by the same mechanism eg. by affecting the function of nerves or by paralysing mouthparts. Hence, if insects (or mites) develop resistance to one insecticide in a particular mode of action group, they may be cross resistant to other insecticides in that group.

What is the scientific basis of the IRMS?

The basis of the IRMS is to minimise selection across consecutive generations of the pest. Pest life cycles therefore determine the length of the ‘windows’ around which the IRMS is built. As the life cycles of *Helicoverpa* spp. and the sucking pests are very different, the strategy for one will not manage resistance for the other.

***Helicoverpa* spp.**

Ideally the length of the ‘windows’ would be 42 days (average) time from egg to moth) to minimise the selection pressure across consecutive generations. Most chemicals are restricted to windows of between one and two generations to account for the practicalities of pest control. To counteract this compromise there are additional restrictions on the maximum number of applications for each chemical group.

Sucking Pests – mites, aphids and whitefly

The resistance strategy for the short life cycle pests depends on rotation of insecticides/miticides between different chemical groups (different modes of action) to avoid selection over successive generations. Non-consecutive uses of chemistries is particularly important for aphids as they reproduce asexually. All offspring from a resistant aphid will be resistant. There are also restrictions on the maximum number of uses for individual products and chemical groups to further encourage rotation of chemistries.

How do refuges help manage resistance to Bt in Bollgard II®, and do they help manage resistance to insecticides in *Helicoverpa*?

Growing refuge crops is a pre-emptive resistance management strategy. It is being implemented to prevent field-scale resistance to Bollgard II®. This is important as the success of the refuge strategy depends on the majority of the general population being susceptible (SS). When a susceptible moth mates with a resistant moth (RR), the offspring carry one allele from each parent (RS). These offspring are referred to as heterozygotes. In the cases of Bt resistance that have so far been identified, heterozygotes are still controlled by Bollgard II® cotton. Because of the high toxic dose in Bollgard II®, it is only RR individuals that can survive. This is not always the case for resistances to other insecticides. For many of the conventional insecticides (to which resistance has already developed), resistance mechanisms are functionally dominant. This means that heterozygotes survive the application and can make up a large part of the resistant population. In such circumstances the dilution effect created by refuges is far less effective.

Refuges are able to help manage Bt resistance through the generation of SS moths. If RR moths are emerging from Bollgard II® fields, they are more likely to mate with SS moths if a refuge has been grown. The RS offspring is susceptible to Bollgard II® and an increase in the frequency of RR individuals can be prevented.

While refuges cannot assist when insecticide resistance is already prevalent in the field population, such as with synthetic pyrethroids, there may be some benefit from the unsprayed refuge options for new chemistries. Unsprayed refuges will produce moths that have not been exposed to insecticide selection pressure.

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

The IRMS has always accounted for moth movement among different cotton growing regions. Several field studies have shown that moths can travel large distances. Recently, some genetic work showed that *H. armigera* moths move up to 1200 kilometres between regions. Insecticide resistance in one region can therefore spread to other regions by moth migration. The TIMS Committee designs the IRMS to reduce the chance that moths migrating between regions would be reselected repeatedly by the same insecticide group. This is done by limiting the time period over which most insecticides are available. The strategies also accommodate the different growing seasons from central Queensland through to southern NSW.

Will the large uptake of Bollgard II® reduce the population sizes of *Helicoverpa* spp.?

It is too early to tell whether the widespread use of Bollgard II® will affect the size of natural populations of *Helicoverpa*. *H. armigera* is closely linked with cropping regions so it is possible that a reduction in numbers of this pest will occur over time. In most seasons, the majority of moths are locally generated, so Bollgard II® may act as a 'sink' and influence the overall population size. However, this species uses hosts other than cotton and, even with widespread use of Bollgard II®, population sizes may be regulated by the abundance of these alternative hosts.

In contrast, large populations of *H. punctigera* moths can be generated in inland areas and migrate to cotton growing regions. As these moths are generated in other environments, Bollgard II® will have little effect on the size of these populations, especially early in the season following the annual spring migration events of this species. However the size of these populations will be strongly influenced by the

availability of hosts, which is largely determined by rainfall. Years where inland areas receive little rainfall may produce few migrating moths.

Why do we need an IRMS in conventional cotton when there are such large areas of Bollgard II®?

Large areas of Bollgard II® will not change the **frequencies** of resistance genes being carried by *H. armigera* moths. The same **proportion** of resistant and susceptible moths will continue to lay eggs in cotton – be it conventional or Bollgard II®. Hence the **likelihood** of resistance development to foliar and soil applied insecticides remains the same, even if the overall size of the *H. armigera* population is reduced. Continuing to follow the IRMS will ensure that the industry retains the ability to control *H. armigera* effectively with insecticides on conventional cotton both now and in the future, in case field-resistance to Bollgard II® develops.

When do stage windows start and stop?

The dates shown on the strategy charts are for the start of each stage. Windows will start at 00:01 h on the date shown as the start (e.g. 15 December for Stage 2 in Central areas) and end at midnight 24:00 h on the day before the start of the next window (e.g. 1 February for Stage 2 in Central areas). For those individual insecticides and miticides that start or end outside window boundaries, the start and end dates are specified and the same principles apply.

What do the terms cross-resistance and multiple resistance mean? How can they be minimised?

Cross-resistance occurs when selection for resistance against one pesticide also confers resistance to another pesticide, either from the same mode of action group or a different group. For example, the mechanism for pirimicarb resistance (Group 1A) in aphids also gives resistance to omethoate/dimethoate (Group 1B). Cross-resistance is important as it means that a pest may be resistant to a chemical to which it has never been exposed (i.e. without selection pressure).

Multiple resistance simply means that an insect is resistant to more than one mode of action group. For instance, *H. armigera* can have metabolic resistance to synthetic pyrethroids (Group 3A) and nerve insensitivity to organophosphates (Group 1B).

The development of both cross-resistance and multiple resistance can be minimised by following the IRMS. The strategy is designed to manage both of these occurrences. For example, in the strategy for aphids, there is a break between the use of pirimicarb and dimethoate/omethoate during which other chemistries should be used. The use of

alternative chemistries should minimise the number of pirimicarb-resistant aphids being exposed to dimethoate/omethoate.

Is pupae busting in conventional cotton still important for resistance management?

Yes. Pupa busting is an effective, non-chemical method of preventing resistance carryover from one season to the next.

In 2007/08 the pupae busting guidelines for sprayed conventional cotton were modified according to the likelihood that larvae will enter diapause before a certain date, allowing for removal of pupae busting operations in field specific situations. The estimated commencement date of diapause is based on the model which drives the *Helicoverpa* Diapause Induction and Emergence Tool on the Cotton CRC website. The model was developed from field research conducted on the Darling Downs by QPI&F and has broad application to farming systems in eastern Australia. The web tool predicts the timing of diapause.

Post Harvest Pupa Destruction statement since 2007/08: Sprayed conventional cotton crops defoliated after the 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* larvae and should be pupae busted as soon as possible after picking and no later than the end of July.

How does the use of insecticide mixtures fit in the IRMS?

When used repeatedly, mixtures are high-risk and a controversial strategy for managing resistance. They can undermine the IRMS by repeatedly selecting for resistance to the common components in mixtures and by selection for resistance across multiple chemical groups. When mixtures are used frequently, it becomes difficult to determine whether each component is contributing equally to efficacy.

The use of mixtures to overcome the effects of resistance requires very careful consideration. Mixtures may provide improved field control of *H. armigera* in situations where a proportion of the pest population is resistant to one insecticide (i.e. pyrethroid) but is susceptible to another chemical group with a different mode of action (i.e.

organophosphate). As a general rule, mixtures are unnecessary in situations where individual products provide adequate control.

Several criteria need to be met for mixtures to be effective. Components of the mixture should;

- be equally persistent,
- have different modes of action,
- not be subject to the same routes of metabolic detoxification,
- be tank-mix compatible.

In addition, the majority of the pest population should not be resistant to any component of a mixture, as this may render it a redundant or 'sleeping partner' in terms of insect control.

When very heavy *Helicoverpa* spp. pressure occurs and egg parasitism percentages have been low, include an ovicide (e.g. amitraz and methomyl) in sprays to take the pressure off larvicides. When targeting sprays against eggs and very small larvae and do not expect 100% control with any insecticide or mixture of insecticides. If larval numbers are reduced below threshold then the treatment should be regarded as effective.

Some mix partners provide more than additive kill (synergism), but this is not always the case. Some mixtures may in fact result in reduced effectiveness. For example the synergists, piperonyl butoxide (PBO) and propargite, may increase the efficacy of pyrethroids against *H. armigera*, but may be antagonistic if mixed with organophosphates or chlorfenapyr.

The Croplife Australia Insecticide Resistance Management Group, recommend that no two compounds from the same chemical group/ mode of action be included in a mixture (e.g. chlorpyrifos and profenofos). The repeated use of any insecticide with different mix partners will also increase selection for resistance e.g. pyrethroid plus propargite, followed by pyrethroid plus amitraz, followed by pyrethroid plus organophosphate.

It is illegal to use rates above those recommended on the label of an insecticide alone or in mixtures. Efficacy will not always improve at rates above the highest label rate or if two insecticides of the same chemical group are applied as a mixture.

TIMS Troubleshooting Committee contacts 2009/10

Name	Telephone	Mobile	Fax	Email
Lewis Wilson (Chair person)	(02) 6799 1550	-	(02) 6793 1186	lewis.wilson@csiro.au
Louise Rossiter	(02) 6799 1500	0429 726 285	(02) 6799 1503	louise.rossiter@industry.nsw.gov.au
CRDC (Tracey Farrell)	(02) 6792 4088	-	(02) 6792 4400	tracey.farrell@crdc.com.au
CA (Greg Kauter)	(02) 9669 5222		(02) 9669 5511	gregk@cotton.org.au

Can emergency changes be made to the IRMS during the season?

Yes, the TIMS Troubleshooting Committee (TTC) was established by TIMS to act on its behalf to respond quickly to requests to vary the Strategy **temporarily** for **specific regions**. The TTC is not able to approve major changes to the Strategy – that is the role of the TIMS Committee.

What is the process for requesting a within-season change to the IRMS?

The TIMS Troubleshooting Committee (TTC) has put in place a clear process for handling requests for within-season changes to the IRMS.

A request to temporarily alter the Strategy for a district or part of a district can be initiated by any grower or consultant, but it will not be considered by the TTC unless it is presented with clear evidence of having been discussed and gained majority support at a local level. This will include:

- Evidence that the local consultants who might be affected by the requested alterations have discussed them and are in agreement.
- A request from the local Cotton Growers Association (CGA) that outlines the problem and the preferred solution.
- Evidence that all reasonable efforts have been made to apply the alternatives available within the strategy.

The request can be faxed or emailed to Louise Rossiter or Lewis Wilson. A return contact name and phone number should be included so that receipt of the request can be acknowledged and further discussion can be held with a TTC member if required.

All members of the TTC will be faxed or emailed the request and asked to respond to an ACRI contact point by 10 a.m. the following morning (or the next working day if the request is lodged on a weekend or public holiday). A decision will then be made and a response issued by 12 noon. All reasonable efforts will be made to meet this level of response, however it should be recognised that complex or poorly communicated requests may take longer to resolve.

The granting of a request by the TTC to temporarily alter the Resistance Strategy applies to a specific district. It does not confer the same temporary changes to other districts unless they have also lodged a request to the TTC in the manner outlined above. TTC changes for a region have a limited duration and do not carry over from one season to the next.

CONSIDERATIONS FOLLOWING A SUSPECTED SPRAY FAILURE

In the event of a suspected pest control failure, don't panic as it is important to assess the situation carefully before deciding on a course of action. The presence of live pests following an insecticide application does not necessarily indicate insecticide failure. What is the insecticide's mode of action? Has it been given enough time to work? Products such as thiodicarb, foliar Bt, NPV, spinosad and indoxacarb are stomach poisons and may not give maximum control until 5–7 days after application. Similarly, propargite, abamectin, pyriproxifen and diafenthiuron are slow acting and may take 7–10 days or longer to achieve maximum control. In some instances pest infestation levels remain high following a treatment but little if any economic damage to the crop occurs (e.g. if the pests are sick and have ceased feeding).

When diagnosing the cause of an insecticide failure, it is important to remember that there are a wide range of variables that influence insecticide efficacy. These include species complex, population density and age, crop canopy structure, application timing, the application method, carrier and solution pH – and their effects on coverage and the insecticide dose delivered to the target, environmental conditions, assessment timing and insecticide resistance expressed in the pest population. For every insecticide application, it is the interaction of all of these factors that determines the outcome. While it will not be possible to optimise all of these variables all of the time, when more compromises are made, there is a greater likelihood that efficacy will be unsatisfactory.

It is also important to maintain realistic expectations of the efficacy that can be achieved. For example, do not expect satisfactory control of medium and large *Helicoverpa* larvae late in the season, regardless of the insecticide treatment used.

If a field failure is suspected to be due to insecticide resistance, collect a sample of the surviving pest from the sprayed field using the industry guidelines and send to the relevant researcher. For *Helicoverpa* surviving conventional insecticides, Louise Rossiter (02) 6799 1500. For *Helicoverpa* surviving Bt, Sharon Downes (02) 6799 1500. For mites and aphids, Grant Herron (02) 4640 6333. For whitefly, Richard Lloyd (07) 4688 1315. Sending samples for testing can confirm or rule out resistance as the cause of the spray failure and is an important part of assessing the presence of resistance across the industry.

After any spray failure, *do not follow up with an application of the same insecticide group alone or in mixture (at any rate)*. Rotate to an insecticide from a different mode of action group.

Northern Regions: Central Highlands, Dawson and Callide Valleys

	Stage 1	Stage 2 Nov 15	Stage 3 Dec 15	Stage 4 Jan 15	Stage 3 Feb 1	Post-Harvest
See Cotton Pest Management Guide for suggested thresholds	Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures					Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing <i>Helicoverpa armigera</i> pupae and should be pupae busted as soon as possible after picking and no later than the end of August
	FOLIAR <i>Bacillus thuringiensis</i> (BT) -on conventional and Bollgard cotton but EXCLUDING any refuges					
	HELICOVERPA VIRUSES (GEMSTAR, VIVUS) avoid season long use of low rates					
	CANOPY OIL , ABRABE - No restrictions					
	AMITRAZ - Max of 4					
	ENDOSULFAN see label for restrictions					
	AFFIRM					
	ABAMECTIN - for <i>H. punctigera</i> , Max of 2, including mite sprays					
	ALTACOR - Max of 3					
	Dec 1 STEWARD* - Max of 3 Feb 15					
	PYRETHROIDS & PYRETHROID MIXES - PBO, Max of 2 - TALSTAR sprays, Max of 2, including mite sprays.					
	CHLORPYRIFOS - Max of 3 including mixtures					
	Other OPs - Max of 3 including mixtures					
	METHOMYL - Max of 4, carbamates Including mixtures					
	THIODICARB - Max of 4 carbamates Including mixtures					
Helicoverpa	* September 15 th No use of Steward or Tracer on chickpeas after this date					
	PRODIGY - Max of 3					
	INTREPID - Max of 1 at any rate including mite sprays					
	TRACER* - Max of 3					
	CHLORPYRIFOS METHYL- Max of 3 including mixtures					
PROFENOFOS - Max of 3 including mixtures						
Registered but currently commercially unavailable insecticides						



	Stage 1	Stage 2 Nov 15	Stage 3 Dec 15	Stage 4 Jan 15	Stage 3 Feb 1	With-holding Period	Post-Crop Management
See Cotton Pest Management Guide for suggested thresholds	1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below. 2. Rotate chemistry. No consecutive use of the same group 3. Failures with neonicotinoids against aphids have been confirmed . Do not follow a seed or planting insecticide with the first foliar spray from the same group. ALTERNATE					91 days 28, 10 & 5 days 21 days 28 days 28 days 14 & 21 days 5 days Nil See label 70 days 28 days 14 days 28 days 21 days 20 days 28 days 14 days 28 days	STOP Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)
	Canopy Oil - No restrictions						
	CRUISER } Seed dressing						
	GAUCHO / GENERO } Seed dressing						
	AMPARO } Seed dressing						
	CONFIDOR Finish date determined by long withholding period						
	ACTARA, INTRUDER, SHIELD						
	PIRIMICARB Use when beneficial conservation is important						
	FULFILL - Crop must be actively growing Finish date determined by crop growth (see label)						
	ENDOSULFAN - see label for restrictions						
	DIMETHOATE & OMETHOATE						
	CHLORPYRIFOS - METHYL see Helicoverpa strategy						
	ALDICARB In furrow at sowing						
	PHORATE in furrow at sowing or side dress						
	Aphids	CHLORPYRIFOS - See Helicoverpa strategy					
Start date determined by canopy closure (see label) PEGASUS							
PROFENOFOS - See Helicoverpa strategy							
Aphids and Mites	PARAMITE - Max of 1						
	ABAMECTIN - Max of 2, including <i>H. punctigera</i> sprays						
	Don't use pre squaring PROPARGITE						
Mites	TALSTAR - Max of 2, including Helicoverpa sprays.						
	INTREPID - Max of 1 at any rate including Helicoverpa sprays						
SLW Mirids	Refer Silverleaf whitefly Threshold Matrix and associated Notes						
	WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.						



2009-2010 Insecticide Resistance Management Strategy for Cotton

Central

Darling Downs, Balonne, Macintyre, Gwydir, Lower & Upper Namoi, Bourke

	Stage 1	Stage 2 Dec 15	Stage 3 Jan 15	Stage 4 Feb 15	
See Cotton Pest Management Guide for suggested thresholds		Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures			Post-Harvest
Helicoverpa		FOLIAR <i>Bacillus thuringiensis</i> (BT) - on conventional and Bollgard cotton but EXCLUDING any refuges			Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing <i>Helicoverpa armigera</i> pupae and should be pupae busted as soon as possible after picking and no later than the end of August
		HELICOVERPA VIRUSES - (GEMSTAR, VIVUS) avoid season long use of low rates			
		CANOPY OIL, ABRABE - No restrictions			
		AMITRAZ - Max of 4			
		ENDOSULFAN see label for restrictions			
		AFFIRM February 1			
		ABAMECTIN - for <i>H. punctigera</i> , Max of 2, including mite sprays			
		December 1	ALTACOR - Max of 3		
			STEWARD* - Max of 3		
			PYRETHROIDS & PYRETHROID MIXES - PBO, Max of 2 - TALSTAR sprays, Max of 2, including mite sprays.		
		February 1	CHLORPYRIFOS - Max of 3 including mixtures Other OPs - Max of 3 including mixtures METHOMYL - Max of 4 carbamates including mixtures THIODICARB - Max of 4 carbamates including mixtures		
	* October 15 th No use of Steward or Tracer on chickpeas after this date				
	PRODIGY - Max of 3				
	December 1	TRACER* - Max of 3		Registered but currently commercially unavailable insecticides	
		INTREPID - Max of 1 at any rate including mite sprays			
		February 1	CHLORPYRIFOS METHYL - Max of 3 including mixtures PROFENOFOS - Max of 3 including mixtures		



	Stage 1	Stage 2 Dec 15	Stage 3 Jan 15	Stage 4 Feb 15			
See Cotton Pest Management Guide for suggested thresholds	1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below. 2. Rotate chemistry. No consecutive use of the same group 3. Failures with neonicotinoids against aphids have been confirmed. Do not follow a seed or planting insecticide with the first foliar spray from the same group. ALTERNATE				With-holding Period	Post-Crop Management	
Aphids		Canopy Oil - No restrictions			Nil See label	STOP Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)	
		CRUISER GAUCHO / GENERO AMPARO } Seed dressing			Nil See label		
		CONFIDOR Finish date determined by long withholding period			91 days		
		ACTARA, INTRUDER, SHIELD			28, 10 & 5 days		
		PIRIMICARB January 1 Use when beneficial conservation is important			21 days		
		FULFILL - Crop must be actively growing Finish date determined by crop growth (see label)			28 days		
		ENDOSULFAN - see label for restrictions			28 days		
			February 1	DIMETHOATE & OMETHOATE CHLORPYRIFOS-METHYL - see Helicoverpa strategy			14 & 21 days 5 days
		ALDICARB In furrow at sowing			Nil See label		
		PHORATE in furrow at sowing or side dress			70 days		
Aphids and Mites			February 1	CHLORPYRIFOS - See Helicoverpa strategy	28 days		
		Start date determined by canopy closure (see label) PEGASUS			14 days		
		February 1	PROFENOFOS - See Helicoverpa strategy		28 days		
Mites	DICOFOL - NSW only + Ground application only				7 days		
	PARAMITE - Max of 1				21 days		
	ABAMECTIN - Max of 2, including <i>H. punctigera</i> sprays				20 days		
	Don't use pre squaring PROPARGITE				28 days		
		TALSTAR - sprays, Max of 2, including Helicoverpa sprays.		14 days			
	INTREPID - Max of 1 at any rate including Helicoverpa sprays				28 days		
SLW Mirids	Refer Silverleaf whitefly Threshold Matrix and associated Notes						
	WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.						



Southern Regions: Macquarie, Lachlan, Murrumbidgee

	Stage 1	Stage 2	Stage 3	Stage 4		
		Dec 15	Jan 15	Feb 15		
See Cotton Pest Management Guide for suggested thresholds	Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures				Post-Harvest	
Helicoverpa	FOLIAR <i>Bacillus thuringiensis</i> (BT) - on conventional and Bollgard cotton but EXCLUDING any refuges				Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing <i>Helicoverpa armigera</i> pupae and should be pupae busted as soon as possible after picking and no later than the end of August 	
	HELICOVERPA VIRUSES - (GEMSTAR, VIVUS) avoid season long use of low rates					
	CANOPY OIL, ABRABE - No restrictions					
	AMITRAZ - Max of 4					
	ENDOSULFAN see label for restrictions					
	AFFIRM		February 1			} Max 3 from 'mectins' group
	ABAMECTIN - for <i>H. punctigera</i> , Max of 2, including mite sprays					
	December 1		ALTACOR - Max of 3			
	STEWARD*- Max of 3					
	PYRETHROIDS & PYRETHROID MIXES - PBO, Max of 2 - TALSTAR sprays, Max of 2, including mite sprays.					
		February 1		} Max 3 from 'mectins' group		
		CHLORPYRIFOS - Max of 3 including mixtures				
		Other OPs - Max of 3 including mixtures				
		METHOMYL - Max of 4 carbamates Including mixtures				
		THIODICARB - Max of 4 carbamates Including mixtures				
* October 15 th No use of Steward or Tracer on chickpeas after this date						
PRODIGY - Max of 3						
December 1		TRACER* - Max of 3				
INTREPID - Max of 1 at any rate including mite sprays						
		February 1		} Max 3 from 'mectins' group		
		CHLORPYRIFOS METHYL - Max of 3 including mixtures				
		PROFENOFOS - Max of 3 including mixtures				

Registered but currently commercially unavailable insecticides

	Stage 1	Stage 2	Stage 3	Stage 4	
		Dec 15	Jan 15	Feb 15	
See Cotton Pest Management Guide for suggested thresholds	1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below. 2. Rotate chemistry. No consecutive use of the same group 3. Failures with neonicotinoids against aphids have been confirmed. Do not follow a seed or planting insecticide with the first foliar spray from the same group. ALTERNATE				With-holding Period
Aphids	Canopy Oil - No restrictions				Nil See label
	CRUISER GAUCHO / GENERO AMPARO		} Seed dressing		Nil See label
	CONFIDOR Finish date determined by long withholding period				91 days
	ACTARA, INTRUDER, SHIELD				28, 10 & 5 days
	PIRIMICARB		January 1 Use when beneficial conservation is important		21 days
	FULFILL - Crop must be actively growing		Finish date determined by crop growth (see label)		28 days
	ENDOSULFAN - see label for restrictions				28 days
			February 1		} Max 3 from 'mectins' group
			DIMETHOATE & OMETHOATE		
			CHLORPYRIFOS-METHYL - see Helicoverpa strategy		14 & 21 days
				5 days	
Aphids and Mites	ALDICARB In furrow at sowing				Nil See label
	PHORATE in furrow at sowing or side dress				70 days
			February 1		} Max 3 from 'mectins' group
			CHLORPYRIFOS - See Helicoverpa strategy		
		February 1		} Max 3 from 'mectins' group	
		PEGASUS			
		PROFENOFOS - See Helicoverpa strategy		28 days	
Mites	DICOFOL - NSW only + Ground application only				7 days
	PARAMITE - Max of 1				21 days
	ABAMECTIN - Max of 2, including <i>H. punctigera</i> sprays				20 days
	Don't use pre squaring PROPARGITE				28 days
		TALSTAR - sprays, Max of 2, including Helicoverpa sprays.		14 days	
		INTREPID - Max of 1 at any rate including Helicoverpa sprays		28 days	
Refer Silverleaf whitefly Threshold Matrix and associated Notes					
WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.					

Post-Crop Management



STOP
Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)



Chemical Groups for Rotation		Effective against		
Group. Chemical:	Sold as	Helicoverpa (14)	Mites (7)	Aphids (7)
16A. METHOXYFENOZIDE (IGR):	PRODIGY			
11C. BT:	DIPEL, COSTAR, MVP2, etc			
VIRUS.	HELICOVERPA VIRUS (NPV's: GEMSTAR, VIVUS)			
OTHERS,	CANOPY, ABRADÉ			Canopy
28. RYNAXYPYR:	ALTACOR			
5A. SPINOSAD:	TRACER			
3A. PYRETHROID:	BULLDOCK, DECIS, DOMINEX, FASTAC, KARATE, etc			
3A. PYRETHROID (BIFENTHRIN):	TALSTAR		Suppress only	
19A. AMITRAZ:	AMITRAZ, OVASYN etc			
2A. ENDOSULFAN:	THIODAN etc.			
22A. INDOXACARB:	STEWARD			
6A. AVERMECTIN:	EMAMECTIN BENZOATE (AFFIRM)		Suppress only	
6A. AVERMECTIN:	ABAMECTIN (WIZARD etc)	H. punctigera only		
1A. CARBAMATES:	METHOMYL (NUDRIN, LANNATE etc), THIODICARB (LARVIN etc)			
1A. CARBAMATE at planting:	ALDICARB			No cross resistance
1A. CARBAMATE Foliar:	(PIRIMICARB) PIRIMOR, APHIDEX			
1B. CHLORPYRIFOS (+ methyl) (OP):	CHLORFOS, LORSBAN, PREDATOR, (RESCUE, DIPLOMAT) etc	No cross resistance		
1B. PROFENOFOS (OP):	CURACRON, SABRE etc	No cross resistance		
1B. Other OPs	At Planting or side-dress : THIMET, PHORATE Foliar: DIMETHOATE, OMETHOATE, PARATHION METHYL.			
13A. CHLORFENAPYR:	INTREPID			
12B. DIAFENTHIURON:	PEGASUS			
4A. NEONICOTINOIDS (IMIDACLOPRID, THIAMETHOXAM, ACETAMIPRID & CLOTHIANIDIN):	Seed treatments: GAUCHO, GENERO, AMPARO, CRUISER Foliar: CONFIDOR, ACTARA, INTRUDER, SHIELD			
9A. PYMETROZINE:	FULFILL			
2B. DICOFOL:	KELTHANE, MITIFOL			
14A. PROPARGITE:	COMITE, BULLET			
10A. ETOXAZOLE:	PARAMITE			

Cross resistance in Aphids - Treat Pirimicarb and group 1B as one chemical group. Do not use first foliar spray from this group if seed or furrow treatment from this group.

Do not use first foliar spray from group 4a if seed /furrow treatment from this group

Key Changes

- Altacor windowed:
Northern regions - Nov 15 - Feb 1
Central and southern regions: Dec 1 - Feb 15.
- Incorporation of the Darling Downs with the Central regions
- New Southern Region IRMS incorporating Macquarie, Lachlan and Murrumbidgee
- Northern: Steward moved 15 days further into the season, Dec 1 - Feb 15.
- Central: pyrethroids moved 1 month further into the season, Jan 15 - end
- Shield (clothianidin) added to Neonicotinoid group
- Chemicals registered but not commercially available identified.

Key Guidelines

- Pupae bust cotton and alternative crop residues as soon as possible.
- Use recommended thresholds for all pests.
- Monitor 1st position fruit retention at flowering.
- Avoid using broad spectrum sprays.
- Monitor pest and beneficial populations.
- Avoid continuous sprays from same group.
- Do not respray apparent failure with same group.
- Control weeds on farm which are hosts for pests.
- Comply with any insecticide use restrictions according to label

For more detailed information see web page:

http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/Insect_Resistance_Management.aspx

Trouble shooting: A TIMS sub-committee has been established to arbitrate in cases where individuals, groups or regions expect to have difficulties following the strategy guidelines. It includes representation from: CSIRO, Industry and Investment NSW; Department of Employment, Economic Development and Innovation Qld; Cotton Australia.

If problems arise, contact: Tracey Farrell Phone 02 6792 4088 Fax: 02 6792 4400 Email: tracey.farrell@crdc.com.au

Produced by: Cotton Catchment Communities CRC, CRDC, CropLife, TIMS