3.3 Objective 3 - Beneficial insects - use them don't abuse them!

3.3.1 Introduction

Predatory and parasitic (beneficial) insects consume pests and other insects in order to survive, develop eggs and / or produce offspring. The most common predators found in cotton farms feed on a wide range of pests and are therefore classified as general predators. In contrast, parasitoids are specific to the insect or stage of insect they attack. For example, *Tricho-gramma* is an egg parasitoid of *Helicoverpa* spp., whereas *Microplitis* is a parasitoid that only attacks *Helicoverpa* spp. larvae. Predators and parasitoids can considerably reduce pest numbers thereby reducing the need to control them using insecticides. The abundance of beneficial insects is affected by food resources, mating partners, overwintering sites, shelter, climatic conditions and insecticide sprays. For an IPM system to work, it is important to know which species are present in a crop, how abundant they are and what pests they attack. Such information is important in evaluating their potential effect on a given pest situation, and in the choice of control measures if required, to conserve the populations.

The Red and Blue beetle is a common predator of *Helicoverpa* spp. eggs, small larvae and other slow moving insects such as aphids.

There are a range of techniques to conserve and enhance beneficial insect activity on cotton farms, including:

- Use of the predator / beneficial to pest ratio in spray decisions
- Use of parasitoid activity in spray decisions (i.e. incorporating parasitism into the predator to pest ratio to become the predator / beneficial to pest ratio)
- Use of beneficial insect attractants (food sprays)
- Use of lucerne strips or blocks to conserve beneficials and manage mirids
- Use of refuge or nursery crops to conserve parasitoids
- The release of *Trichogramma* in cotton crops
- Tolerating non-economic early season damage
- Use of insect resistant transgenic cotton varieties
- Appropriate use of insecticides

For more information on the conservation of predatory and parasitic insects, refer to the '*Integrated Pest Management Booklet'* in the '*Australian Cotton Best Management Practices'* manual, and for identification of predators and parasites see the '*Pest and Benificial Guide'* on the Australian Cotton CRC website.

3.2.2 Use of the predator to pest ratio in spray decisions

Using the predator to pest ratio allows the grower to incorporate the activity of predatory insects into spray decisions. The calculation of the ratio includes *Helicoverpa* eggs and very small (VS) plus small (S) larvae per

Helicoverpa brown eggs are collected to determine levels of egg parasitism.

visual metre assessed using standard visual sampling, but does not include medium (M) or large (L) larvae since many of the common predatory insects are not effective on these stages. Total predators per metre assessed using a standard visual check or the equivalent with other techniques, should also be used in the calculation. However, to be confident in the ratio, at least 3 insects of the most common predators within the families Coccinellidae, Melyridae, Nabidae, Lygaeidae, Reduviidae, Chrysopidae, Hemerobiidae and Pentatomidae should be present in a 20 metre d-vac sample or 3-5 metre visual checks. For more information on these families refer to the section '*Sampling beneficial insects and spiders*' in objective 2.

The predator to pest ratio is calculated as:

$$\frac{\text{The number of predators per metre}}{(\textit{Helicoverpa}\text{ eggs} + \text{larvae (VS + S))}}$$

If this ratio is 0.5 or higher then predators will generally provide effective control of *Helicoverpa* spp. If the ratio is less then 0.5 then there are a range of options that can be taken, see '*Use of beneficial insect attractants (food sprays) to conserve and enhance beneficial insects*' in this objective.

3.3.3 Use of parasitoids in pest management decisions - using the beneficial to pest ratio

A female *Trichogramma* wasp lays an egg inside a *Helicoverpa* egg.

Some parasitoids are particularly effective against pests and every effort should be made to consider parasitism levels when making pest management decisions. This is best achieved by assessing the levels of pest parasitism. For example, if you suspect that *Trichogramma* are active in your region then you should collect brown *Helicoverpa* eggs and determine the levels of egg parasitism. If you find high levels of egg parasitism then you may choose not to spray, or you may decide to use a 'softer' insecticide to manage the hatching of *Helicoverpa* larvae. In this way you have incorporated an assessment of parasitism into your spray decision. For further information on determining levels of egg parasitism, refer to the section '*Sampling and determination of Trichogramma parasitism in cotton farms*'.

The beneficial insect to pest ratio
The predator to pest ratio does not incorporate parasitoid activity, particularly egg parasitism in the calculation. Subsequently, for a grower to use both predators and parasitoids (especially *Trichogramma*) in spray decisions, the level of egg parasitism (i.e. percentage egg parasitism) should be deducted from the *Helicoverpa* spp. eggs per visual check before the predator to pest ratio is calculated. In doing so, the predator to pest ratio then becomes the "*beneficial to pest ratio*".

Thus the beneficial to pest ratio is calculated as:

$$\frac{\text{Total number of predators per visual metre}}{(\textit{Helicoverpa}\text{ eggs per metre} - \text{(\% egg parasitism)} + \text{larvae (VS + S))}}$$

If this ratio is 0.5 or higher then predators and parasitoids will generally provide effective control of *Helicoverpa* spp. Percentage parasitism used in the calculation should be based on the trend for parasitism on the farm. Parasitism levels in the previous or (last 2-3 days) count should be used to calculate the beneficial to pest ratio in the next check.

Example: In a grower or consultant's check the following were recorded:

- Total predators per visual metre or beat sheet equivalent = 20
- No. of *Helicoverpa* eggs per metre = 40
- No. of VS+S per metre = 1.2
- Percent egg parasitism from previous check = 50%
- Beneficial to pest ratio (including trend of parasitism):
  = 20 predators ÷ (40 eggs per metre – (50% of 40 eggs = 20 eggs) + 1.2
  = 20 ÷ (40- 20) + 1.2
  = 20 ÷ 21.2 = 0.94 which is higher than 0.5.

This means, the system is working well and the grower need not apply any control for *Helicoverpa* spp.at this stage.

In contrast, if a predator to pest threshold was used for decision making, the ratio based on the above check would have been:

Predator to pest ratio = 20÷ 41.2 = 0.49.

This means that it is unnessesary to spray, but since the ratio is lower than 0.5 and *Helicoverpa* population is predominantly eggs, options to enhance predator numbers would be recommended. This could include the application of a yeast-based food spray to attract more predators, or slashing a beneficial nursery crop to encourage predators to move to the cotton crop.

Including the impact of egg parasites therefore allows for more accurate pest management decisions.

Calculating the beneficial to pest ratio should not include medium and large larvae because predators and parasitoids are not effective on these stages. The number of adult *Trichogramma* parasitoids per metre is not included directly in the calculation because *Trichogramma* adults are very tiny and cannot be counted visually.

3.3.4 Sampling and determination of Trichogramma parasitism

It is very important not to spray *Helicoverpa* based on egg counts alone. Parasitism of *Helicoverpa* spp. eggs by *Trichogramma* on cotton and other crops can result in significant egg mortality and reduce the number of larvae hatching from these eggs even at high *Helicoverpa* spp. egg densities. Consequently, growers should make every effort to consider parasitism levels when making spray decisions.

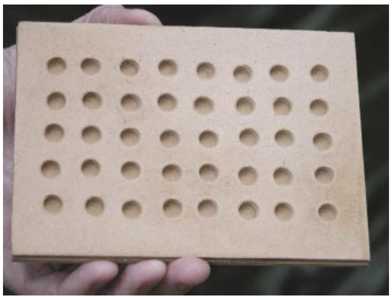
It is important to consider natural levels of *Helicoverpa* egg parasitism caused by parasitoids such as *Trichogramma*.

Egg collections
The best way to determine the level of egg parasitism in your crop is to collect eggs and wait to see how many hatch and how many turn jet black. It is important to only collect brown eggs (eggs that are about two days old) when assessing parasitism. White eggs may have just been laid and *Trichogramma* may not have had sufficient time to find them. If you collect white eggs you will generally underestimate the levels of egg parasitism.

In cotton you should randomly collect at least 20 eggs on leaves or squares from different plants in a field. In vegetative sorghum and maize you can also collect eggs on leaves. For heading sorghum it is best to sample pre-flowering heads just after they have fully emerged from the boot, i.e. before the first yellow flowers appear on the top of the head. To collect the eggs from sorghum you remove the head using secateurs and spin it into a plastic bucket. The eggs will fall into the bucket and can be stored in a container to be sorted later. Try to collect at least 50 eggs from a minimum of ten heads.

It is also important to keep the eggs cool in an esky after you have collected them because exposure to high temperatures, e.g. in a car glove box or on a dash board may kill them.

Storing Eggs
Helicoverpa larvae are cannibalistic, and caterpillars that hatch from unparasitised eggs will eat nearby eggs if they are free to roam. To prevent this, the eggs must be isolated individually in a multi-celled egg tray. To make your own egg tray use 3 mm thick craftwood and drill a series of 6 mm diameter holes in one piece and glue this to a solid piece of craftwood.



An egg tray made using 3 mm thick craft wood.

To transfer the brown eggs to the egg tray use a fine paint brush. Be careful when removing the eggs from the leaves as they are fragile and can be easily damaged. When the egg tray is full, cover the holes securely with sticky tape to prevent the larvae that hatch from unparasitised eggs moving into nearby cells and eating eggs. Store the egg trays at room temperature, e.g. in your office or kitchen, but don't leave them in the shed as it may get too hot during summer.

Calculating the levels of egg parasitism
The levels of parasitism can be estimated 2-3 days after you have collected the eggs. This is when all of the unparasitised eggs should have hatched, and you will see a small caterpillar in the cell of your egg tray. The number of eggs that don't hatch can be used to estimate parasitism, i.e.

% Estimated egg parasitism = (UHE / TE) x 100
where:

UHE = The number of unhatched eggs in the egg tray.
TE = The total number of eggs in the egg tray.

The actual level of egg parasitism can be calculated 4-5 days after you have collected the eggs. This is when the parasitised eggs should have turned jet black.

% Actual egg parasitism = BE / (BE + HE) x 100
where:

BE = The number of jet black parasitised eggs in the egg tray.
HE = The number of hatched eggs (caterpillars) in the egg tray.

Nymph and adult damsel bugs use piercing sucking 'beaks' to feed on many insects including *Helicoverpa* spp. eggs, larvae and mites.

Sometimes brown eggs collapse or don't hatch for other reasons and these unviable eggs should be excluded when you calculate the actual levels of egg parasitism, i.e. only use viable eggs. If you collect 60 brown eggs and you find that 45 turn jet black, 5 hatch and 10 collapse, then the actual level of egg parasitism is:

% Actual egg parasitism = (45 / (45 + 5)) x 100
= (45 / 50) x 100
= 90% egg parasitism

If you cannot collect eggs to assess *Trichogramma* activity, then you should look very carefully at the *Helicoverpa* counts. In particular you should look at the ratio of very small / small larvae to eggs. If *Trichogramma* are active you will find eggs, but few VS / S larvae. This indicates high egg, and / or early larval, mortality. However if you find as many VS / S larvae as eggs, then you know that egg hatch and early larval survival is high, which indicates low *Trichogramma* activity.

For more information on parasitoids of *Helicoverpa* spp., please contact: Entomologist, Agency for food and fibre sciences, DPI&F, Toowoomba, Queensland 07 4688 1200.

3.3.5 Use of beneficial insect attractants (food sprays) to conserve and enhance beneficial insects

A common predator - the three-banded ladybird adult.

The application of food sprays in cotton crops enables beneficial insects (particularly predators) to be attracted, retained and conserved in the cotton crop. Food sprays alone cannot manage cotton pests to achieve economically viable yields, although combined with other IPM compatible tools they can enhance the abundance of beneficial insects which will contribute to the control of pests and minimise the use of insecticides, without sacrificing yield. Commercially, there are two groups of food sprays made up of four different food spray products. The food spray groups are (1) yeast based food sprays and (2) sugar based food sprays. The yeast based food sprays are sold commercially as Envirofeast® and Predfeed® and the sugar based food sprays are Mobait® and Aminofeed®. The yeast based food sprays attract beneficial insects, whereas the sugar based ones retain them. Consequently these two groups are used differently to maximise their effectiveness. The yeast based food sprays should be applied when a cotton field does not have enough beneficial insects and there is the need to attract more into the field. In contrast, the sugar based food sprays should be used to maintain the beneficial insects already present in the field.

The guidelines described here make use of a predator / beneficial to pest ratio to incorporate the activity of the beneficial insects into pest management decisions. For the success of this type of IPM, it is important to select a field or whole farm that is not, or less likely, to be affected by insecticide drift as this will reduce beneficial abundance and reduce the likely success of this approach.

3.3.5.1 Decision making protocol for food sprays on conventional crops

The accepted beneficial to pest threshold is 0.5 or higher. Reference is made below to pest thresholds for *Helicoverpa*. These can be found in the latest '*Cotton Pest Management Guide*' or in the section '*Pest thresholds*' in objective 2.

The beneficial to pest ratio does not include medium or large larvae as many predators prefer eggs or smaller larvae.

- When the beneficial to pest ratio is 0.5 or higher and *Helicoverpa* numbers are below a threshold of 2 larvae per metre or the pest threshold is not exceeded, it means the IPM system is functioning well.
- When the ratio falls below 0.5 but is higher than 0.4 and *Helicoverpa* numbers are below threshold and the population is mostly eggs, a yeast based food spray can be applied to attract beneficial insects into the crop to feed on the eggs.
- If the beneficial to pest ratio falls below 0.5 but is higher than 0.4 and *Helicoverpa* numbers are below threshold but the population is predominately larvae (rather than eggs), then a sugar based food spray and biological pesticide or a petroleum spray oil (PSO) (Canopy® or Biopest oils® under permit) should be applied to restore the beneficial to pest ratio to 0.5 or higher by attracting predators and reducing *Helicoverpa* numbers.
- If a grower has lucerne strips or a centrally located lucerne crop on the farm, then before applying a food spray / biological insecticide spray, 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. 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 after applying the sugar based food spray / biological insecticide mixture since this will force too many mirids into the cotton where they may cause damage.
- If *Helicoverpa* larvae levels are above threshold in the next check following the application of a food spray / biological insecticide spray and the beneficial to pest ratio is 0.4 or lower, use a selective insecticide to control the larvae before they develop to mediums.

Table 9. Food spray decision making table for conventional and Bollgard II® cotton

Ratio	*Helicoverpa* spp.	Action
=0.5	<2	Do nothing
0.4-0.5	<threshold (mostly eggs)	Yeast based food spray might be applied.
0.4-0.5	<threshold (mostly larvae)	Sugar based food spray, Biological pesticide or Petroleum spray oil (see section on lucerne below)
≤0.4	>threshold	Selective pesticide

3.3.5.2 *Decision making protocol for food sprays on Bollgard II® crops*

The application of the beneficial to pest threshold of 0.5 is essentially the same in Bollgard II® cotton as in conventional cotton. i.e. predators per metre / (*Helicoverpa* eggs + larvae (VS + S)) = 0.5 and above

- When the ratio is 0.5 or higher it means the IPM program on Bollgard II® is functioning well. Do nothing.
- If the ratio falls below 0.5 but is higher than 0.4 and the *Helicoverpa* population is below threshold and consists mostly of eggs (rather than neonates), apply a yeast based food spray to attract beneficial insects into the crop to feed on the eggs. This will help to restore the ratio to above 0.5.
- If the ratio falls below 0.5 but is higher than 0.4 and the *Helicoverpa* population is below threshold and consists mostly of neonates (rather than eggs), then a mixture of a sugar based food spray or a PSO (Canopy® or Biopest oils® under permit) as a stand alone or in mixtures with a biological insecticide should be applied. NB: The decision to slash half of the lucerne strips after food or PSO / biological insecticide application on Bollgard II® cotton should follow the same guidelines recommended for IPM on conventional cotton.
- If *Helicoverpa* neonate numbers in the next check following the application of a food spray or PSO / biological insecticide are above threshold but the check indicates an improvement in the beneficial to pest ratio, then re-apply a food spray / biological insecticide mixture to reduce *Helicoverpa* and help restore the ratio to 0.5 or higher. However if *Helicoverpa* neonate numbers in the next check following PSO / biological insecticide spray are above threshold and the check indicates no effect on the beneficial to pest ratio or the ratio is between 0.42-0.45 and larval numbers are still high, repeat the treatment.
- However, if the ratio has continued to decline after applying a food spray or PSO / biological insecticide mixture, reaching 0.4 or lower, and *Helicoverpa* are over threshold, then it is necessary to intervene with a selective insecticide to reduce *Helicoverpa* numbers before they moult to mediums.

3.3.5.3 *The application of food sprays*

Recommended rates of food sprays

Envirofeast® and Predfeed® products should be applied at 2.0 kg per hectare or label rate. Aminofeed® should be applied at 1 L / ha and Mobait® at 1 L / ha. Avoid applying the Aminofeed® attractant rate of 3 L / ha as studies have indicated it attracts *Helicoverpa* moths which may result in increased egg lays. Food spray rates can be applied as a band or skip row early season or over the entire field in the mid and late season. The first food spray of the season should be applied when the crop has 4-6 true leaves or when the number of *Helicoverpa* eggs reaches 1 per metre. Food sprays can be applied by ground or air as described below.

- *Ground rig application:* Application volume will vary according to the stage of growth of the cotton crop. Application to run off is recommended to ensure good coverage. The volume of food sprays may range from 80-120 L / ha depending on crop stage.
- *Aerial application:* A minimum application volume of 30-50 L / ha should be used.

Mixing and application of food sprays

Yeast based food sprays (Envirofeast® and Pred feed®) should be mixed as a slurry using a premix tank with agitation provided by a pipe connected to a water pump. Top up the mixture with water to reach the total volume required. The mixed product should be agitated constantly throughout mixing and transferral to the ground rig or aircraft.

Sugar based food sprays (Amino feed® and Mobait®) should be mixed by adding the required rate of the product to the required volume of water or product solution.

All food sprays should be applied using flat fan nozzles or any nozzle that can concentrate the product on the top of the leaves. Coverage of the lower surface of the leaves is not essential, though an additional benefit will be gained from the product if the lower surface of the leaves are also covered.

To determine whether you have got the right concentration of yeast based food sprays on the leaves, look at them after the product has dried to see whether the leaf surface looks muddy. Also if the odour of the yeast is scented in the field this indicates there are residues of the product on the leaf. For sugar based food sprays look at the leaves to see whether the leaves look like a cream has been rubbed on them or are shiny compared to unsprayed plants.

Use food sprays the same day you mix them. With the yeast based food sprays, the product will go off or perish if the mixture or solution is left overnight. Clean ground rigs, aeroplanes, and premix tanks thoroughly with water before and after food spray to avoid fungal growth. Contamination of food sprays with the residues of earlier broad spectrum insecticides left over in spray tanks, may dramatically reduce predator numbers when applied to the cotton crop.

3.3.6 Using lucerne to manage mirids and as a nursery for beneficials

Cotton systems are moving toward less early season insecticide use due to the incorporation of Bollgard II® cotton and IPM. In the past, some pests, such as mirids, were often controlled unintentionally by early season insecticides applied for pests such as *Helicoverpa*. Hence mirids may become a more significant pest in the future and greater emphasis should be placed on managing them in IPM compatible ways. An option for non-chemical management of mirids is to use lucerne as a trap crop, as lucerne is more attractive to mirids than cotton.

For this option to work, lucerne needs to occupy a minimum of 2.5% of the whole cotton crop. It can be planted as strips consisting of 8, 12 or 16 rows of lucerne planted every 300 rows of cotton. However research has indicated that the preferred strategy is to plant lucerne as a block in a field adjacent to the cotton fields or as a centrally located block on the farm. The lucerne should be watered as needed to maintain active growth and half of each strip should be slashed or mowed every 4 weeks or as the lucerne begins to flower to maintain new growth and attractiveness to green mirids throughout the season. Mowing the entire strip will force the mirids into the cotton, as will letting the lucerne become stressed and unattractive.

The lucerne should be sown in mid to late autumn so it is established by the time the cotton crop emerges. In such a system it should not be necessary to use insecticides for the control of green mirids, however if insecticides are necessary, preference for more selective insecticides (low impact on beneficial insects) is essential.

Slashing1/2 of the lucerne every 4 weeks ensures that some is always attractive to mirids.

The lucerne also serves as a nursery for beneficial insects. This is important because cotton fields are often large (50 - 150 ha) which means that re-colonisation of fields by beneficials may be slow after broad spectrum insecticide has been applied, especially if sources of predators are limited to farm perimeters. This approach can be further enhanced by use of a food spray to attract predators from the lucerne into the cotton and retain them there, enabling a degree of manipulation of predator / beneficial to pest ratios.

Size and placement of lucerne strips

Options for planting lucerne:

1. Strips within the cotton field at a ratio of 8, 12 or 16 rows of lucerne per 300 rows of cotton (i.e. lucerne area = 2.5% of whole field)

2. As a field border. It is preferable to plant lucerne on both sides of the field. In this case, a minimum area of 5% of the whole field should be planted to lucerne (i.e. 24 rows each side of a 1000 row wide field).
3. As a block. A lucerne crop can also be planted in a centrally located block on the farm.

Note: Options 2 and 3 may be slightly less effective than strips grown within the field for green mirid control. Also note that it is essential that the lucerne should remain green and not allowed to become dry or hay off.

A strip of lucerne grown between cotton.

Establishment
It is critical that the lucerne strips are established before cotton planting.

- *Sowing rate:* For lucerne strips to act as a trap crop, an effective plant stand needs to be established. Seeding rates of around 5 kg / ha should be used in dryland situations and 10 to 15 kg / ha for irrigated crops.
- *Seed bed preparation:* Good seed bed preparation is essential to achieve good establishment. For best results seek advice from an experienced lucerne grower.

Planting windows
Sowing time will vary according to the variety of lucerne selected and the growing district. In general, autumn and spring are the best periods for sowing. Avoid winter sowings in colder, wetter locations especially if the variety is winter dormant. Spring sowings should be used only under irrigation or in districts where spring rainfall is reliable.

Two planting windows have been used successfully:

- *April / June planting:* This produces a well established lucerne stand by the time the cotton is planted.
- *July / August planting:* Ensure lucerne is established by the end of August. This is the best option for establishing lucerne in back-to-back cotton fields. For irrigated crops, the lucerne strips should be formed into two equal beds by joining 4 rows into a bed in the case of an 8 row strip and 6 rows per bed in a 12 row strip. Run a furrow from head ditch to tail drain between the beds in each strip. This will ensure that water runs through the lucerne strip from head to tail during irrigation. However, if the lucerne is to be planted directly into the cotton beds, avoid planting in the furrows as this will block the furrow and create irrigation problems once the crop is established.

Irrigation management
For maximum production of lucerne in Northern NSW, irrigation should occur on a 20 day cycle from September to December and on a 10 day cycle from December onwards. Since cotton growers are not striving for maximum production from the lucerne the irrigation recommendations can be simplified to make them more compatible with typical cotton irrigation cycles. A first watering should be done when the cotton starts to square. Thereafter, to simplify irrigation management, irrigate the lucerne and the cotton at the same time. During the late cotton season, when broad spectrum insecticides such as synthetic pyrethroids are used on the farm or neighbouring farms, the lucerne is of no further use as a refuge or trap crop and can be slashed or mowed. Growers should note that a good stand of lucerne can contribute up to 200 kg N / ha in the soil every year in a crop rotation.

Management of mirids in lucerne strips or blocks
Green mirids prefer lucerne to cotton. Therefore, inter-planting lucerne strips in commercial cotton can be used to manage this pest. Lucerne grown for green mirid management should not be allowed to hay off. New regrowth of the lucerne should be maintained through the season by slashing or mowing half of each lucerne strip every 4 weeks, or when the crop is in flower as described below.

- Poorly established lucerne strips can reduce the crops ability to attract green mirids from cotton.
- It is important to do mirid counts and fruit retention counts in cotton

to confirm the level of mirid abundance (or damage) before applying a mirid spray. If an insecticide is applied to control green mirids select one that will have minimum impact on beneficial insects.

- The lucerne strips should be kept attractive through the cotton growing season, especially during the cotton crop's early squaring and flowering period. Once lucerne begins to flower, vegetative growth is limited and it is less attractive to green mirids. These could then move into cotton and cause problems. The attractiveness of the lucerne can be maintained by slashing or mowing half of each lucerne strip. This will ensure that the strip is always composed of older and younger lucerne growth. Mowing or slashing only half at a time means that the other half is still attractive to mirids. The first cut should be early, i.e. at or just before first square. Subsequent cuts should occur just as the other half starts to flower (provided there is sufficient re-growth in the other strips). Sometimes slashing may also occur in order to manipulate predator numbers in cotton.

Removing lucerne strips or blocks
Established lucerne can be killed either with cultivation or with herbicides. When the soil is dry, heavy cultivation such as a crawler with a cutter bar across the rippers has proved to be effective in removing established lucerne plants. The success of this technique requires dry soil during the cultivation and dry weather afterwards to prevent the lucerne from re-establishing. Herbicides are only effective for controlling lucerne when it is actively growing. Trial work shows that a tank mix of 2,4-D amine at 3 L / ha plus glyphosate at 1 L / ha will effectively control established lucerne, and most other broadleaf weeds present in the lucerne strip. However 2,4-D has a high risk of damaging cotton and extreme care should be taken with its application in cotton growing areas. The application should be made well before cotton planting as a 14 day plant-back period applies for cotton planted after herbicide application. This 14 day period only commences following rainfall of at least 15 mm. Thorough decontamination of spraying equipment is essential after 2,4-D applications.

For optimal control of lucerne, plants should be at least 10-15 cm tall and growing actively at the time of herbicide application. If moisture limitations are present and lucerne must be removed, cultivation is likely to give better control than herbicide options.

For further details on establishing and managing lucerne see DPI, NSW AGFACT P2.2.25 "*Lucerne for pasture and fodder*".

3.3.7 Conserving and enhancing parasitoids

There are some simple practices that can be employed to conserve and enhance parasitoids on a cotton farm, including:

- Not spraying insecticides of any kind unless it is necessary. This is best achieved by adhering to the general IPM guidelines and following the recommended thresholds for spraying, i.e. avoid spraying below threshold populations of pests.
- Choosing insecticides carefully when you have to spray. Some insecticides, such as Dipel® and Gemstar®, have very little impact on parasitoids. These and other selective products should be used to manage pests if possible. Broad spectrum insecticides, including the synthetic pyrethroids, are usually very toxic to parasitoids and should be avoided whenever possible.
- Maintaining habitat diversity on-farm. This can be achieved by growing a mixture of crops and avoiding cotton monocultures. Sorghum, maize and sunflowers are all good nursery crops for parasitoids. Sunflower is a nursery crop for green mirids and can become a source of green mirid infestation in the cotton crops. Avoid using sunflower as a parasitoid nursery unless there is a lucerne crop adjacent to the cotton. The capacity of sorghum and maize to act as parasitoid nurseries can be

Sorghum can be an effective nursery crop for parasitoids.

extended by growing staggered plantings, i.e. by sowing these crops on 2 or more separate occasions. Some crops, such as chickpea, are not good nursery crops for all parasitoids i.e. *Trichogramma* are not effective in chickpea because the acidic chickpea leaves are toxic to the adult wasps. It is important to manage pests carefully in the nursery crops to conserve parasitoids. For example, if you have to spray sorghum to manage *Helicoverpa* try to use Gemstar®, or another selective insecticide, so that you don't kill the *Trichogramma*, *Microplitis* and other parasitoids that may be in the crop. Refer to Table 10, '*The impact of insecticides and miticides on predators in cotton'*.

Bollgard II® cotton will act as a nursery for parasitoids because it will receive few insecticide sprays. If you find high levels of egg parasitism in a Bollgard II® crop then manage the non *Helicoverpa* pests carefully. By conserving the parasitoids they may move into adjacent, or nearby, conventional cotton and other crops.

3.3.7.1 Releasing Trichogramma

A *Trichogramma* wasp emerging from a parasitised *Helicoverpa* egg.

The *Trichogramma* wasp is an egg parasitoid which is a very important beneficial causing high mortality of *Helicoverpa* spp. The wasp kills its host by laying an egg inside a *Helicoverpa* egg. The wasp larvae then feeds on the developing *Helicoverpa* larvae killing it before it hatches.

Trichogramma can be purchased and released into crops to kill *Helicoverpa* eggs. They are available from 'Bugs for Bugs', Mundubbera Queensland, and the company should be contacted for details of costs and release methods.

One release method that is suitable for small acreages is the use of small cardboard capsules. Each capsule contains about 1,000 wasps, and they can be stapled to cotton leaves to prevent them from falling on the ground. This prevents the possible exposure of the wasps to potentially deadly high soil temperatures.

It is important not to think of *Trichogramma* releases as a substitute for an insecticide spray. They will give inconsistent results if they are used in this fashion. This is primarily because *Helicoverpa* eggs hatch in 2-3 days during summer, and many may hatch before you can order *Trichogramma* and release them into your crop.

It is best to think of *Trichogramma* as part of an IPM program, where the careful selection of 'soft' insecticides can be used in conjunction with the wasps to manage *Helicoverpa*. In recent years some cotton growers have released wasps to 'kick start' *Trichogramma* populations, i.e. to establish populations before they would naturally appear. This approach, called inoculative release, normally involves completing two releases of 30 capsules per hectare about a week apart. This process can be completed in cotton, or in adjacent crops on your farm, e.g. sorghum or maize. Avoid spraying the release crops with broad spectrum insecticides so that you don't kill the *Trichogramma*. You may not notice an immediate impact from the inoculative releases, but you should notice an impact after the wasps have completed one generation in the field, i.e. about 10 days after a release.

A key difference between predators and *Trichogramma* is the nature of their impact. An egg that is eaten is removed from the crop and isn't counted by consultants. However, an egg that is parasitised remains in the crop and can be accidentally counted by consultants, unless it has turned jet black and is recognised as being parasitised. So you really need to assess egg parasitism if you want to avoid unnecessary sprays, and get the most out of your *Trichogramma*. For more information on *Trichogramma* parasitism refer to '*Sampling and determination of Trichogramma parasitism*' in this objective.

3.3.8 Tolerate non-economic early season damage to help conserve beneficials

The cotton plant has the ability to compensate for a reasonable level of damage without affecting yield or crop maturity. It is therefore important to monitor leaf and tip damage on pre-squaring cotton and to assess fruit retained early in the season (post-squaring to flowering) and to tolerate a level of non-economic damage (refer to Table 8, '*Pest threshold summary*' in objective 2). Combining pest and damage thresholds to assist with pest management decisions, maximises the opportunity to reduce the number of insecticide applications which consequently helps to conserve the beneficial insect population (Refer to section '*Early season damage*' in objective 2).

3.3.9 Insect resistant transgenic cotton varieties

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. This provides an opportunity to retain a good population of beneficial insects in the crop. However, Bollgard II® cotton does not provide protection against pests such as mirids, so it is important to monitor the insects and damage in the same way as a conventional crop.

3.3.10 Appropriate use of insecticides

The use of insecticides if often the major factor limiting the buildup of beneficial insects on cotton farms. When using insecticides there are some simple practices that can be employed to conserve and enhance beneficial insects on your farm. They include:

- Not spraying insecticides of any kind unless it is necessary. This is best achieved by adhering to the general IPM guidelines and following the recommended threshold for spraying, i.e. avoid spraying below threshold populations of pests (refer to Table 8, '*Pest threshold summary*' in objective 2).
- Choosing insecticides carefully when you have to spray. Some insecticides, such as Dipel® and Gemstar®, have very little impact on beneficial insects including parasitoids. These and other selective products should be used to manage pests, if possible. Broad spectrum insecticides including the synthetic pyrethroids are usually very toxic to beneficial insects and should be avoided whenever possible. Refer to Table 10, '*The impact of insecticides and miticides on predators in cotton*'.
- Site specific pest management. Many beneficial insects frequently move in and out of cotton, other crops and non-crop habitats. Therefore the timing and location of insecticide applications must be carefully considered. It is important to manage pests on a field by field basis or by a small management unit, not an entire farm or large management unit. This way, only those fields that actually require pest control should be sprayed. This leaves other fields which are not being sprayed to serve as sources of beneficials to help re-colonize sprayed fields. Pests such as aphids or mites often infest the edge of a field, not the entire field area. It is therefore possible to manage this type of infestation by only spraying the field borders. This minimises the field area treated which is likely to kill a smaller proportion of beneficials and enables the beneficial population to re-establish much faster.

Checking Bollgard II® cotton for pests and beneficials.

Table 10. The impact of insecticides and miticides on beneficial insects in cotton

		Target Pest(s)						Beneficials																Pest resurgence[12]			
									Predatory beetles				Predatory bugs							Hymenoptera							
Insecticides (in increasing rank order of impact on beneficials)	rate (g ai / ha)	Helicoverpa	Mites	Mirids	Aphids	Thrips	Persistence[3]	Overall ranking[10]	Total[1]	Red & Blue beetle	Minute 2-sp t lady	Other Lady Beetles	Total[2]	Damsel bugs	Big-eyed bugs	Other Predatory	Apple Dimpling	Lacewing adults	Spiders	Total (wasps)	Trichogramma	Ants	Thrips	Mite	Aphid	Helicoverpa	Toxicity to bees[14]
Bt[11]		•					very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL				VL
NP Virus		•					very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL				VL
Pirimicarb	250				•		short	very low	VL	VL	VL	VL	L	L	M	VL	VL	VL	VL	VL	H	VL	L				VL
Methoxyfenozide	400	•					medium long	very low	L	VL	VL	L	L	L	L	VL	VL	VL	VL	VL	VL	VL	VL				VL
Dicofol[2]	960		•				long	low	L				L				L		L				VL				VL
Spinosad	96	•					medium	low	VL	M	L	VL	M	L	H	VL	L	VL	VL	M	H	H	H	+ve			H[15]
Diafenthiuron	350		•				medium	low	M	H	VL	M	L	M	VL	L	H	VL	L	L	L	H	L			+ve	M
Pymetrozine	150				•		short	low	M	M	M	M	L	L	L	VL	H	M	L	L	L	M	VL				VL
Indoxacarb[13]	127.5	•		•			medium	low	H[14]	L	VH	VH	L	L	L	L	VH	L	VL	L	L	VH	VL		+ve		H[15]
Abamectin	5.4	•[6]	•				medium	moderate	L	M	H	VL	M	L	M	M	H	VL	M	M	M	H	M				H
Emamectin	8.4	•					medium	moderate	L	VL	M	VL	H	H	H	H	H	L	M	M	M	VL	M				H
Endosulfan (low)	367.5	•		•	•	•	medium	moderate	M	VL	VH	M	M	M	M	L	H	L	M	VL		VH	H				M[15]
Propargite	1500		•				medium	moderate	M	H	H	M	M	H	VL	VL	L	VL	M	M	H	H	M		+ve	+ve	L
Acetamiprid	22.5				•		medium	moderate	M	M	VH	H	M	M	H	M	VH	L	VL	L	VH	VH	VH				M[15]
Amitraz	400	•	•[9]				medium	moderate	H	M	VH	H	L				H	VL	M	M	M	H	M				L
Fipronil (low)	12.5			•		•	medium	moderate	L	VL	H	L	L	H	L	L	VH	VL	M	M	VH	VH	VH		+ve	+ve	VH
Chlorfenapyr (low)	200	•	•				medium	moderate	M	L	VH	VL	M	VL	H	H	VH	L	L	M	VH	H	M				H
Thiamethoxam	100				•		medium	moderate	H	H	H	H	M	M	M	H	H	M	VL	M	H	VH	H	+ve		+ve	H
Endosulfan (high)	735	•		•	•	•	medium	moderate	M	VL	VH	M	M	M	M	M	H	L	M	L	VH	VH	H				M[15]
Fipronil (high)	25			•		•	medium	moderate	L	VL	H	L	M	H	H	L	VH	VL	M	M	VH	VH	VH	+ve		+ve	VH
Imidacloprid	49			•	•		medium	moderate	H	L	VH	H	H	M	H	L	VH	L	L	L	VH	H	H	+ve		+ve	M
Methomyl	169	•					very short	high	H	L	VH	VH	M	L	VH	L	VH	M	M	M	H	H	H	+ve			H[15]
Thiodicarb	750	•					long	high	VH	M	VH	VH	M	M	L	L	VH	VL	M	M	H	M	H	+ve	+ve		M[15]
Chlorfenapyr (high)	400	•	•				medium	high	H	M	VH	L	H	H	H	H	VH	L	M	M	VH	VH	M		+ve		H
OP's[5]		•	•	•	•	•	short-medium	high	H	M	H	H	H	M	H	H	VH	L	M	H	H	VH	H	+ve			H
Carbaryl[3]							short	high	H				H						–	–	–	–	H				H
Pyrethroids 4		•	•[7]	•[7]			long	very high	VH				VH				VH	VH	VH	VH	VH	VH	VH	+ve	+ve	+ve	H

1. Total predatory beetles – lady beetles, red and blue beetles, other predatory beetles
2. Total 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. Information; Citrus pests and their natural enemies, edited by Dan Smith; University of California Statewide IPM project, Cotton, Selectivity and persistence of key cotton insecticides and miticides.
4. Pyrethroids; alpha-cypermethrin, cypermethrin, beta-cyfluthrin, cyfluthrin, bifenthrin, fenvalerate, esfenvalerate, deltamethrin, lambda-cyhalothrin,
5. Organophosphates; dimethoate, omethoate, monocrotophos, profenofos, chlorpyrifos, chlorpyrifos-methyl, azinophos ethyl, methidathion, parathion-methyl, thiometon
6. *Helicoverpa* punctigera only.
7. Bifenthrin is registered for mite control; alpha-cypermethrin, beta-cyfluthrin, bifenthrin, deltamethrin and lambda-cyhalothrin are registered for control of mirids
8. Persistence of pest control; short, less than 3 days; medium, 3-7 days, long, greater than 10 days.
9. Suppression of mites only.
10. Impact rating (% reduction in beneficials following application, based on scores for the major beneficial groups); VL (very low), less than 10%; L (low), 10-20%; M (moderate), 20-40%; H (high), 40-60%; VH (very high), > 60%. A '-' indicates no data available for specific local species.
11. *Bacillus thuringiensis*
12. Pest resurgence is +ve if repeated applications of a particular product are likely to increase the risk of pest outbreaks or resurgence. Similarly sequential applications of products with a high pest resurgence rating will increase the risk of outbreaks or resurgence of the particular pest species.
13. Very high impact on minute two-spotted lady beetle and other lady beetles for wet spray, moderate impact for dried spray.
14. Data Source: British Crop Protection Council. 2003. The Pesticide Manual: A World Compendium (Thirteenth Edition),. Where LD50 data is not available impacts are based on comments and descriptions. Where LD50 data is available impacts are based on the following scale: very low = LD50 (48h) > 100 ug / bee, low = LD50 (48h) < 100 ug / bee, moderate = LD50 (48h) < 10 ug / bee, high = LD50 (48h) < 1 ug / bee, very high = LD50 (48h) < 0.1 ug / bee. Refer to the Protecting Bees section in this booklet.
15. Wet residue of these products is toxic to bees, however, applying the products in the early evening when bees are not foraging will allow spray to dry, reducing risk to bees the following day.

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3.3.11.1 The beneficial disruption index

The Beneficial Disruption Index (BDI) provides a basis to measure or benchmark the 'softness' or 'hardness' of an individual fields' 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 Table 10. A chemical that is more disruptive has a higher score or rank. Each BDI point equals a 10% reduction in beneficials after application of the chemical. 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 more friendly the spray regime.

BDI point	Impact rating from Table 10.
1	VL (very low), less than 10%
2	L (low), 10-20%
4	M (moderate), 20-40%
6	H (high), 40-60%
8	VH (very high), > 60%