3. IPM strategies - 'how to do it'

3.1 Objective 1 - Growing a healthy crop

3.1.1 Introduction

IPM can help reduce crop losses by pests, but cannot directly improve the yield potential and fibre quality of cotton. These are primarily influenced by crop agronomy and variety choice.

Crop management can affect IPM. For instance, poor fertiliser or irrigation management can affect crop maturity, increasing the length of time that the crop requires protection from pests, which can increase insecticide resistance selection. Excessive fertilisation or irrigation can also produce crops that may be more attractive to pests which may require protection. Thus appropriate water and nutrient management are essential in producing a healthy crop and in supporting an effective IPM system.

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

3.1.2 Field selection

A Bollgard II® cotton crop growing in a sensitive area close to a river.

Selecting which fields to plant to cotton can affect the success of IPM on the farm. Considerations include proximity to sensitive areas such as rivers, watercourses, stock routes, pastures, domestic dwellings, workshops, neighbours and the prevailing wind direction. As Bollgard II® varieties have a reduced requirement for insecticides to control *Helicoverpa*, they may be appropriate for fields near sensitive areas. Although to help achieve maximum returns, Bollgard II® should also be planted in fields that can be watered effectively and have a history of reliable production. Shorter season varieties may also be considered for sensitive areas as the shorter growing period reduces the time the crop needs to be protected from pest damage.

If a grower is experimenting with IPM tools and strategies on part of the farm, then these 'IPM' fields should be situated so as to reduce the risk of drift contamination from sprays applied to the rest of the farm or to fields on neighbouring farms. Other considerations include the proximity of these IPM fields to other crops or orchards which can potentially act as a source for secondary pests such as mites, aphids or whiteflies. Growers could consider keeping pest resistant varieties together, such as Bollgard II® or okra leaf types, rather than intermingling them with other varieties. This will help reduce the chance of sprays applied to one type of cotton, i.e. conventional, disrupting IPM on other fields that do not need spraying at that time, i.e. Bollgard II®.

3.1.3 Do I pre-irrigate or water-up cotton?

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.

Unless rainfall provides adequate soil moisture either before planting or directly after planting, pre-irrigating or watering-up the field will be necessary. There are advantages and disadvantages with both methods.

Pre-irrigation before planting
The advantages of pre-irrigating are:

- less cracks in the seed bed at planting for optimum establishment
- the encouragement of weed emergence prior to planting to allow effective application of a pre-plant knockdown herbicide
- warmer soil conditions at planting, as the soil has time to warm up between the irrigation and planting. This may help speed germination and early growth and reduce losses to seedling diseases.

The disadvantage is that hot conditions may cause the soil to dry quickly so that the top of the hills must be knocked off to expose moist soil for planting. This reduces bed height which increases the risk of seedling disease and waterlogging. In some cases the grower may need to 'flush' the field with water after planting to ensure even germination and avoid a 'gappy' plant stand.

Watering-up after planting
Watering-up allows the grower to plant in a more timely manner, especially when planting into standing wheat stubble.

However, watering-up often reduces soil temperatures which can slow seedling vigour and increase the risk of seedling disease. Watering-up also encourages weeds to germinate at the same time as the cotton, and unless the variety is herbicide tolerant, a post-emergent knockdown herbicide is not an option.

Watering-up a cotton field after planting allows more flexibility with the timing of planting, but may decrease soil temperature, promoting seedling disease.

3.1.4 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 resulting in plants that are able to tolerate seedling disease better, achieve high yields and early crop maturity. 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. However, there are management issues associated with standing stubble, such as an increased risk of waterlogging from heavy rainfall, or rainfall following an irrigation and the potential to reduce soil temperatures. Some of these risks can be reduced by careful management, see section 3.1.8 '*Planting into standing wheat stubble*'. Adopting a system of planting cotton into standing wheat stubble requires a significant change in management in terms of planting regime, fertiliser application, equipment for sowing and irrigation. For more information see the publication '*Planting Cotton in Standing Wheat Stubble*', available from the TRC or Australian Cotton CRC website.

3.1.5 Selecting a cotton variety

The cotton variety planted should be matched to the region and likely pests and diseases (see seed company variety guides or websites). Planting a variety with a long growing period and a high yield potential in a cooler, shorter season region is likely to create problems with late maturity, poor fibre quality, prolonged protection and difficulty with defoliation. This issue is important if wet weather delays ground preparation.

Okra leaf varieties have a degree of resistance to both *Helicoverpa* spp., spider mite and silverleaf whitefly, which potentially reduces sprays for each pest by about 1 per season. Penetration of insecticides into the crop canopy is also better with okra leaf cultivars, which can contribute to better control.

Disease tolerance is also an important consideration. Selection of tolerant

Okra cotton varieties (left) are more tolerant of *Helicoverpa*, mite and silverleaf whitefly.

varieties is advisable in fields with a history of verticillium or fusarium wilt. Planting of a Cotton Bunchy Top (CBT) resistant variety, in areas where there is a risk of a high aphid population e.g. following a wet winter, or in a field with poor weed control. This will reduce the risk of the crop being infected with CBT, thereby reducing the temptation to control aphids at very low densities to prevent the spread of CBT and the associated risk of developing insecticide resistant aphids.

3.1.6 Planting window

Use of a specified period for planting, known as a planting window, reduces the spread of crop maturation in a region at the end of the season, which helps avoid very late crops that require pest management for a prolonged period. Such late crops increase the risk of selecting for insecticide resistance. In some regions, e.g. Central Queensland, planting windows are used with Bollgard II® management to help with their insecticide resistance management strategy.

Coordinating planting in a region to a specified planting window avoids a wide spread of crop maturation and prolonged insecticide use. This helps manage insecticide resistance and support IPM.

In each cotton region there is a period when the soil temperatures become suitable for cotton germination. Planting at this time usually maximises plant establishment and avoids the risk of frost. Early soil preparation to optimise soil structure and seedbed tilth will facilitate early planting. Very early planting (mid September) in cool districts increases the risk of cold shock (min temperature <11^{o}C), which slows early growth and reduces tolerance to herbicide damage, seedling diseases and early pest damage, especially from thrips. Late planted cotton runs the risk of declining yield potential, is more susceptible to pests such as whitefly, and late season infestations of *H. armigera* which are difficult and expensive to control because many are resistant to most of the chemicals used against them. A planting window that reduces the time insects are exposed to chemicals, also reduces the number of generations that are exposed, thereby reducing selection for resistance and the likelihood of overwintering pupae developing.

Soil temperature is used to assist in planting decisions. A minimum soil temperature of 17^{o}C at 7.00 am at planting depth for 3 consecutive days before planting is recommended. This ensures rapid germination and good seedling growth. Monitor weather forecasts for impending cold fronts.

Planting windows are critical to the success of area wide management strategies for monocultures such as cotton. Planting windows limit the time period during which cotton can be planted. This mainly seeks to reduce the spread of maturity dates, generally avoiding late cotton crops. By limiting planting dates, there is the opportunity to reduce exposure of cotton to pests and hence the need for pest control. This is particularly an issue for Bollgard II® cotton, where prolonged exposure by having late crops, will expose the technology to more generations of *Helicoverpa* spp.

Plant establishment

It is desirable in irrigated cotton, in most cotton regions, to have 8-12 plants per metre of row, distributed along the row as uniformly as possible. However, plant densities as low as 4 plants per metre will produce near maximum yield as long as the stand is uniform. Where factors like soil type may restrict the plant size, the optimum plant density should be at the higher end of the range, i.e.12 plants per metre.

Checking the establishment of an Ultra Narrow Row experiment.

For dryland cotton systems the plant density should be about ½ that of irrigated cotton along the row, i.e. 6-8 plants per metre of row for a skip row or solid planting configuration. For Ultra Narrow Row (UNR) intended for finger stripper harvesters, the plant density should be about 25-35 plants per square metre, or for 15 inch cotton intended for spindle harvesting, about 20-25 plants per square metre.

3.1.7 Optimising earliness

Although managing a crop for earliness is a good strategy, it does not always maximise yield. Figure 2 presents two years of data from two different sowing times and a range of cultivars with varying maturity potentials. This shows that decreasing the days from sowing to maturity also decreases lint yield. Therefore both the advantages and potential disadvantages of growing an early crop should be weighed up.

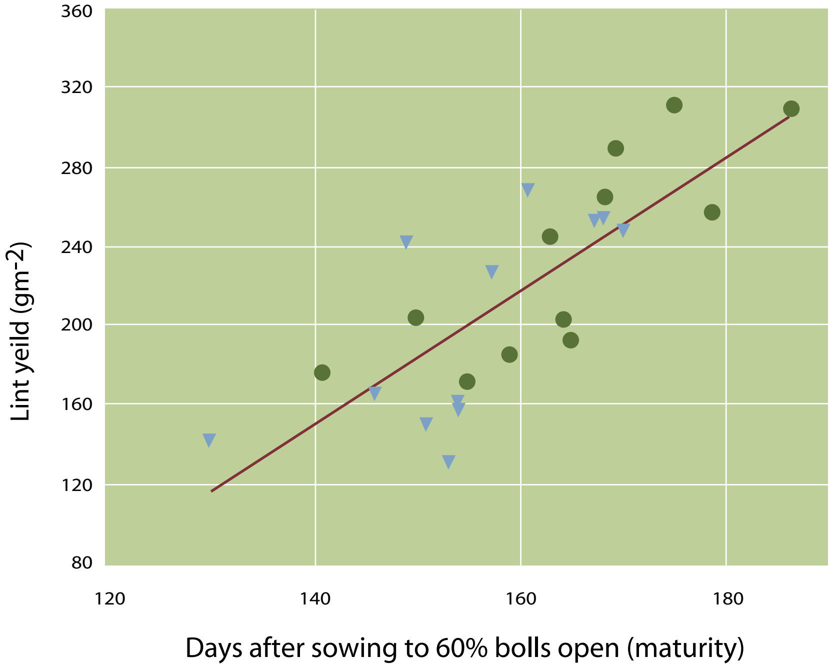

Figure 2.

Relationship between yield and crop maturity for a range of cultivars, years and sowing dates at Narrabri. For each week that the crop matures earlier, yield decreased by about 1 bale / ha. Similar relationships have been found in a number of studies. (*Milroy et al.* 2002. Is earliness really next to Godliness? Proceedings 11th Australian Cotton Conference 13th - 15th August 2002, Australian Cotton Growers Research Association Inc.)

For Bollgard II® crops with the potential to produce a higher boll load, research has shown that later sowing times have not effected the time taken to reach crop maturity. Sowing later has a number of potential benefits:

1. Better germination and seeding survival with warmer soil temperatures. With increased seedling vigour, the plants have a better chance of surviving seedling diseases. Increased seedling survival improves plant stand.
2. Avoids high temperatures during fibre development.
3. Can achieve a bigger plant before fruit development to help maximise yields.

For more information on how to manage a crop 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'*.

3.1.8 Planting into standing wheat stubble

Planting cotton into wheat stubble can help minimise the off-farm movement of pollutants such as fertilisers and insecticides. The wheat stubble slows the movement of water off a field, thereby reducing the movement of sediments that may contain pollutants. A number of other benefits such as improved water infiltration, increased organic matter, improved soil condition at planting and during seedling growth and reduced early season *Helicoverpa* pressure have been shown in some studies.

Planting cotton into wheat stubble.

Planting cotton into standing wheat stubble can offer benefits for an IPM system but brings new challenges to the farming system. Wheat stubble can slow the movement of water across the field and increase water infiltration which increases the chance of excess deep drainage and waterlogging. Consequently, adjusting the irrigation technique may be necessary. Additionally, it is possible to reduce the risk of waterlogging by remov ing stubble from the furrows, except for the last 20 metres near the tail drain. This improves water flow, reduces the risk of waterlogging, but the stubble in the furrow catches sediment before it can be carried off the field. (*Hulugalle et.al.* Aust. Cottongrower magazine Oct-Nov 2004 pg. 58-62.)

Crop nutrition may also need modifying to avoid nitrogen problems. These changes will vary depending on factors such as soil type and climate.

3.1.9 Seed treatments, granular insecticides and in-furrow insecticides

Granular insecticides applied at planting do not effect beneficial populations such as the bigeyed bug.

The main pests targeted by seed treatments, granular insecticides and in-furrow insecticides are wireworms (false and true wireworm), early thrips, mirids, mites and black field earwigs. Sprays applied to the seed furrow at planting can provide good control of these pests for 4-6 weeks after emergence. Seed treatments can provide moderate control of thrips for about 2-4 weeks after emergence, and light to moderate control of wireworm infestations. Granular insecticides applied into the seed furrow at planting will provide good protection against wireworms and control of thrips, aphids, mirids and mites for 4-6 weeks after emergence depending upon the product type and rate used. The decision to use any of these products must be made before there is a pest problem, which means their use is 'prophylactic'. This does not mean they are incompatible with IPM, as they are selective against many beneficial groups. They are likely to have less impact on beneficials than a foliar application of an insecticide that targets thrips or mirids (refer to the latest '*Cotton Pest Management Guide*'). Their selectivity is based on the fact that they do not contaminate the surface of foliage but are absorbed by the plants. Since most beneficials do not directly feed on cotton foliage, they are unaffected by the insecticide.

Large false wireworm larvae attack seedling cotton and if severe can cause 'gappy' plant stands.

Wireworms attack the top of the root just below the soil surface and can cause a reduction in plant stand. They tend to be worse in fallow fields with high levels of stubble and following dry winters, and less of a problem in back to back cotton where insecticides used against other pests usually reduce the abundance of the adult beetles. The decision to control wireworms should be made only after sampling the soil for the pest. This decision must be made before planting, as wireworms cannot be controlled after plant establishment without destroying the plant population.

Thrips are both a seedling pest and a predator of mites, so they should only be controlled where there is a reasonable expectation of an economic benefit. In cool regions (Upper Namoi, Hillston, parts of the Darling Downs and Macquarie) controlling thrips will give a significant yield benefit in 1 year in 2, while in warmer regions control of thrips will give a significant yield benefit in only 1 year in 10 and thrips will cause little, if any, delay in crop maturity (average about 4 days). Plants may have initial leaf area significantly reduced, but they generally recover from the damage 40-60 days after sowing, without yield loss or delay. Thus use of longer lasting and more expensive control options such as a seed treatment or at-planting insecticide (granular or sprayed) is rarely justified in warm areas, but should be considered in cool areas. Treated seed will provide short term control of thrips, facilitating establishment of the seedling plants and is compatible with IPM. As the effect of the seed treatment diminishes and the crop grows and becomes less sensitive to thrips damage, thrips can re-infest and help control mites by eating their eggs.

Thrips are pests but also predators of mite eggs.

Selection of seed treatments may also interact with spider mite management, as thrips are important predators of mites. Some insecticides control thrips well but do not affect mites, thereby increasing the potential risk of mite outbreaks. Some seed treatments or in-furrow insecticides can help to control spider mites on seedling cotton for about 4-6 weeks depending upon the rate which may delay the development of mite populations (refer to the latest '*Cotton Pest Management Guide*').

Often other ground dwelling insects are present in fallow fields, but these have little or no impact on cotton seeds or seedlings. For example, millipedes are usually abundant very early in the season, however they prefer to feed on decaying matter rather than fresh plant material. Others such as centipedes and carabid beetles are regarded as beneficials.

Another consideration in the decision to use treated seed or an at-planting insecticide is the risk of the crop being colonised by aphids. Some of these aphids may be carrying the agent for the disease known as Cotton Bunchy Top (CBT). A number of the insecticide options will control aphids, potentially reducing the risk of yield loss from this disease. Growers planting in fields that had CBT the previous season should consider using an at-planting insecticide or seed treatment effective against aphids following the resistance management guidelines found in the '*Cotton Pest Management Guide'*.

3.1.10 Water budgeting and interaction with nitrogen

Irrigation should be based on information from neutron probes or other soil water measuring instruments and / or an irrigation management program such as HydroLOGIC. Irrigation decisions should be based on crop requirements and the recognised soil water deficit for the particular soil. Too much nitrogen fertiliser and water can promote excessive growth and therefore the need for an additional irrigation late in the season. This can cause late season problems with the control of *Helicoverpa* spp., and can undermine the value of 'last generation' trap crops, as the cotton crop will be very attractive to pests.

Using a neutron probe to measure soil moisture.

More information on water management can be found in *WATERpak*, available from the TRC or on the Australian Cotton CRC website.

3.1.11 Nitrogen rate and crop nutrition

The amount of nitrogen available to the crop affects pest management, yield potential and maturity. Too little nitrogen will prevent the crop from achieving its yield potential. Too much nitrogen creates excessive cotton growth toward the end of the season. This makes the crop more attractive to pests, requiring additional inputs of insecticides (and mixes) for control, and application of high rates of growth regulators to retard growth. It also undermines the effectiveness of the 'last generation' trap crop by maintaining the attractiveness of cotton relative to the trap crop (refer to objective 6 '*Using trap crops effectively*').

Excessive use of N fertiliser can cause rank growth and delays in maturity.

Excessive nitrogen can also delay crop maturity by 1-2 weeks and make crops harder to defoliate. Nitrogen should be managed on a field by field basis and the soil sampled in winter or early spring to determine the background level of nitrogen. The web-based NutriLOGIC decision support tool can then help determine the optimal nitrogen rate for each field, based on the results of soil tests. Petiole nitrate assessments can be used during early crop growth to determine the need to apply supplementary nitrogen during the season. NutriLOGIC can be found on the Australian Cotton CRC website.

Most nitrogen is applied to the soil in winter or early spring. The timing and method of nitrogen application should minimise the risk of excessive losses due to denitrification. However, this needs to be balanced against the risk of wet weather preventing timely application. At this time other nutritional needs of the crop should also be considered as indicated by the soil tests.

For Bollgard II® crops with the potential to produce a higher boll load, it is possible that the demand for nitrogen may be earlier and greater. Therefore to ensure that there is adequate nitrogen available when the crop needs it, monitoring soil and plant nitrogen to determine optimum fertiliser rates is essential. However the plants ability to extract nutrients is influenced by the soils physical and chemical status. For example, increasing the fertiliser rate for a Bollgard II® crop grown on a compacted field will not result in increased yields. Therefore selecting the best fields for your Bollgard II® crops will help achieve maximum returns.

Adequate nutrition will ensure healthy growth of plants that are more tolerant of pests and diseases. Further information on cotton nutrition can be found in *NUTRIpak*, which is available from the TRC or Australian Cotton CRC website.

3.1.12 Growth regulators

Optimal irrigation scheduling and nitrogen rates will generally prevent excessive vegetative growth, apart from during hot growing conditions. Such growth is a problem because it reduces the retention of fruit and can delay harvest. Reduced efficacy of insecticides due to poor penetration of the canopy is also a problem.

Use of growth regulators is recommended if required according to the guidelines published by the cotton seed companies. Appropriate use of growth regulators can help to reduce the likelihood of a rank crop that will not cut-out. Growth regulators are also occasionally used at or near cut-out, to reduce the amount of fresh regrowth and the attractiveness of the crop to pests. This strategy is used to lessen the likelihood of late pest infestations and reduce the number of late season sprays.

See the Cotton Seed Distributors website (www.csd.net.au/) for information on calculating vegetative growth rates to determine crop needs, or the Deltapine website (www.deltapine.com.au/) to view the Pix® response guide.

3.1.13 Final irrigation

3.1.13.1 Objective of the last irrigation

Optimising timing and amount of water applied will help achieve good yields, increase water use efficiency and avoid late crops which are attractive to pests.

The prime objective of the last irrigation is 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 *Helicoverpa* spp.

At the time of the last irrigation all bolls have been set, vegetative growth is limited and the majority of carbohydrates are used to satisfy boll demands. The abscission layer to cause boll shed cannot form once a boll reaches 10-14 days old. This is why boll numbers are not significantly reduced by late water stress. However fibre development can be affected resulting in less secondary thickening of cotton fibres (reflected in micronaire), reducing yield and potentially resulting in immature fibres.

Crops that come under stress prior to defoliation, which normally occurs at 60% of bolls open or 4 Nodes Above Cracked Boll (NACB), can suffer some yield and fibre quality reduction. The level of yield reduction increases the longer the stress occurs.

3.1.13.2 Crop water use

End of season water requirements can be estimated from the date of the last effective flower which is when the Nodes Above White Flower (NAWF) measurement is equal to 4. The last harvestable bolls take 600 to 650 degree days to reach maturity. Therefore for crops to be defoliated towards the end of March, the last effective flower needs to occur in the last week of January. Crop water use needs to be considered for this period. At the time of first open boll, crop water use may be 5-7 mm per day and may decline to around 4 mm per day prior to defoliation.

3.1.13.3 Determining end of season crop water requirements

Factors to consider:
1. Days to defoliation
2. Boll maturity
3. Crop water use
4. Plant available water - ability to extract water below normal refill point
5. Soil moisture objective at defoliation

Days to defoliation (general example - need to generate values for your own district)
- Defoliate when NACB is equal to 4

- Takes 42 degree days, around 3 days (up to 4 days in cooler regions) for each new boll to open on each fruiting branch
- (Total NACB - 4) x 3 = days to defoliation
- Aim to be at or close to refill point at time of defoliation

Two examples are listed below on final water requirements.

Table 2. Timing of irrigation

If refill deficit for the particular soil is 70 mm

	Crop A	Crop B
Total fruiting branches	13	13
% open bolls	25-30%	Zero
NACB	9	13
Days to defoliation	(9-4) * 3	(13-4) * 3
(NACB = 4)	15	27
Estimated daily water use until defoliation	5 mm / day	5.5 mm / day
Total Water Requirement	75 mm	148 mm

Crop A Irrigate now?

- This will depend on the capacity of the crop to extract moisture below its normal refill point. If the crop can extract moisture to 90 mm, at the end of the season, and there is 35 mm (half a profile) of available water still in the profile, irrigation may not be necessary. However if the crop can not extract below 70 mm, an irrigation may be recommended (even if there is 35 mm left in the profile).

Crop B Requires close to two full irrigations.

- Rainfall needs to be considered in such decisions. (don't forget to apply a rainfall efficiency of 40-50%)

The 'HydroLOGIC' decision support package allows growers to schedule irrigation, and ask 'what if' questions regarding irrigation options and yield outcomes.

Impact of late water stress

- *One irrigation short*
  If the crop is one irrigation short (i.e. reaches refill point at 20% of bolls open), boll size will generally be reduced rather than resulting in a significant reduction in boll numbers. This will reduce yield and can also affect fibre quality (reduced micronaire, little effect on length).
- *Two irrigations short*
  Boll numbers will be reduced. Provided the crop does not move into rapid stress, boll size may actually be increased due to the shedding of younger bolls (< 10-14 days old). However, the loss of these younger bolls is a loss of potential yield. Fibre micronaire may be increased in the remaining larger bolls, while length and micronaire may be reduced on those younger bolls that do survive.

Significant yield reductions are likely to occur because the boll number is reduced. In large vegetative crops that come under stress prior to boll opening, both boll size and number can be reduced, with significant reduction in yield and fibre quality.

OZCOT simulation - dry harvest years

OZCOT is the crop development model developed by the CSIRO in Narrabri. Using historical weather data from past years, a range of yield reductions can be predicted from late water stress as shown in Table 3.

Table 3. Yield predictions from late water stress

Stage at which stress occurs	Average yield (b / ha)	Yield reduction (b / ha)	Range (b / ha)
nil - full irrigation (average)	8.37		
20% of bolls open (one irrigation short)	7.77	0.60	0.2 - 1.1 (2% - 13%)
6-8 days prior to first open boll	7.11	1.2	0.8 - 1.9 (10% - 23%)

In terms of value per megalitre, if the last irrigation takes 70 mm of water (including losses) and the average benefit of the irrigation is 0.60 bales per ha, then the value of the extra water is 0.86 bales per megalitre.

HydroLOGIC - irrigation management software
HydroLOGIC helps cotton farmers manage their irrigations better and improve water use.

The primary aim of HydroLOGIC is to assist in the effective and timely application of irrigations for furrow irrigated cotton crops. It is also able to provide information to help growers assess the consequences of different irrigation strategies on crop growth, yield and water use.

Based on information such as the soil moisture deficit, fruit load, leaf area and historical climate data, HydroLOGIC uses the OZCOT model to simulate the most likely outcome, and report on yield and overall water use with different management strategies.

HydroLOGIC is provided free to Australian cotton growers and consultants. For more information or to receive a copy contact your local cotton industry development officer, the TRC or visit the Australian Cotton CRC website.

3.1.14 Defoliation

You can assess maturity by counting the nodes above the first position cracked cotton boll (NACB).

Defoliate promptly when the crop is mature. 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).

Crops should only be defoliated earlier than the above recommendations if you are confident that the upper bolls are sufficiently mature, otherwise a reduction in yield or fibre quality could occur. The maturity of bolls can be assessed with care by cutting bolls and checking the development of the seeds. Cotton bolls are mature when the fibre is well developed, the seeds are firm and the seed coats are turning brown in colour.

The timing of defoliation can be an important IPM tool, as late *Helicoverpa* problems can sometimes be overcome by a successful defoliation. This can minimise the need for late season insecticides.